GEOLOGICAL SURVEY OF NEW JERSEY

HENRY B. KÜMMEL, State Geologist

The Clays and Clay Industry

of New Jersey

BY

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AND

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ASSISTED BY

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STATE GEOLOGIST,

HENRY B. KÜMMEL.

Letter of Transmittal.

To His Excellency, Franklin Murphy, Governor of the State of New Jersey and ex-officio President of the Board of Managers of the Geological Survey:

SIR—I have the honor to submit herewith a Report upon the Clay Deposits and Clay Industry of New Jersey, and to request that it be published as Vol. VI of the Final Report Series of the State Geologist.

Respectfully,
HENRY B. KÜMMEL,
State Geologist.

March 22, 1904.

PREFACE.

THIS REPORT is Vol. VI, in the Final Report series of the Geological Survey, the previous volumes being as follows: Vol. I, Topography (out of print); Vol. II, Pt. I, Mineralogy and Botany (postage, 25 cents); Vol. II, Pt. II, Zoology (postage, 30 cents); Vol. III, Water Supply (postage, 21 cents); Vol. IV, Physical Geography (very scarce),[1] and Vol. V, Glacial Geology (postage, 35 cents).

The value and importance of the New Jersey clays and clay industry have long been known and much attention has been given to them by the Geological Survey. In his report entitled "The Geology of New Jersey," published in 1868, Prof. Cook described the clays about Woodbridge and South Amboy, and gave numerous chemical analyses. Ten years later the Survey issued an elaborate report upon the Clay Deposits of Woodbridge, South Amboy and other places in New Jersey. This volume was accompanied by a map showing the location of all the clay pits in the Woodbridge-Amboy district, and also the geographical distribution of the beds of fire clay, feldspar and potter's clay. The information made public by this report and map was of great importance.

Prospecting for clays was stimulated and at the same time large sums of money were saved to the clay miners by the information given as to the distribution of the clay and the regions where success was to be sought. A striking commentary upon the accuracy of this map is that all the new clay openings made since 1878 are within the areas marked as clay, in so far as they are within the area covered by the map. Considerable clay is now dug from areas beyond the limits of the former map, but for the area covered, it was accurate and reliable, as shown by subsequent developments.

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[1] **For sale, prepaid, $1.35, without the accompanying photo relief map; $2.85 with map; map alone, $1.50.**

The fact that the map of the same district accompanying this report—Plate XI—differs from it in detail does not contradict the above statement. The differences are more apparent than real, and are due to the slightly different classification adopted. Many clay beds, formerly thrown aside as worthless and not included on Dr. Cook's map, have been delimited on the present map. Then, too, the attempt has been made to indicate not only the outcrop of each clay belt, but also its probable underground extension, so far as it is not too deeply buried by later deposits to permit its being worked.

Subsequent to the publication of the Report on Clays in 1878, an exhaustive study of the fusibility of New Jersey clays was made, as well as of all the important fire clays of other states and foreign countries. The results of these tests were published in the Annual Report for 1880. Owing, however, to the fact that it was not considered practicable to determine the intensity of the heat obtained, nor to measure the pyrometric effects, other than as indicated by the fusing of platinum before the more refractory clays were melted, these tests show only the relative infusibility of the clays tried, and cannot be used in comparison with the fusion tests in this report, where the conditions were different and the temperature effects are indicated in terms of the standard Seger cone numbers.[1]

In 1897 and 1898 a thorough canvass of the brick and clay industries (not including pottery) of the State was made and the results published in the Annual Reports of the State Geologist for those years. It showed that during 1898, 7,510 men were employed, 403,711,708 brick were made, and that the total value of the clay industry (exclusive of pottery) was $5,748,726.

Requests are frequently received by the Survey for information regarding the clays of the State, and, although a few copies of the Clay Report for 1878 are still available for distribution, yet it has been felt for some time that that volume did not fairly represent the present condition of the clay industry, particularly as there has been a marked development in the southern portion of the State, a region almost entirely untouched by the earlier report. Accordingly, field work was commenced in the fall of

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[1] Pages 101 *et seq.*

1901 upon a new report, which should consider not only the known and developed clay deposits, but which, so far as possible, should contain definite and practical information concerning unworked beds, which future demands may render profitable. It was felt, too, that a new clay report should consider more in detail the technology of the clay industry, and so be of value not only to the miners of clay, but also to the manufacturers.

The present volume is the result of the work commenced in 1901 and continued, with some interruption, to the present time. While three names appear upon the title page, it is but fair to Dr. Ries to state that the general plan of the report is his. He visited in the field nearly all the clay deposits noted and nearly all the important clay-working establishments. All of the physical and some of the chemical analyses and tests, except the breaking and crushing tests upon the brick, were made by him, and he is the authority for the statements regarding the economic value of the clays, as well as the methods of manufacture.

For several years Mr. Knapp has been engaged in a detailed study of the formations in southern New Jersey, and while his work has not been primarily upon the clay deposits, nevertheless he had accumulated a large amount of valuable information regarding the occurrence of clay beds, which very much simplified the task of locating undeveloped deposits. His studies also assisted materially in the correlation of the clay deposits and their reference to the proper geological horizon. The geological data on the general map of the State, Plate X, and of the Alloway clay, Plate XIII, were furnished mainly by him.

The stratigraphy of the clay deposits has been the particular work of the State Geologist, assisted, as above noted, by data furnished by Mr. Knapp. He is also responsible for most of the detailed mapping of the clay beds in the district from Woodbridge to Keyport, Plates XI and XII. Although Parts I and III and Chapter XVIII of Part IV were written by Heinrich Ries, Part II by H. B. Kümmel and Chapter XIX of Part IV conjointly, yet both authors have had the benefit of the others' suggestions and criticisms.

In the present report, in Part I, Dr. Ries discusses in considerable detail the origin, modes of occurrence and physical and chemical properties of clay. In Part II the stratigraphy of the New Jersey clay deposits is considered, and the geological formations of the State which contain workable clays are described. Brief mention is made of all the worked deposits, reference being made to the maps by locality numbers. In Part III the methods of manufacture of the various classes of clay products are discussed, with particular reference to New Jersey methods. No attempt is made to describe individual plants for two reasons. No advantage was to be gained by repeating details of manufacture, where commonly accepted methods were employed and similar types of machinery used, and on the other hand it was felt that all manufacturers had a right to have their trade secrets, in so far as they had any, respected and preserved inviolable. Inasmuch as the technology of the pottery industry, particularly of the higher grades, is exceedingly complex, its full treatment would transcend the limits of a report of this character. Moreover, inasmuch as comparatively little New Jersey clay is used in the higher grades of pottery ware, in which flint and feldspar are large ingredients, it was thought best to restrict the chapter on pottery to somewhat narrow limits. In Part IV the economic geology of the New Jersey clays is considered, and they are discussed, first by formations, their physical and chemical characters being summarized, and then by counties. In this chapter mention more or less brief is made of all the clay deposits of the State, so far as known. In the case of those districts, however, where the clays have been worked for many years, and clay banks are so frequent that descriptions of each bank would pad the report unnecessarily, only the most important banks or the more representative types of clay have been tested and described.

In preparing the report the endeavor has been to make it of interest and value to all clay workers. The fact has been recognized that the great majority of them are not thoroughly familiar with chemical and geological terms. It has not been possible, however, to avoid the use of these, but the endeavor has been made either to explain them when first used, or to use them in such a way that their meaning is apparent. For this reason, also, the use of chemical symbols, unless accompanied by their names, has been avoided as far as possible.

It will be noticed that comparatively few chemical analyses have been made, most of those published being copied from earlier reports. On the other hand, several hundred physical tests were made, that is, tests of the air shrinkage, fire shrinkage, color in burning, temperature of vitrification, and of fusion, etc. It was believed that these tests would better supply the information needed by the practical clay worker, particularly since an ultimate chemical analysis may not be a true index of the character of the clay. In other words, two clays of nearly the same chemical composition may behave quite differently in working, owing to the different ways in which the chemical elements may be combined.

As already indicated, the endeavor was made to obtain information regarding the location and character of undeveloped clay deposits. That we have succeeded in locating all the unworked clay deposits of the State, particularly in the sandy pines district, is, of course, improbable. It is likewise certain that all the outcrops of the clay deposits, which occur in regularly defined belts, like the Raritan clays, the Clay Marl clays, I and II, and the Alloway clay, have not been seen, but the zones within which these may be looked for have been accurately determined and shown upon Plates X—XIII, and many localities have been sampled. Private endeavor must do the rest. Certain it is that very few, if any, reports have ever been issued which give so much detailed information regarding unworked and heretofore unknown deposits.

Two other special features of the report may be emphasized. The first of these is the series of tests on the breaking and crushing strength of New Jersey brick and the deductions which may be drawn from them (Chap. XI). So far as known they are the most complete tests along these lines ever published in this country, and it is believed that these results will be accepted as a standard by all engineers. Acknowledgment must be made to Prof. I. H. Woolson, of Columbia University, for the painstaking care with which these experiments were made.

The other important line of investigation is that relating to the chemical composition of fire brick and its relation to their refractoriness. The series of tests carried out in this connection include all the brands made in the State, with the exception of those of three manufacturers, one of whom maintains only a branch establishment in New Jersey, who declined to permit their brick to be tested. It is, of course, impossible to say whether this reluctance on their part arose from a disbelief in the express promise of the State Geologist that the identity of the various brands would not be made known, or from a consciousness that their brick would not compare favorably with other brands, or from some other reason. In strong contrast to this attitude was that of the other manufacturers, most of whom were not only willing to have the tests made, but were willing to have the results published under their own names.

So far as known, this set of fire-brick tests is the most complete ever published in this country. A careful study of the fusion temperatures in comparison with the chemical composition cannot fail to indicate many important points, one of the most marked of which is the effect upon the fusion of a large amount of free silica, and of the fineness or coarseness of its grain.

It is with great pleasure that acknowledgment is made to all who have supplied information or assisted in the preparation of this report. By clay miners and clay manufacturers, by foremen and superintendents, by laborers and proprietors, we have been received with a courtesy and attention so uniform that the very few instances where information has been refused and the door shut in our faces stand out strongly by contrast. While thanks are due to many, especial mention must be made of favors received from Messrs. J. A. Campbell and E. C. Stover, of the Trenton Potteries Company; Alfred Lawshe, of the Trent Tile Works; J. E. Rossi, of Perth Amboy; M. D. Valentine, of Woodbridge; E. C. Fisher, of the Sayre & Fisher Company, and Mr. O. Speir, of the Perth Amboy Terra Cotta Company. Messrs. L. C. Gratton, Fellow in Geology, and W. E. McCourt, Assistant in Economic Geology, at Cornell University, gave very material assistance in the chemical and physical analyses, and the latter also made most of the drawings for the report.

It is, perhaps, too much to hope that no errors have crept into these pages. The compilation and sifting of all the data collected has been a long and tedious work. If any errors or omissions are noted, the reader will confer a favor by calling the attention of the undersigned to them.

HENRY B. KÜMMEL,
State Geologist.

PART I.

CLAY AND ITS PROPERTIES.

By HEINRICH RIES.

CHAPTER I.

CLAY AND ITS MODE OF OCCURRENCE

CONTENTS.

Definition.—Clay is the term applied to those earthy materials occurring in nature, whose most prominent property is that of plasticity when wet. On this account they can be molded into almost any desired shape, which is retained when dry. Furthermore, if heated to redness, or higher, the material becomes hard and rock-like. Physically, clay is made up of a number of small mineral particles, ranging from grains of coarse sand to those which are of microscopic size, or under one one-thousandth of an inch in diameter. (Figs. 30–34.) Mineralogically, it consists of many different mineral fragments, some of them fresh, but others in all stages of decay, and representing chemically many different compounds, such as oxides, carbonates, silicates, hydroxides, etc. (See Chap. III.)

The discussion of the chemical and physical properties of the clay will be left until later, but it may simply be stated here that two prominent minerals in clay are quartz (silica) and kaolinite (a mixture of water, silica and alumina, and known chemically as a hydrated silicate of alumina).

ORIGIN OF CLAY.[1]

Clay results primarily from the decomposition of other rocks, and very frequently from rocks containing feldspar, so that for this reason most writers have stated that it was derived from feldspathic rocks. There are some rock species, however, that contain no feldspar (such as serpentine), and others with very little (as some gabbros), which, on weathering, produce some of the most plastic clays known. In all of these clays there is found a variable amount of the mineral kaolinite, which is of secondary origin, *i. e.,* it is derived from other minerals by decomposition. This is termed the *clay base.*

In order to trace the process of clay formation, let us take the case of granite, a rock which is commonly composed of three minerals, viz., quartz, feldspar, and mica. When such a mass of rock is exposed to the weather, minute cracks are formed in it, due to the rock expanding when heated by the sun and contracting when cooled at night, or they may be joint planes formed by the contraction of the rock as it cooled from a molten condition. Into these cracks the rain water percolates and, when it freezes in cold weather, it expands, thereby exerting a prying action, which further opens the fissures, or may even wedge off fragments of the rock. Plant roots force their way into these cracks and, as they expand, in growth, supplement the action of the frost, thus further aiding in the breaking up of the mass.

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[1] **In this chapter the different kinds of clay are discussed according to their origin. A classification according to uses is given in the Introduction to Part III.**

This process alone, if kept up, may reduce the rock to a mass of small angular fragments.

The rain water, however, acts in another way. It not only carries oxygen into the pores of the rock, but also acids in solution, the latter having been gathered in part from the decaying vegetable matter in the soil and in part from the air. The result of this is that the oxygen and the acids attack many of the mineral grains of the rock and change them into other compounds. Some of these are soluble and can be carried off by the water circulating through the mass, but others are insoluble and are left behind. It will thus be seen that one effect of this action is to withdraw certain elements from the rock, and, the structure of the minerals as well as the rock being destroyed, it crumbles down to a clayey mass.

The three minerals mentioned as being commonly present in granite are not equally affected, however, by the weathering agents. Thus the quartz grains are but slightly attacked by the soil waters, while the feldspar loses its lustre and changes slowly to a white, powdery mass, which is usually composed entirely of grains of kaolinite. The mica, if whitish in color, remains unattacked for a long time, and the glistening scales of it are often visible in many clays. If the mica is dark colored, due to iron in its composition, it rusts rapidly and the iron oxide, thus set free, may permeate the entire mass of clay and color it brilliantly.

If now a granite, which is composed chiefly of feldspar, decays under weathering action, the rock will be converted into a clayey mass, with quartz and mica scattered through it. Remembering that the weathering began at the surface and has been going on there for a longer period than in deeper portions of the rock, we should expect to find on digging downward from the surface, a) a layer of fully formed clay, b) below this a poorly defined zone containing clay and some partially decomposed rock fragments, c) a third zone, with some clay and many rock fragments, and d) below this the nearly solid rock. (Fig. 1.) In other words, there is a gradual transition from the fully formed clay at the surface into the parent rock beneath. The only exception to this is found in clays formed from limestone, where the passage from clay to rock is sudden. The reason for this is that the change from limestone into clay does not take place in the same manner as granite. Limestone consists commonly of carbonate of lime, with a variable quantity of clay impurities, so that when the weathering agents attack the rock, the carbonate of lime is dissolved out by the surface waters, and the insoluble clay impurities are left behind as a mantle on the undissolved rock, the change from rock to clay being, therefore, a sudden one, and not due to a gradual breaking down of the minerals in the rock, as in the case of granite.

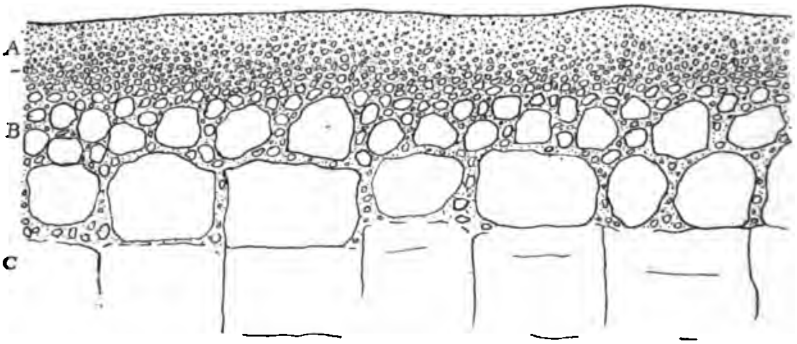

Fig. 1.

Section showing the passage of the fully formed residual clay on the surface into the solid bed rock below.

A. Clay. B. Clay and partly decomposed rock. C. Bed rock below, passing upward into rock fragments with a little clay.

RESIDUAL CLAY.

Where the clay is thus found overlying the rock from which it was formed, it is termed a residual clay, because it represents the residue of rock decay, and its grains are more or less insoluble.

A residual clay formed from a rock containing little or no iron oxide is usually white, and is termed a *kaolin,* and deposits of this type generally contain a high percentage of the mineral *kaolinite.* On the other hand, a residual clay derived from a rock containing much iron oxide will be yellow, red, or brown, depending on the iron compounds present. Between the pure white clays and the brilliantly colored ones, others are found representing all intermediate stages, so that residual clays vary widely in their purity.

The form of a residual clay deposit, which is also variable, depends on the shape of the parent rock. Where the residual clay has been derived from a great mass of granite or other clay-yielding rock, the deposit may form a mantle covering a considerable area. On the other hand, some rocks, such as pegmatites (feldspar and quartz), occur in veins, that is, in masses having but small width as compared with their length, and in this case the outcrop of residual clay along the surface will form a narrow belt.

The depth of a deposit of residual clay will depend on climatic conditions, character of the parent rock, topography and location. Rock decay proceeds very slowly, and in the case of most rocks the rate of decay is not to be measured in months or years, but rather in centuries. Only a few rocks, such as some shales or other soft rocks, change to clay in an easily measurable time. With other things equal, rock decay proceeds more rapidly in a moist climate, and consequently it is in such regions that the greatest thickness of residual materials is to be looked for. The thickness might also be affected by the character of the parent rock, whether composed of easily weathering minerals or not. Where the slope is gentle or the surface flat, much of the residual clay will remain after being formed, but on steep slopes it will soon wash away.

In some cases the residual materials are washed but a short distance and accumulate on a flat or very gentle slope at the foot of the steeper one, forming a deposit not greatly different from the original ones,[1] although they are not, strictly speaking, residual clays. Shallow deposits of clay of this sort are not uncommon in the Highlands of New Jersey.

Residual clays, usually of low purity, are widely distributed over the southern portion of the United States, and they probably existed at one time to an equal depth in the northern states, but were removed by the great continental ice sheet, which, in the glacial period, spread over that part of the country. The northern portion of New Jersey was involved in this change, the southern

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[1] Clays accumulated in this manner are termed colluvial by G. P. Merrill.

limit of the ice sheet during its latest advance extending from Perth Amboy to Belvidere, along the line now marked by the terminal moraine (Pl. X).[1] For this reason no extensive deposits of residual clay are to be looked for north of this line, while south of it a few small deposits are known, but they have no great economic value.

SEDIMENTARY CLAY.

As mentioned above, residual clays rarely remain on steep slopes, but are washed away by rain storms into streams and carried off by these to lower and sometimes distant areas. By this means residual clays possibly of very different character may be washed down into the same stream and become mixed together. This process of wash and transportation can be seen in any abandoned clay bank, where the clay on the slopes is washed down and spread out over the bottom of the pit.

As long as the stream maintains its velocity it will carry the clay in suspension, but if its velocity be checked, so that the water becomes quiet and free from currents, the particles begin to settle on the bottom, forming a clay layer of variable extent and thickness. This may be added to from time to time, and to such a deposit the name of sedimentary clay is applied. All sedimentary clays are stratified or made up of layers, this being due to the fact that one layer of sediment is laid down on top of another (Pl. I, Fig. 1). If there were absolutely no difference in the character of the material deposited, it would form one thick, homogeneous bed, but there is usually more or less variation, a layer of very fine material being laid down at one time, and a layer of coarser material on top of it, or *vice versa*. These layers may also vary in thickness, and, since there is less cohesion between unlike particles, the two layers will tend to separate along their line of contact.

As the finer material can only be deposited in quiet water, and coarse material in disturbed waters, so from the character

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[1] For a full account of the Glacial Deposits of the State, see Vol. V of the N. J. Survey Reports.

Fig. 1.

A series of sedimentary clay beds. W. H. Cutter's pit, Woodbridge.

Fig. 2.

Cross-stratified beds of sand near Florida Grove. Standard Fireproofing Company.

of the deposit we can read much regarding the conditions under which it was formed. If, therefore, in the same bank alternating layers of sand, clay and gravel are found, it indicates a change from disturbed to quiet water, and still later rapid currents over the spot in which these materials were deposited. The commonest evidence of current deposition is seen in the cross-bedded structure of some sand beds, where the layers dip in many different directions, due to shifting currents, which have deposited the sand in inclined layers (Pl. I, Fig. 2). The beds of thinly stratified or laminated sands and clays, found in many cases over the Woodbridge fire-clay bed, are another example of rapid changes in the conditions of deposition.

Sedimentary clays can be distinguished from residual clays chiefly by their stratification, and also by the fact that they commonly bear no direct relation to the underlying rock on which they may rest.

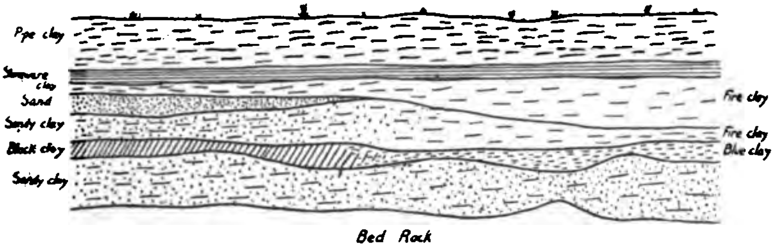

Fig. 2.

Generalized section showing how beds of clay may vary horizontally and vertically.

All sedimentary clays resemble each other in being stratified, but aside from this they may show marked irregularities in structure.

Thus, any one bed, if followed from point to point, may show variations in thickness, pinching or narrowing in one place and thickening or swelling in others, as shown in Fig. 2.

In digging clay the miner often finds streaks of sand extending through the deposit and cutting through several different layers, these having been caused by the filling of channels cut in the clay deposits by streams after the elevation of the former to dry land. Occasionally a bed of clay may be extensively worn away or corraded by currents subsequent to its deposition, leaving its upper surface very uneven, and on this an entirely different kind of material may be deposited, covering the earlier bed, and filling the depressions in its surface. If the erosion has been deep, adjoining pits dug at the same level may find clay in one case and sand in the other (Fig. 3).

While in many instances the changes in the deposit are clearly visible to the naked eye, variations may also occur, due to the same cause, which would only show on burning. Thus, for example, the so-called retort clay, found in the Woodbridge region, is similar in its plastic qualities wherever found, but the shrinkage of that found in the different pits is not always the same, because it varies in fineness from place to place. It may also vary in color. Similarly, the Woodbridge fire-clay member of the Raritan (Chapter VIII) contains a layer known as the top-sandy in many pits of the Woodbridge district, but around Perth Amboy it is wanting, either because it was not deposited there, or, if it was, subsequent scouring action by ocean currents in that portion of the area may have worn it away. In strong contrast to this we may take the black, micaceous, laminated sands and clays, overlying the refractory members of the Woodbridge fire-clay bed. These are found at Woodbridge, Perth Amboy, South River and intermediate points, and were widely developed, although, even here, the individual beds are very changeable.

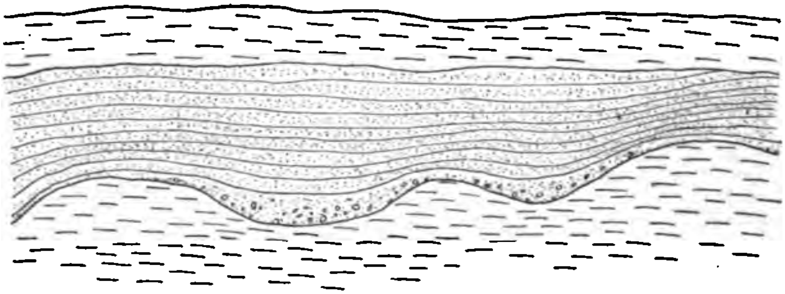

Fig. 3.

Section showing uneven boundary between two clay beds, due to erosion of one before the deposition of the other.

The general character of sedimentary clays is more or less influenced by the locality and conditions of deposition, which enables us, therefore, to divide them into the following classes:[1]

Marine clays.—This class includes those sedimentary clays deposited on the ocean bottom, where the water is quiet. They have, therefore, been laid down at some distance from the shore, since nearer the land, where the water is shallower and disturbed, only coarser materials can be deposited. Beds of clay of this type may be of vast extent and great thickness, but will naturally show much variation, horizontally at least, because the different rivers flowing into the sea usually bring down different classes of material.

Thus, one stream may carry the wash from an area of iron-stained clay, and another the drainage from an area of white or light-colored clay. As the sediment spread out over the bottom, the areas of deposition might overlap, and there would thus be formed an intermediate zone made up of a mixture of the two sediments. This would show itself later as a horizontal transition from one kind of clay to another. These changes may occur gradually or at other times within the distance of a few feet (Pl. II, Fig. 1).

The laminations produced by vertical changes are shown in Plate XLVI, Fig. 2.

The most persistent beds of this nature are found in the rocks of the Silurian and Devonian systems, but beds of considerable horizontal extent are found in New Jersey in the Clay Marl series of the Upper Cretaceous.

Estuarine clays.—These form a second type of some importance in New Jersey. They represent bodies of clay laid down in shallow arms of the sea, and are consequently found in areas that are comparatively long and narrow, with the deposits showing a tendency towards basin shapes. If strong currents enter the estuary from its upper end, the settling of the clay mud may be prevented, except in areas of quiet water in recesses of the bay shore. Or, if the estuary is supplied by one stream at its head,

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[1] A person lacking geological training will not always be able to tell to which one of the following classes a deposit belongs.

and this of low velocity, the finer clays will be found at a point most distant from the mouth of the river. In such cases, we should anticipate an increase in coarseness of the clay bed or series of beds as they are followed from what was formerly the old shore line up to the mouth of the former river that brought down the sediment.

Estuarine clays often show sandy laminations, and are not infrequently associated with shore marshes, due to the gradual filling up of the estuary and the growth of plants on the mud flats thus formed. The clays of the Hackensack region are probably estuarine deposits, formed at the close of the Glacial period, when the region west of the Palisades stood somewhat lower in respect to sea level than at present.[1]

Swamp and lake clays.—Swamp and lake clays constitute a third class of deposits, which have been formed in basin-shaped depressions occupied by lakes or swamps. They represent a common type, of variable extent and thickness, but all agree in being more or less basin-shaped. They not infrequently show alternating beds of clay and sand, the latter in such thin laminæ as to be readily overlooked, but causing the clay layers to split apart easily. Many of the lake clays are directly or indirectly of glacial origin, having been laid down in basins or hollows along the margin of the continental ice sheet, or else in valleys that have been dammed up by the accumulation of a mass of drift across them. This wall of drift serves to obstruct the drainage in the valley, thus giving rise to a lake, in which the clay has been deposited. Clay beds of this type are extremely abundant in all glaciated regions. They are usually surface deposits,[2] often highly plastic, and more or less impure. Their chief use is for common brick and earthenware, and none of the New Jersey ones have been found to be refractory.

Flood plain and terrace clays.—Many rivers, especially in broad valleys, are bordered by a terrace or plain, there being sometimes two or more, extending like a series of shelves or steps up the valley side. The lowest of these is often covered by

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[1] N. J. Geol. Survey, Vol. V. Report on Glacial Geology, p. 196.

[2] Not necessarily thin.

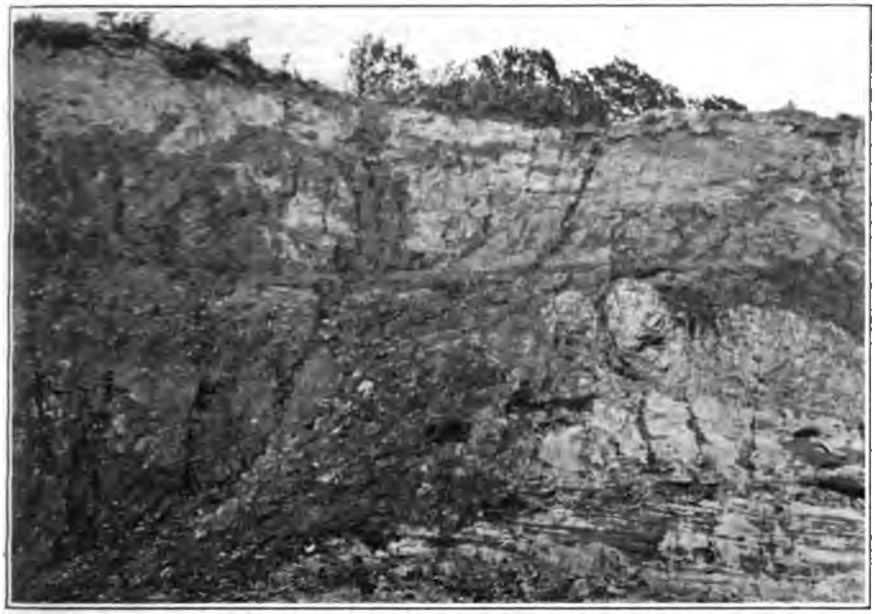

Fig. 1.

Raritan clay bank showing white sand on the right passing into a black clay on the left. S. Graham & Co., Kinkora.

Fig. 2.

Crusts of iron oxide cutting through the clay. They produce the ridged appearance on the surface. Haines & Son, Yorktown.

the river during periods of high water, and is consequently termed the flood plain. In such times much clayey sediment is added to the surface of this flood terrace, and thus a flood-plain clay deposit may be built up.

Owing to the fact that there is usually some current setting along over the plain when it is overflowed, the finest sediments cannot settle down, except in protected spots, and, consequently, most terrace clays are rather sandy, with here and there pockets of fine, plastic clay. They also frequently contain more or less organic matter. Along its inner edge the terrace may be covered by a mixture of clay, sand and stones, washed down from neighboring slopes.

Where several terraces are found, it indicates that the stream was formerly at the higher levels, and has cut down its bed, each terrace representing a former flood plain. Even along the same stream, however, the clays of the several terraces may vary widely in their character, those of one terrace being perhaps suitable for pottery, and those of a second being available only for common brick and tile.

Drift or bowlder clays.—In that portion of the State formerly covered by the continental ice sheet (Pl. X), there are occasional deposits of clay formed directly by the glacier. These are usually tough, dense, gritty clays, often containing many stones. The material deposited by the ice (till) was usually too stony and sandy to serve as clay, although often known as bowlder clay. Locally, however, where the ice-transported material had been largely ground to a fine rock flour, the bowlder clay is plastic enough and not too full of stones for use. Such deposits are mostly of limited extent, impure and of little value.

In addition to this type of clay formed directly by the ice, there were clays deposited in lakes or along flood plains by the streams issuing from the glacier. These were composed of material derived from the ice, but since they were deposited by water, they were stratified and may properly be classed as lacustrine, estuarine or flood-plain clays of glacial age. These types are discussed in detail under their respective heads on the preceding pages. The clays of Singac, Mountain View and Hackensack are of this type.

SECONDARY CHANGES IN CLAY DEPOSITS.

Changes often take place in clays subsequent to their deposition. These may be local or widespread, and in many cases either greatly improve the deposit or render it worthless. The marked effect of some of these changes is often well seen in some clay beds of which only a portion has been altered. These secondary changes are of two kinds, viz., mechanical and chemical.

Mechanical Changes.

Tilting, Folding, Faulting.—From the above explanation of the origin of sedimentary clays, it has been seen that they were laid down under water. Since they now appear at the surface, the water has been drained off, either by the water level falling, or the sea bottom being elevated. In the latter case, since the elevation of a large area is rarely the same at all points, a tilting of the beds may occur during the uplift. This is the case with all the beds of clay and sand in South Jersey, all of which now tilt or dip gently to the southeast, although they were essentially horizontal when deposited. Beds of clay and shale sometimes show folds or undulations. In the case of consolidated or hard beds, these may be due to lateral pressure, caused by movements in the earth's crust, while in soft beds the cause is frequently local. Thus, in the clay beds about Woodbridge, instances of local folding were noted where the disturbance seems to have been due to the shoving action of the ice sheet during the Glacial period. Such folds, however, are of minor account and affect only a few beds.

Where beds of clay are gently folded into arches (anticlinal folds) and troughs (synclinal folds), each bed slopes or dips away from the axis of an anticlinal fold and towards the axis of a synclinal fold, but if followed parallel to the axis it will remain at the same level, provided the axis itself is horizontal. Since, however, the clay strata, of New Jersey are rarely folded, these considerations are not important here.

Where a bed is not sufficiently elastic to bend under pressure, it breaks, and if, at the same time, the beds on opposite sides of the break slip past each other, faulting is said to occur. When the breaking surface or fault plane is at a low angle, one portion of the bed may be thrust over the other for some distance. In other cases the displacement may amount to but a few inches. Figs. 4 and 5 represent sections in faulted strata, and in these it will be noticed that every bed terminates

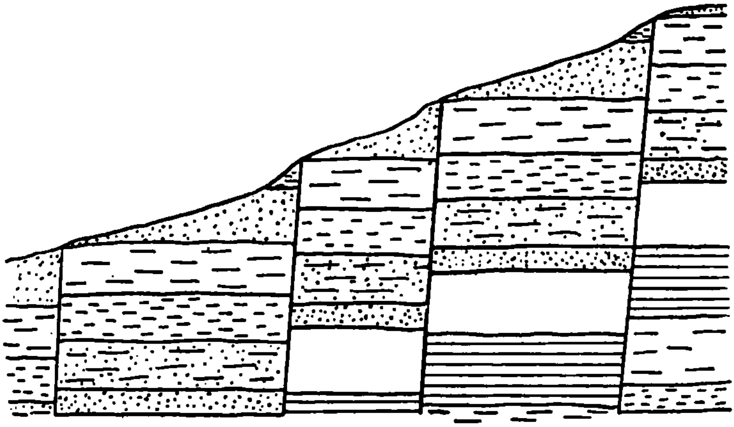

Fig. 4.

Section showing strata broken by a series of parallel fault planes.

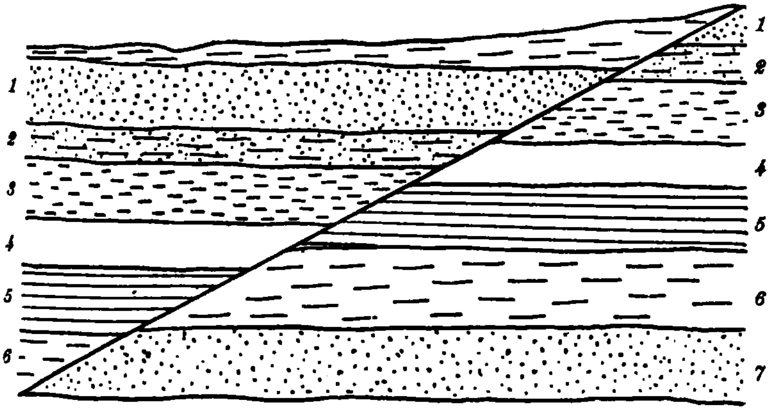

Fig. 5.

Strata broken by a fault plane of low inclination.

abruptly at the fault plane, its continuation on the other side being at higher or lower level. Faulting is rarely seen in the New Jersey clay deposits, but a series of small displacements were noticed in W. H. Cutter's pits (Pl. III, Fig. 1).

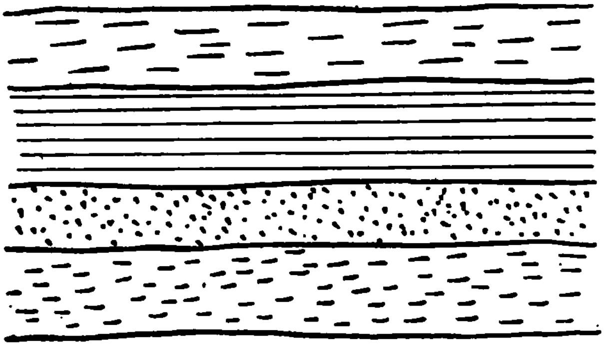

Fig. 6.

Section of horizontal strata, with only the top one exposed at the surface.

Both tilting and folding exert an important influence on the form and extent of the outcropping beds. Where no tilting has occurred, that is, where the beds are flat, only one bed, the upper one of the section will be exposed at the surface, where the latter is level (Fig. 6), and lower beds will be exposed, only where stream valleys have been carved (Fig. 7).

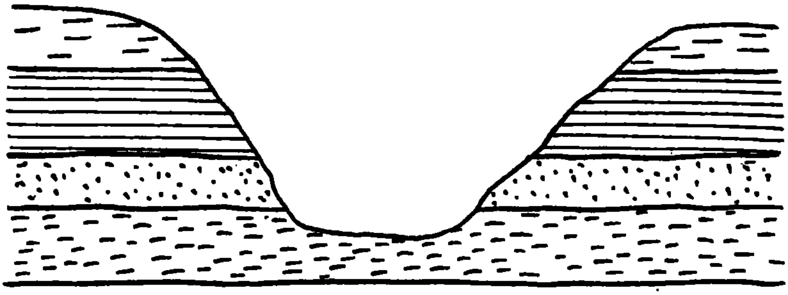

Fig. 7.

Showing how horizontal beds are exposed along the sides of a valley.

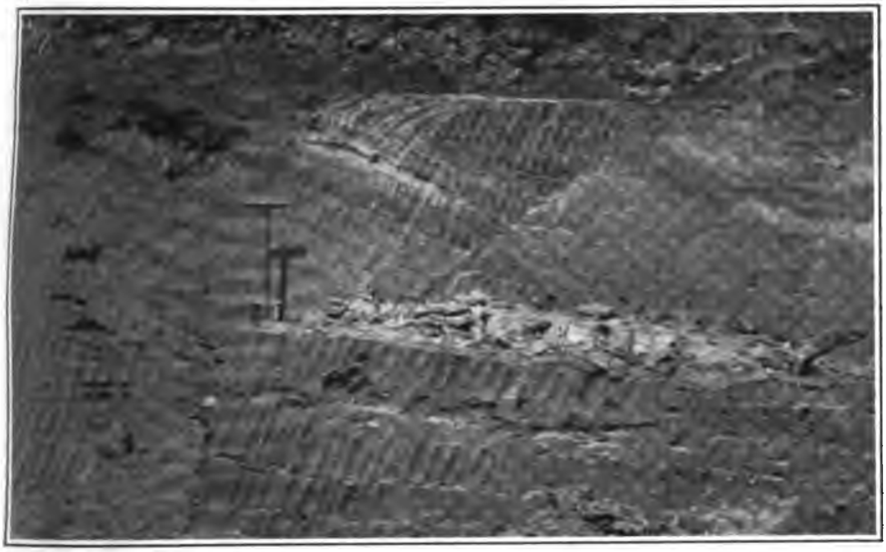

Fig. 1.

Faults in W. H. Cutter's clay bank. Woodbridge.

Fig. 2.

White sand discolored by iron compounds which were derived from the overlying formation.

If the beds are tilted (Figs. 8 and 9), or folded and the crests of the folds worn off (Fig. 10), then the different beds will outcrop on the surface as parallel bands, whose width of outcrop will decrease, with an increase in the amount of dip (Figs. 8 and 9).

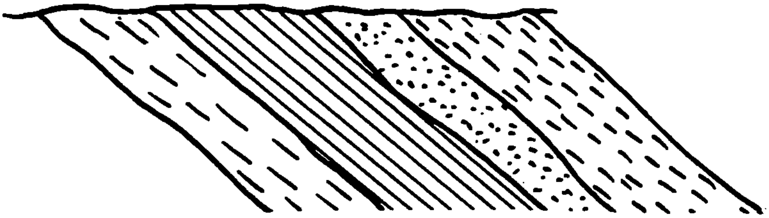

Fig. 8.

Section showing outcropping beds of tilted strata.

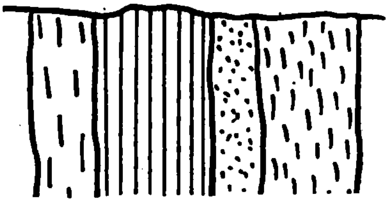

Fig. 9.

Section of vertical beds. The width of outcrop is the same as the actual width of the bed.

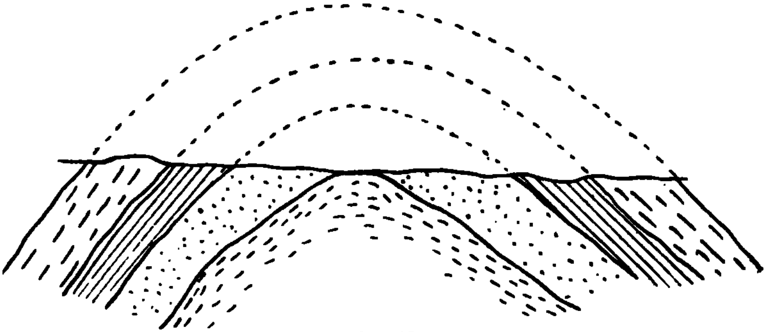

Fig. 10.

Section of folded beds, with crest worn away, thus exposing the different layers.

Erosion.—All land areas are being constantly attacked by the weathering agents (frost, rain, etc.,). The effect of this is to disintegrate the surface rocks and wash away the loose fragments and grains. This brings about a general sculpturing of the surface, forming hills and valleys, the former representing those parts of the rock formations which have not yet been worn away. The effect of this is to cause phenomena or conditions, which may at first sight appear puzzling, but are nevertheless quite simple, when the cause of them is understood.

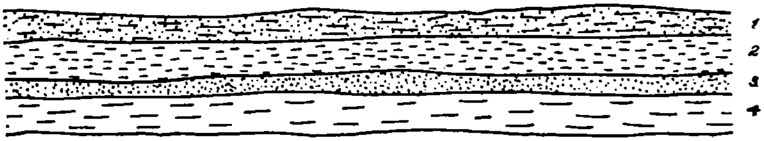

Fig. 11.

Horizontal beds, only the top layer showing at the surface, when the latter is flat.

Let us take, for example, a section of horizontal clay beds, which originally covered an extensive area and were interstratified with sand beds. In Figs. 11 and 12, beds 1 and 3 may be taken to represent the clays. In Fig. 11, we have indicated the surface as it originally was, and in Fig. 12, the outline as it appears after the land has been exposed to weathering and erosion for an extended period. Here we see that the upper bed is left only on the highest hills, and has been removed over a large area, while No. 2 caps the smaller knolls and No. 3 outcrops in the sides of the deeper valleys. Many small areas of clay thus represent all that is left of a formerly extensive bed.

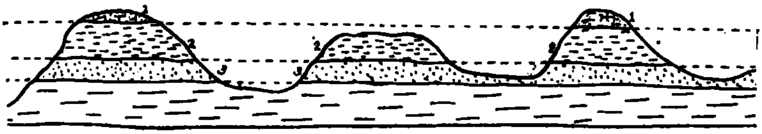

Fig. 12.

Horizontal beds with several layers exposed, by wearing down of the land surface.

If the beds had a uniform dip, the conditions may be as indicated in Fig. 13. Here, bed 1 appears at the summit of 2 hills, a and b, but its rise carries it, if extended, above the summit of hill c, which is capped by bed 2. If one did not know that the beds rose in that direction, it might be assumed that bed 1 passed into bed 2, because they are at the same level. This dipping of the layers or beds sometimes accounts for the great dissimilarity of beds at the same level in adjoining pits.

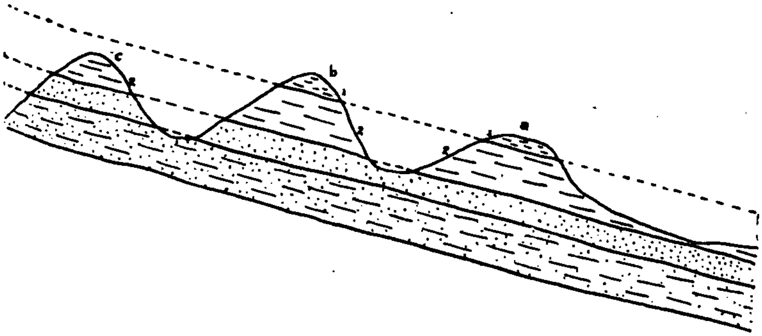

Fig. 13.

Inclined strata, showing rise of the bed above sea level, when followed up the slope or dip.

Where a bed of clay is found outcropping at the same level on two sides of a hill it is reasonable to assume that it probably extends from one side to the other, but it is not safe to predict it with certainty, for as has been mentioned above, clay beds may thin out

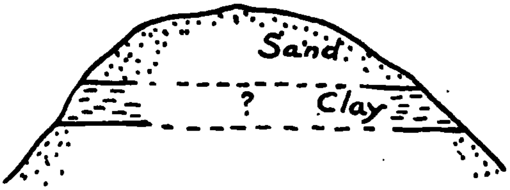

Fig. 14.

Outcrops of a clay bed on two sides of a hill and its probable extension into the same.

within a short distance. Furthermore, the overlying material or overburden will become thicker towards the centre or summit of the hill, so that even if present, the clay may be economically unworkable. (Fig. 14.)

Chemical Changes.

Nearly all clay deposits are affected superficially, at least, by the weather. The changes are chiefly chemical, and can be grouped under the following heads:

Change of color.
Leaching.
Softening.
Consolidation.

Change of Color.—Most clay outcrops which have been exposed to the weather for some time show various tints of yellow or brown. This coloration or rather discoloration is due to the oxidation or rusting of the iron oxide which the clay contains. This iron compound is usually found in the clay as an original constituent of some mineral, and rusts out as the result of weathering, so that the depth to which the weathering has penetrated the material can often be told by the color. The lower limit of this is commonly not only irregular, but the distance to which it extends from the surface depends on the character of the deposits, sandy open clays being affected to a greater depth than dense ones. The discoloration of a clay due to weathering does not always originate within the material itself, for in many instances, especially where the clay is open and porous, the water seeping into the clay may bring in the iron oxide from another layer (Pl. III, Fig. 2), and distribute it irregularly through the lower clay.

The changes of color noticed in clay are not in every case to be taken as evidence of weathering, for in many instances the difference in color is due to differences in mineral composition. Many clays are colored black at one point by carbonaceous matter, whereas a short distance off the same bed may be white or light gray due to a smaller quantity of carbonaceous material. In many of the Woodbridge pits there is often a change from blue to red and white mottled and from this into red clay. This is not the result of weathering, but is due to local variations in the iron oxide contents of the different layers.

It may be asked, therefore, how changes in color due to weathering can be distinguished from differences in color of a primary character. Discoloration caused by weathering begins at the surface and works its way into the clay, penetrating to a greater distance along planes of stratification or fissures, and even following plant roots as shown in Fig. 15.

Where the clay deposit outcrops on the top and side of a hill, it does not follow that because the whole cliff face is discolored, the weather will have penetrated to this level from the surface, but indicates simply that the weathering is working inward from all exposed surfaces. The overburden often plays an important role in the weathering of clay, for the greater its thickness, the less will the clay under it be affected. This fact is one which the clay worker probably often overlooks, and, therefore, does not appreciate the important bearing which it may have on the behavior of his material. Some unweathered clays crack badly in drying or burning, but weathering seems to mellow and loosen them, as well as to increase their plasticity, so that the tendency to crack is sometimes either diminished or destroyed. If a clay which is being worked shows this tendency it will be advisable to search for some part of the deposit which is weathered, and if the clay is covered by a variable thickness of overburden, the most weathered part will be found usually under the thinnest stripping as shown in Fig. 16.

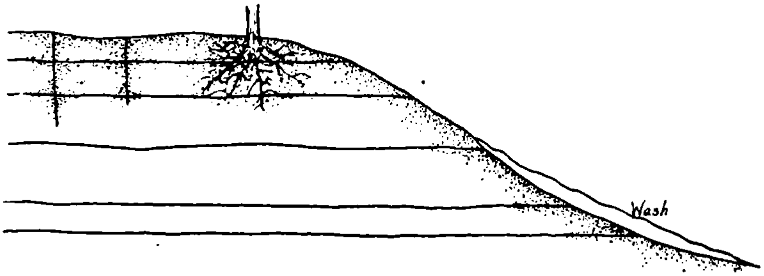

Fig. 15.

Shows how weathering penetrates a clay bed particularly along roots, cracks and joint planes.

Illustrations of this were found at several clay pits, but the operators, instead of recognizing the true reason for the presence of the yellow clay, presumed that it was a different bed, entirely separate from the unweathered blue.

Leaching.—More or less surface water seeps into all clays and in some cases drains off at lower levels. Such waters contain small quantities of carbonic acid which readily dissolves some minerals, most prominent among them carbonate of lime. In some areas, therefore, where calcareous clays occur, it is not uncommon to find that the upper layers of the deposit contain less lime carbonate than the lower ones, due to this solvent action of the percolating waters.

Softening.—Most weathering processes break up the clay deposits, either by disintegration or by leaching out some soluble constituents that served as a bonding or cementing material, thus mellowing the outcrop, and many manufacturers recognize the beneficial effect which weathering has on their clay. They consequently sometimes spread it on the ground after it is mined and allow it to slake for several months or in some cases several years. The effect of this is to disintegrate thoroughly the clay, render it more plastic, and break up many injurious minerals such as pyrite (see p. 46). Although mentioned under chemical changes it will be seen that the process of softening is partly a physical one.

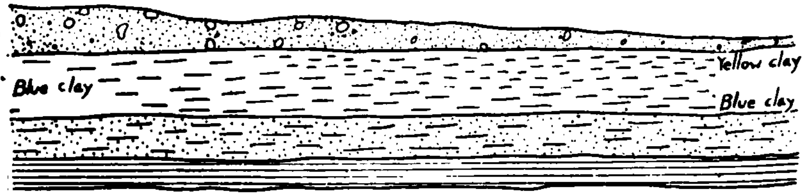

Fig. 16.

Section showing weathered (yellow) clay where the overburden is least.

Consolidation.—This change is found to have taken place in a few deposits, notably in some of the Clay Marls, and is due to the formation of limonite crusts in the clay. At times these may form at a few points in the deposit, or only along certain layers, but in other instances they have originated in all parts of the mass both along the stratification planes, as well as in every joint or crack. They thus permeate the clay deposit with such a network of rusty, sandstone-like chunks, nodules, and strips as to seriously interfere with the digging of the clay, and requiring powerful machinery to break up the hard parts. A surface view of a clay outcrop showing these iron crusts projecting above the surface in the form of small ridges is shown in Plate II, Fig. 2 (p. 12).

Concretions.—In some deposits the limonite or siderite (carbonate of iron) collects around nuclei,[1] such as pebbles or grains of sand, and grows into more or less symmetrical ball-like concretions, which if large can be avoided or thrown out in mining. These are most abundant in the weathered portions of the clay. (Fig. 17.) They are not to be confused, however, with the nodules and lumps of pyrite that are found throughout some clay beds, and are of yellow color and glistening metallic lustre. These latter, although of secondary origin, are not necessarily due to weathering.

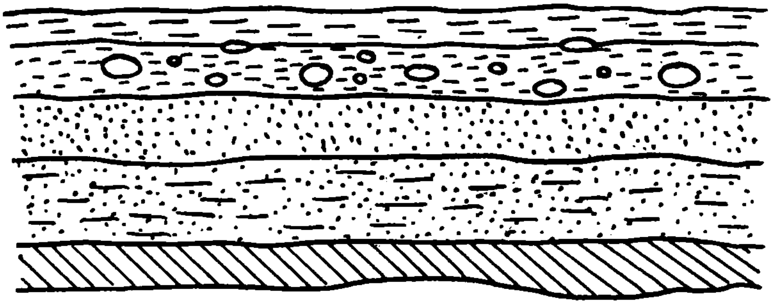

Fig. 17.

Section showing occurrence of concretions in certain layers.

In many calcareous clays concretions are specially abundant, being found not uncommonly along lines of stratification (Plate

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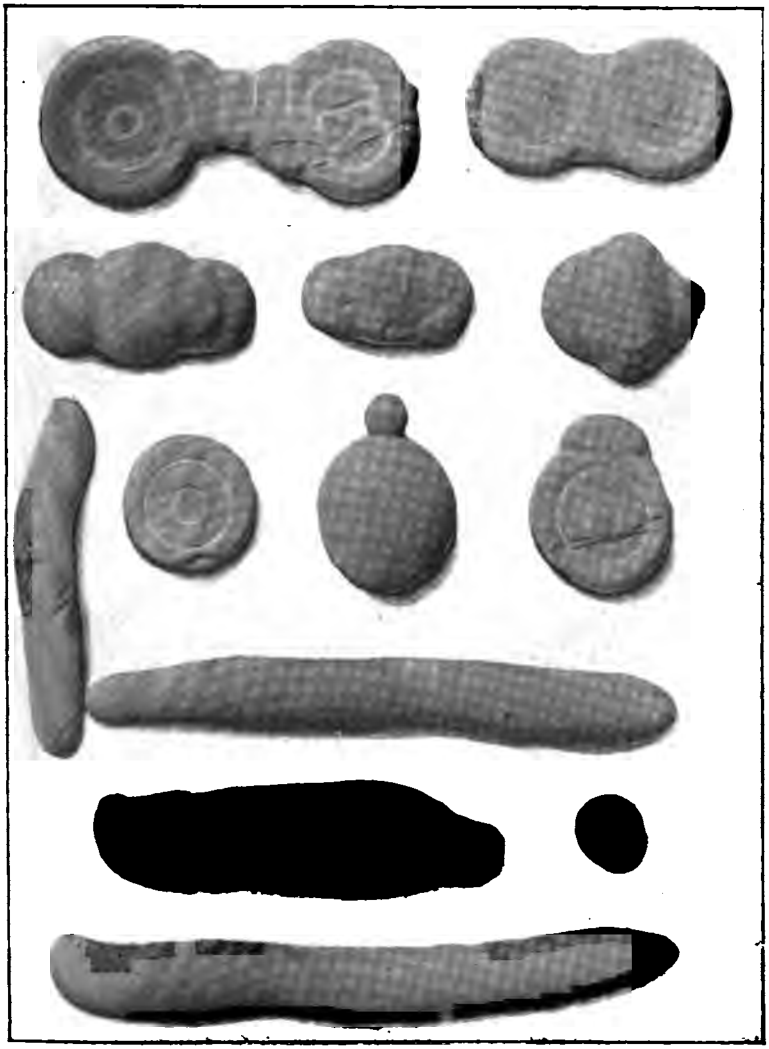
[1] The way in which natural physical forces act, to bring about this segregation of chemical compounds of the same kind, is not yet satisfactorily explained, although it is a common phenomenon.

IV). Many of the drift clays, though free from lime, show concretionary lumps, and in some deposits they have been formed by the deposition of lime carbonate around tree roots. In this case they would be closely associated with weathering.

Formation of shale.—Many sedimentary clays, specially those of marine origin, after their formation are covered up by many hundred of feet of other sediments, due to continued deposition on a sinking ocean bottom. It will be easily understood that the weight of this great thickness of overlying sediment will tend to consolidate the clay by pressure, converting it into a firm rock-like mass, termed shale. That the cohesion of the particles is due mostly to pressure alone is evidenced by the fact that grinding the shale and mixing it with water will develop as much plasticity as is found in many surface clays. An additional hardening has, however, taken place in many shales, due to the deposition of mineral matter around the grains, as a result of which they become more firmly bound together.

In regions where mountain-making processes have been active and folding of the rocks has taken place, heat and pressure have been developed, and the effect of this has sometimes been to transform or metamorphose the shale into slate or even mica-schist (when the metamorphism is intense), both of which are devoid of any plasticity when ground. The Hudson River slates found in northwestern New Jersey owe their low plasticity partly to a slight metamorphism, and partly to the deposition of cement around the grains. The red shales of the Triassic formation of New Jersey are in most cases consolidated sandy clay, but with one exception all those examined are of poor plasticity and very low fusibility.

PLATE IV.



Calcareous concretions found in clay.

CHAPTER II.

METHODS OF WORKING CLAY DEPOSITS.

CONTENTS.

PROSPECTING FOR CLAYS.

A knowledge of the facts given in the preceding chapter will, if borne in mind, be of much aid to the clay worker in prospecting for clays, but several additional points may be mentioned, by which beds of clay may be located.

Outcrops.—The presence of a clay bed is usually detected by means of an outcrop. These exposures are commonly to be found on inclined surfaces, such as hill slopes, or where natural or artificial cuts have been made. The washing out of gullies by heavy rains, the cutting of a stream valley, railroad cuts and wagon-road cuts, all form good places in which to look for outcropping clay beds. The newer the cut, the better the exposure, for the sides of such excavations wash down rapidly, and a muddy-red surface clay or loam will often run down over a bed of lighter colored clay beneath so as to completely hide it from view. If the cut is deep and freshly made, the depth of weathering can frequently be determined.

Springs.—In many cases the presence of clay is shown by the occurrence of one or more springs issuing from the same level along some hill slope. These are caused by surface waters seeping down from the surface (Fig. 18), until they reach the top of some impervious clay stratum, which they then follow to the face of the bank where they issue. The presence of springs, however, cannot be used as a positive indication of clay, for a bed of cemented iron sand, or even dense silt, may produce the same effect (Fig. 19).

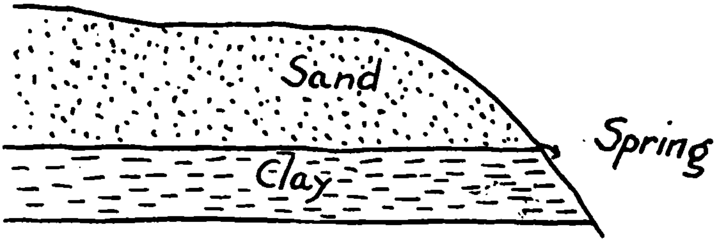


Fig. 18.
Formation of spring due to ground water following a clay layer.

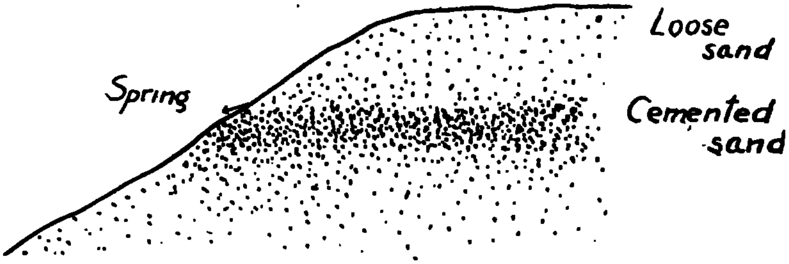


Fig. 19.
Formation of a spring due to a layer of cemented sand.

Ponds.—In many regions covered by glacial drift, pools of water are often retained in depressions because of the presence

Fig. 1.
View around Carmel. Surface sandy.

Fig. 2.
General view in the region around Woodstown, underlain by Alloway clay. A fertile farming country.

below of a water-tight bed of clay (Fig. 20). It does not necessarily indicate a thick deposit, for a very thin layer may often hold up a considerable body of water. Such ponds may likewise in rarer instances be caused by ground water seeping down from higher levels, even in the absence of clay.

Vegetation.—Clay deposits in some areas produce a different type of plant growth from other soils. In Salem county a rather striking contrast was noticed between the fertile farming land of the Alloway clay around Woodstown, and the pine-barren land with its sandy soil to the southeast. (Pl. V, Figs. 1 and 2.)

EXPLOITATION OF CLAY DEPOSITS.

The location of a clay deposit is followed by a determination of its thickness, extent, character and uses. The first two points and some facts bearing on the third are determined in the field; the behavior of the clay when mixed up and burned is found out by tests made in the laboratory or at some factory, and the information thus obtained indicates the commercial value of the material.

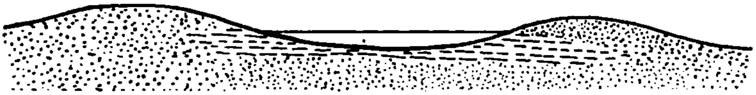


Fig. 20.

Formation of a pond due to a clay bed underneath a depression.

To determine the thickness and extent of the deposit, a careful examination should be made of all clay outcrops in neighboring gullies, or other cuts on the property having the clay. Since, however, most clay slopes wash down easily it may be necessary to dig ditches from the top to the bottom of the cut or hillside in order to uncover the undisturbed clay beds. In most cases, however, the cuts are not sufficiently close together and additional means have to be taken to determine the thickness of the deposit at intermediate points. Such data are sometimes obtainable from wells or excavations made for deep cellars, but the information thus obtained has to be taken on hearsay. Borings made with an auger furnish a more satisfactory and rapid means of determining the thickness of the clay deposit away from the outcrop. An auger for this purpose (Fig. 21) can be made easily and cheaply by welding a one and one-half inch, or two-inch carpenter's auger to a piece of three-fourths inch gas pipe. The latter is cut into short sections and by means of a T joint, a handle can be screwed to the upper length. When the bore hole is started only one section is used, but additional ones are added as the hole increases in depth. In very wet, sandy clays augers are of little value as the bore hole washes in and fills up as soon as the auger is withdrawn. The only way to prevent this is to drive a pipe down in the bore hole, keeping the auger slightly in advance of the lower end of the pipe. It is of the highest importance that a sufficient number of borings should be made to determine the extent and thickness of the clay deposit.

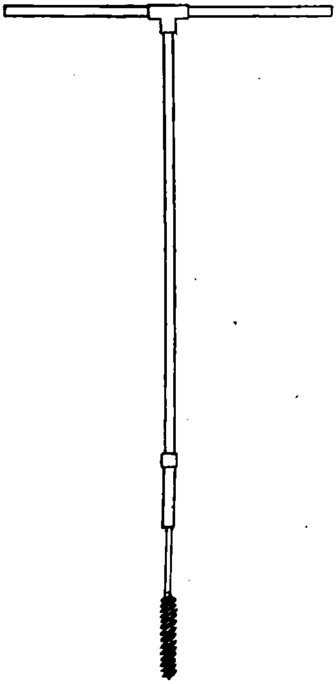


Fig. 21.
Auger used for boring clay.

From comparison of the data obtained from the bore holes and outcrops, any vertical or horizontal variations in the deposit can usually be traced. Limonite concretions or crusts, if present in any abundance, are almost sure to be discovered, and even the dryness of the beds can be ascertained. Variations in the thickness of the bed and amount of stripping are also determinable. If small samples are desired for laboratory testing these can be taken from the outcrops and bore holes, but if large samples are wanted from the intermediate points it is best to sink test pits where the borings were made.

Many of the clay miners in Middlesex county make use of the auger to guide them in their digging operations, this being often necessary on account of the rapid variations that may occur in any one deposit. The auger used in this case consists generally of one thin stem, often of square cross section and eight or ten feet long. A small handle, fastened by means of two clamps, slides up and down the stem and can be clamped at any point. As the auger is pushed deeper into the clay, the handle is unclamped and fastened higher up the stem.

ADAPTABILITY OF CLAY FOR WORKING.

Having determined the thickness, extent and character of the clay, there still remain several important points which have to be considered.

One of these is the amount of stripping. Unless the clay is of high grade it will not pay to remove much overburden unless the latter can be used. It is sometimes utilized for filling where the factory is to be erected next to the bank, or for admixture with the clay, especially if the latter is too plastic or fat. In such event, however, the overburden should be free from pebbles, or if not it should be screened. Frequent neglect of this often injures the bricks. If the overburden is clean sand, there is in some localities a market for it for foundry use, building or other purposes.

Drainage facilities must be looked out for, since dryness is essential for successful and economic working of the clay bed, In some districts, the clay is underlain by a stratum of wet sand, which should not be penetrated. In rare cases an underlying sand bed is dry and may even serve for drainage purposes, as at Fish House and City Line station, Camden. If the clay deposit lies below the level of the surrounding country, drainage will be more difficult than where the bed outcrops on a hillside, although in the latter case trouble may be and often is caused by springs.

Some banks contain several different grades of clay, and it then remains to see whether they are all of marketable character, or if not, whether the expense of separating the worthless clay will overbalance the profit derived from the salable earth.

Transportation facilities are not to be overlooked, either for the raw clay, or for the product, where the factory is located at the pit or bank. Long haulages with teams are costly, and steam haulage is far more economical when the output warrants it. But even with the establishment of favorable conditions in every case, the successful marketing of the product is sometimes a long and tedious task, for many manufacturers hesitate to experiment with new clays.

METHODS OF MINING.

The methods of mining employed are slightly different for clays and shales, the latter on account of their greater hardness requiring stronger machinery. All of what follows regarding mining methods will apply to clay, the mining of shale being referred to in a separate paragraph at the end of the section. Clays may be mined by underground methods or by open pits.

1. *Underground workings.*—This method may be resorted to when the clay bed is covered by such a great thickness of overburden that its removal would be too costly. If the bed sought outcrops on the side of a hill, a tunnel or drift is driven in along the clay bed, as shown in Fig. 22, but in case no outcrop is accessible it is necessary to sink a vertical shaft (Fig. 23) until the bed of clay is reached, and from this levels or tunnels may be driven along the clay bed.

Underground methods are desirable, however, only under certain conditions, which may be enumerated herewith:

1. In the case of high-grade clays.
2. Where there is much overburden as compared with the thickness of the clay deposit.

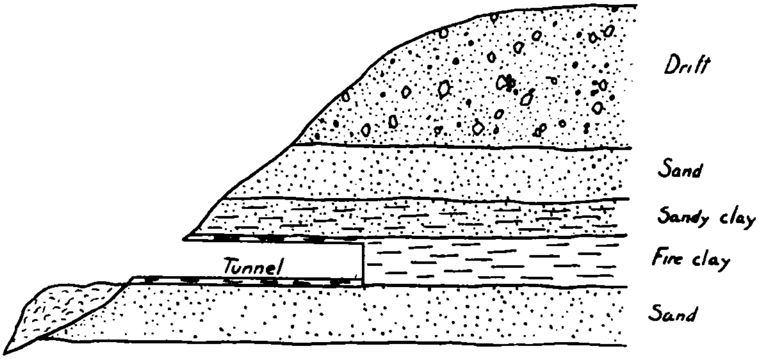


Fig. 22.

Underground method of working a deposit by a tunnel into the hillside.

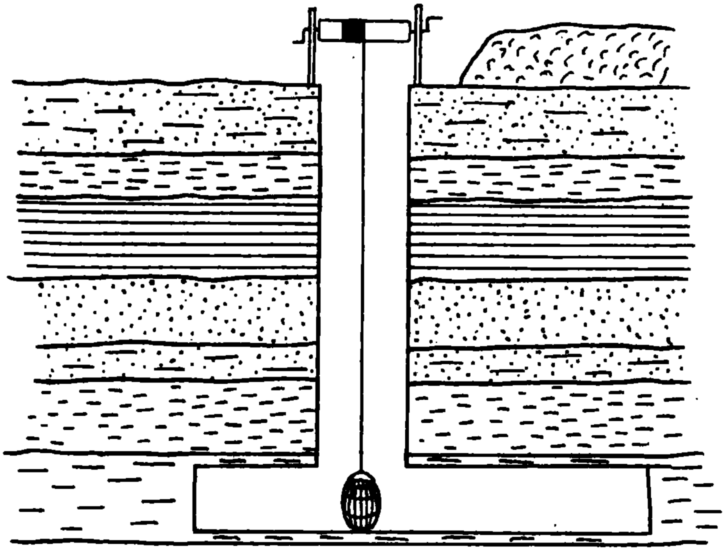


Fig. 23.

Mining clay by a shaft and tunnels.

3. There should, if possible, be a solid dense layer overlying the clay stratum, otherwise the expense of timbering for support-

ing the roof may be too great. Timbering is always necessary in underground clay work in New Jersey. Where the clay is not interstratified between dense water-tight beds, it is often necessary to leave the upper and lower foot of clay to form a roof and floor, as shown in the diagrams. (Figs. 22 and 23.)

4. The workings should be free from water, both on account of the cost of removing the same and because of the tendency of wet ground to slide.

5. The output is usually restricted, unless the workings underlie a large area, and can be worked by several shafts or drifts.

In New Jersey, underground mining has been attempted in the South Amboy district, but abandoned in most cases. No drift mining is now carried on, but shaft mining is employed at one or two points in the South Amboy district along Cheesequake creek, where the overburden is very heavy.

Surface working.—This consists in digging the material from open pits or cuts of variable size. Where the pit is small, it is commonly the custom to use picks and shovels to dig the clay, and, indeed, this method is necessary in those cases where the clay is not of uniform quality from top to bottom, or when a number of layers of different kinds, as terra-cotta, fire and stoneware clay are present. It is then necessary to strip off each one separately and place it in a separate storage pile. This is notably the custom in the Woodbridge and Perth Amboy districts of New Jersey, and the practice followed there may be described in some detail.

When a pit is to be opened, the top dirt, stripping or bearing, as it is variously called, is first removed to some place, where it will not have to be disturbed, in order to avoid the cost of a second moving, but, after one pit has been started, it is often customary to use the stripping from a new pit for filling the old one.

The cost of removing the stripping will depend on its character, whether hard or soft, the distance to be moved, and the possibility of its being used for any purpose, such as filling or grading. The methods of removal employed will also affect the expense. If the thickness of the overburden is considerable, and a large quantity has to be removed, it is cheaper to dig it with a steam shovel than by hand. Wheel scrapers are also employed at times, and, if the distance to the dump heap is short, the material can be carried there in the scraper. If the stripping can be used to mix with the clay, it is sometimes dug with shovels and screened to free it from pebbles. A method tried at some localities is to remove the sandy or gravelly overburden by washing. This is done by directing a powerful stream of water from a hose against the face or surface of the gravel and washing it down into some ditch along which it runs off.

In selecting the site for a dump heap, care should be taken not to locate it over any clay deposit which is to be worked out later, but the presence or absence of such clay under the proposed dump can commonly be determined by a few bore holes made with an auger.

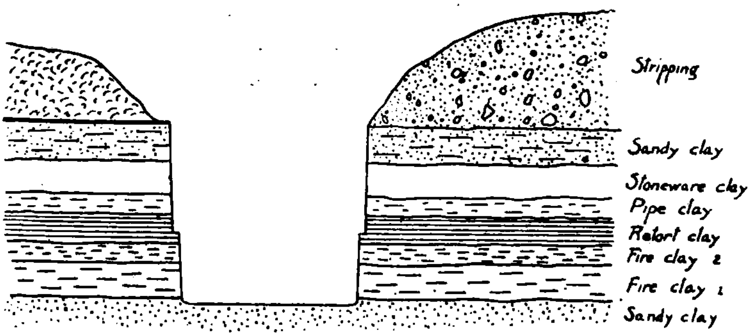


Fig. 24.
Section of pit working of Middlesex district.

In the Middlesex county district, the better grades of clay are generally dug by small pits. These are commonly square, and about ten to fifteen feet or more on a side (Fig. 24), and the depth is usually that of the thickness of the good clay in the bed. Around Woodbridge the miners commonly penetrate the No. 1 fire clay, or sometimes the extra sandy below, but the depth is oftentimes determined by the character of the ground and presence or absence of water underneath. Where there is danger of the pit caving in, the sides are sometimes protected in the weak parts by planking, held in place by cross timbers.

The clay is dug by a gouge spade, which differs from an ordinary spade in having a curved or semicylindrical blade, as well as a tread on its upper edge, to aid the digger in forcing it into the tough clay. A lump of clay dug by the pitman is termed a *spit,* and in taking out the material it is customary to dig over the area of the bottom of the pit to the depth of a spade and then begin a new *spit.* The thickness of any bed of clay, therefore, is always judged in spits.

Where a pit is dug so deep that it is not possible for the workman to throw or lift the lumps to the surface of the ground, a platform may be built in the pit, halfway up its side, or else the clay is loaded into buckets (Pl. VI) and hoisted to the surface by means of a derrick operated by steam-power or horse-power. As soon as a pit is worked out, a new one is begun next to it, but a wall of clay, 1 to 2 feet thick, is commonly left between the two. When the second pit is done, as much as possible of this wall is removed. A platform of planking is laid on one side of the pit on the ground, and the clay thrown upon this, the different grades being kept separate.

When the clay lies above the ground or road level, there is less trouble with water, and it is not necessary to work the clay in pits, although the general system of working forward in a succession of pit-like excavations or recesses is followed. In such banks, the cart or car is backed against the face of the excavation and the clay thrown into it.

Unless a number of pits are being dug at the same time, the output of any one deposit or of any one grade is necessarily small, since five or six different kinds are sometimes obtained from one pit. It would also seem that by this method any one grade of clay might show greater variation than if the excavation were more extended, for the reason that since clay beds are liable to horizontal variation, the material extracted from one pit might be different from that taken from another farther on. Against this we may, of course, argue that the clays from different pits get mixed up on the storage pile.

As these pits are small, and the time required for sinking one, viz., two or three days, is not very great, but little water runs into them, although, in some, much water comes from sand

Showing the working of clay by a deep pit. J. J. Moon, Dogtown, near Trenton.

Fig. 1.

Digging clay by means of open pits. At the top of the bank, in the background, a workman is driving a wedge into the clay in order to break it off. The clay is hauled to the yard in carts. Hackensack.

Fig. 2.

Working a clay deposit with the long working face, and loading material upon cars for haulage to the works. Winslow Junction.

or other layers that are sometimes interstratified with the clay. The surface drainage is commonly diverted by means of ditches dug around the top of the pit (Plate VIII, Fig. 2). In some districts there is a bed of water-bearing sand underlying the lowest clay dug, and, as this is approached, hand pumps have to be used to keep down the water until the last spit of clay is all taken out.

In digging a pit of clay, it is well to avoid discarding a clay of lower grade, or mixing it with the dirt stripping, because it has no market value at the time. Careless handling of the medium-grade clays in the Woodbridge and Perth Amboy districts in the early days of their activity has been the means of spoiling much clay that would now be salable.

At most other localities in the State the clay is obtained from banks or large irregular pits (Pl. VII, Figs. 1 and 2), and the run of the bank or pit is commonly used, although the clay worker may find it preferable to dig at some particular point, or points, because of local improvements in the clay. No attempt is then made to hold up the other parts of the bank, as the excavation is so large that a small amount of washing does not affect the work in other parts. Since surface waters often trickle through the soil until they reach a clay surface and follow it, there is not infrequently a series of small springs emerging along the top of a clay bank, and the water from these is usually diverted by means of properly constructed ditches. In addition to these ditches, however, it is commonly necessary to have additional ditches on the ground at the base of the bank. If the bank is high, that is seventy-five feet or more, it is safer to work it in several benches or steps, and not as a vertical face, for this will be apt to slide. Neither should the factory be located close to the base of such a bank, for there is danger of slides in case the clay becomes soaked, and the writer has seen several instances in which yards have been buried in this manner.

When clay deposits are worked as a bank or large pit, the clay is commonly dug by means of pick and shovels, but, if the scale of operations warrants, a steam shovel (Pl. VIII, Fig. 1) is far better and more economical. The latter method is used at Lorillard, Keasbey, Sayreville and South River. If the clay is tough, the material is sometimes loosened by means of a blast, but more often by undermining or falling. This is done by digging a narrow cut into the bank at its base, and then driving in a line of wedges on top, one or two feet from the edge. In this manner large masses weighing many tons are pried off and break in falling (Plate VII, Fig. 1, and XVI, Fig. 1).

Haulage.—If the distance from the bank to works or shipping point is short, wheelbarrows or one-horse carts (Plate VII, Fig. 1) are used, but, if a longer haulage is necessary, it is more economical to lay light tracks and haul the clay in cars drawn by horses or small engines. The latter method is much used around South River, Sayreville, Keasbey, Lorillard, Woodmansie and Winslow Junction. Steam haulage (Plate VII, Fig. 2) is economical for a distance of perhaps not less than 1,000 feet, and provided the locomotive is kept constantly employed.

Shale mining.—There are only two localities in this State, Port Murray, Warren County, and Kingsland, Bergen County, where shale is being mined (Pl. LVI, Fig. 1) for clay products. The shale generally has to be loosened by blasting, and can then be loaded into cars and hauled to the works. Many soft shales can, however, be easily excavated with a steam shovel.

PREPARATION OF CLAY FOR MARKET.

Unless clay is to be used for higher grades of ware, it rarely requires much preparation to make it marketable, for, since the impurities in clay often run in streaks or beds, they can be avoided in mining. Large concretions, pyrite nodules and lumps of lignite are often picked out by hand and thrown to one side. Where the impurities are present in a finely divided form and distributed throughout the clay, screening or hand picking may be ineffective, and washing is necessary. In New Jersey, this is practiced only in the case of ball clays, which are commonly prepared from a No. 1 fire clay.

Washing.—The method of washing most commonly adopted is the troughing method, in which the clay, after being stirred up and disintegrated with water, is washed into a long trough

Fig. 1.

Digging clay with a steam shovel. Sayreville.

Fig. 2.

H. Maurer & Son's pit, near Woodbridge. On the left a square pit, from which the best grade of clay is dug; the line of boards supports a soft, water-saturated layer of sand and marks the line of a drainage ditch. Wagons are removing the overburden.

along which it passes, dropping its sandy impurities on the way and finally reaching the settling vats, into which the clay and water are discharged, and where the clay finally settles.

Details.—The disintegration of the clay is generally accomplished in washing troughs. These consist of cylindrical or rectangular troughs, in which there revolves a shaft, bearing a series of arms or stirrers (Pl. IX, Fig. 1). The clay, after soaking a short time in a pit, is shoveled into the washer, into which a stream of water is also directed, and the revolving blades break up the clay so that it goes more readily into suspension. The water, with suspended clay, then passes out at the opposite end from which the water entered.

The troughing into which the material is discharged is constructed of planking and has a rectangular cross section. Its slope is very gentle, not more than 1 inch in 20 feet usually, and its total length may be from 500 to 700 feet, or even 1,000 feet. In order to economize space, it is usually built in short lengths, which are set side by side, and thus the water and clay follow a zigzag course. The pitch, width and depth of the troughing may be varied to suit the conditions, for at some localities it is necessary to remove more sand than at others. If the clay contains much very fine sand, the pitch must be less than if the sand is coarse, since fine sand will not settle in a fast current. In the case of very sandy clays, it is customary to place sand wheels at the upper end of the troughing. These are wooden wheels bearing a number of iron scoops on their periphery. As the wheel revolves the scoops pick up the coarse sand which has settled in the trough and, as the scoop reaches the upper limit of its turn on the wheel, by its inverted position, it drops the sand upon a slanting chute, which carries it outside the trough. None of the New Jersey fire clays, which are washed, contain sufficient sand to require the use of these wheels.

By the time the water reaches the end of the troughing, nearly all the sand has been dropped and the water and clay are discharged into the settling tanks (Pl. IX, Fig. 2), passing first, however, through a screen of about 80 or 100 mesh. This catches any particles of dirt or twigs and thus keeps the clay as clean as possible.

The settling tanks are of wood, usually about 4 feet deep, 8 wide and 40 or 50 feet long. As soon as one is filled, the water and clay is diverted into another. When the clay has settled, most of the clear water is drawn off, and the cream-like mass of clay and water in the bottom of the vat is drawn off by means of slip pumps and forced into the presses. These consist of flat iron or wooden frames, between which are flat canvas bags. The latter are either connected by nipples with the supply tubes, or else there may be a central opening in all the press bags and frames, which, being in line, form a central tube when the press is closed up. By means of pressure from the pumps, the slip is then forced into the press, and the water is also driven out of it. It commonly takes about two hours to fill a press. When the water has been squeezed out the press is opened, and the sheets of clay are removed from the press cloths and sent to the drying room or racks.

Air separation.—This is a method of cleansing clays which has been rarely tried, yet in some of the cases where it has been used it is said to have met with success. It is especially applicable to those clays from which it is necessary to remove simply coarse or sandy particles. The process consists, in brief, in feeding the dry clay into a pulverizer, which reduces it to the condition of a very fine powder. As the material is discharged from the pulverizer into a long box or tunnel, it is seized by a powerful current of air, which at once picks up the fine particles and carries them along to the end of the airway, where they are dropped into a bin. The coarser particles, which are too heavy to be picked up by the current, drop back and are carried through the pulverizer once more. Such a method would be especially applicable to kaolins that are free from iron, but probably would not be found adaptable to many of those containing ferruginous particles.

There are several forms of separators on the market. In the Raymond pulverizer and separator, the material is pulverized in the lower part of the machine and then thrown upward, the finer particles being carried off by a fan to the discharge hopper, the coarser ones falling back into the hopper.

Fig. 1.

Log washer for disintegrating clay before it passes to the washing troughs. Edgar's ball-clay pits. Sayreville.

Fig. 2.

View of J. R. Such's washing plant. Settling tanks in foreground, and portion of washing troughs on near side of larger tank.

CHAPTER III.

CHEMICAL PROPERTIES OF CLAY.

CONTENTS.

- Organic matter.
- Soluble salts.
  - Origin.
  - Quantity present in clays.
  - Prevention of coating.
  - Method of use.

Introductory.—A discussion of the physical properties of clay should, perhaps, have preceded a description of the chemical properties, because they are considered more important, but for the sake of clearness it is probably better to discuss the chemical ones first.

Before taking up the main theme of discussion of this chapter, it may be well to give a few explanatory statements regarding the occurrence of mineral compounds in the rocks of the earth's crust, of which the clay bearing formations are a part.

Many chemical elements are found in the rocks of the earth's crust,[1] yet only a few of them are widespread and important. But, by averaging up the analyses of several hundred rocks from all parts of the world, a fairly accurate estimate can be made of the average quantity of each element present. This has been done by F. W. Clarke, chief chemist of the United States Geological Survey, and the results obtained by him are given in the following table. The name of the element is given first, followed by its symbol in parenthesis, and then the average per cent.

Table showing percentage of elements found in the earth's crust.

Oxygen (O), ...	47.02	Hydrogen (H), ...	0.17
Silicon (Si), ...	28.06	Carbon (C), ...	0.12
Aluminum (Al), ...	8.16	Phosphorus (P), ...	0.09
Iron (Fe), ...	4.64	Manganese (Mn), ...	0.07
Calcium (Ca), ...	3.50	Sulphur (S), ...	0.07
Magnesium (Mg), ...	2.62	Barium (Ba), ...	0.05
Sodium (Na), ...	2.63	Strontium (Sr), ...	0.02
Potassium (K), ...	2.32	Chromium (Cr), ...	0.01
Titanium (Ti), ...	0.41		

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[1] For the benefit of those who have not studied geology it may be stated that the earth was probably originally a nebula. As this cooled many of the gaseous elements became molten solids and finally cooled to solid rock. The watery vapor surrounding this early globe condensed eventually to form

Of those mentioned in the above list, carbon and sulphur are the only ones ever found in the elementary condition in clays. The others are usually found in combination with each other. Thus, for example, silicon unites with oxygen to form the compound known as silica, which consists of one atom of silicon and two atoms of oxygen, and which would be designated by the symbol SiO_2. Similarly, two of aluminum will unite with three of oxygen, forming the compound known as alumina and represented by the symbol Al_2O_3; again, iron in similar combination may give either FeO or Fe_2O_3; or CaO (lime) may be formed from calcium and oxygen. Carbon and oxygen form CO_2, known as carbon dioxide or carbonic acid gas. If the latter unites with CaO, we get a compound expressed by the symbol $CaCO_3$, and called lime carbonate; CaO and SiO_2 may unite, giving $CaSiO_3$, which is called a silicate of lime, because it is a compound containing calcium, silicon and oxygen.

The elements are divisible into two groups, the one known as acid elements, the other as basic elements or bases. The latter are commonly oxides of the metallic elements, and include CaO (lime), MgO (Magnesia), Al_2O_3 (alumina), Fe_2O_3 (ferric oxide), K_2O (potash), Na_2O (soda). The acids and bases are strongly opposed in their characters, and, while there is little or no affinity between members of the same group, those of opposite groups show a marked affinity for each other. An acid, therefore, tends to unite with a base under favorable conditions, these conditions being either the presence of moisture or heat, both of which promote chemical activity and combination. Compounds formed by the union of acid elements and basic elements are termed salts, and the different ones possess a different degree of permanence or destructibility. Thus, some exist only at low temperatures, and are broken up or pass off in gaseous form at a red heat, while others may form only at a temperature of redness or higher.

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oceans, and those portions of the original rocks which projected above the ocean were attacked by the weather, in the same manner as described on pages 4-6, the products of rock decay being washed down into the seas, where they were deposited as sediments. The elements of the original rocks would, therefore, be found partly in these sediments and partly in solution in the sea water.

Clays contain a great many different chemical compounds of more or less definite chemical composition, and often having a definite form. Each of these represents a mineral species, possessing definite physical characters, which could be easily seen if the grains of clay were large enough. The latter is the case, however, with only a few of the scattered, coarse grains, which a clay may contain, and, consequently, it is necessary to use a microscope in order to identify the various mineral grains present in any clay, as even a powerful hand glass cannot ordinarily distinguish them.

MINERALS FOUND IN CLAY.

The number of different minerals present in a clay is often large and depends partly on the mineralogical composition of the rock or rocks from which the clay has been derived, and partly on the extent to which the mineral grains in the clay have been destroyed by weathering. As the result of this weathering action, new minerals are sometimes formed, and we can thus recognize two groups of minerals in the clay, viz., primary and secondary constituents. Those which are probably in most cases of primary character include quartz, feldspar, calcite, gypsum, mica, pyrite, dolomite, iron ores, hornblende and rutile. The chief secondary ones are kaolinite, together with closely allied mineral species and limonite, but calcite, quartz,[1] gypsum and pyrite may also be of secondary origin.

Quartz.—This mineral, which is silica chemically, is found in at least small quantities in nearly every clay, whether residual or sedimentary, but the grains are rarely large enough to be seen with the naked eye. They are translucent or transparent, usually of angular form in residual clays, and rounded in sedimentary ones, on account of the rolling they have received while being washed along the river channel to the sea, or dashed about by the waves on the beach previous to their deposition in deeper still water. Quartz may be colorless, but it is often colored

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[1] Some writers argue that much of the quartz found in soil is of secondary origin, but this is often difficult to prove.

superficially red or yellow by iron oxide. It breaks with a glassy, shell-like fracture, and is a very hard mineral, being seven in the scale of hardness.[1] It will, therefore, scratch glass, and is much harder than most of the other minerals commonly found in clay, with the exception of feldspar. Quartz at times forms nodules, which have no crystalline structure, and are termed flint. These are sometimes seen in the Pensauken gravels of the State. Quartz pebbles are not at all uncommon in some of the Cape May and Cohansey clays, and most of the sand grains found in the coarse, gritty surface clays are quartz. This mineral also forms most of the hard pebbles found in the "feldspar" beds of the Woodbridge district.

Both quartz and flint are highly refractory, being fusible only at cone 35 of the Seger series (see Fusibility, Chap. IV), but the presence of other minerals in the clay may exert a fluxing action and cause the quartz to soften at a much lower temperature. (See Silica, below, and also The Fire Clays and Fire-Brick Industry, Chap. XVI.)

Feldspar.—Feldspar is a mineral of rather complex composition, being a mixture of silica and alumina, with either potash, or with lime and soda, and occurring usually in red, pink or white grains. When fresh and undecomposed, the grains have a bright lustre, and split off with flat surfaces or cleavages. Feldspar is slightly softer than quartz, and while the latter, as already mentioned, scratches glass, the former will not. Feldspar rarely occurs in such large grains as quartz, and, furthermore, is not as lasting a mineral, being easily attacked by the weather or soil waters, and so decomposed to a whitish clay. This change can be seen in the so-called "feldspar" deposits of the Woodbridge district, which were originally a mixture of quartz and feldspar pebbles; the latter, however, have been mostly changed to kaolinite, and it is possible to find pieces showing all stages in the change from feldspar to kaolin in the same bank.

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[1] The hardness of minerals is expressed in terms of Mohs' scale, which is made up of ten minerals, No. 1 being the softest and No. 10 the hardest. The series includes the following minerals: 1, Talc; 2, Gypsum; 3, Calcite; 4, Fluorite; 5, Apatite; 6, Orthoclase; 7, Quartz; 8, Topaz; 9, Corundum; 10, Diamond.

There are several species of feldspar, which vary somewhat in their chemical composition, and are known by different names, as shown below.

Composition of Feldspars.

	Chemical composition.				
Feldspar species.	*Silica.*	*Alumina.*	*Potash.*	*Soda.*	*Lime.*
Orthoclase,	64.70	18.40	16.90	....	....
Albite,	68.00	20.00	....	12.00	12.00
Oligoclase,	62.00	24.00	....	9.00	5.00
Labradorite,	53.00	30.00	....	4.00	13.00
Anorthite,	43.00	37.00	....	....	20.00

Mica.—This is one of the few minerals in clay that can be easily detected with the naked eye, for it occurs commonly in the form of thin, scaly particles, whose bright shining surface renders them very conspicuous, even when small. Very few clays are entirely free from mica, even in their washed condition, for, on account of the light scaly character of the mineral, it floats off with the clay particles. The so-called "kaolins" of the Woodbridge district contain much mica, and it is also noticeable in the hollow-ware clays used along the Raritan river, as well as in Clay Marl I. Mica is rarely seen in the Alloway and Cape May clays.

There are several species of mica, all of rather complex composition, but all silicates of alumina, with other bases. Two of the commonest species are the white mica or muscovite, and the black mica or biotite. The former is a silicate of alumina and potash, and the latter a silicate of alumina, iron oxide and magnesia. Of these two, the muscovite is the most abundant in clay, because it is not readily attacked by the weathering agents. The biotite, on the other hand, rusts and decomposes much more rapidly on account of the iron oxide which it contains. The effect of mica in burning is mentioned under alkalies.

Iron Ores.—This title includes a series of iron compounds, which are sometimes grouped under the above heading, because they are the same compounds that serve as ores of iron, when found in a sufficiently concentrated form. The mineral species included under this head are:

Limonite, ($2Fe_2O_3,3H_2O$).
Hematite (Fe_2O_3).
Magnetite (Fe_3O_4).
Siderite ($FeCO_3$).

The first is an oxide, with three parts of water (a hydrous oxide), the second and third are oxides, and the fourth is a carbonate.

Limonite.—This has the same composition as iron rust. It occurs in various forms, and is often widely distributed in many clays, its presence being shown by the yellow or brown color of the material. When the clay is uniformly colored, the limonite is evenly distributed through it, sometimes forming a mere film on the surface of the grains; at other times it is collected into small rusty grains, or again forms concretionary masses of spherical or irregular shape; in still other clays it is found in the form of stringers and crusts, extending through the clay in many directions (Pl. II, Fig. 2). These crusts are common in some portions of Clay Marl II, as at Collingswood, or occasionally also in the Miocene clays. The concretions are abundant in some of the weathered clays at Lorillard, and the beds of sandstone, found in many of the sand and gravel deposits associated with the clays, are caused by limonite cementing the sand grains together.

Hematite, the oxide of iron, is of a red color and may be found in clays, but it changes readily to limonite on exposure to the air and in the presence of moisture.

Magnetite, the magnetic oxide of iron, forms black magnetic grains, and, while not common, is sometimes found when the material is examined microscopically. Like the hematite, it changes to limonite.

Siderite, the carbonate of iron, may occur in clay in the following forms: 1. As concretionary masses of variable size and shape, often strung out in lines parallel with the stratification of the clay. These are more abundant in shales than in clay, and, if near the surface, the siderite concretions change to limonite on their outer surface. 2. In the form of crystalline grains, scattered through the clay and rarely visible to the naked eye. 3. As a film coating other mineral grains in the clay.

This mineral will also change to limonite, if exposed to the weather.

Pyrite.—This is another mineral, which is not uncommon in some clays, and can be often seen by the naked eye. It is sometimes called ***iron pyrites***, or ***sulphur***, and, chemically, is a sulphide of iron (FeS_2). It has a yellow color and metallic lustre, and occurs in large lumps, in small grains or cubes, or again in flat rosette-like forms. Not infrequently it is formed on or around lumps of lignite, and is a familiar object to all the clay miners of the Woodbridge district, and other districts where clays of the Raritan formation are dug, but it is rare in other New Jersey clays.

When exposed to weathering action, pyrite is a rather unstable compound, that is to say, it tends to alter, and changes from the sulphide of iron (FeS_2) to the sulphate of iron ($FeSO_4$), by taking oxygen from the waters filtering into the clay. This also destroys its form, the yellow metallic particles changing to a white powdery mineral, which has a bitter taste and is soluble in water. Clays containing pyrite are not, as a rule, desired by the potters. (See Soluble Salts.)

Glauconite.—This mineral, which is sometimes termed greensand, and in bulk greensand marl or simply marl, is an important one in some of the New Jersey clays. Chemically, it is a compound containing silica, potash, iron and water (a hydrous silicate of potash and iron), occurring in the form of greenish sandy grains. Its composition is often somewhat variable, and it may contain other ingredients as impurities. Thus a sample from New Jersey[1] analyzed: Silica, 50.70 per cent.; Alumina, 8.03 per cent.; iron oxide, 22.50 per cent.; magnesia, 2.16 per cent.; lime, 1.11 per cent.; potash, 5.86 per cent.; soda, 0.75 per cent.; water, 8.95 per cent. It is an easily fusible mineral, and hence a high percentage of it is not desired in a clay. Greensand is restricted[2] to the clays of the Clay Marl series, and is most abundant in Clay Marl I.

Kaolinite.—This mineral is a compound of silica, alumina and water (a hydrated silicate of alumina), represented by the

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[1] Dana, System of Mineralogy, p. 684.

[2] In so far as it occurs in New Jersey *clays*.

formula of Al_2O_3, $2SiO_2$, $2H_2O$, which corresponds to a composition of Silica (SiO_2), 46.3 per cent.; Alumina (Al_2O_3), 39.8 per cent.; Water (H_2O), 13.9 per cent. It is rarely found in pure masses, but when isolated is found to be a white, pearly mineral, the crystals forming small hexagonal plates, which are often found to be collected into little bunches, that can be separated by grinding. When the mineral *kaolinite* forms large masses, the name of *kaolin* is applied to it.[1] It is plastic, and is also highly refractory, fusing at cone 36. The amount of kaolinite present in clays varies, some white kaolins containing over 98 per cent., while other sandy impure clays may have less than 20 per cent.

Associated with kaolinite, there have been found one or more species of allied minerals, which are all hydrated silicates of alumina. They are known as halloysite, rectorite, newtonite, allophane, etc. Some have been found in the form of crystals, and others have not.

Rutile.—The oxide of titanium (TiO_2) rutile is of widespread occurrence in clays, and is usually found on chemical analysis, when proper tests are made. Rutile grains can be seen under the microscope in many fire clays, and the analyses show the presence of titanium oxide to the extent of nearly two per cent.[2] The presence of this mineral, however, is unfortunately too commonly ignored in the analysis of clay, and yet, as will be shown later, its effect on the fusibility of the clay is such that it should not be neglected in the higher grades, at least.

Calcite.—This mineral is composed of carbonate of lime, and, when abundant, is found chiefly in clays of recent geological age, but some shales also contain considerable quantities of it. It can be easily detected for it dissolves rapidly in weak acids, and effervesces violently upon the application of a drop of muriatic acid or even vinegar. When in grains large enough to be seen with the naked eye, it is found to be a translucent

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[1] The material termed kaolin, which is found in the Woodbridge district of New Jersey, is not such, but a quartz sand with a considerable percentage of white mica and clay.

[2] See the Fire Clays and Fire-Brick Industry, Chap. XVI.

mineral with a tendency to split into rhombohedral fragments, due to the presence in it of several directions of splitting or cleavage; it is also soft enough to be easily scratched with a knife. Few clays contain grains of calcite sufficiently large to be seen with the naked eye, although in some the calcite, as well as some other minerals, may form concretions.[1] In some swamps, clay beds are found which are highly charged with lime carbonate, and known as marl (not to be confused with the Greensand marls of the Cretaceous). Very little lime carbonate is found in the New Jersey clays, except in those of glacial origin.

Gypsum.—This mineral, the hydrous sulphate of lime, contains lime (CaO, 32.6 per cent.), sulphuric acid (SO_3, 46.5 per cent.) and water (H_2O, 20.9 per cent.). It may occur in clays, even in large lumps, but, so far as known, these have not been found in New Jersey. Gypsum, when present in clay, and large enough to be visible without the use of a microscope, forms crystals or plate-like masses. It is much softer than calcite and can be scratched with the finger nail, has a pearly lustre, is transparent, and does not effervesce with acid or vinegar. When heated to a temperature of 250° C. (482° F.), the gypsum loses its water of combination, and, when burned to a still higher temperature, at least a part of the sulphuric acid passes off.

Hornblende and Garnet.—These are both silicate minerals of complex composition, which are probably abundant in many impure clays, but their grains are rarely larger than microscopic size. Both are easily fusible and weather readily, on account of the iron oxide in them, and, therefore, impart a deep red color to clays formed from rocks in which they are a prominent constituent.

Dolomite.—Dolomite, the double carbonate of lime and magnesia, and also magnesite, the carbonate of magnesia, may both occur in clay. They are soft minerals resembling calcite, and either alone is highly refractory, but, when mixed with other minerals, they exert a fluxing action, although not at so low a temperature as lime.

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[1] See Limonite, Siderite.

THE CHEMICAL ANALYSIS OF CLAYS.

There are two methods of quantitatively analyzing clays. One of these is termed the ultimate analysis, the other is known as the rational analysis.

The ultimate analysis.[1]—In this method of analysis, which is the one usually employed, the various ingredients of a clay are considered to exist as oxides, although they may really be present in much more complex forms. Thus, for example, calcium carbonate ($CaCO_3$), if it were present, is not expressed as such, but instead it is considered as broken up into carbon dioxide (CO_2) and lime (CaO), with the percentage of each given separately. The sum of these two percentages would, however, be equal to the amount of lime carbonate present. While the ultimate analysis, therefore, fails to indicate definitely what compounds are present in the clay, still there are many facts to be gained from it.

The ultimate analysis of a clay might be expressed as follows:

		Silica,	(SiO_2)
		Alumina,	(Al_2O_3)
Fluxing impurities,		Ferric oxide,	(Fe_2O_3)
		Lime,	(CaO)
		Magnesia,	(MgO)
	Alkalies,	Potash,	(K_2O)
		Soda,	(Na_2O)
		Titanic oxide,	(TiO_2)
		Sulphur trioxide,	(SO_3)
		Carbon dioxide,	(CO_2)
		Water,	(H_2O)

In most analyses, the first seven of these and the last one are usually determined. The percentage of carbon dioxide is usually small, and commonly remains undetermined, except in very calcareous clays. Titanic oxide is rarely looked for, except in fire clays, and even here its presence is frequently neglected. Since the sulphur trioxide, carbon dioxide and water are volatile at a

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[1] The method followed was in general that given by Hillebrand, in Bulletin 176 of the United States Geological Survey.

red heat, they are often determined collectively and expressed as *"Loss on ignition."* If carbonaceous matter, such as lignite, is present this also will burn off at redness. To separate these four, special methods are necessary, but they are rarely applied, and, in fact, are not very necessary, except in calcareous clays, or black clays. The loss on ignition in the majority of *dry*[1] clays is chiefly chemically combined water. The ferric oxide, lime, magnesia, potash and soda are termed the fluxing impurities, and their effects are discussed under the head of iron, lime, magnesia, etc., and also under Fusibility, in Chapter IV.

As can be seen from the experiments described in Chapter IV, all clays contain a small but variable amount of moisture in their pores, which can be driven off at 100° C. (212° F.). In order, therefore, to obtain results that can be easily compared, it is desirable to make the analysis on a moisture-free sample, which has been previously dried in a hot-air bath. This is unfortunately not universally done.

The facts obtainable from the ultimate analysis of a clay are the following:

1. The purity of the clay, showing the proportions of silica, alumina, combined water and fluxing impurities. High-grade clays show a percentage of silica, alumina and water, approaching quite closely to those of kaolinite (pp. 46, 47).

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

3. The color to which the clay burns. This may be judged approximately, for clays with several per cent. or more of ferric oxide will burn red, provided the iron is evenly and finely distributed in the clay, and there is no excess of lime. The above conditions will be affected by a reducing atmosphere in burning, or the presence of sulphur in the fire gases.[2]

4. The quantity of water. Clays with a large amount of chemically combined water sometimes exhibit a tendency to

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[1] This means dried at 100° C. until their weight is constant. See under Moisture.

[2] See Lime in this chapter.

crack in burning, and may also show high shrinkage. If kaolinite is the only mineral present containing chemically combined water, the percentage of the latter will be approximately one-third that of the percentage of alumina, but if the clay contains much limonite or hydrous silica the percentage of chemically combined water may be much higher.[1]

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

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

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

These are the main points determinable from the ultimate analysis.

Analyses of several different types of clay:

	1	*2*	*3*	*4*	*5*	*6*
Silica (SiO_2), ...	46.3	46.11	61.6	56.10	60.18	46.55
Alumina (Al_2O_3), ...	39.8	39.55	28.38	27.42	23.23	12.66
Ferric oxide (Fe_2O_3), ...	...	0.35	0.52	2.68	3.27	4.92
Lime (CaO), ...	...	....	0.46	....	1.00	14.02
Magnesia (MgO), ...	...	0.13	0.36	0.18	.67	4.67
Potash (K_2O), ...	...	....	....	2.71	2.58	2.05
Soda (Na_2O), ...	...	....	....		.80	
Water (H_2O), ...	13.9	13.78	....	6.00	...under CO_2	
Sulphur trioxide (SO_3),...	...	0.07	....	....	....	....
Loss on ignition, ...	...	....	5.08	....	8.54	....
Titanium Oxide (TiO_2),...	...	....	3.60	1.00	....	....
Moisture, ...	...	....	....	2.90	....	....
Carbon dioxide (CO_2), ...	...	....	....	....	....	14.92
	100.00	99.99	100.00	98.99	100.27	99.79

1. Kaolinite.
2. Ball clay, Edgar, Florida.
3. Fire clay, Woodbridge, N. J., W. B. Dixon Est.
4. A buff-burning clay, Sayreville, N. J.

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[1] See analysis of yellow clay from Tilton's yard, Toms River (Loc. 206), Chapter XIX, Ocean County.

5. A red-burning brick clay, Sayreville, N. J.
6. A calcareous clay, Canandaigua, N. Y.

Rational analysis.[1]—This method has for its object the determination of the percentage of the different mineral compounds present, such as quartz, feldspar, kaolinite, etc., and gives us a much better conception of the true character of the material. Most kaolins and other high-grade clays consist chiefly of kaolinite, quartz and feldspar, the kaolinite forming the finest particles of the mass, while the balance is quartz, feldspar and perhaps some mica. The finest particles are known as the clay substance, which may be looked upon as having the properties of kaolinite. Now, as each of these three compounds of the kaolin—clay substance, quartz and feldspar—have characteristic properties, the kaolin will vary in its behavior according as one or the other of these constituents predominates or tends to increase.

As to the characters of these three, quartz is nearly infusible, nonplastic, has very little shrinkage, and is of low tensile strength; feldspar is easily fusible, and alone has little plasticity; kaolinite is plastic and quite refractory, but shrinks considerably in burning. The mica, if extremely fine, may serve as a flux, and even alone is not refractory. It is less plastic than the kaolinite, and, when the percentage of it does not exceed 1 or 2 per cent., it can be neglected. To illustrate the value of a rational analysis, we can take the following example: Porcelain is made from a mixture of kaolin, quartz and feldspar. Suppose that a manufacturer of porcelain is using a kaolin of the following rational composition:

Clay substance,	67.82%
Quartz,	30.93%
Feldspar,	1.25%

If now to 100 parts of this there are added 50 parts of feldspar, it would give a mixture whose composition is:

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[1] The method is described in the Manual of Ceramic Calculations, issued by the American Ceramic Society. See also Langenbeck, Chemistry of Pottery, 1895, p. 8.

Clay substance,	45.21%
Quartz,	20.62%
Feldspar,	34.17%

If, however, it became necessary to substitute for the one in use a new kaolin, which had a composition of:

Clay substance,	66.33%
Quartz,	15.61%
Feldspar,	18.91%

and added the same quantity of it as we did of the old kaolin, it would change the rational analysis of the body to the following proportions:

Clay substance,	44.22%
Quartz,	10.41%
Feldspar,	45.98%

Such an increase of feldspar, as shown by this formula, would greatly increase the fusibility and shrinkage of the mixture; but, knowing the rational composition of the new clay, it would be easy, by making a simple calculation, to ascertain how much quartz and feldspar should be added to bring the mixture back to its normal composition.

The rational composition of a clay can be determined from an ultimate analysis, but the process of analysis and calculation becomes much more complex. The rational analysis is furthermore useful only in connection with mixtures of high-grade clays, in which the variation of the ingredients can only be within comparatively narrow limits. For ordinary purposes the ultimate analysis is of greater value.

Clays may agree closely in their ultimate analysis, and still differ widely in their rational composition.

MINERAL COMPOUNDS IN CLAY AND THEIR CHEMICAL EFFECTS.

All the constituents of clay influence its behavior in one way or another, their effect being often noticeable when only small amounts are present. Their influence can perhaps be best discussed individually.

Silica.[1]

This is present in clay in two different forms, viz., uncombined as silica or quartz, and in silicates, of which there are several. Of these one of the most important is the mineral kaolinite, which is found in all clays and is termed the clay base or clay substance. The other silicates include feldspar, mica, glauconite, hornblende, garnet, etc. These two modes of occurrence of silica, however, are not always distinguished in the ultimate analysis of a clay, but when this is done, they are commonly designated as "Free" and "Combined silica," the former referring to all silica except that contained in the kaolinite, which is indicated by the latter term. This is an unfortunate custom, for the silica in silicates is properly speaking combined silica, just as much as that contained in the kaolinite. A better practice is to use the term sand to include quartz and silicate minerals, other than kaolinite, which are not decomposable by sulphuric acid. In the majority of analyses, however, the silica from both groups of minerals is expressed collectively as total silica.

The percentage of both quartz and total silica found in clays varies between wide limits, as can be seen from the following examples. Wheeler gives a minimum[2] of 5 per cent. in the flint clays, and the sand percentage as 20 per cent. to 43 per cent. in the St. Louis fire clays, and 20 per cent. to 50 per cent. in the loess clays. Twenty-seven samples of Alabama clays analyzed by the writer contained from 5 per cent. to 50 per cent. of insoluble residue mostly quartz.[3] In seventy North Carolina clays[4] the insoluble sand ranged from 15.15 per cent. to 70.43 per cent.

The following table[5] gives the variation of total silica in several classes of clays, the results being obtained from several hundred analyses:

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[1] See also description of the minerals quartz, feldspar, kaolinite, and mica above.

[2] Mo. Geol. Surv., Vol. XI, p. 54.

[3] Ala. Geol. Survey, Bull. No. 6, 1900.

[4] N. Car. Geol. Survey, Bull. No. 13, p. 24, 1898.

[5] Bull. N. Y. State Museum, No. 35, p. 525.

Amount of Silica in Clays.

Kind of clay.	*Per cent. of total silica.* *Min.*	*Max.*	*Aver.*
Brick clays,	34.35	90.877	59.27
Pottery clays,	45.06	86.98	45.83
Fire clays,	34.40	96.79	54.304
Kaolins,	32.44	81.18	55.44

With the exception of kaolinite, all of the silica-bearing minerals mentioned above are of rather sandy or silty character, and, therefore, their effect on the plasticity and shrinkage will be similar to that of quartz. In burning the clay, however, the general tendency of all is to affect the shrinkage and also the fusibility of the clay, but their behavior is in the latter respect more individual.

Sand (quartz and silicates) is an important antishrinkage agent, which greatly diminishes the air shrinkage, plasticity and tensile strength of clay, its effect in this respect increasing with the coarseness of the material; clays containing a high percentage of very finely divided sand (silt) may absorb considerable water in mixing, but show a low air shrinkage. The brickmaker recognizes the value of the effects mentioned above and adds sand or loam to his clay, and the potter brings about similar results in his mixture by the use of ground flint.

In considering the effects of sand in the burning of clays, it must be first stated that the quartz and silicates fuse at different temperatures, and each changes its form but little up to its fusion point. A very sandy clay will, therefore, have a low fire shrinkage as long as none of the sand grains fuse, but when fusion begins a shrinkage of the mass occurs. We should, therefore, expect a low fire shrinkage to continue to a higher temperature in a clay whose sand grains are refractory.

Of the different minerals to be included under sand, the glauconite is the most easily fusible, followed by hornblende and garnet, mica (if very fine grained), feldspar and quartz. The glauconite would, therefore, other things being equal, act as an antishrinkage agent only at low temperatures. Variation in the size of the grain may affect these results, but this point is discussed under *Fusibility* (Chapter IV).

Iron Oxide.

Sources of iron oxide in clays.—Iron oxide is one of the commonest ingredients of clay, and a number of different mineral species may serve as sources of it, the most important of which are grouped below:

Hydrous oxide. Limonite.
Oxides. Hematite, magnetite.
Silicates. Biotite, glauconite (greensand), hornblende, garnet.
Sulphides. Pyrite.
Carbonates. Siderite.

In some, such as the oxides, the iron is combined only with oxygen, and is better prepared to enter into chemical combination with other elements in the clay when fusion begins. In the case of the sulphides and carbonates, on the contrary, the volatile elements, viz., the sulphuric acid gas of the pyrite and the carbonic acid gas of the siderite, have to be driven off before the iron contained in them is ready to enter into similar union. In the silicates, the iron is chemically combined with silica and several bases, forming mixtures of rather complex composition and all of them of low fusibility, particularly the glauconite. Several of these silicates are easily decomposed by the action of the weather, and the iron oxide which they contain combines with water to form limonite.

The range of ferric oxide as determined from a number of clay analyses is as follows:[1]

Amount of Ferric Oxide in Clays.

Kind of clay.	*Min.*	*Max.*	*Aver.*
Brick clays,	0.126	32.12	5.311
Fire clays,	0.01	7.24	1.506
Kaolins,	....	6.87	1.29

Effects of iron compounds.—Iron is the great coloring agent of both burned and unburned clays. It may also serve as a flux and even affect the absorption and shrinkage of the material.

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[1] Bull. N. Y. State Museum, No. 35. p. 520.

Coloring action of iron in unburned clay.—Many clays show a yellow or brown coloration due to the presence of limonite, and a red coloration due to hematite; magnetite is rarely present in sufficient quantity to color the clay; siderite or pyrite may color it gray, and it is probable that the green color of many clays is caused by the presence of silicate of iron. In New Jersey this is specially true of glauconitic clays. The intensity of color is not always an indication of the amount of iron present, since the same quantity of iron oxide may, for example, color a sandy clay more intensely than a fine grained one, provided both are nearly free from carbonaceous matter; the latter, if present in sufficient quantity, may even mask the iron coloration completely. The coloring action will moreover be effective only when the iron is evenly distributed through a clay in an extremely fine form. It is probable that the limonite coloring clays, is present in an amorphous or noncrystalline form, and forms a coating on the surface of the grains.

Coloring action of iron oxide on burned clay.—All of the iron ores will in burning change to the form of oxide, provided the clay is not vitrified, and so affect the color of the burned material; if vitrification occurs, the iron oxide enters into the formation of silicates of complex composition. The color and depth of shade produced by the iron will, however, depend on 1st, the amount of iron in the clay; 2d, the temperature of burning; 3d, condition of the iron oxide, and 4th, the condition of the kiln atmosphere.

1. Clay perfectly free from iron oxide burns white. If a small quantity, say 1 per cent., is present, a slightly yellowish tinge is imparted to the burned material, but an increase in the iron contents to 2 or 3 per cent. produces a buff product, while 4 or 5 per cent. of iron oxide makes the clay burn red.

2. If a clay is heated at successively higher temperatures, it is found that, other things being equal, the color usually deepens as the temperature rises. Thus if a clay containing 4 per cent. of iron oxide is burned at a low temperature, it will be pale red, and harder firing will be necessary to develop a good brick red, which will pass into a deep red and then reddish purple.

3. Among the oxides of iron, two kinds are recognized, known respectively as the ferrous oxide (FeO) and ferric oxide

(Fe_2O_3). In the former we see one part of iron united with one of oxygen, while in the latter one part of iron is combined with one and one-half parts of oxygen. The ferric oxide, therefore, contains more oxygen per unit of iron than the ferrous salt, and represents a higher stage of oxidation. In the limonite and hematite the iron is in the ferric form, representing a higher stage of oxidation. In magnetite both ferrous and ferric iron are present, but in siderite the ferrous iron alone occurs. In the ultimate chemical analysis the iron is usually determined as ferric oxide, no effort being made to find out the quantity present as carbonate or sulphide.

Iron passes rather readily from the ferric to the ferrous form and vice versa. Thus, if there is a deficit of oxygen in the inside of the kiln, the iron does not get enough oxygen and the ferrous compound results, but the latter changes at once to the ferric condition, if sufficient air carrying oxygen is admitted. Similarly if ferric oxide is present in a clay containing considerable carbonaceous matter, the latter will, if it cannot get enough oxygen from the kiln atmosphere, take it from the ferric oxide and so reduce the latter to the ferrous condition. The same change may be produced by smoky fires. The necessity for recognizing these two forms of iron oxide is because they affect the color of the clay differently. Ferrous oxide alone is said to produce a green color when burned, while ferric oxide alone may give purple or red, and mixtures of the two may produce yellow, cherry red, violet, blue and black.[1] Seger[2] found that combinations of ferric oxide with silica produced a yellow or red color in the burned clay. We may thus get a variation in the color produced in burning clay depending on the character of oxidation of the iron, or by mixtures of the two oxides.[3]

It is found sometimes that bricks after burning show a black core, due to the iron in the centre of the brick being prevented from oxidizing, but this should not be confused with the black coloration seen on the ends of many arch brick, which is caused by the slagging action of the impurities in the fuel.[4]

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[1] Keramic, p. 256.

[2] Notizblatt, 1874, p. 16.

[3] See "Flashing of brick," Chap. X, and "Burning pottery," Chap. XV.

[4] See "Burning bricks," Chap. X.

4. Since the stage of oxidation of the iron is dependent on the quantity of air it receives during burning, the condition of the kiln atmosphere is of great importance. If there is a deficiency of oxygen in the kiln so that the iron oxide, if present, is reduced to the ferrous condition, the fire is said to be *reducing*. If on the contrary there is an excess of oxygen, so that ferric oxides are formed, the fire is said to be *oxidizing*. These various conditions are often used by the manufacturer to produce certain shades or color effects in his ware. Thus, for example, the manufacturer of flashed brick produces the beautiful shading on the surface of his product by having a *reducing* atmosphere in his kiln followed by an *oxidizing* one. The potter aims to reduce the yellow tint in his white ware by cooling the kiln as quickly as possible to prevent the iron from oxidizing.

Fluxing action of iron oxide.—Iron oxide is a fluxing impurity, lowering the fusing point of a clay, and this effect will be more pronounced if the iron is in a ferrous condition or if silica is present. A low iron content is, therefore, desirable in refractory clays, and the average of a number of analyses of these shows it to be 1.3 per cent. Brick clays, which are usually easily fusible, contain from 3 to 7 per cent. of iron oxide.

Effect of iron oxide on absorptive power and shrinkage of clay.—So far as the writer is aware no experiments have been made to discover the increased absorptive power of a clay containing limonite, although the clay soils show that the quantity of water absorbed is greater with limonite present. This greater absorptive power may be accompanied by an increased shrinkage. The fire shrinkage might also be great because of the increased loss of combined water due to the presence of limonite.[1]

Lime.

Lime is found in many clays, and in the low-grade ones may be present in large quantities at times. Quite a large number of minerals may serve as sources of lime in clays, but all fall into one of the three following groups:

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[1] See tests, under Fire shrinkage, Chap. IV.

1. Carbonates. Calcite, dolomite.
2. Silicates containing lime, such as feldspar, garnet.
3. Sulphates. Gypsum.

Whenever the ultimate analysis of a clay shows several per cent. of lime (CaO), it is usually there as an ingredient of lime carbonate ($CaCO_3$), and in such cases its presence can be easily detected by putting a drop of muriatic acid or vinegar on the clay.[1] When present in this form it is apt to be finely divided, although it may occur as concretions or limestone pebbles; in either case, it is usually restricted to drift clays, especially in New Jersey.

When lime is present as an ingredient of silicate minerals, such as those mentioned above, its presence cannot be detected with muriatic acid. It is doubtful, however, if many calcareous clays contain much lime in this combination, and the fact that practically all limy clays, shown to be such on chemical analysis, give a strong test with muriatic acid, strengthens this theory. Gypsum, which is found in a few clays, is often of secondary character, having been formed by the action of sulphuric acid on lime-bearing minerals in the clay. Since these three groups of minerals behave somewhat differently, their effects will be discussed separately.

Effect of lime carbonate on clay.—Lime is probably most effective in the form of the carbonate. When clays containing it are burned, they not only lose their chemically combined water, but also their carbon dioxide, but while the water of hydration passes off between 450° C (842° F.) and 600° C (1112° F.), the carbon dioxide (CO_2) does not seem to go off until between 600° C. (1112° F.) and 725° C. (1562° F.). In fact it more probably passes off between 850° C. (1562° F.) and 900° C. (1652° F.). The result of driving off this gas in addition to the chemically combined water is to leave calcareous clays more porous than other clays up to the beginning of fusion.

If the burning is carried only far enough to drive off the carbonic acid gas, the result will be that the quicklime thus formed

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[1] See Minerals in Clay, Calcite.

will absorb moisture from the air and slake. No injury may result from this if the lime is in a finely divided condition, and uniformly distributed through the brick, but if, on the contrary, it is present in the form of lumps, the slaking and accompanying swelling of these may split the brick.

If, however, the temperature is raised higher than is required simply to drive the carbon dioxide, and if some of the mineral particles soften, a chemical reaction begins between the lime, iron and some of the silica and alumina of the clay, the result being the formation within the clay of a new silicate compound of very complex composition. The effects of this combination are several. In the first place, the lime tends to destroy the red coloring of the iron, and impart instead a buff color to the burned clay. This bleaching action, if we may call it such, is most marked when the percentage of lime is three times that of the iron. It should be remembered, however, that all buff-burning clays are not calcareous, and that a clay containing a low percentage of iron oxide may also give a buff body. Another effect of lime, if present in sufficient quantity, is to cause the clay to soften rapidly, thereby sometimes drawing the points of incipient fusion and viscosity within 41.6° C. (76° F.) of each other. This rapid softening of calcareous clays is one of the main objections to their use, and on this account also, it is not usually safe to attempt the manufacture of vitrified products from them, but, as mentioned under magnesia, the presence of several per cent. of the latter substance, will counteract this. It has also been found possible to increase the interval between the points of incipient fusion and viscosity by the addition of quartz and feldspar.[1]

Clays with much lime carbonate[2] require only 20 to 24 per cent. of water to convert them from a dry condition into a workable paste, whereas other clays needed 28 to 35 per cent. to develop the same degree of plasticity.[3]

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[1] The Collected Writings of H. A. Seger, Vol. I, p. 336.

[2] The proper name for such is marly clay, but the term should not be confused with the greensand marls of New Jersey.

[3] Loc. cit.

Many erroneous statements are found in books, regarding the allowable limit of lime in clays, some writers putting it as low as 3 per cent.; still a good building brick can be made from a clay containing as much as 20 per cent. or 25 per cent. of lime carbonite provided it is in a finely divided condition,[1] and a vitrified ware is not attempted. If, however, that much lime is contained in the clay in the form of pebbles, then much damage may result from bursting of the bricks, when the lumps of burned lime slake, by absorbing moisture from the air.

Clays containing a high percentage of lime carbonate are used in the United States, especially in Michigan, Wisconsin and Illinois, for making common bricks, common earthenware, roofing tile, and some terra cotta.

Effect of lime-bearing silicates.—The effect of these is much less pronounced than that of lime carbonate. They contain no volatile elements, and hence do not affect the shrinkage as lime carbonate does. They serve as fluxes, but do not cause a rapid softening of the clay.

Effect of gypsum.—Lime, if present in the form of gypsum, seems to behave differently from lime in the form of carbonate, although few clays contain large percentages of it.

Gypsum as already shown[2] is a hydrous sulphate of lime. In calcining gypsum for making plaster of Paris, the chemically combined water is driven off at 250° C., and it has probably been usually taken for granted that the sulphuric acid was driven off at a red heat. In order to determine what amount of loss actually occurred, and at what temperature this took place, the writer made a mixture consisting of 75 per cent. of a white-burning clay and 25 per cent. of white gypsum, which was nearly chemically pure. The two were ground together in a ball mill to mix them thoroughly, dried until stiff enough to mold, and then formed into bricklets which were dried in a hot-air bath at 100° C. The white clay contained 13.24 per cent. of chemically combined water. The gypsum contained 46.6 per cent. sulphur trioxide,

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[1] For analyses and uses of calcareous clays see H. Ries, Clays and Shales of Michigan, Mich. Geol. Sur., Vol. VIII, Pt. I; and E. R. Buckley, Clays and Clay Industries of Wis., Wis. Geol. Sur., Bull. 2, Economic Series.

[2] Chap. III, Minerals in Clay.

and 20.9 per cent. chemically combined water. The mixture referred to above would therefore contain 15.11 per cent. of combined water and 11.65 per cent. of sulphur trioxide (SO_3).

In order to determine the loss that occurred in burning, two of the bricklets which had been previously dried in the air bath were carefully weighed and heated in succession to temperatures of 860° C. (1580° F.), 1000° C. (1832° F.), 1100° C. (2012° F.), 1200° C. (2192° F.) and 1300° C. (2372° F.), respectively. The total loss at each of these temperatures is given below.

Table showing loss in weight by burning.

	Loss in weight, per cent.	
Temperature.	*Sample No. 1.*	*Sample No. 2.*
860° C. (1580° F.)	11.60%	11.50%
1000° C. (1832° F.)	13.18%	12.59%
1100° C. (2012° F.)	19.93%	19.58%
1200° C. (2192° F.)	23.15%	23.05%
1300° C. (2372° F.)	23.21%	23.11%

These figures are certainly interesting, for at 860° C. the loss only slightly exceeds the amount of combined water contained in the white clay. At 1000° C. the loss does not equal the sum of the water contained in the clay and gypsum. A large loss occurred between 1100° C. and 1200° C., while between the latter temperature and 1300° C. the loss was exceedingly small. Therefore, even at 1300° C., or slightly above the theoretic melting point of cone 8, there is still over 3 per cent. of what would be considered volatile material remaining in the mixture. It is presumed that this represents sulphur trioxide which has not been driven off. Furthermore, the clay behaves differently from what it would if *carbonate of lime* had been the source of the lime, for at cone 8 it had only begun to soften, while a mixture with the same quantity of CaO derived from lime carbonate, as shown by Mäckler's experiments,[1] warped at cone 1.

The range of lime, as determined from a series of clays, is as follows:[2]

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[1] See Magnesia.

[2] Bull. N. Y. State Museum, No. 35, p. 523. Owing to an error in the analysis of one of the brick clays, the averages in this table have been recalculated.

Amount of lime in clays.

Kind of clay.	*Min.*	*Max.*	*Aver.*
Brick clays,	0.024	15.38	1.513
Pottery clays,	0.011	9.90	1.098
Fire clays,	0.03	15.27	0.655
Kaolins,	tr.	2.58	0.47

Magnesia.

Magnesia (MgO) rarely occurs in clay in larger quantities than 1 per cent., and, so far as known, none of the New Jersey clays are exceptions to this rule. When present, its source may be any one of several classes of compounds, *i. e.*, silicates, carbonates and sulphates.

In the majority of clays the silicates, no doubt, form the most important source, and minerals of this type carrying magnesia are the black mica or biotite, hornblende, chlorite and pyroxene. These are scaly or bladed minerals, of more or less complex composition, and containing from 15 per cent. to 25 per cent. of magnesia. The biotite mica decomposes or rusts very easily, and its chemical combination being thus destroyed, the magnesia is set free in the form of a soluble compound, which may be retained in the pores of the clay. Hornblende is not an uncommon constituent of some clays, especially in those which are highly stained by iron, and have been derived from dark-colored igneous rocks. Like biotite, it alters rather rapidly on exposure to the weather. Dolomite, the mixed carbonate of lime and magnesia, is no doubt present in some clays, and would then serve as a source of magnesia. Magnesium sulphate, or Epsom salts, probably occurs sparingly in clays, and might form a white coating either on the surface of clay spread out to weather, or else on the ware in drying. It is most likely to occur in those clays which contained pyrite, the sulphide of iron (FeS_2), for the decomposition of the latter would yield sulphuric acid, which, by attacking any magnesium carbonate in the clay, might form magnesium sulphate. This substance has a characteristic bitter taste.

It is only recently, however, that the true effects of magnesia in clay have been discovered, for since it was often derived from similar minerals as lime, and resembled it chemically, it was thought to exert the same effect on clays. That it does not has been shown in an interesting series of experiments conducted by Mäckler.[1] As his results have been published in a German magazine, and are probably inaccessible to many of the readers of this report, it may be well to quote from them. Mäckler noticed that certain kinds of fireproofing, made from a calcareous clay containing several per cent. of magnesia, behaved somewhat differently from most products made from limy clays, and concluded that the effects were due to the magnesia contents of the material. In order to prove this point, he selected a clay, which was free from lime or magnesia, and in its raw and burned condition had the following composition:

Analysis of clay used by Mäckler in tests on effects of magnesia.

	Raw.	*Burned.*
Loss on ignition,	7.07	....
Silica (SiO_2),	63.25	68.06
Alumina (Al_2O_3),	22.97	24.72
Ferric oxide (Fe_2O_3),	4.98	5.36
Lime (CaO),	....	....
Magnesia (MgO),	....	....
Alkalies (Na_2O, K_2O),	2.07	2.22
	100.34	100.36

To one hundred parts by weight of this clay, either lime or magnesium carbonate were added in the proportions given below, the percentages given in parenthesis representing the quantity of lime or magnesia contained in the amount of carbonate added. The physical tests of these mixtures are also given below.

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[1] Thonindustrie Zeitung, Vol. XXVI, p. 706.

Physical tests on Mäckler's mixtures.

	Water required.	Air shrinkage.	Loss of weight in firing.	Fire shrinkage Cone Nos.				
				010	05	1	3	5
A. Clay alone,	28.8	6.4	9.8	—.15	3.5	7.2	7.9	6.7
B. Clay + 25 $CaCO_3$ (14 CaO),	31.1	8.4	14.3	1.4	1.8	*	....	....
C. Clay + 12.5 $CaCO_3$ (7 CaO),	33.6	8.3	10.4	1.0	1.7	†	..	....
D. Clay + 21 $MgCO_3$ (10MgO),	34.0	8.2	16.3	0.6	3.0	11.7	11.9	*
E. Clay + 10.5 $MgCO_3$ (5MgO),	32.4	7.5	11.1	1.7	3.7	11.1	11.3	†

* Melted.
† Warped.

It will be seen here that the effect of magnesia was quite different from that exerted by the lime. The mixtures containing magnesia did not vitrify suddenly, as did the limy clays, nor did the magnesia exert as strong a bleaching action on the iron, and the points of incipient fusion and viscosity were also separated.

With a mixture of kaolin and magnesia, similar results were obtained. The mixture of kaolin and magnesia showed a higher shrinkage at the beginning of the burning than the kaolin alone, and then increased but little until a high temperature was reached, when the shrinkage suddenly began again. A hard body was obtained at cone 1 with the kaolin-magnesia mixture.

The effect of magnesia, therefore, if present in sufficient quantity is to act as a flux and make the clay soften slowly instead of suddenly, as in the case of calcareous clays.

Of the various kinds of clay found in New Jersey, the brick clays usually contain the highest percentages of magnesia, but even in these it is rarely present in sufficient quantity to exert a noticeable effect. The fire clays contain the least.

The range of magnesia in several classes of clays, as figured from a number of analyses, is as follows:[1]

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[1] Bull. N. Y. State Museum, No. 35, p. 524. Owing to an error in an analysis of a brick clay the figures in this table have been recalculated.

Amount of magnesia in clays.

Quality.	*Min.*	*Max.*	*Aver.*
Brick clays,	0.02	7.29	1.052
Pottery clays,	0.05	4.80	0.85
Fire clays,	0.02	6.25	0.513
Kaolins,	tr.	2.42	0.223

Alkalies.

The alkalies include potash (K_2O), soda (Na_2O) and ammonia (NH_3). There are other alkalies, but they are probably of rare occurrence in clays.

The amount of total alkalies contained in a clay varies from a mere trace in some to 7 per cent. or 9 per cent. in others. The range of alkalies in several classes of clays was determined to be as follows:[1]

Amount of total alkalies in clays.

	Range.	*Average.*
Kaolins,	0.1 – 6.21	1.01
Fire clay,	0.048– 5.27	1.46
Pottery clays,	0.52 – 7.11	2.06
Brick clays,	0.17 –15.32	2.768

Ammonia is, no doubt, present in some raw clays, judging from their odor, and it may possibly exert some effect on the physical structure of the clay, it being found that the bunches of grains in a clay tend to separate more easily, when the clay is agitated with water, if a few drops of ammonia are added. As ammonia is easily volatile, it leaves the clay as soon as the latter is warmed, and, therefore, plays no part in the burning of the clay. The two other common alkaline substances, potash and soda, are more stable in their character, and are, therefore, sometimes termed *fixed alkalies*. These have to be reckoned with in burning, for they are present in nearly every clay.

Several common minerals may serve as sources of the alkalies. Feldspar may supply either potash or soda. Muscovite, the white mica, contains potash. Greensand or glauconite contains potash.

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[1] Bull. 35, N. Y. State Museum, p. 515.

Other minerals, such as hornblende or garnet, might serve as sources of the alkalies, but are unimportant, as they are rarely present in clays in large quantities.

Orthoclase, the potash feldspar, contains 17 per cent. of potash (K_2O), while the lime-soda feldspars contain from 4-12 per cent of soda (Na_2O), according to the species. The lime-soda feldspars fuse at a lower temperature than the potash ones, but are also less common.[1]

Muscovite mica contains nearly 12 per cent. of potash and may contain a little soda. Muscovite flakes, if heated alone, seem to fuse at cone 12, but, when mixed in a clay, they appear to act as a flux at different temperatures, according to the size of the grains. If very finely ground, the mica seems to vitrify at as low a temperature as cone 4,[2] but, if the scales are larger, they will retain their individuality up to cone 8, or even 10. The latter is true of the micaceous talc-like clays found in the Miocene formation around Woodstown, which are composed chiefly of white mica. We, therefore, see that the minerals supplying alkalies are all silicates of complex composition. Each has its fixed melting point, and the temperature at which the alkalies flux with the clay will depend on the containing mineral, and also on the size of the grains. If the alkali-bearing mineral grains decompose, the potash or soda are set free and form soluble compounds.[3]

Alkalies are considered to be the most powerful fluxing material that the clay contains, and, if present in the form of silicates, are a desirable constituent, except in clays of a refractory character. On account of their fluxing properties, they serve, in burning, to bind the particles together in a dense, hard body, and permit a white ware, made of porous-burning clays, to be burned at a lower temperature. In the manufacture of porcelain, white earthenware, encaustic tiles and other wares made from white-burning clays, and possessing an impervious or nearly impervious body, feldspar is an important flux.

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[1] See Seger Ges. Schr., p. 413.

[2] Trans. American Ceramic Society, Vol. IV, p. 255.

[3] See Origin of Clay, Chap. I.

Alkalies alone seem to exert little or no coloring influence on the burned clay, although in some instances potash seems to deepen the color of a ferruginous clay in burning.

Titanium.

Titanium is an element which is found in several minerals, some of which are more common in clays than is usually imagined, although they appear rare because they are seldom found in large quantities. Among the titanium-bearing minerals, the commonest is *rutile,* which is an oxide of titanium (TiO_2), containing 60 per cent. of metallic titanium and 40 per cent. of oxygen. So far as known, it is never found in clays in sufficiently large grains to be visible to the naked eye, although a microscopic examination may often show its presence in the form of little needles or grains. Its frequent occurrence is, no doubt, due to the fact that it is quite resistant to weathering.

It may be asked, why, if the material is so widespread, the presence of titanium is so rarely shown in an analysis of clay. This is because its determination by chemical methods is attended with more or less difficulty and is rarely carried out. In the ordinary process of chemical analysis it is included with the alumina. Very few state geological surveys, in investigating their clay resources, have made special determination of this mineral, but in an investigation of clays of New Jersey, made in 1877, Prof. Cook found that in 21 clays examined (p. 276),[1] it ranged from 1.06 to 1.93 per cent. In a series of Pennsylvania fire clays[2] the percentage of titanium oxide ranged from 0.87 per cent. to 4.62 per cent. The clay at Hackensack contained 0.85 per cent., and analyses of a number of fire bricks from this State gave percentages ranging from 0.85 per cent. up to 4.30 per cent., so that the probable effect of such a widespread substance is well worth investigation.

Unfortunately, but little experimental work seems to have been done along this line, although some years ago, Messrs.

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[1] Report on the Clays of New Jersey, 1878, Cook and Smock.

[2] Second Geological Survey of Pennsylvania, Rept. MM, pp. 261 et seq.

Seger and Cramer, of Berlin, made experiments to determine the effect of this substance in clay. They took two samples of Zettlitz kaolin (which contained 98.5 per cent. of kaolinite or clay substance), and to these were added 6.5 per cent. and 13.3 per cent. of titanium oxide, respectively; both were then heated to a temperature above the fusing point of iron, the result being that the first softened considerably on heating and showed a blue fracture, while the second fused to a deep-blue enamel. A second series of mixtures, consisting each of one hundred parts of kaolin, with 5 per cent. and 10 per cent. of silica, respectively, showed no signs of fusion, and burned simply to a hard white body, thus indicating that the titanium acts as a flux at a lower temperature than quartz.

As these experiments were not sufficiently extensive to be applicable to New Jersey materials, which contain small but persistent quantities of titanium, it was thought desirable to make some mixtures of a white-burning refractory clay, with varying percentages of titanium. The clay employed was a white-burning sedimentary clay from Columbia, South Carolina, the fusing point of which is above that of cone 34. The titanium was added in the form of rutile, which had been very finely ground in a ball mill, most of it being fine enough to remain in suspension for several days.

Series of mixtures for tests on effect of Titanium oxide.

I. Clay plus ½% TiO_2 by weight.
II. Clay " 1% " " "
III. Clay " 2% " " "
IV. Clay " 3% " " "
V. Clay " 4% " " "
VI. Clay " 5% " " "

These mixtures were then formed into small cones and tested in the Deville furnace, the results of these tests being shown graphically by the curve in Fig. 25. In this figure the vertical line at the left represents the cone number of the Seger series,[1] and the horizontal line at the bottom the per cent. of titanium

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[1] See Fusibility, Chapter IV.

oxide. No. VII, at the extreme left, represents the fusion point of the clay alone, while I, II, etc., indicate, respectively, the fusion points of the clay and titanium mixtures. From this it will be seen that even one-half per cent. of titanium oxide lowered the fusing point of the clay half a cone, while 5 per cent. lowered it two cones. All the mixtures, when heated to cone 27, were apparently vitrified, and showed a deep-blue fracture. This coloration was, however, destroyed by the presence of a few per cent. of silica. At lower temperatures (cone 8), a mixture containing 5 per cent. of titanium oxide burned yellow.

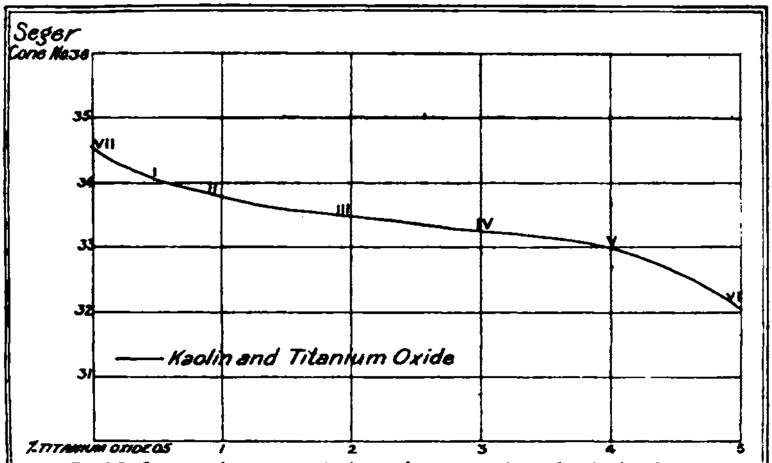

Fig. 25. Curve showing effect of Titanium oxide on fusibility of clay.

The effect produced by replacing silica by titanium oxide in a mixture of silica and kaolin is mentioned on another page.[1]

Water in Clay.

Under this head are included two kinds of water. 1. Mechanically combined water or moisture. 2. Chemically combined water.

Mechanically combined water.—The mechanically combined water is that which is held in the pores of the clay by capillary

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[1] Chapter XVI, Fire Clays and Fire-Brick Industry.

action, and fills all the spaces between the clay grains. When these are all small, the clay may absorb and retain a large quantity, because each interspace acts like a capillary tube. If the space exceeds a certain size, they will no longer hold the moisture by capillary action, and the water, if poured on the clay, would fast drain away. The fine-grained clays and sands, for these reasons, show high powers of absorption and retention, while coarse sandy clays or sands represent a condition of minimum absorption. This same phenomenon shows itself in the amount of water required for tempering a clay. Thus, a very coarse sandy clay mixture from near Herbertsville required only 15.9 per cent. of water, while a very fat one from Woodbury took 45 per cent. of water. It is not the highly aluminous ones, however, that always absorb the most water. The total quantity found in different clays varies exceedingly. In some air-dried clays it may be as low as 0.5 per cent., while in those freshly taken from the bank it may reach 30 to 40 per cent., without the clay being very soft.

Water held mechanically in a clay will pass off partly by evaporation in air, but can all be driven off by heating the clay to 100° C. (212° F.). The evaporation of the mechanical water is accompanied by a shrinkage of the mass, which ceases, however, when the particles have all come in contact, and before all the moisture is driven off, because some remains in the pores of the clay. This last portion is driven off during the early stages of burning, and this part of the burning process is referred to as water-smoking or steaming. The shrinkage that takes place when the mechanical water is driven off varies, and ranges from 1 per cent. or less in very sandy clays up to 10 per cent. or 12 per cent. in very plastic ones.

Since most clays having a high absorption shrink a large amount in drying, there is often danger of their cracking, especially if rapidly dried, owing to the rapid escape of the water vapor. Mechanical water may hurt the clay in other ways. Thus, if the material contains any mineral compounds which are soluble in water, the latter, when added to the clay, will dissolve a portion of them at least. During the drying of the brick, the water rises to the surface to evaporate, and brings out the compounds in solution, leaving them behind when it vaporizes. It may also help the fire gases to act on certain elements of the clay, a point explained under burning.

Chemically combined water.—Chemically combined water, as its name indicates, is that which exists in the clay in chemical combination with other elements, and which, in most cases, can be driven out only at a temperature ranging from 400° C. (752° F.) to 600° C (1112° F.).[1] This combined water may be driven from several minerals, such as kaolinite which contains nearly 14 per cent., white mica or muscovite with 4 per cent. to 5½ per cent., and limonite with 14.5 per cent. Unless a clay contains considerable limonite or hydrous silica, the percentage of combined water is commonly about one-third the percentage of alumina found in the clay. In pure or nearly pure kaolin, there is nearly 14 per cent., and other clays contain varying amounts, ranging from this down to 3 per cent. or 4 per cent., the latter being the quantity found in some very sandy clays. The loss of its combined water is accompanied by a slight, but variable shrinkage in the clay, which reaches its maximum some time after all the volatile matters have been driven off.

Organic Matter.

Under this head are included all fragments of vegetable origin, large and small, found in clay, which have been washed into the water where the clay was being deposited, and settled down with it. In many cases the material has settled down in layers, and these, on account of their coarseness and foreign character, destroy the cohesiveness between the clay particles, causing the clay to split along these planes when taken from the bank.

Indeed, the gray or black color given by organic matter to many clays is so strong as to obscure the presence of other coloring agents, such as iron oxide, so that two clays both colored black, may burn nearly white and red, respectively. The black

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[1] See Bourry, Treatise on Ceramic Industries, p. 103, also W. M. Kennedy Transactions American Ceramic Society, Vol. IV, p. 146, and, further, experiments under Fire Shrinkage (Chap. IV).

and carbonaceous character of the organic matter found in the clay is due to its having decayed, out of contact with the air, such conditions bringing about a slow carbonization of the material. In some clay beds a considerable layer of organic matter may accumulate, producing a bed of coaly material, which represents the early stage in the formation of true coal.[1]

Many surface clays contain organic matter in the form of plant roots that have grown down into the clay from the surface, but the effect of these is probably not very material. The amount of organic matter which a clay contains is usually small, and 3 per cent. or 4 per cent. may color a sandy clay deep black. The depth of color will, however, be influenced by the way in which the organic matter is distributed in the clay, finely divided and evenly distributed particles producing a deeper and more uniform tint. As long as any organic matter remains in the clay, it will tend to exert a reducing action during the burning, because the carbon, in changing to carbon dioxide, requires oxygen, and takes it greedily from the atmosphere within the kiln. Under such conditions, there is little opportunity for other compounds requiring it to get any, until the organic material has been consumed. The organic matter in clays will, however, pass off during the early stages of burning, if sufficient air can enter the kiln, and the clay is not heated too rapidly. In fact, if the clay contains considerable organic matter, the combustion of the latter may even add to the temperature of the kiln. In burning clays, which by their color clearly show that much organic matter is present the burning should proceed slowly until all the organic matter is driven off, for, if this is not done, the surface of the clay may burn dense, and form a skin which the oxygen cannot penetrate. Consequently, the carbonaceous matter will not be consumed, but will remain in the interior of the ware. Moreover, the clay may swell up and become porous, due to the presence possibly of hydrocarbons (compounds of hydrogen and carbon), which are decomposed by the heat, and the gases, in endeavoring to expand and escape, bloat the clay. Many of the Clay Marls show this phenomenon, if heated too rapidly.

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[1] See description of Raritan clays, Chap. XVIII.

It has not been determined definitely whether finely divided organic matter exerts any influence on the plasticity or tensile strength, but it, no doubt, increases the absorptive power of the clay for water.

In most chemical analyses the organic matter is rarely determined separately, but is included in the "loss on ignition," for, in fact, the amount is commonly so small as not to require separate determination.

Soluble Salts.

Origin.—It has been pointed out in Chapter I (Origin of Clay) that in the decomposition of mineral grains in clay, soluble compounds are often formed. During the drying of the clay the moisture brings these to the surface and leaves them there when it evaporates, thus forming a scum on the air-dried ware and sometimes a white coating on the clay after it is burned. Those found in the clay are commonly sulphates of lime, iron or alkalies, and their formation is generally due to the decomposition of the iron pyrite frequently contained in the clay. A much greater quantity of soluble sulphates will be formed if the pyrite is in a finely divided condition and evenly distributed through the clay, but these compounds may also be formed without the aid of pyrite, as when the carbonates are set free by the decomposition of silicates such as feldspar. When the soluble compounds have formed in the green clay their presence can often be detected by spreading the dug clay out to weather, which will result in their forming a crust on the surface of the mass.

Their formation does not cease, however, when they are removed from the ground, for in some cases fresh pyrite grains remain in the clay after mixing, and if the clay is stored in a moist place these may decompose, yielding an additional amount of soluble material. One means of preventing this would seem to be to use the clay as soon as possible after mixing.

In some cases soluble sulphates may be even introduced into the clay by the water used for tempering, for distilled water is the only kind that is free from soluble salts. All well and spring waters contain some at least, and if these flow or drain from clays or rocks containing any pyrite they are almost sure to contain soluble salts. Those flowing from lime rocks are usually "hard" on account of the lime carbonate which they contain. Still another source of soluble salts in raw clay lies in some of the artificial coloring materials which are sometimes used.

Soluble sulphates are sometimes formed, in burning, through the use of sulphurous fuel, that is, coal containing more or less iron pyrite. When the coal is burned part of the sulphur in the pyrite is expelled, and, uniting with the oxygen, forms sulphuric acid gas (SO_3). This passes through the kiln, and, if it comes in contact with carbonates in the clay, converts them into sulphates, because many substances, such as lime (CaO), have a stronger affinity for sulphur trioxide (SO_3) than for carbon dioxide (CO_2).

It frequently happens that clay products come from the kiln apparently free from any superficial discoloration or coating, but develop one later on if subjected to moisture. In this case the salts had been formed within the body of the ware during burning, and are brought to the surface after the ware is exposed to the weather. The moisture, which is then absorbed, brings the salts to the surface upon drying out.

The coatings thus far mentioned are all white in color. In some instances, however, the product becomes covered with a yellow or green stain, which is caused either by the growth of vegetable matter on the surface of the bricks or by soluble compounds of the rare element vanadium. Some white coatings seen on brick, however, come from the mortar.

Quantity of soluble salts in a clay.—The amount of soluble salts present in a clay is never very great, but less than 0.1 per cent. is often sufficient to produce a white incrustation. A number of soluble salt determinations were made on clays from different localities in the State in order to obtain some idea of the quantity to be found in the clays of different formations. In making these tests a five-grain sample of clay was taken and heated in distilled water for about one-half hour, after which the solution was forced through a small pasteur filter connected with a force pump, and the clear filtrate evaporated to dryness in a platinum dish. The results obtained on a number of samples were as follows:

Soluble salts in Clay Marl I.

Loc.[1]	*Lab. No.*[2]	*Per cent.*
131	614	0.60
142	624	1.49
192	602	0.60
228	601	0.60

Soluble salts in Clay Marl I and II.

Loc.	*Lab. No.*	*Per cent.*
149	647	0.51
194	609	0.81
128	610	0.08

Soluble salts in Clay Marl II.

Loc.	*Lab. No.*	*Per cent.*
231	607	0.08

Soluble salts in Cohansey clays.

Loc.	*Lab. No.*	*Per cent.*
185	683	0.20
185	682	0.29
191	619	0.45

Soluble salts in Alloway clays.

Loc.	*Lab. No.*	*Per cent.*
162	617	0.08
164	680	0.38

Soluble salts in Raritan clays.

Loc.	*Lab. No.*	*Per cent.*
131	614	0.00
6	7	0.17
54	28	0.33
84	34	0.06
6	9	0.00
24	4	0.00

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[1] These numbers as used here and elsewhere in this Report refer to localities as indicated upon the maps, Plates X, XI, XII, XIII.

[2] These numbers wherever used refer to numbers of the test, on file in Dr. Ries' laboratory.

Loc.	*Lab. No.*	*Per cent.*
77	15	0.18
67	20	0.06
132	622	0.15
101	644	0.06
81	25	0.08
24	13	0.18
14	12	0.28
67	21	0.34
222	603	1.35

Soluble salts in Pleistocene clays.

Loc.	*Lab. No.*	*Per cent.*
276	726	0.30
290	727	0.21
291	618	0.47

From these it will be seen that the samples of Clay Marl I showed the highest percentage of soluble salts, and that as a series the Raritan clays showed the lowest percentage of soluble salts.

The Raritan samples tested, with the exception of locality *222*, are of the higher grade clays, and do not include any of those used for fireproofing. It is probable that these, if tested, would yield percentages as high as Clay Marl I, since they contain considerable pyrite.

Prevention of soluble salts.—If a brick is vitrified the soluble compounds are rendered insoluble, but in the manufacture of many grades of ware the clay is not carried to vitrification, and therefore the soluble salts must be rendered insoluble if possible. This is most effectively done by adding some chemical to the wet clay which will react with the soluble salts in it, and either render them insoluble or else change them into some very easily soluble compound that can be readily washed from the surface of the ware.

The substance commonly added is either barium chloride or barium carbonate. When barium salts come in contact with soluble sulphates, barium sulphate is formed, a combination which is absolutely insoluble in water. This is expressed by the first of the following chemical reactions if barium carbonate is used, and by the second if barium chloride is employed.

1. $CaSO_4 + BaCO_3 = CaCO_3 + BaSO_4$.
2. $CaSO_4 + BaCl_2 = CaCl_2 + BaSO_4$.

We thus see that in both cases we get compounds which are insoluble or nearly so. If soluble sodium compounds are present the addition of barium carbonate or barium chloride will form either sodium carbonate or sodium chloride (common salt), but since both of these are easily soluble in water they can be washed off without much trouble.

Method of use.—As carbonate of barium is insoluble in water, in order to make it thoroughly and uniformly effective it should be used in a finely powdered condition and distributed through the clay as thoroughly as possible, because it will only act where it comes into immediate contact with the soluble sulphates. While only a small quantity of barium is necessary, still it is desirable to use somewhat more than is actually required.

According to Gerlach,[1] a clay containing 0.1 per cent. sulphate of lime, which is the same as 0.4 grains per pound, would need 0.6 of a grain of barium carbonate per pound of clay. For safety, however, 6 or 7 grains should be added to every pound of clay. This would be about 100 pounds for every thousand bricks, based on the supposition that a green brick weighs 7 pounds. As a pound of barium carbonate costs about two and one-half cents, the amount of it required for 1,000 bricks would be $2.50. It is cheaper to use barium chloride, for the reason that the salt is soluble in water, and hence can be distributed more evenly with the use of a smaller quantity; the chemical reaction also takes place much more rapidly when it is used. There is this objection to it, however, that as near the theoretic amount as possible must be used, for if any remains in the clay unchanged, that is, without having reacted with the soluble salts, it may of itself form an incrustation.

In the case of a clay containing 0.1 per cent. calcium sulphate, it would require 26 pounds of barium chloride per thousand bricks, and this, at two and one-half cents a pound, would mean an outlay of $0.65. With the barium chloride treatment, chloride of lime is formed, but this is decomposed in burning.

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[1] The Brickbuilder, 1898, p. 59 et seq.

Since in drying molded-clay objects the evaporation is greatest from the edges and corners of the ware, the incrustations may be heaviest at these points, but the more rapidly the water is evaporated the less will be the quantity of soluble salts deposited on the surface. Incrustations which appear during drying are found more commonly on bricks made from very plastic clays, which, owing to their density, do not allow the water to evaporate quickly.

CHAPTER IV.

THE PHYSICAL PROPERTIES OF CLAY.

CONTENTS.

Under physical properties there are included plasticity, tensile strength, shrinkage, fusibility, texture, color, slaking, absorption, and specific gravity.

PLASTICITY.

This property permits the clay to be molded into any desired form when wet, which shape it retains when dry, and while many theories have been advanced to explain its cause, none of them are perhaps wholly satisfactory. As is well known to all, clays show a wide range in their plasticity, some being but slightly plastic or lean, and others highly so or fat. Very sandy clays containing but little clay substance are usually lean, and the same is true of some fine-grained ones, such as many washed kaolins.

Several theories have been advanced to explain the cause of plasticity. For a long time it was supposed to be directly connected with kaolinite (the hydrated silicate of alumina) and clays high in kaolinite were said to be very plastic, but it was found before long that the plasticity does not stand in close relation to the amount of kaolinite. High-grade koalins containing 13 per cent. to 14 per cent. of combined water, and therefore a large percentage of kaolinite, are usually lean, while clays with but 4 per cent. or 5 per cent. of combined water may be very plastic. That there is some connection between plasticity and the presence of minerals containing combined water would appear from the fact that if a clay is heated sufficiently high to lose its combined water, it also seems to lose its plasticity. Another theory considers it due to fineness of grain. If, however, we take quartz and grind it very fine in a ball mill it is not plastic, although it is true that if an excess of water is mixed with it, it becomes soft and pasty. If this wet mass is pressed it will pack to a hard mass, entirely lacking the mobility of form possessed by a plastic clay, so that fineness of grain is not the sole cause of plasticity. Still another theory considers that it is due to a plate structure, the idea being that the clay particles are plate-like in form, and that the plasticity is caused by these plates sliding over each other. One serious objection to this theory is that many clays when examined under the microscope do not appear to be made up entirely of plates.

In studying clays from different formations, and different parts of the same layer even, some interesting facts bearing on this subject were obtained.

A residual clay (kaolin from Webster, near Dillsboro, N. Car.) was compared with a sedimentary clay of the same composition (Florida ball clay). The residual clay was found to possess a decidedly less degree of plasticity than the sedimentary clay, the particles of which had been transported long distances and had been more or less rubbed and ground together previous to their deposition. Inasmuch as the kaolinite particles, as shown by the microscope, are more or less bunched, it is to be expected that this rubbing and grinding action during transportation would break up the bunches to some extent, and it is believed that the increased plasticity of the sedimentary clay is due to this cause. This conclusion is in accord with facts noted[1] by the former State Geologist, Prof. Geo. H. Cook, who found that by rubbing a mass of kaolin in a mortar the bunches of kaolinite plates were easily broken apart and that the mass afterwards showed increased plasticity. From what has been just said it must not be inferred that all residual clays are of low plasticity, for some are just the opposite.

If an exceedingly plastic clay is examined under the microscope, it is found that in addition to the regular particles of either a scaly or irregular shape, there are often a large number of extremely minute, apparently spherical, structureless particles, which may be of colloidal character.[2] It seems to the writer that a mixture of the mineral particles and these spherical particles might develop a high degree of plasticity.

This same view has been independently expressed by A. B. Cushman.[3]

TENSILE STRENGTH.

The tensile strength of a clay is the resistance which it offers to rupture or being pulled apart when air dried. It is an important property by virtue of which the unburned clay ware is able to withstand shocks and strains of handling and the shrinkage in drying. Through it, also, the clay is able to carry a large quantity of nonplastic material such as flint or feldspar.

There may be some relation between the plasticity and the tensile strength of a clay, but it is neither a constant nor a simple one. While high tensile strength and high plasticity often go together, there are marked exceptions. A clay low in tensile strength may yet have high plasticity, as is seen in the case of some New Jersey clays, and, on the other hand, however, a clay of only moderate plasticity may have high tensile strength.

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[1] Report on Clays, 1878, pp. 281, 287.

[2] Maryland Geol. Surv., Vol. IV, p. 251.

[3] Jour. Amer. Chem. Soc., XXV, No. 5, 1903.

The tensile strength is measured by molding the tempered clay into briquettes, of the form and dimensions shown in Fig. 26, and, when they are thoroughly air dried, pulling them apart in a suitable testing machine. The cross section of the briquettes when molded is 1 square inch, and, after being formed, they are allowed to dry first in the air and then in a hot-air bath at a temperature of 100° C. (212° F.). When thus thoroughly dried the briquette is placed in a machine, in which its two ends are held in a pair of brass clips, and is subjected to an increasing tension until it breaks in two. Theoretically the briquette should break at its smallest cross section, with a smooth, straight fracture, and when this does not occur it is due either to a flaw in the briquette or because the clips tend to cut into the clay. In such event the briquette breaks across one end, and to prevent this it is necessary to put some soft material, such as asbestos, pasteboard or rubber between the inner surface of the clip jaws and the sides of the briquette. If the briquettes

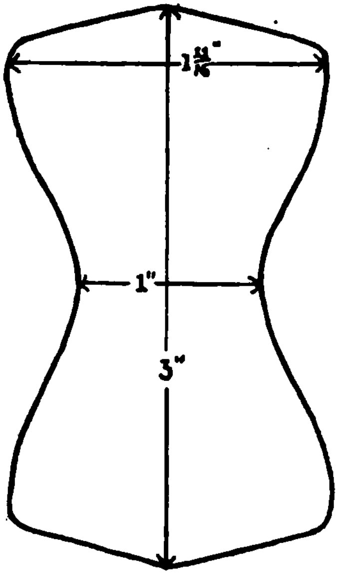

Fig. 26.
The outline and dimensions of a briquette made for testing the tensile strength of clay.

are molded and dried with care, the variation in the breaking strength of the individual briquettes should not vary more than 15 or 20 per cent., but with some very plastic clays it is extremely difficult to keep the variation within these limits.

In making a complete test of the New Jersey samples the tensile strengths given are usually the average of 10 or 12 briquettes. In a number of cases where it was only desired to get an approximate idea of the strength of a clay, but two or three were broken. The greatest variation usually appeared in clays of high tensile strength, in which case the fracture nearly always occurred in the head, indicating that the briquettes broke before the limit of their strength was reached.

The tensile strength of clay briquettes is expressed in pounds per square inch, but, since the briquette shrinks in drying, the strength actually obtained in testing will be less than that for a square inch, and the result must be increased in proportion to the amount the briquette has shrunk.

The following figures give the range in tensile strength shown by clays from the different formations in New Jersey, and it will be seen from an inspection of these figures that the clays of any one formation may show a wide range in their tensile strength.

Range of tensile strength of clays from different formations in New Jersey expressed in pounds per square inch.

	Minimum.	*Maximum.*
Post-Pleistocene and Pleistocene other than Cape May,	65	297
Cape May,	90	291
Cohansey,	54	293
Asbury Clay,	107	182
Alloway Clay,	80	453
Clay Marl IV,	195 (one sample tested)	
Clay Marl III,	134 (one sample tested)	
Clay Marl II,	126	286
Clay Marl I,	127	251
Raritan (extreme limits),	20	251

If the tensile strength tests of a number of clays from different localities are grouped according to the kind of clay, a somewhat similar variation is found.

	Minimum.	*Maximum.*
Kaolins,	20	60
Fire clays,	0 (Flint clays)	150
Brick clays,	50	300
Pottery clays,	50	250

The washed ball clays of New Jersey showed the lowest tensile strength of all the samples tested, while the clay from the railroad cut north of Alloway was the strongest of the series examined, and had an average tensile strength of 453 pounds per square inch, with a maximum of 506 pounds.

With such a variation existing in the tensile strength of clays, it becomes a matter of importance to know the cause of this variation. It is a well known fact that all clays shrink in drying, and that this shrinkage is accompanied by a drawing together of the particles. Indeed, some clays shrink to such a hard mass as to suggest a close interlocking of the grains, which, it seems to the writer, may be the explanation of the tensile strength shown; that is to say, those clays in which the interlocking of the particles is the tightest will show the highest tensile strength, and vice versa. If this is true it becomes necessary to determine, if possible, what arrangement or size of particles produces the tightest and strongest structure.

When any series of clays is tested it is evident that the highly sandy ones have a low tensile strength,[1] and very fine-grained ones are in all cases, as far as the writer's experience goes, also low in their tensile strength.[2] Many samples having a high tensile strength have considerable grit, but still they shrink to a very dense body, indicating a considerable percentage of fine particles. E. Orton, Jr.,[3] attempted to determine the effect of the fineness of grain on the tensile strength of clays by taking a very fine-grained clay and mixing different sizes of sands with it, the sand being obtained by grinding and screening vitrified bricks. His conclusions were "(1) that the tensile strength of mixtures of a plastic ball clay with equal quantities of nonplastic sands

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[1] See Asbury clay, sample 695 S, Table, Chap. XVIII.

[2] See Raritan clay, sample 723. Table, Chap. XVIII.

[3] Transactions American Ceramic Society, Vol. II, p. 100, and Vol. III, p. 198.

will vary inversely with the diameter of the grains of the sand from grains of 0.04 inch down to the finest sizes obtainable. (2.) That the nonplastic ingredients of clay influence its tensile strength inversely as the diameter of their grains, and fine-grained clays will, other things being equal, possess the greatest tensile strength." In other words, the coarser the grains of sand, the less the tensile strength of the mixture containing them.

In order to obtain some information regarding the relation of texture to tensile strength the writer selected 5 clays at random from the New Jersey series tested for this report, the only precaution taken being to pick out samples ranging from high to low tensile strength. These 5 samples were the following:

1. Alloway clay from the railroad cut north of Alloway (Loc. 164, Lab. No. 680). This is a very plastic, slightly gritty, dense, red-burning clay, with an average tensile strength of 453 pounds per square inch.
2. Pleistocene clay from the brickyard near Somerville (Loc. 234, Lab. No. 659). This was also a gritty, plastic clay, but not as dense as the previous one. Its average tensile strength was 297 pounds per square inch.
3. A Cape May clay from along the river south of Millville (Loc. 181, Lab. No. 645). A gritty, plastic clay, with an average tensile strength of 289 pounds per square inch.
4. Sample of Raritan clay from Cliffwood (Loc. 220, Lab. No. 615). A black, sandy, micaceous clay, with an average tensile strength of 105 pounds per square inch.
5. A soft, powdery, washed ball clay from near Sayreville (Loc. 268, Lab. No. 723). It was plastic to the feel, with very little grit, and a tensile strength of under 20 pounds per square inch.

Each of these clays was put through a mechanical analysis and separated into the 5 classes of grains,[1] shown in the table below.

The percentage of these sizes in each of the 5 samples is shown in the following table:

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[1] For explanation of sizes, see "Texture" in this chapter.

Mechanical Analyses of some New Jersey Clays.

Conventional Names.	*1* *Lab. No. 680.*	*2* *Lab. No. 659.*	*3* *Lab. No. 645.*	*4* *Lab. No. 615.*	*5* *Lab. No. 723.*
Clay substance, ...	59.00%	44.00%	22.00%	30.645%	87.96%
Fine silt, ...	11.00	7.11	5.66	14.21	6.95
Silt and fine sand,...	14.70	24.35	26.55	5.585	3.00
Medium sand, ...	3.50	7.80	11.45	6.400	1.00
Sand, ...	11.40	16.35	33.44	42.950	....
	99.60	99.61	99.10	99.790	98.91

These figures seem to throw some light on the relation of the texture to the tensile strength, but, while highly suggestive, are not to be taken as final. The writer hopes, however, to have the opportunity of supplementing them by additional tests at some later date. Before discussing the bearing of the mechanical analyses given above it seems desirable to plot them in the form of curves, as shown in Fig. 27. Here the horizontal lines represent percentages. Of the 6 columns, the first 5 represent the grain sizes and the sixth the tensile strength.

Taking No. 5 of the above table of analyses we find that it contains 87.96 per cent. of clay substance. This point is plotted in the first column. The point representing the percentage of fine silt is then plotted in the next column, and so on with the other sizes. These points are then connected with a curved line. In the same way the percentages of the different sizes of grains of the other samples were plotted and connected by curved lines. The lines are drawn in different ways so that those representing the different clays can be more readily distinguished at a glance. From a study of this table it is seen that the clay having the lowest tensile strength (No. 5) contains a very high percentage of the finest clay particles. Furthermore, the clay having the second lowest tensile strength (No. 4) contains the largest percentage of sand (42.9 per cent.). From this it appears that an excess of either coarse or fine grains lowers the tensile strength. On the other hand, in those clays having the high tensile strength the percentages of fine, medium and coarse particles are more nearly equal. This is perhaps what might be expected, for if the tensile strength is due to the interlocking of the grains, a mixture of different sizes would fit together more closely than if particles of one size predominated, as in Nos. 4 and 5 of the table. It is rather difficult, however, to compare these results with Orton's, as in his artificial mixtures the nonplastic particles were of uniform size, while in the natural mixtures a variety of sizes existed.

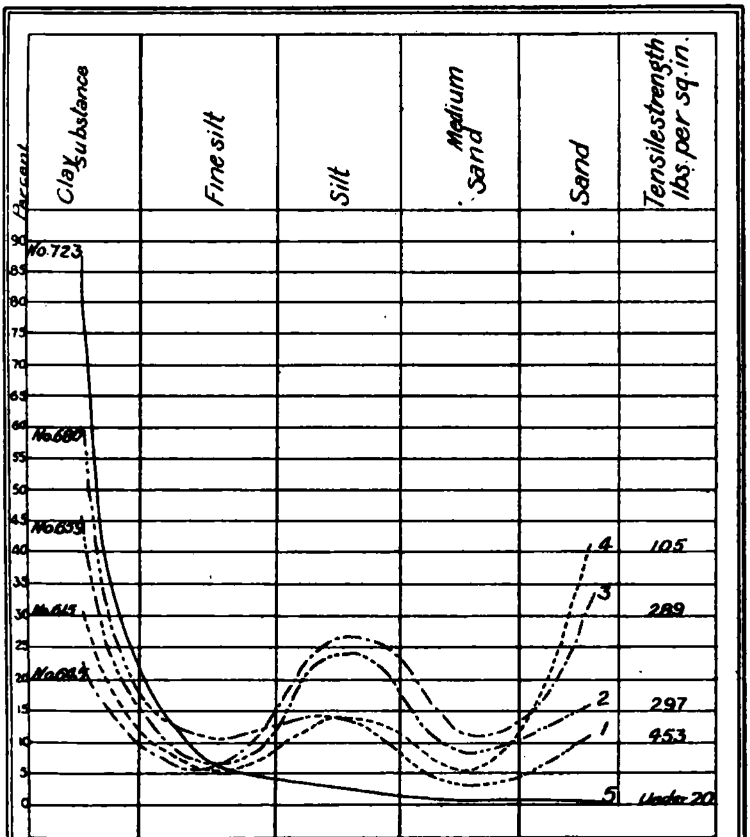


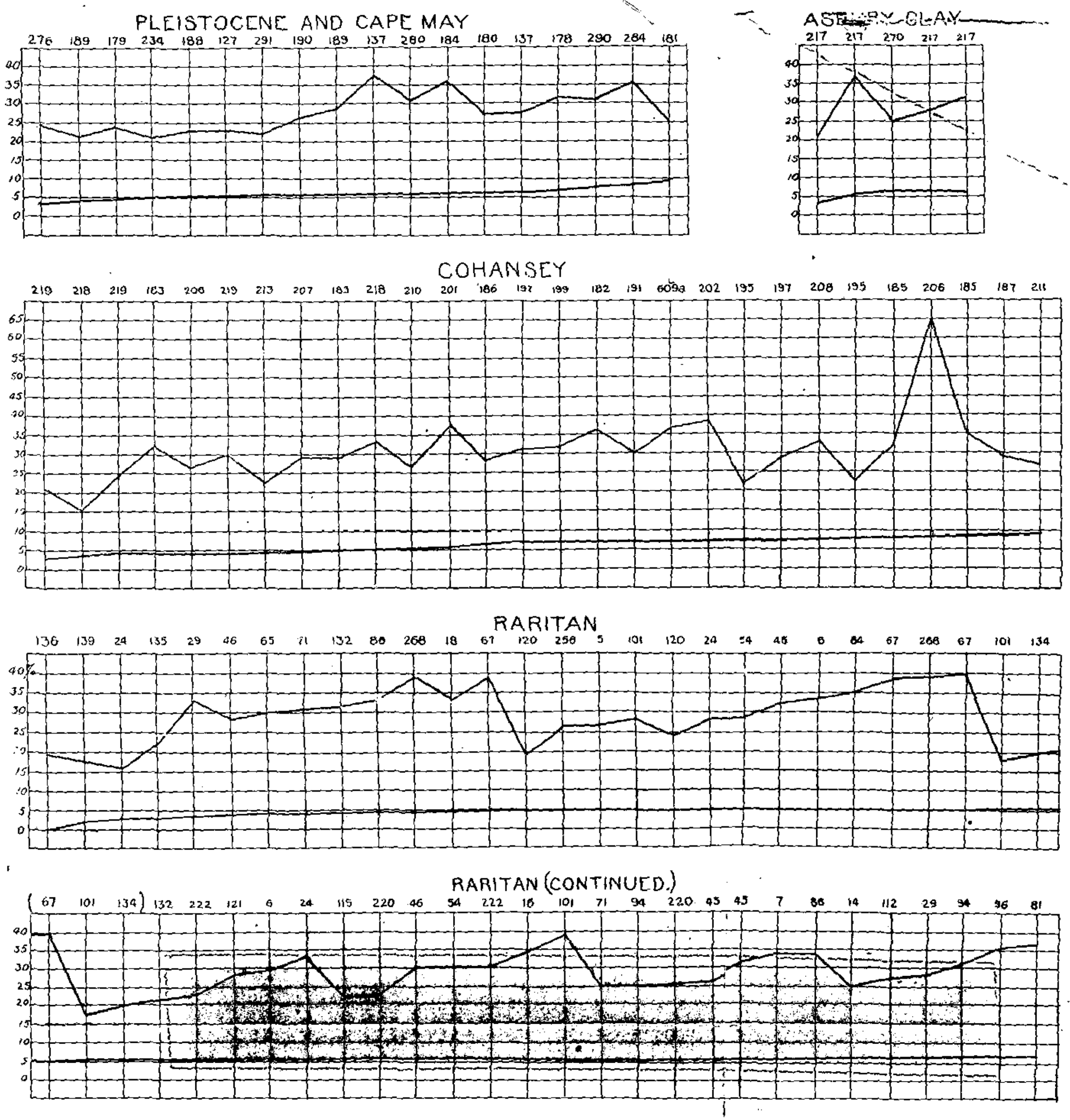
Fig. 27. Curves showing relation of texture to tensile strength.

If the theory of interlockment is true, then it should be possible to make a mixture of two clays, whose tensile strength is higher than that of either of the clays alone, or vice versa. While no experiments were made with the object of proving this point, some results were obtained in the course of the physical work on the New Jersey clays that have an important bearing, as follows:

Of several clays tested from the Asbury clay, near Asbury Park, one was a slightly gritty, black clay, with an average tensile strength of 182 pounds per square inch. The other was a plastic loam, whose average tensile strength was 137 pounds per square inch. A mixture of the two in equal proportions, however, had an average tensile strength of 258 pounds per square inch. Another clay from a different formation (Lab. No. 695) had an average tensile strength of 108 pounds per square inch, while a mixture of equal parts of this clay and sand showed a tensile strength of but 65 pounds per square inch. In the latter case the decrease in strength was due to the excess of sand.

The tensile strength of a clay is used by some as a means of measuring its plasticity, but there are probably fewer advocates of this idea than there were a few years ago. It is true that many very plastic clays have a high tensile strength, and that many very lean ones have a low tensile strength, but we cannot say more than this. Many clays, as, for example, some of the Clay Marls, have a lean, gritty feeling when wet, and yet show a high tensile strength when air dried. Again, many of the Raritan clays feel very sticky and plastic, and yet their tensile strength may be under 100 pounds per square inch. Some clays of high bonding power will, when tested alone, develop little tensile strength, but this is because the high plasticity of the clay causes it to shrink, warp and crack so much in drying that it is impossible to get a briquette free from flaws. When mixed with sand or grog, its shrinkage and cracking are greatly reduced, and the proper texture is developed for high tensile strength. Some of the No. 1 fire clays of the Woodbridge district, which are very fine grained, crack so much when dried alone that it is impossible to get a flawless briquette for testing.

PLATE XIII A.



Diagrams showing the relation of the air shrinkage (lower line) to the water absorbed in tempering (upper line) New Jersey clays.

SHRINKAGE.

All clays shrink in drying and burning, the former loss being termed the air shrinkage, and the latter the fire shrinkage.

Air shrinkage.[1]—When a mass of clay is mixed up with water, each of the grains of clay can be considered as being surrounded by a film of the liquid, which may prevent them from coming into close or actual contact. As soon as the wet, molded mass is set aside to dry, however, evaporation of the water contained in the pores of the clay begins, and, as it passes off, the particles of clay draw closer together, causing a shrinkage of the mass. This will continue until all the particles come in contact, but since they do not fit together perfectly, there will still be some spaces left between the grains, and these will hold moisture, which cannot be driven off except by gentle heating. The air shrinkage, may, therefore, cease before all the water has passed off. This fact can be told by the loss of weight which takes place in the clay, if put in a hot-air bath (at 100° C.) after the air shrinkage ceases. The amount of air shrinkage is usually low in lean clays, and high in very plastic clays, for the reason that the latter absorb considerable water in mixing, which they then give off in drying. At the same time, however, it must be noted that all clays which require a high percentage of water in mixing, do not show a high air shrinkage, as is shown by the diagrams on Plate XIII A.

In these, the horizontal lines indicate percentages; the numbers at the top of each diagram represent the locality, arranged according to the percentage of air shrinkage which they showed, the lowest being placed at the left end, and the highest at the right.

Taking the diagram for the Cohansey clays, the first one is No. 219 (Lab. No. 699). A point was marked indicating its air shrinkage, viz., 2.5,[2] and above this a second point was marked.

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[1] Whenever the term air shrinkage is used in this report it refers, unless otherwise stated, to the linear shrinkage, expressed in terms of the length of a freshly molded brick, and measured on its greatest dimension.

[2] The percentage of both air and fire shrinkage is expressed in terms of the length of the freshly molded bricklet.

corresponding to the amount of water required to mix it, viz., 21.3 per cent. of the weight of dry clay taken. In the same way similar pairs of points were plotted for the other localities, and each series of points was then connected by a line. Since the different clays were arranged according to the amount of their air shrinkage, the line representing this will naturally rise from left to right. If now the amount of water required for mixing stood in direct relation to the air shrinkage, the upper line should also rise steadily from left to right, which it does not do in all cases. In the Cape May clays there seems to be less irregularity than in the case of the other formations, in all of which the upper line is very irregular, due, no doubt, to the variation in texture of the clays.

The air shrinkage of a clay will not only vary with the amount of water added, but also with the texture of the material. Soft-mud bricks may shrink more than stiff-mud ones, because in the latter case less water is added to the clay, and it is molded under greater pressure. At the same time, the shrinkage of many soft-mud bricks is low, because so much sand is often added to the clay. The effect of the sand on the air shrinkage is well seen by comparison of samples 695 and 695S, both from locality 218, 1 mile south of Herbertsville. In preparing sample 695S, 50 per cent. of sharp sand was added.

Table showing effect of sand on the air shrinkage and tensile strength of a clay.

	Per cent. of water required.	*Per cent. of air shrinkage.*	*Tensile strength lbs. per sq. in.*
Lab. No. 695, Loc. 218,..	32.6	5.3	108
" " 695S, " " ..	15.6	3.3	65

From the above it is seen that the addition of 50 per cent. of sharp sand reduced the amount of water required a little over one-half. The air shrinkage was reduced 37.73 per cent., but it was accompanied by a loss in the tensile strength of very nearly 40 per cent. Similar examples can be seen by an inspection of the tabulated tests in Chapter XVIII, where it will be seen that in some cases a gain is made all around by the mixing process, as for instance, in the clays from the Raritan, used at locality 222, near Keyport. Here, sample 606 (Lab. No.) represents a fat, black clay, which cannot be used alone for bricks, as it shrinks too much, especially in burning, and consequently a more sandy clay (Lab. No. 603) is added to it.

Table showing air shrinkage and tensile strength of a fat and of a sandy clay.

	Per cent. of water required.	*Per cent. of air shrinkage.*	*Tensile strength lbs. per sq. in.*
Lab. No. 606, Loc. 222, . .	30	6.	91
" " 603, " " . .	23	5.3	106

While coarse or sandy clays shrink less than fine-grained ones, they may sometimes absorb considerable water, especially if they are silty in their character, but the fact that their pores are much coarser allows the water to escape rapidly, and thus often permits more rapid drying. The cracking of some fine-grained clays in drying is due partly to the surface shrinking more rapidly than the interior, because the evaporation there is greatest. As the outer portion of the product cannot stretch, it must pull apart and crack.

Fire shrinkage.—All clays shrink during some stage of the burning operation, even though they may expand slightly at certain temperatures. The fire shrinkage varies within wide limits, the amount depending partly on the quantity of volatile elements, such as combined water, organic matter and carbon dioxide present in the clay, and partly on the texture. It reaches a maximum when the clay vitrifies, but does not increase uniformly up to that point, and, in fact, is very irregular. Thus a certain amount of shrinkage takes place when the combined water begins to pass off, namely, at 400° C. (752° F.), and an additional amount occurs at higher temperatures, but not apparently the result of contraction following volatilization of some of the elements.

Wherever the fire shrinkage is given in this report, it refers to the linear shrinkage occurring during burning, and is expressed in terms of the length of the bricklet when molded. Thus, if the fire shrinkage at cone 1 is given as 4 per cent., it means that the amount of fire shrinkage at that cone is 4 per cent. of the length of the bricklet when freshly molded.

As an example of the rate of fire shrinkage and accompanying loss of weight, a series of eight clays was selected and burned at temperatures 100° C. (180° F.) apart from 500° C. (932° F.), up to 1100° C. (2012° F.), inclusive.

TABLE SHOWING PROGRESSIVE SHRINKAGE AND LOSS OF WEIGHT AT DIFFERENT TEMPERATURES.

Lab. No.	Per cent. of air shrinkage.	Per cent. weight lost in air bath.	500° C. 932° F.	600° C. 1112° F.		700° C. 1292° F.		800° C. 1472° F.		900° C. 1652° F.		1000° C. 1832° F.		1100° C. 2012° F.	
			Per cent. weight lost.	Per cent. weight lost.	Per cent. fire shrinkage.	Per cent. weight lost.	Per cent. fire shrinkage.	Per cent. weight lost.	Per cent. fire shrinkage.	Per cent. weight lost.	Per cent. fire shrinkage.	Per cent. weight lost.	Per cent. fire shrinkage.	Per cent. weight lost.	Per cent. fire shrinkage.
648	9.0	2.69	6.38	1.72	0.3	0.70	.0	0.88	0	0.56	0	0.19	0.7	0.38	4.0
655	4.6	1.36	6.10	1.38	0.0	0.55	.0	0.33	0	0.33	0	0.12	0.7	0.21	2.4
663	5.3	1.50	4.24	1.37	0.7	0.35	.3	0.05	0	0.27	0	+0.06	0.0	0.19	1.3
665	7.0	1.43	8.65	1.07	0.3	0.48	.0	0.39	0	0.12	0	0.10	2.7	0.00	12.6
696	5.6	3.48	9.42	2.61	0.4	1.61	.0	0.46	0	0.33	0	0.14	1.3	0.22	4.7
703	1.0	0.63	2.52	1.05	0.0	0.26	.0	0.10	0	0.02	0	0.09	1.4	0.03	0.0
717	8.0	3.29	5.32	1.70	0.3	0.83	.0	0.41	0	0.49	0	0.34	1.3	0.24	4.0
728	2.0	0.70	3.23	1.03	0.6	0.61	.0	0.22	0	0.15	0	0.10	1.3	0.12	2.7

Explanation of table.—The clays tested were the following:

648. Fat, black micaceous clay, of Clay Marl I from Maple Shade (Loc. 149).
655. A clay marl. Exact locality unknown.
663. A Pleistocene clay from Vineland (Loc. 183).
665. A yellow, finely gritty, Cohansey clay, heavily stained with limonite from Toms River (Loc. 206).
696. Black, Asbury clay from west of Asbury Park (Loc. 217).
703. Sandy, Raritan clay from near Fish House (Loc. 136).
717. A very plastic clay from Clay Marl III, south of Woodbury (Loc. 156).
728. Hudson River shale from Port Murray (Loc. 282).

The bricklets had been standing in a warm room for several weeks and although they appeared perfectly dry, they were placed in a hot-air bath and kept at a temperature of 110° C. for a day, being weighed both before and after. This drove off the moisture remaining in the pores, and the resulting loss in weight indicated in the third column of the above table shows the quantity of moisture that may remain in a brick after the air shrinkage has ceased. It is least in the sandy, lean clays, and highest in the black one which is colored by organic matter. The second column indicates the per cent. of air shrinkage, calculated upon the length of a freshly molded bricklet. The fourth column, headed 500° C. (932° F.), gives the loss in weight from the thoroughly dried condition up to 500° C., calculated on the weight of the air-dried sample. The following columns give the additional loss in weight for each 100° C. (180° F.), as well as the fire shrinkage taking place in this temperature interval. From an inspection of the table it is seen that most of the volatile substances, such as the chemically combined water contained in kaolinite, mica, or limonite, and organic matter pass off before 500° C. (932° F.), and that an additional appreciable amount is expelled between 500° C. and 600° C. Between 600° C. (1112° F.) and 1100° C. (2012° F.) there was a small but steady loss, while in one case (No. 663), there was even a gain in weight at 1000° C. (1832° F.). Two samples, Nos. 696 and 665, showed a high loss at 500° C. and 600° C., as compared with the others, but this was due to the former containing considerable organic matter, and the latter having a very high percentage of limonite, which would supply an additional quantity of chemically combined water.[1]

The amount of fire shrinkage shown by these samples is equally interesting, for it is seen that although the loss in weight between 500° C. (932° F.) and 900° C. (1652° F.) is considerable, still there is little or even no shrinkage, so that after the volatile elements have been driven off the clay must be very porous, and remains so until the fire shrinkage begins again. From the table it will be seen that with one exception, no shrinkage occurred between 600° C. (1112° F.) and 900° C. (1652° F.), but between 900° C. (1652° F.) and 1000° C. (1832° F.), all except No. 663 decreased in size, and there was an additional but greater shrinkage between 1000° C. (1832° F.) and 1100° C. (2012° F.). None of the bricklets became steel-hard, that is, sufficiently hard to resist scratching with a knife until 1000° C. (1832° F.), or even 1100° C. (2012° F.). In the case of those burning red, a good red coloration began to appear at 1000° C. (1832° F.). From this it can be seen, and this is a fact already known, that up to 600° C. (1112° F.), a clay should be heated slowly, but from that point up to 1000° C., the temperature can be raised quite rapidly, unless much carbonaceous matter is present. The gradual burning off of this carbon is well shown in Pl. XVII, Fig. 1, which represents a series of bricks taken from a kiln, at regular intervals as the burning proceeded. Further heating should be done slowly, as the shrinkage recommences at the last mentioned temperature.

Since many clays when used alone shrink to such an extent as to cause much loss from warping and cracking, it is necessary to add materials, which of themselves have no fire shrinkage, and so decrease the shrinkage of the mixture in burning. Sand or sandy clays are the materials most commonly used for this purpose, but ground bricks (grog) and even coke or graphite may be employed. These materials serve not only to decrease the shrinkage in drying and burning, but also tend to prevent blistering in an easily fusible ferruginous clay when hard fired. They furthermore add to the porosity of the ware, and thus

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[1] See Chapter III, p. 73.

facilitate the escape of the moisture in drying and in the early stages of burning, as well as enable the product to withstand sudden changes of temperature. If sand is added for this purpose, it may act as a flux at high temperatures, and this action will be the more intense the finer its grain.[1]

Large particles of grog are undesirable, especially if they are angular in form, because in burning the clay shrinks around them, and the sharp edges, serving as a wedge, open cracks in the clay, which may expand to an injurious degree. Large pebbles will do the same, and at many of the common brickyards in the State, the writer has seen numbers of bricks split open during the burning because of some large quartz pebble left in the clay, as the result of improper screening of the tempering sand. For common brick, the type of sand used does not make much differen, as long as it is clean, but if sand is to be added to fire brick mixtures, it should be coarse, clean quartz sand. Burned clay grog is more desirable than sand for high-grade wares, since it does not affect the fusibility of the clay, or swell with an increase of temperature as sand does, but precaution should be taken to burn the clay to its limit of shrinkage before using it.

FUSIBILITY.

The changes occurring in the early stages of burning have already been referred to on pp. 93-96, and in the table of tests there given it was seen that the clay had become steel-hard. The temperature at which this occurs varies with the character of the material, impure, easily fusible clays becoming so at a low temperature, such as cone 05, while others, such as kaolins, will not become steel-hard before cone 5 or possibly 8.[2]

The attainment of a steel-hard condition represents the beginning of fusion, not of the whole mass, but of some of the more fusible elements in the clay, the result of this preliminary soften-

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[1] See Chapter on Fire Clays and Fire-Brick Industry.

[2] The cones referred to are small pyramids of definite chemical composition and a theoretic fixed fusion point. Their exact nature and method of use are explained on p. 101.

ing being to stick the grains together. This is termed incipient fusion, but the softening has not been sufficient to prevent identification of the coarser grains in the clay. With a further variable increase in the temperature, depending in amount on the clay, and ranging from 27.7° C. (50° F.) to 111.1° C. (200° F.) or sometimes even more, an additional amount of shrinkage occurs, and most of the particles become sufficiently soft to allow them to settle into a compact impervious mass, thus closing up all the pores in the clay. This condition is termed vitrification, and a piece of vitrified clay when broken shows a very smooth fracture and sometimes a slight luster, since all the particles except the coarse quartz grains have been welded into a dense solid mass. This condition, since it represents one of the closest compactness of the clay particles, also represents the maximum of shrinkage. If the heat is raised still further the clay softens so that it can no longer hold its shape and flows or gets viscous.

We can, therefore, recognize three stages in the burning of a clay,[1] viz.:

Incipient fusion.
Vitrification.
Viscosity.

It is sometimes difficult to recognize precisely the exact attainment of these three conditions, for the clay may soften so slowly that the change from one to the other is very gradual.

The difference in temperature between the points of incipient fusion and viscosity varies with the composition of the clay. In many calcareous clays these points are within 27.7° C. (50° F.) of each other, while in refractory clays they may be 377.7° C. (700° F.) to 444.4° C. (800° F.) apart. The glass-pot clays, which are refractory, but still burn dense at a comparatively low temperature, approach the last mentioned condition quite closely.

It is of considerable practicable importance to have the points of incipient fusion and viscosity well separated, because in the manufacture of many kinds of clay products the ware must be vitrified or rendered impervious. If, therefore, the temperature interval between the points of vitrification and viscosity is great,

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[1] H. A. Wheeler, Vitrified Paving Brick, p. 12, 1895, Indianapolis.

it will be safer to bring the ware up to a condition of vitrification, without the risk of reaching the temperature of viscosity and melting all the wares in the kiln, because it is impossible to control the kiln temperature within a range of a few degrees. In many clays the point of vitrification seems to be midway between that of incipient fusion and viscosity, but in others it is not.

Temperature of fusion.—The temperature at which a clay fuses depends on: 1) the amount of fluxing impurities; 2) the condition of the fluxes; 3) the size of the grains, and 4) the condition of the kiln atmosphere, whether oxydizing or reducing.

1. Other things being equal, the temperature of fusion of a clay will fall with an increase in the percentage of total fluxes. If we compare the analyses of a brick clay and a fire clay we shall find that the analysis of the former shows perhaps 12 or 15 per cent. of fluxing or fusible ingredients, while that of the latter may show only 2 or 3 per cent., and that their fusion points are perhaps 1093° C. (2000° F.) and 1644° C. (3000° F.) respectively. All fluxing impurities do not, however, act with equal energy, some being more active than others.

2. The condition of chemical combination may also affect the result. Thus lime, for example, will induce a fluxing action in clay at a lower temperature if present in the form of carbonate of lime than as silicate of lime.

3. The size of the mineral grains in a clay undoubtedly exerts more effect than some investigators have been willing to admit.[1] Other things being equal, a fine-grained clay will fuse at a lower temperature than a coarse-grained one,[2] for the reason that when the particles of a clay begin to fuse or flux with each other, this action begins on the surface of the grains and works inward towards the centre. If, therefore, the easily fusible grains are of small size, they fuse more rapidly, and are more effective in their fluxing action than if the grains were large. Since some of the mineral grains in the clay are more refractory than others, the clay in the earlier stages of fusion can be regarded as a mixture

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[1] H. O. Hofman, Trans. Amer. Inst. Min. Engrs. XXVIII, p. 440, 1898.

[2] See Chapter XVI, The Fire Clays and Fire-Brick Industry; also paper by H. Ries, Trans. Amer. Inst. Min. Engrs., Feb., 1903.

of fused particles, with a skeleton of unfused ones. If the proportion of the former to the latter is very small there will be a strong hardening of the clay with little shrinkage, and the burned clay will still be porous. With an increase of temperature, and the fusion of more particles, the pores fill up more and more, and the shrinkage goes on until, at the point of vitrification, the spaces are completely filled. Above this point there is no longer a sufficiently strong skeleton to hold the mass together, and the clay begins to flow. The conditions which influence the difference in temperature between vitrification and viscosity still remain to be satisfactorily explained, but it probably depends on the relative amounts of fluxes and nonfluxes and the size of grain of the latter.

4. Finally, it is found that the same clay will fuse at a lower temperature, if in burning it is deprived of oxygen, than it will if burned in an atmosphere containing plenty of the latter.[1]

Classification of clays based on fusibility.—The fact that different clays fuse at different temperatures makes it possible to divide them into several different groups, the divisions being based on the degree of refractoriness of the material. Such a grouping however is more or less arbitrary, since no sharp natural lines can be drawn between the different groups, and it is to be expected that no grouping proposed will meet with universal approval. The following classification has been adopted in this report:

1. *Highly refractory clays,* those whose fusing point is above cone 33. Only the best of the so-called No. 1 fire clays belong to this class.
2. *Refractory clays,* those whose fusion point ranges from cone 31–33 inclusive. This group includes some of the New Jersey No. 1, as well as some No. 2 fire clays.
3. *Semirefractory clays,* those whose fusion point lies between cone 27 and 30 inclusive.
4. *Clays of low refractoriness,* those whose fusion point lies between cone 20 and 26 inclusive.

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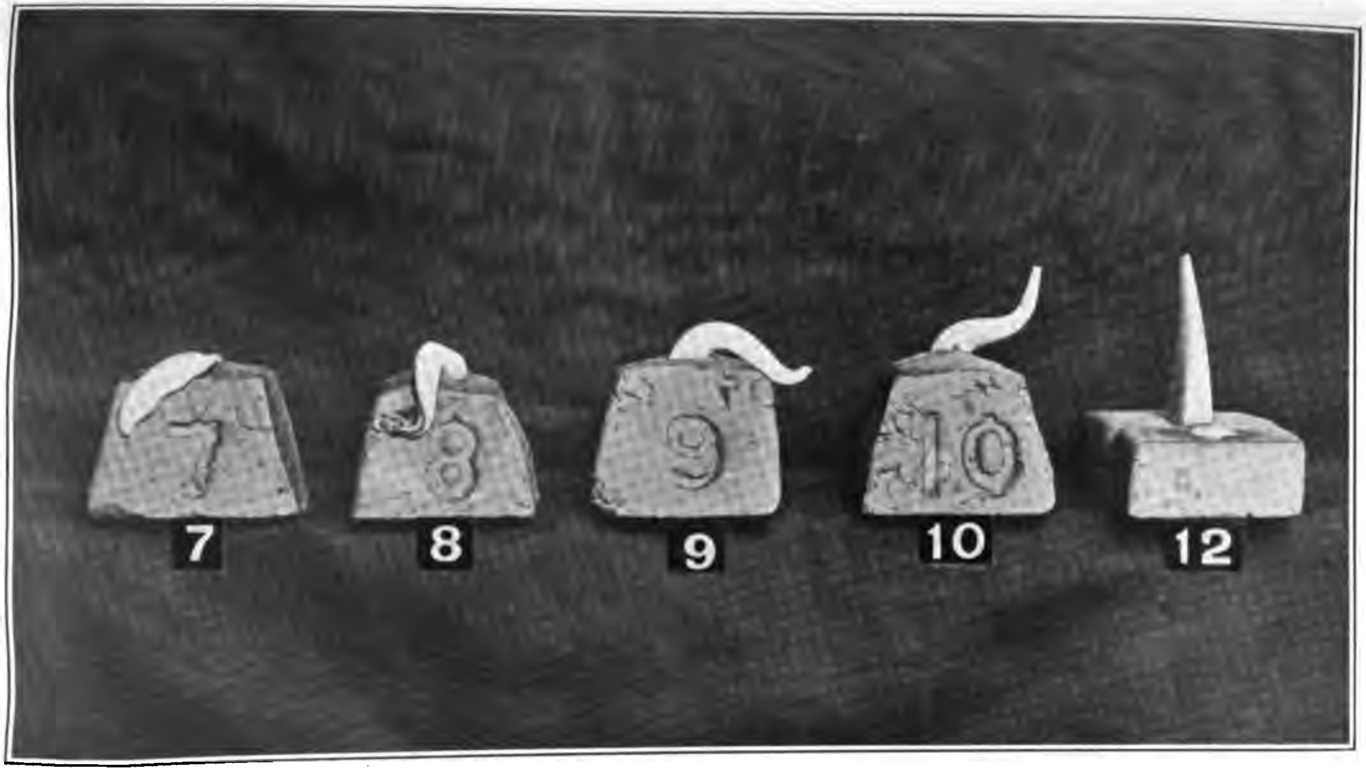
[1] See also "Iron Oxide," Chap. III, pp. 58, 59.

PLATE XIV.



Seger cones used for determining the temperature in kilns. Numbers 7 and 8 were completely melted; No. 10 was slightly softened; No. 12 was unaffected; No. 9 was bent completely over, but not melted. Temperature reached the fusing point of cone 9, or a little above.

5. *Nonrefractory clays,* fusing below cone 20.

Determination of fusibility.—The temperature at which a clay fuses is determined either by means of test pieces of known composition, or by some form of apparatus or mechanical pyrometer, the principle of which depends on the expansion of gases or solids, thermoelectricity, spectrophotometry, etc.

Seger cones.—These test pieces consist of a series of mixtures of clay with fluxes, so graded that they represent a series of fusion points, each being but a few degrees higher than the one next to it. They are so called because originally introduced by H. Seger, a German ceramist. The materials which he used in making them were such as would have a constant composition, and consisted of washed Zettlitz kaolin, Rörstrand feldspar, Norwegian quartz, Carrara marble, and pure ferric oxide. Cone No. 1 melts at the same temperature as an alloy composed of one part of platinum and nine parts of gold, or at 1100° C. (2012° F.). Cone No. 20 melts at the highest temperature obtained in a porcelain furnace, or at 1530° C. (2786° F.). The difference between any two successive numbers is 20° C. (36° F.), and the upper member of the series is cone 36, which is composed of a very refractory clay slate, while cone 35 is composed of kaolin from Zettlitz, Bohemia. A lower series of numbers was produced by Cramer, of Berlin, who mixed boracic acid with the materials already mentioned. Hecht obtained still more fusible mixtures by adding both boracic acid and lead in proper proportions to the cones. The result is that there is now a series of 58 numbers, the fusion point of the lowest being 590° C. (1094° F.), and that of the highest 1850° C. (3362° F.).

As the temperature rises the cone begins to soften, and when its fusion point is reached it begins to bend over until its tip touches the base, Plate XIV.

For practical purposes these cones are very successful, though their use has been somewhat unreasonably discouraged by some. They have been much used by foreign manufacturers of clay products and their use in the United States is increasing. The full series can be obtained from Messrs. Seger and Cramer, of Berlin, for $0.01 each (or about two and one-half cents apiece, including duty and expressage), or numbers .010 to 35 can be obtained for $0.01 each from Prof. E. Orton, Jr., of Ohio State University, Columbus, O. The table of fusing points of these cones and their composition is given below.

Composition and fusing points of Seger cones.

No. of cone.	Composition.			Fusing point.	
				°F.	°C.
.022	0.5 Na_2O 0.5 PbO		2.0 SiO_2 1.0 B_2O_3	1,994	590
.021	0.5 Na_2O 0.5 PbO	0.1 Al_2O_3	2.2 SiO_2 1.0 B_2O_3	1,148	620
.020	0.5 Na_2O 0.5 PbO	0.2 Al_2O_3	2.4 SiO_2 1.0 B_2O_3	1,202	650
.019	0.5 Na_2O 0.5 PbO	0.3 Al_2O_3	2.6 SiO_2 1.0 B_2O_3	1,256	680
.018	0.5 Na_2O 0.5 PbO	0.4 Al_2O_3	2.8 SiO_2 1.0 B_2O_3	1,310	710
.017	0.5 Na_2O 0.5 PbO	0.5 Al_2O_3	3.0 SiO_2 1.0 B_2O_3	1,364	740
.016	0.5 Na_2O 0.5 PbO	0.55 Al_2O_3	3.1 SiO_2 1.0 B_2O_3	1,418	770
.015	0.5 Na_2O 0.5 PbO	0.6 Al_2O_3	3.2 SiO_2 1.0 B_2O_3	1,472	800
.014	0.5 Na_2O 0.5 PbO	0.65 Al_2O_3	3.3 SiO_2 1.0 B_2O_3	1,526	830
.013	0.5 Na_2O 0.5 PbO	0.7 Al_2O_3	3.4 SiO_2 1.0 B_2O_3	1,580	860
.012	0.5 Na_2O 0.5 PbO	0.75 Al_2O_3	3.5 SiO_2 1.0 B_2O_3	1,634	890
.011	0.5 Na_2O 0.5 PbO	0.8 Al_2O_3	3.6 SiO_2 1.0 B_2O_3	1,688	920
.010	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.50 SiO_2 0.50 B_2O_3	1,742	950
.09	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.55 SiO_2 0.45 B_2O_3	1,778	970
.08	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.60 SiO_2 0.40 B_2O_3	1,814	990
.07	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.65 SiO_2 0.35 B_2O_3	1,850	1,010
.06	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.70 SiO_2 0.30 B_2O_3	1,886	1,030
.05	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.75 SiO_2 0.25 B_2O_3	1,922	1,050
.04	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.80 SiO_2 0.20 B_2O_3	1,958	1,070
.03	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.85 SiO_2 0.15 B_2O_3	1,994	1,090

No. of cone.	Composition.	Fusing point.	
		°F.	°C.
.02	$\begin{Bmatrix}0.3\ K_2O\\0.7\ CaO\end{Bmatrix}\ \begin{matrix}0.2\ Fe_2O_3\\0.3\ Al_2O_3\end{matrix}\ \begin{Bmatrix}3.90\ SiO_2\\0.10\ B_2O_3\end{Bmatrix}$	2,030	1,110
.01	$\begin{Bmatrix}0.3\ K_2O\\0.7\ CaO\end{Bmatrix}\ \begin{matrix}0.2\ Fe_2O_3\\0.3\ Al_2O_3\end{matrix}\ \begin{Bmatrix}3.95\ SiO_2\\0.05\ B_2O_3\end{Bmatrix}$	2,066	1,130
1	$\begin{Bmatrix}0.3\ K_2O\\0.7\ CaO\end{Bmatrix}\ \left.\begin{matrix}0.2\ Fe_2O_3\\0.3\ Al_2O_3\end{matrix}\right\}4\ SiO_2$	2,102	1,150
2	$\begin{Bmatrix}0.3\ K_2O\\0.7\ CaO\end{Bmatrix}\ \left.\begin{matrix}0.1\ Fe_2O_3\\0.4\ Al_2O_3\end{matrix}\right\}4\ SiO_2$	2,138	1,170
3	$\begin{Bmatrix}0.3\ K_2O\\0.7\ CaO\end{Bmatrix}\ \left.\begin{matrix}0.05\ Fe_2O_3\\0.45\ Al_2O_3\end{matrix}\right\}4\ SiO_2$	2,174	1,190
4	$\begin{Bmatrix}0.3\ K_2O\\0.7\ CaO\end{Bmatrix}\ 0.5\ Al_2O_3 4SiO_2$	2,210	1,210
5	$\begin{Bmatrix}0.3\ K_2O\\0.7\ CaO\end{Bmatrix}\ 0.5\ Al_2O_3 5SiO_2$	2,246	1,230
6	$\begin{Bmatrix}0.3\ K_2O\\0.7\ CaO\end{Bmatrix}\ 0.6\ Al_2O_3 6SiO_2$	2,282	1,250
7	$\begin{Bmatrix}0.3\ K_2O\\0.7\ CaO\end{Bmatrix}\ 0.7\ Al_2O_3 7SiO_2$	2,318	1,270
8	$\begin{Bmatrix}0.3\ K_2O\\0.7\ CaO\end{Bmatrix}\ 0.8\ Al_2O_3 8SiO_2$	2,354	1,290
9	$\begin{Bmatrix}0.3\ K_2O\\0.7\ CaO\end{Bmatrix}\ 0.9\ Al_2O_3 9SiO_2$	2,390	1,310
10	$\begin{Bmatrix}0.3\ K_2O\\0.7\ CaO\end{Bmatrix}\ 1.0\ Al_2O_3 10SiO_2$	2,426	1,330
11	$\begin{Bmatrix}0.3\ K_2O\\0.7\ CaO\end{Bmatrix}\ 1.2\ Al_2O_3 12SiO_2$	2,462	1,350
12	$\begin{Bmatrix}0.3\ K_2O\\0.7\ CaO\end{Bmatrix}\ 1.4\ Al_2O_3 14SiO_2$	2,498	1,370
13	$\begin{Bmatrix}0.3\ K_2O\\0.7\ CaO\end{Bmatrix}\ 1.6\ Al_2O_3 16SiO_2$	2,534	1,390
14	$\begin{Bmatrix}0.3\ K_2O\\0.7\ CaO\end{Bmatrix}\ 1.8\ Al_2O_3 18SiO_2$	2,570	1,410
15	$\begin{Bmatrix}0.3\ K_2O\\0.7\ CaO\end{Bmatrix}\ 2.1\ Al_2O_3 21SiO_2$	2,606	1,430
16	$\begin{Bmatrix}0.3\ K_2O\\0.7\ CaO\end{Bmatrix}\ 2.4\ Al_2O_3 24SiO_2$	2,642	1,450
17	$\begin{Bmatrix}0.3\ K_2O\\0.7\ CaO\end{Bmatrix}\ 2.7\ Al_2O_3 27SiO_2$	2,678	1,470
18	$\begin{Bmatrix}0.3\ K_2O\\0.7\ CaO\end{Bmatrix}\ 3.1\ Al_2O_3 31SiO_2$	2,714	1,490
19	$\begin{Bmatrix}0.3\ K_2O\\0.7\ CaO\end{Bmatrix}\ 3.5\ Al_2O_3 35SiO_2$	2,750	1,510
20	$\begin{Bmatrix}0.3\ K_2O\\0.7\ CaO\end{Bmatrix}\ 3.9\ Al_2O_3 39SiO_2$	2,786	1,530
21	$\begin{Bmatrix}0.3\ K_2O\\0.7\ CaO\end{Bmatrix}\ 4.4\ Al_2O_3 44SiO_2$	2,822	1,550

No. of cone.	Composition.	Fusing point.	
		°F.	°C.
22	$\begin{Bmatrix} 0.3\ K_2O \\ 0.7\ CaO \end{Bmatrix}$ 4.9 $Al_2O_3 49SiO_2$	2,858	1,570
23	$\begin{Bmatrix} 0.3\ K_2O \\ 0.7\ CaO \end{Bmatrix}$ 5.4 $Al_2O_3 54SiO_2$	2,894	1,590
24	$\begin{Bmatrix} 0.3\ K_2O \\ 0.7\ CaO \end{Bmatrix}$ 6.0 $Al_2O_3 60SiO_2$	2,930	1,610
25	$\begin{Bmatrix} 0.3\ K_2O \\ 0.7\ CaO \end{Bmatrix}$ 6.6 $Al_2O_3 66SiO_2$	2,966	1,630
26	$\begin{Bmatrix} 0.3\ K_2O \\ 0.7\ CaO \end{Bmatrix}$ 7.2 $Al_2O_3 72SiO_2$	3,002	1,650
27	$\begin{Bmatrix} 0.3\ K_2O \\ 0.7\ CaO \end{Bmatrix}$ 20 $Al_2O_3 200SiO_2$	3,038	1,670
28	Al_2O_3 10 SiO_2	3,074	1,690
29	Al_2O_3 8 SiO_2	3,110	1,710
30	Al_2O_3 6 SiO_2	3,146	1,730
31	Al_2O_3 5 SiO_2	3,182	1,750
32	Al_2O_3 4 SiO_2	3,218	1,770
33	Al_2O_3 3 SiO_2	3,254	1,790
34	Al_2O_3 2.5 SiO_2	3,290	1,810
35	Al_2O_3 2 SiO_2	3,326	1,830
36	Al_2O_3 1.5 SiO_2	3,362	1,850

If the heat is raised too rapidly the cones which contain much iron swell and blister and do not bend over, so that the best results are obtained by the slow softening of the cone under a gradually rising temperature. In actual use they are placed in the kiln at a point where they can be watched through a peep hole, but at the same time will not receive the direct touch of the flame from the fuel. It is always well to put two or more cones of different numbers in the kiln, so that warning can be had, not only of the end point of firing, but also of the rapidity with which the temperature is rising.

In determining the proper cone to use in burning any kind of ware, several cones are put in the kiln, as for example, numbers .08, 1 and 5. If .08 and 1 are bent over in burning and 5 is not affected, the temperature of the kiln is between 1 and 5. The next time numbers 2, 3 and 4 are put in, and 2 and 3 may be fused, but 4 remains unaffected, indicating that the temperature reached the fusing point of 3.

The cone numbers used in the different branches of the clay working industry in New Jersey are as follows:

Common brick,	08-01
Hard-burned, common brick,	1- 2
Buff front brick,	6- 8
Hollow blocks and fireproofing,	03- 1
Terra cotta,	5- 7
Conduits,	7- 8
White earthenware,	8- 9
Fire bricks,	9-12
Porcelain,	11-13
Red earthenware,	08-05
Stoneware,	6- 8

While the temperature of fusion of each cone number is given in the preceding table, it must not be understood that these cones are for measuring temperature, but rather for measuring pyrochemical effects. Thus if certain changes are produced in a clay at the fusing point of cone 5, the same changes can be reproduced at the fusion point of this cone, although the actual temperature of fusion may vary somewhat, due to variations in the condition of the kiln atmosphere. As a matter of fact, however, repeated tests with a thermoelectric pyrometer demonstrate that the cones commonly fuse close to the theoretic temperatures.

Manufacturers occasionally claim that the cones are unreliable and not satisfactory, forgetting that their misuse may often be the true reason for irregularities in their behavior. It is unnecessary, perhaps, to state that certain reasonable precautions should be taken in using these test pieces. The cones are commonly fastened to a brick with a piece of wet clay, and should be set in a vertical position. After being placed in a position where they can be easily seen through a peephole, the latter should not be opened widely during the burning lest a cold draft strike the cones, and a skin form on its surface and interfere with its bending. Moreover, one set of cones cannot be used to regulate an entire kiln, but several sets should be placed in different portions of the same. One advantage possessed by a cone over trial pieces is that the cone can be watched through a small peephole, while a larger opening must be made to draw out the trial piece. If the cones are heated too rapidly, especially those containing a large percentage of iron, they are apt to blister.[1]

Thermoelectric pyrometer.—This pyrometer, which is the only one that will be described in this report, is one of the best instruments for measuring temperatures. It is based on the principle of generating an electric current by the heating of a thermopile or thermoelectric couple. This consists of two wires, one of platinum and the other of an alloy of 90 per cent. platinum and 10 per cent rhodium. These two are fastened together at one end, while the two free ends are carried to a galvanometer which measures the intensity of the current. That portion of the wires which is inserted into the furnace or kiln is placed within two fire-clay tubes, one of the latter being smaller and sliding within the other in order to insulate the wires from each other. The larger tube has a closed end to protect the wires from the action of the fire gases.

To measure the temperature of a furnace or kiln the tube containing the wires is placed in it either before starting the fire, or else during the burning. If the latter method is adopted, the tube must be introduced very slowly to prevent its being cracked by sudden heating. The degrees of temperature are measured by the amount of deflection of the needle of the galvanometer.

Thermoelectric pyrometers are useful for measuring the rate at which the temperature of a kiln is rising, or for detecting fluctuations in the same. It is not necessary to place the galvanometer near the kiln, for it can be kept in the office some rods away. This pyrometer is not to be used as a substitute for Seger cones but to supplement them. The more modern forms have an automatic recording device. As at present put on the market, the thermoelectric pyrometer costs about $180, and the price, delicacy of the instrument, and lack of realization of its importance have all tended to restrict its use. However, many of the larger clay-working plants are adopting it, as it is better than other forms of pyrometer for general use and probably more accurate. It can be used up to 1600° C. (2912° F.)

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[1] In this connection see paper by A. F. Hottinger, Trans. Amer. Ceramic Society, Vol. III, p. 180.

TEXTURE.

By the texture of a clay is meant its size of grain. Many clays contain sand grains of sufficient size to be visible to the naked eye, but the majority of clay particles are too small to be seen without the aid of a microscope, and are, therefore, so small that it becomes impossible to separate them with sieves. In testing the texture of a clay it is perhaps of sufficient importance for practical purposes to determine the per cent. of any sample that will pass through a sieve of 100 or 150 meshes to the inch, since in the preparation of clays for the market by the washing process they are not required to pass through a screen any finer than the one above mentioned.

If it is desired to measure the size of all the grains found in the clay, some more delicate method of separation becomes necessary. In many clays the grains cohere more or less, forming compound ones, and these have to be disintegrated by some preliminary treatment such as boiling, or better still by agitating.

The simplest and least accurate method of separating the grains is by settling. This is done by stirring up the disintegrated sample in a beaker of water and allowing it to stand just long enough to let the coarse sand grains settle, and then pouring it into a second beaker, where it again remains long enough to let the finer sand particles drop. The sample is thus run from beaker to beaker until only the finest clay particles are left in suspension. This method is not very accurate.

A second method consists in separating the pebbles and coarse sand particles out of the disintegrated clay by means of sieves, and then placing the finer portions in a tube where it is exposed to an upward current of water. Since the carrying power of the current will increase with its velocity, a current of water rising very slowly in the tube will carry off only the finest particles, while the heavier ones remain behind. If the velocity of the current be kept at this speed it will finally become clear when all the finest particles are carried off. The velocity is then increased a slight amount, so that the next coarsest size is carried off, the current being thus gradually increased until all the particles have been removed. The water is drawn off from the top of the tube by a suitable pipe and led into a settling jar, the different sizes of course being carried into separate receptacles. This method requires a long time and much water, but is more accurate than the preceding.

The most satisfactory method is that known as the centrifugal method. The apparatus used consists of a fan motor[1] placed with the armature shaft in a vertical position. This carries a framework with eight test-tube holders, trunioned so that they can swing outward and upwards as the frame revolves.

The disintegrated sample in suspension in water is placed in these tubes, and twirled at a high speed for several minutes. As a result of this all particles except the finest clay grains are thrown to the bottom of the tube by centrifugal force. These are then decanted off, the tubes refilled with water and the sediment again stirred up. A second twirling of the tubes either at a lower speed or for a shorter period precipitates everything except the fine silt, which is then also decanted off. The subsequent sizes are then separated from each other partly by settling and partly by sieves.

The different sizes which can be so separated and their dimensions are shown in the table below:

Table showing size of grains of sand, silt and clay.

	Conventional name.	*Size of Diameters.* *Inches.*	*Millimeters.*
1	Gravel, ...	1/12–1/25	2-1
2	Coarse sand, ...	1/25–1/50	1–.5
3	Medium sand, ...	1/50–1/100	.5–.25
4	Fine sand, ...	1/100–1/250	.25–.1
5	Very fine sand, ...	1/250–1/500	.1–.05
6	Silt, ...	1/500–1/2500	.05–.01
7	Fine silt, ...	1/2500–1/5000	.01–.005
8	Clay, ...	1/5000–1/25000	.005–.0001

In making the mechanical analyses mentioned under tensile strength, the centrifugal method was used, but only 5 sizes were determined, or rather 5 groups of sizes; numbers 8, 7 and 6

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[1] For complete description see Bulletin No. 64, Bureau of Soils, Dept. of Agriculture, Washington, 1900.

were determined separately, 5 and 4, and 3 and 2 being grouped together. None of the samples tested contained any gravel.

If a raw clay is examined under the microscope, it is usually seen to be composed of a number of different sized grains. These may show a wide range of sizes as given in Fig. 30, which represents a gritty clay from the Cape May formation. In other clays, such as those of the Alloway formation, there is often less variation in the size of the grains (Fig. 31), the grains in the latter being bunched together more than in the former. Figs. 32, 33, and 34 represent several sizes of grains from a sample of Clay Marl I which have been separated by the mechanical analysis. Fig. 32 shows the grains of sand enlarged 115 dia-

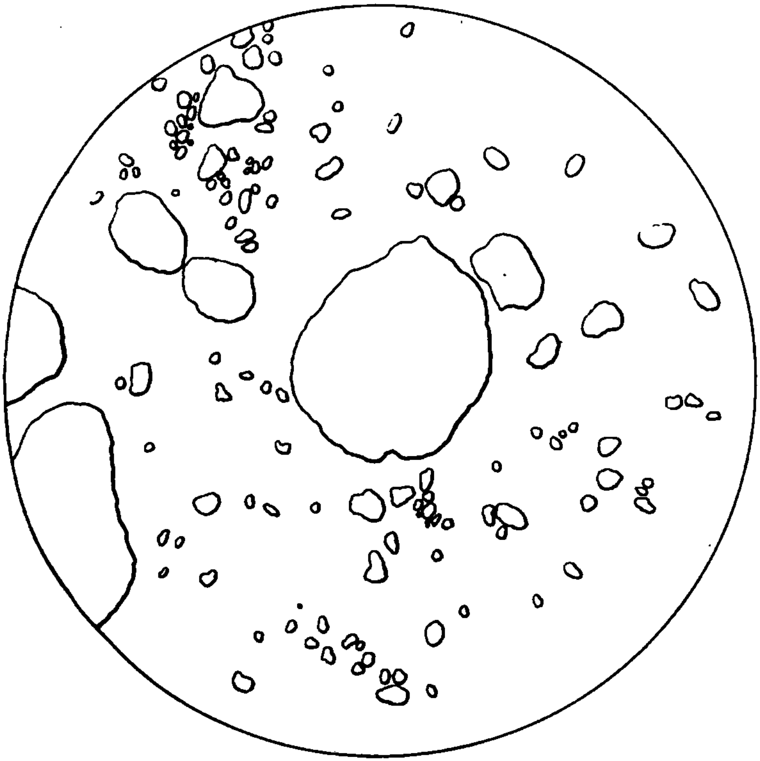

Fig. 30.

Drawing showing particles of a Cape May clay enlarged 362 diameters.

meters, and consisting of quartz (Q), mica (M), feldspar (F) and lignite (L), the cloudiness of the feldspar being due to partial kaolinization. Fig. 33 shows the grains of fine and medium sand, and Fig. 34 the clay particles, the former being enlarged 115 diameters, the latter 362 diameters.

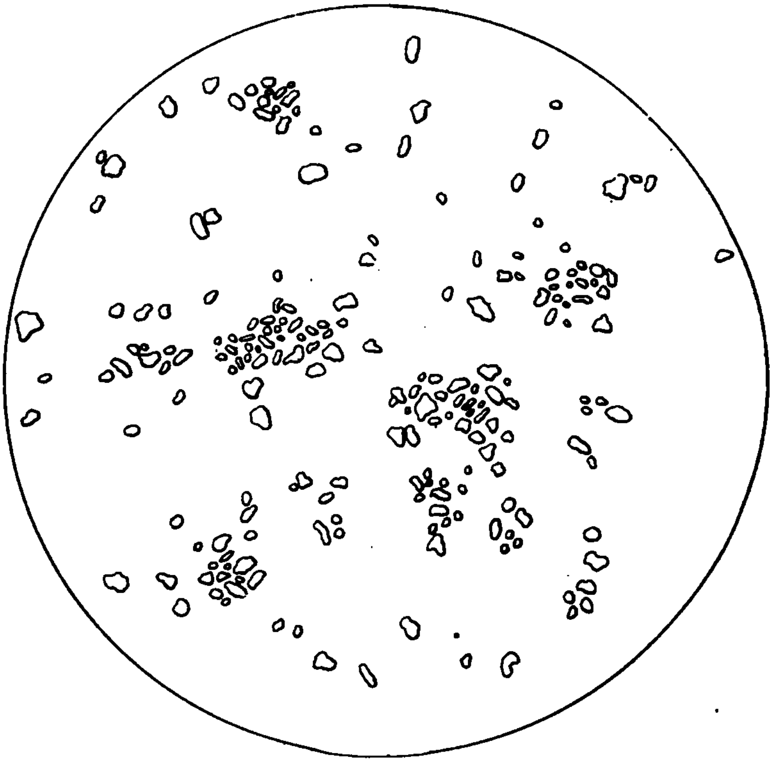

Fig. 31.

Drawing of an Alloway clay enlarged 362 diameters.

COLOR.

An unburned clay owes its color commonly to some iron compound or carbonaceous matter, a clay free from either of these being white. Carbonaceous matter will color a clay gray or black, depending on the quantity present, 3 to 4 per cent. being usually sufficient to produce a deep black. A sandy clay will, however, be more intensely colored by the same quantity than one with many clay particles.

Iron oxide colors a clay yellow, brown, or red, depending on the form of oxide present. The greenish color of many of the Clay Marls is due to the presence of the mineral glauconite.[1] The iron coloration is, however, often concealed by the black coloration due to carbonaceous matter. It is often more or less difficult to make even an approximate estimate of the iron content in a clay from its color. Thus, for example, two clays from the Perth Amboy district which were of nearly the same

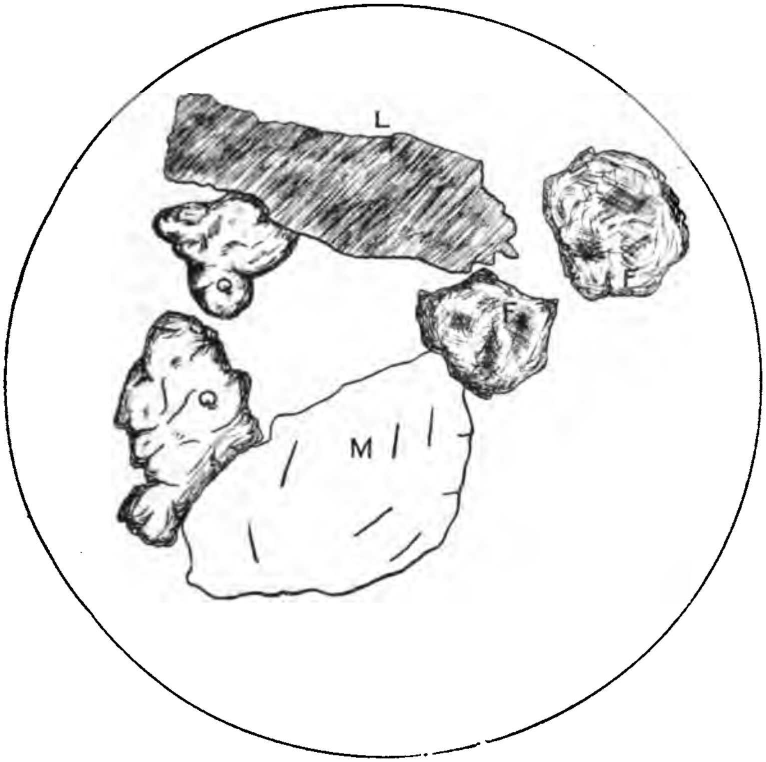

Fig. 32.

Showing grains of sand in a Clay Marl I, enlarged 115 diameters. M, mica; Q, quartz; F, feldspar; L, lignite.

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[1] See Iron, p. 57.

color, had respectively 3.12 per cent. and 12.46 per cent. of ferric oxide.

The color of a green or raw clay is not always an indication of the color it will be when burned. Red clays usually burn red; deep yellow clays may burn buff; chocolate ones commonly burn red or reddish brown; white clays burn white or yellowish white, and gray or black ones may burn red, buff or white. Calcareous clays are often either red, yellow or gray and may burn red at first, but turn yellow or buff as vitrification is approached.

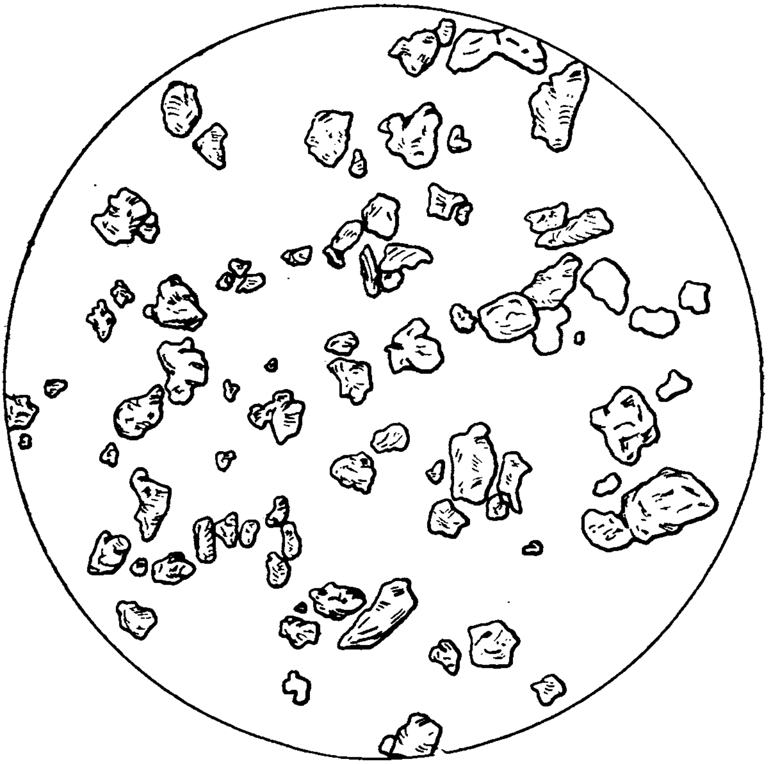

Fig. 33.

Grains of fine and medium sand from a sample of Clay Marl I, enlarged 115 diameters.

SLAKING.

When a lump of raw clay is thrown into water it fall to pieces or slakes, but the rapidity with which this takes place varies greatly in different clays. Open, porous, sandy ones fall rapidly to a powdery mass; others may spall or chip off slowly when immersed, while still others either do not slake at all, or only after long soaking. The slaking property is one of some practical importance, as easily slaking clays temper more readily, or, if the material is to be washed, it disintegrates more rapidly in the log washer.

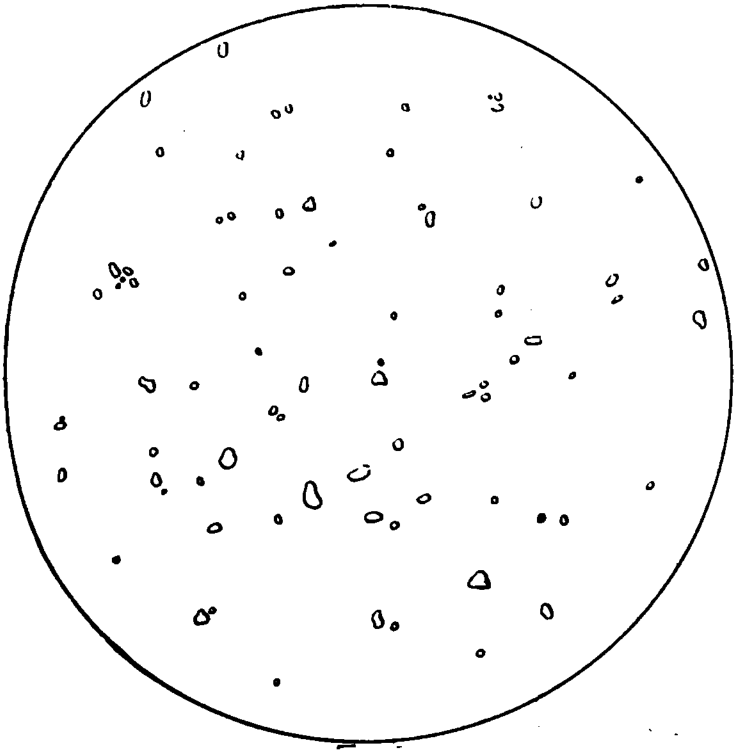

Fig. 34.

Particles of a Clay Marl I, enlarged 362 diameters.

The slaking qualities of the clays from the different formations are referred to in Chapter XVIII, where the different groups are discussed collectively.

SPECIFIC GRAVITY.

The specific gravity of a clay stands in more or less close relation to the density of its mineral particles, and affects its weight per cubic foot, but most clays do not vary much in their specific gravity, ranging commonly from about 1.80 to 2.60. That is they weigh 1.80 to 2.60 times as much as an equal amount of water.

The specific gravity of a number of samples from New Jersey was determined and the figures are given below. It will be noticed that there is not as much variation as one might expect.

Specific Gravity of New Jersey Clays.

Pleistocene and post-Pleistocene.

Locality No.	*Lab. No.*	*Sp. G.*
291,	618	2.68
234,	659	2.68
127,	651	2.64
276,	726	2.60
290,	727	2.60
181,	645	2.63

Cohansey.

Locality No.	*Lab. No.*	*Sp. G.*
183,	653	2.53
185,	683	2.61
185,	682	2.58
206,	665	2.84
209,	666	2.62
182,	661	2.55
195,	642	2.64
195,	634	2.64
191,	619	2.63
183,	663	2.60
218,	695	2.62

Alloway.

Locality No.	*Lab. No.*	*Sp. G.*
167,	688	2.49
164,	680	2.52
162,	617	2.55
169,	674	2.59
160,	675	2.44
162,	677	2.54

Asbury.

Locality No.	*Lab. No.*	*Sp. G.*
217,	697	2.47

Raritan.

Locality No.	*Lab. No.*	*Sp. G.*
222,	603	2.69
222,	606	2.60
220,	615	2.39
109,	600	2.59
268,	723	2.34
120,	654	2.60
134,	621	2.65

If we compare these figures with the figures obtained by Prof. Cook in 1878, we find that his were in most cases much lower, but the reason for this is due to the fact that the determinations for this report were made on the clay powder with a pycnometer, while those in the 1878 report were on lumps of the clay coated with a film of paraffin. The former method, therefore, considers the specific gravity of the clay to be the same as its mineral grains, while the latter method considers the pore spaces between the grains as a part of the clay mass, and the specific gravity depends consequently both on the porosity and mineralogical composition.

PART II.

THE STRATIGRAPHY OF THE NEW JERSEY CLAYS.

By HENRY B. KÜMMEL and GEORGE N. KNAPP.[1]

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[1] The stratigraphy of the South Jersey clays is based largely upon the field work of G. N. Knapp, whose familiarity with the deposits of that portion of the State has been of great assistance both in locating clay deposits and in their correlation. The senior author, however, is responsible for the presentation of these facts as here given.

CHAPTER V.

THE POST-PLEISTOCENE CLAYS.

CONTENTS.

GEOLOGICAL DISTRIBUTION OF CLAY.

The clays of New Jersey belong to a wide range of geological formations, occurring in fact in nearly all the larger geological subdivisions in the State. They are not all of equal value, however, and in the following table, which shows the major geological subdivisions of the State, only the important clay-bearing members are indicated by the asterisk. Small clay deposits, some of which are worked, occur in most of the other groups, as will be shown in the following pages.

Table of Geological Formations in New Jersey.

	Post-Pleistocene.

Cenozoic, ...	Pleistocene.*
	Tertiary.
	  Pliocene.* (?)
	  Miocene.*
	  Eocene.

Mesozoic, ...	Upper Cretaceous.* Lower Cretaceous.* Triassic.*
Paleozoic, ...	Devonian. Silurian. Ordovician.* Cambrian.
Pre-Paleozoic,..	

POST-PLEISTOCENE CLAYS.

Character.—The clay deposits which are to be considered as belonging to the post-Pleistocene or recent period[1] are small, impure and of local importance only.

Along some of the streams shallow beds of sandy and often stony clay occur on the flood plains, *i. e.,* those areas subject to overflow in times of high water. They are clearly the result of the deposition by the stream of the finest material it carries in time of flood. Elsewhere swamps and marshes are underlain by clay, which has resulted from the fine mud washed into them by rain and streams. This clay is usually more or less sandy and often contains a large amount of vegetable matter. In still other localities of the State beds of sandy or stony clay have accumulated at the foot of slopes, as the result of the wash, by rain water, of the finest material from the hills above. Since in such locations there has been very little mixing of the material, these deposits often resemble closely the residual clay formed by the decay of rock in place. All these clays are usually either of a mottled yellow or red color, due to iron staining or black, as a result of the large amount of vegetable matter contained in them. They are of limited extent, both in area and thickness, and are rarely of any value save for the manufacture of common brick. For this purpose, however, they often serve admirably and afford workable clay for small brickyards supplying a local demand. Owing to the diverse ways in which these deposits originate, the clay varies considerably in character and the value of each deposit has to be judged separately.

Localities.—Clay of this nature is used at several localities in New Jersey. At Dunellen (235),[2] Rajotte's clay pits are located along the swampy flood plain of Green brook. The clay is 4 to 6 feet thick, covers at least 14 acres, and is underlain by gravel of late Glacial age. The clay is evidently a swamp and flood plain accumulation of post-Glacial or recent time.

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[1] It is not possible to estimate accurately geological periods in years, but their length is to be calculated in thousands rather than hundreds of years.

[2] These numbers all refer to localities shown on Plates X, XI, XII, XIII.

At Hand & Son's yard (236), North Plainfield, a sticky clay 7 feet thick is used. The clay grades downward into fine sand of glacial derivation. Beneath the sand (7 ft.) is the red shale of the Newark formation. The clay occurs in a slight depression, adjoining a tributary to Green brook, and is perhaps a flood plain and wash deposit of post-Glacial age. It may, however, be connected in origin with the closing stage of the Glacial period, and so more properly belong under the head of glacial clays. Near its borders, where it adjoins a much older gravel formation at a slightly higher level, pebbles from the latter are mixed with it

At Benward's brickyard, Brass Castle, Warren county (279), a sandy, gritty clay containing numerous partially disintegrated bowlders of gneiss, and derived by wash from the steep hillside adjoining, is used in a small way for the manufacture of common brick. A clay formed in a similar manner, but of better quality, is found at Flemington (276), at Pedrick's yard. It is from 3 to 7 feet thick, and rests upon the red Triassic shale. The lower portion of the clay is simply the weathered part of the shale and contains minute shale bits. The upper 4 feet is yellowish in color, contains minute bits of partially decomposed trap rock, as well as some larger fragments of the same rock, and is evidently the result of wash from a steep hill of trap a few rods west of the yard.

Clay loams.[1]—At many points in the State there are clay loams, which are used by themselves or in combination with other clays. They occur at all elevations up to 200 feet and more. They are by no means continuous, even within the areas in which they occur, and not infrequently they are so poorly defined as to be indistinguishable from the weathered products of the formations on which they rest. They sometimes occur, however, in such relations, and have such a composition that they cannot be regarded as a part of the underlying formation, nor as the product of local wash, nor as a wind deposit. Their average thickness is 4 or 5 feet; they rarely exceed 8 feet, although thicknesses of 20 feet are not unknown. They are com-

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[1] Geol. Surv. of N. J., Vol. V, Report on Glacial Geology, pp. 206-210.

monly pebbly in their basal portion, and not infrequently they are stony throughout.

Certain of them at levels not exceeding 60 feet, contain marine organisms, and are, therefore, positively of marine origin. They rest directly upon deposits made during the closing stages of the retreat of the glacier from New Jersey, and so may be regarded as of post-Glacial age, or at most as marking the very latest stages of Glacial time. Many of the loams at greater elevations are indistinguishable from these low-level loams, and are apparently continuous with them, so that the post-Glacial or very late Glacial age of the highest loams is probable, although not demonstrable. While it is impossible to assert that all these loams have had a common origin, yet many facts in the possession of the Survey point to this conclusion, and suggest, even if they do not prove, the post-Glacial origin of these deposits. In this report, therefore, they will be so considered, although the possibility of other interpretation is not overlooked.

It is impossible to give in a few words their distribution, since they are so widespread over the State, and yet so discontinuous. They may be looked for at all levels below 200 feet. They are extensively used for brick at Trenton and Trenton Junction, and northward to Pennington, where they have been stripped off the surface over many acres, at elevations between 100 and 200 feet. At many points, also, between Trenton and Camden, and in the vicinity of the latter place, there is a loam so clayey as to be used for brick. This is the case at The Bordentown Brick Company's brickyard (109), Bordentown; S. Graham & Co.'s yard (102), near Fieldsborough; Murrill Dobbin's yard (113), Kinkora; Joseph Martin's yard (115), Kinkora, and Budd Brothers (143), Camden. At all of these places, however, other clay is mixed with the clay loam.

Very similar clay loam is also used at Brocklebank's (214), Howell, Monmouth Co., and at Lippincott's (215), near Farmingdale. At B. H. Reed & Bros. (193), Hightstown, one of their pits is in a bluish surface clay, somewhat stony, which may be correlated in age with these clay loams. At other points, too numerous to mention, the clayey loam occurs, but is not worked. The illustrations in Plate XV show the shallow character of the clay.

Fig. 1.

Clay loam near Trenton. Showing its shallow character.

Fig. 2.

Shallow character of clay-loam deposit west of Mount Holly, locality 123.

CHAPTER VI.

PLEISTOCENE CLAYS.

CONTENTS.

The Pleistocene formations, as at present recognized in New Jersey, may be subdivided as follows:

A. Glacial and aqueo-glacial.[1]
  1. Late deposits (Wisconsin age).
  2. Earlier deposits (Kansan (?) age).
B. Non-glacial.
  1. Cape May.
  2. Pensauken.
  3. Bridgeton.

Extensive clay deposits of late-Glacial age occur at several points in northern New Jersey. In southern New Jersey, both the Cape May and Pensauken formations contain beds of workable clay, and thin seams occur in the Bridgeton formation.

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[1] These deposits are described in full in Vol. V, Report on Glacial Geology.

GLACIAL CLAYS.

Origin.—During the Glacial period a mantle of debris of varying constitution and thickness was spread over the surface by the ice. This deposit, termed *till,* is commonly very stony and gritty, although containing so large a percentage of clayey material that the whole deposit has often been called bowlder clay. Locally, however, it is so free from stones, comparatively speaking, and so largely made up of clay that it is used for the manufacture of brick, the few stones being previously either screened out or crushed by grinding. This finer ice-deposited material may be called a glacial clay.

The streams issuing from the edge of the great ice field which covered northern New Jersey carried vast amounts of rock debris. Most of this was gravel and sand, but a considerable quantity was fine, impalpable rock flour, the finest product of the glacial grinding. This extremely fine material was the last to be deposited by the streams, since it was the most readily transported, and, for the most, it was carried far out to sea. But, under favorable circumstances, it was deposited in lakes of more or less transient character, near the edge of the ice, or in estuaries which now, by reason of a slow elevation of the land, are wholly or in part above the sea. Wherever deposited by streams, this rock flour gave rise to beds of clay of variable thickness and extent, which may be classed as *aqueo-glacial* clay, since both water and ice were concerned in their formation. Since the glacier covered only the northern part of the State, clays of glacial or aqueo-glacial origin are not to be looked for far south of the line of the terminal moraine, as shown on Plate X, in pocket.

Clays of the Hackensack valley.—"Beneath the stratified sand and gravel of much of the Hackensack valley there is a considerable body of laminated clay. It is well exposed only about Hackensack, especially in the pits at the brickyards below the city, on the west side of the river, and at a few points in the river bank north of the city. It is known to occur at Riveredge and New Milford, on the Henry Bartch place; is reported to lie beneath Oradell, and is present just south of Old Hook. It is not known north of this point in the valley of the Hackensack itself, but it is said to occur north of Closter, at Norwood, and at Neuvy. At Neuvy the clay was formerly worked, and its thickness is said to be 28 feet. The clay at this point is not now accessible.

"In the valley of Overpeck creek the clay is also present as far north as Englewood, and probably beyond.

"This laminated clay was deposited in standing water, which was moderately quiet. Into the water, masses of ice carrying bowlders were sometimes floated, as shown by the occasional large, glaciated bowlders in the clay.

"The clay is known to overlie till at many points, and its deposition is therefore later than the occupancy of the region by the ice. At the north the surface of the clay is some thirty feet above sea level, while at Little Ferry its surface is about at sea level. Its surface, therefore, declines slightly to the south.

"The depth of the clay is one of its most remarkable features. The following data on this point have been reported:

"At Neuvy, surface elevation 20 to 30 feet, 28 feet of clay.

"North of Closter, surface elevation about 40 feet, 10 feet of clay.

At Oradell, surface elevation about 30 feet, 185 feet of clay, beneath 15 feet of sand.[1]

"At Hackensack numerous borings have tested the depth of clay, which varies from a few feet at the more northerly brickyards to 85 feet at Mehrhof's lower yard, and at the gas works.

"West of Bogota, on the east side of the river, the clay is reported to be 215 feet thick. These figures make it clear that the surface of the rock east and north of Hackensack is far below sea level, and that, if the drift were removed, or even that part of it which lies above the till, a great bay would cover the Hackensack meadows, and extend far to the north. A branch of the bay would run up the valley of Overpeck creek, for the surface of the rock at Englewood is known to be locally as much as 60

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[1] It is suspected that the boring here may have been in soft shale, not distinguished in the drilling from clay.

feet below sea level. Even as far north as Closter the surface of the rock is at least 20 feet below the sea level, according to the records of wells.

"The records of borings in the vicinity of Newark are in keeping with the above figures.

"This clay was deposited in standing water. Such a body of water, therefore, covered the lower lands west of the Palisade ridge, probably as far north as Neuvy, after the departure of the ice. The surface of the clay at the north is about 30 feet above sea level. The surface of the water in which the clay was deposited was, therefore, at least this much above present sea level in the latitude of Neuvy. Not only this, but the water in which the clay was deposited was probably not extremely shallow. While no considerable depth need be assumed for it, it is safe to conclude that the surface of the clay is somewhat below the surface of the water in which it was deposited. Furthermore, the clay was deposited after the ice was sufficiently far north of the site of deposition, so that coarse materials were not readily available. It is not certain that the clay at Hackensack and below was strictly contemporaneous with that at Neuvy. The deposition of clay to the south may well have begun earlier than its deposition to the north.

"It is commonly believed that the ice sheet depressed the surface on which it rested, and that, as it melted, the unburdened earth crust reacted by rising. Before the deposition of the clay in the northern part of the Hackensack basin, the land may have risen, so as to make the water shallower than at an earlier time. At any rate, there is good evidence of post-Glacial submergence to the extent of fully 30 feet near the northeastern corner of the State. Considering the depth of water necessary for the deposition of the clay, and the rise which may have taken place as the ice melted back, it is not unreasonable to suppose that the region about Westwood was submerged to the extent of 60 to 80 feet, the height of what appear to be delta fronts, at the time the ice was retreating; for these deltas, if such they are, were probably made while the edge of the ice was in the immediate vicinity, and somewhat before the deposition of the clay.

"The hypothesis that the water which covered this area was a lake, rather than a bay, is worthy of consideration, though it is, on the whole, less satisfactory The moraine and other drift deposits may have blocked the southern outlet of this region to the height of 25 or 30 feet, between New Jersey and Staten Island. If a similar dam obstructed Kill van Kull, or the Narrows and East river, a lake would have come into existence in the tract where the clay is. As the outlet was cut down, the lake was drained. But even on this hypothesis, differential movement of the surface must be supposed, for the surface of the clay is higher to the north than to the south.

"It may here be added that there is abundant evidence of a late submergence, at least to the extent of 40 feet, at various points about the coast of southern New Jersey. The date of this submergence was not earlier than the close of the last Glacial epoch.

"The clay of the Hackensack valley is everywhere covered by sand, generally 8 to 15 feet in depth. At some points the surface of the clay below the sand is leached and oxidized. It is, in most places, not possible to say whether this leaching and oxidation is the result of exposure before the deposition of the sand, or whether it has taken place beneath the sand. The latter would be somewhat out of keeping with the extent to which the drift so far beneath the surface has generally been altered since its deposition.

"At two points specific evidence on this point has been obtained. In 1893 one of the clay pits below Hackensack showed the following section:

"(5) 8 feet of fine, stratified sand, containing a few gneiss bowlders.

"(4) Stratified sand, 2 feet in depth, overlain by a few inches of blue clay containing fragments of leaves and woody stems.

"(3) 1 foot of black soil.

"(2) 6 feet of laminated clay, containing an occasional bowlder, calcareous up to within a foot of its upper limit.

"(1) Till, seen in the bottom of the pit on its west side.

"The old soil (3) was not far from sea level. A similar section, so far as the old soil was concerned, was seen by Mr. Peet, at Riveredge, a little south of the depot, in a temporary excavation. Here the section was as follows:

"(3) Sand, 4 feet.

"(2) Clay and sand, interlaminated, 6 feet.

"(1) Clay, black from the presence of organic matter.

"The old soil in this case was about 10 feet above sea level.

"These sections show that after the clay was deposited, the surface was exposed for a time, and that vegetation grew upon it, after which it was depressed sufficiently to allow of the deposition of the overlying sand."[1]

Clay of the lower Passaic valley.—Clay, very similar in appearance to that at Hackensack, was formerly dug in the valley of a little creek on the west side of the Passaic, one-half mile or more below Passaic Bridge. It lies beneath several feet of coarse gravel, which increases in thickness towards the hill. The clay is reported to be 13 feet in thickness, the upper 6 or 8 feet being yellow, the lower part blue. Owing to the heavy overburden it is not readily available.

Clays of the upper Passaic basin.—Clay occurs over wide areas in the basin of the upper Passaic and its tributaries in the area formerly occupied by the glacial Lake Passaic.[2] It underlies all the area of Great swamp and the surrounding low ground, where it does not occur above an altitude of 240 feet. The clay of the eastern half of this area, as far west as the road from New Vernon to Gillette, is covered with fine sandy loam, which east of the longitude of Green Village changes into sand and gravel. Clay more or less buried by sand and gravel has also been found 1) south of Morristown, 2) on the banks of the brook southwest of Convent and 3) at the bottom of deep wells southwest of Madison.

The clay in the Great swamp area attains a considerable thickness. Wells 25 or 30 feet deep do not pass through it except along the edge near the higher ground. At one locality, a mile and a half south of Green Village, clay is reported to be over

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[1] N. J. Geol. Surv., Vol. V, Report on Glacial Geology, pp. 616-619.

[2] N. J. Geol. Surv., Ann Rep. for 1893, and Vol. V, Report on Glacial Geology. See, also, Plate X, in pocket, for the outline of Lake Passaic.

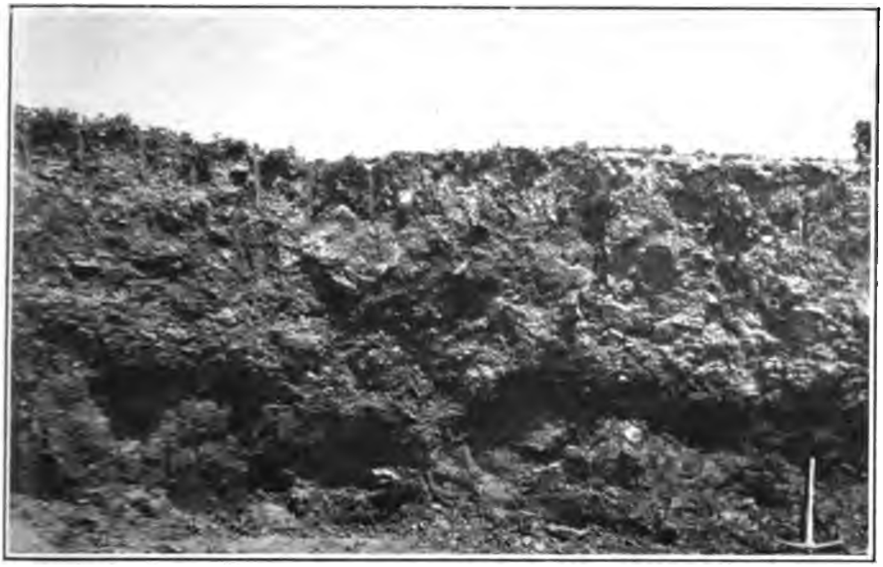

Fig. 1.

Stony clay (glacial till) on laminated lacustrine clay. Conner's brickyard, Little Falls.

Fig. 2.

Another view of same, showing many stones in the clay and at the top of the bank the marks that have been made by the wedge in breaking off masses of it. Laminated lacustrine clay occurs at the bottom of the bank under the stony clay.

a hundred feet thick. Outside the swamp, similar clay occurs at somewhat greater elevations, but yet within the limits occupied by Lake Passaic. At the clay pits south of Morristown (elevation 310-320 ft.) it is overlaid by 2 or 3 feet of glacial till. Three miles south of Morristown, on the property of Mr. F. F. Lippman, slightly stony clay is exposed along the road, its vertical range being 30 feet. Between Second mountain and Long hill, along the Passaic and Dead rivers, there is considerable clay at elevations below 225 feet. This clay may in part be post-Glacial, since it is hardly above the present flood plain of the river.

Northeast of the morainal ridge which extends from Morristown to Chatham, lacustrine clay occurs at several localities, chiefly at low levels. Some of it may be in part post-Glacial in origin, but other beds are wholly of earlier date. The clays found in the marshes along the Whippany river belong to the former class, while a brownish-blue clay, on the hill midway between Whippany and Hanover, at an elevation of 230 feet and overlain by several feet of glacial till, belongs to the second class.

North of West Livingston a low area (200 ft.) seems to be underlain with clay. A mile and a half northwest of the south end of Hook mountain the Rockaway river has cut through a thin coating of glacial sand and gravel into underlying clay. Extensive deposits are said to occur on the property of J. B. Ricketts, near Parsippany. In the vicinity of Little Falls, Singac and Mountain View there are extensive areas—at low levels—underlain by clay which is dug at a number of points, Plate XVI. In places the laminated clay is overlain by till, some of which is not too stony to be used also for brick; elsewhere by stratified sand and gravel. Clay also underlies the low ground northward from Mountain View nearly to Preakness, but it is deeply buried by sand and silt, except along the borders.

The clay at the lower levels is always finely laminated, the thin clay laminæ being separated by fine sandy partings. It is calcareous and frequently contains concretions of carbonate of lime, some of which are shown on Plate IV (p. 24). These are very abundant in certain layers, occurring in clumps at certain horizons rather than equally distributed. They vary greatly in size and shape, some cylindrical forms being 6 inches in length.

The clays at higher levels are usually less distinctly laminated and generally contain a few glacial pebbles. Locally, as at Morristown, they grade upward into stony till.

Other localities.—Clay apparently of Glacial age has also been observed at a few other localities. It was formerly dug for brick along Clove brook near Sussex (Deckertown), not far from Fuller's mill.

At Somerville a red clay occurs at Ross' brickyard, where it is used for common brick. It contains many bits of waterworn red shale and some yellow quartz pebbles, which are more common in the upper layer. The body of the clay is composed of the finest material derived from the disintegration of the red shale. It is clearly a slack water deposit, and the readiest, but not necessarily the only, explanation, is that it was formed during the Glacial period, when the Raritan valley was temporarily dammed by sand and gravel discharged into it from the north near Bound Brook.[1]

CAPE MAY CLAYS.[2]

Origin.—Around much of the coast there is an ill-defined terrace 30 to 50 feet above tide. In some places it seems to have been cut by the waves in older formations. In other localities it has been built by them of debris gathered where their work was destructive. Terraces, corresponding in elevation to these wave-cut and wave-built forms, extend up the streams, and, except near the sea, are the result of stream action. Traced up the Delaware bay, these river terraces, although often poorly defined, pass into that formed of the glacial gravels brought down the Delaware river from the melting glacier farther north. Corresponding stream terraces occur along the tributaries of the Delaware river below Trenton, just as they do along the valleys leading to the Atlantic coast. The fact seems well established that

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[1] Ann. Rep. State Geologist of N. J., 1892, p. 123.

[2] See N. J. Geol. Surv., Vol. V, Report on Glacial Geology, for a fuller discussion of the Cape May formation.

at least during the closing stages of the Glacial period the southern portion of the State stood from 40 to 60 feet lower than at present, at which time the waves and streams constructed the terraces just mentioned.

They are for the most part composed of gravel and sand. In certain localities, however, they contain workable beds of clay, and in many places they are covered with the clay loam already described (pp. 121-2). To the material of these terraces south of the region where it is glacial, the name *Cape May formation* has been given. It may be equivalent in age, in whole or in part, to the glacial and aqueo-glacial clays just described, but owing to the different manner of accumulation, its clay beds are separately considered.

Localities.—As already indicated, the Cape May formation is partly marine and partly river made. The land stood 40 to 60 feet lower than at present, and estuaries were formed at the mouths of all the streams. In several of these estuaries there seems to have been a certain area where the conditions favored the accumulation of beds of clay. Such conditions apparently prevailed in Cohansey creek, near Bridgeton; in Maurice river, near Buckshutem, south of Millville; in Great Egg Harbor river, at High Bank Landing, near Mays Landing; in the Delaware, near Kinkora, and perhaps also at Edgewater Park. At these points the clay is sandy, usually dark in color, due to carbonaceous material, and somewhat pebbly. It is commonly covered with several feet of sand or gravel, or both. Near Port Elizabeth it is overlain by a layer of oyster shells of recent age, 2 feet thick.[1] The beds of clay are apparently of limited extent and grade horizontally into sand or gravel. This is well shown at the line of old pits on the right bank of Cohansey creek below Bridgeton. The maximum thickness observed was about 17 feet at Hess & Golder's pit, near Buckshutem, on Maurice river.

At the time of our investigations these clays were being dug at Hess & Golder's pit (181) and A. Burchem's yard (180), both on the Maurice river, near Buckshutem. They were also formerly dug by Isaac Mulford, near Millville; by Isaac Hil-

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[1] N. J. Geol. Surv., Ann. Rep. 1878, p. 64.

liard, near Buckshutem, and by B. F. Lupton, at Bridgeton. The black clay overlying a yellow quartz sand resembling the Pensauken at Martin's brickyard, Kinkora (115), is clearly a comparatively recent deposit, and may belong in the Cape May formation.

At Henry C. Adams' clay pit and brickyard at Edgewater Park (127) 8 feet of yellowish and black clay, overlain by several feet of wind-blown sand, rests upon a reddish-brown sand, which is apparently of glacial derivation. The clay is a local deposit, grading laterally into sand, and in places contains great numbers of rootlets, which suggest a swamp or estuary deposit of comparatively recent origin, although the surroundings are not at all swampy at present. On the contrary, the clay bed is located on the top of a gentle swell, but its elevation is not more than 40 feet above tide, so that it is within the limits of an area which was submerged during and since late Glacial time. The clay is either Cape May or later in time of origin.

In addition to the above-mentioned areas, the clays at Belle Plain (188), Woodbine (189) and Bakersville (275) are thought to belong to this horizon.[1] At these three localities the clay occurs at elevations of 40 feet or less. It forms shallow, sandy deposits, somewhat pebbly and overlain by several feet of sand or gravel. They are apparently thin clayey lenses in the sand and gravel which form the great mass of the Cape May formation. The Bakersville deposit is said to cover something over 200 acres, but the extent of the other beds is not known. It is not unlikely that similar deposits, at present undeveloped, may be found at points along the coast within the elevation—50 feet—of the Cape May formation. Owing, however, to a surfacing of sand and gravel, their presence can only be detected by boring.

The clays of the Cape May formation are of value chiefly for the manufacture of red brick or drain tile. There are, however, some small lenses of buff-burning clay.

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[1] It is not impossible that the clays at Belle Plain and Woodbine belong to the Cohansey formation, although in the absence of any decisive evidence we have placed them in the Cape May, chiefly on the basis of their elevation.

PENSAUKEN.

The Pensauken formation has been somewhat fully discussed in the previous reports of the Survey.[1] It is predominantly a sand and gravel formation occurring chiefly in two belts. "One of these runs across the State in a northeast-southwest direction from the head of Raritan bay nearly to Salem; the other runs along the east side of the State from the vicinity of Asbury Park to Bridgeton. The former belt is narrow and clearly defined, and within it the formation occurs in a series of closely associated patches, some of which are large and some small; the latter belt is wider and less well defined, the patches of the formation being more widely separated."[2] The Pensauken formation is believed to be contemporaneous in age with an earlier ice epoch than that to which the Belvidere-Perth Amboy moraine is referred. The extent to which the formation has been removed by erosion, and the deeply dissected condition of the remnants, indicate a much greater age than the Cape May formation or the great mass of glacial drift.

The Fish-House clays.—Although this formation is predominantly sand and gravel, yet at Fish House (137), a few miles north of Camden, there are thick beds of black clay which are apparently intercalated in the sands of this formation. Since these clays are somewhat fossiliferous, they have long attracted the attention of geologists, and many diverse views have been held as to their age. A few years ago a series of borings was made to determine their extent, and the data thus obtained made it possible to fix their stratigraphic position. The sections were carefully examined at the time by Lewis Woolman, and the following facts both as to stratigraphy and fossils are mainly summarized from his report.[3]

In the excavations the clay attains a thickness of 27 or 28 feet. The upper 2 or 3 feet is yellowish in color, as is also the

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[1] Notably the Ann. Rep. for 1896, 1897.

[2] Ann. Rep. 1897, p. 15.

[3] Ann. Rep. of the State Geologist of N. J., 1896, pp. 201-244.

basal foot. The great bulk of the clay, however, when freshly dug, and before weathering, is black. Immediately beneath the clay and forming the floor of the excavation is a layer of "ironstone" a few inches thick, beneath which occurs coarse yellow sand (Pensauken). Above the clay occurs a few feet of clayey loam, usually with a well-marked line of pebbles at its base.

In the southeastern portion of the excavation a wedge-shaped mass of white plastic clay of Cretaceous age was found. The black clay abutted against this, and, toward the thin edge of the wedge, overlay it unconformably.[1] The same white Cretaceous clay is also exposed in adjoining excavations on the south at the same level as the black clay, which is there absent. Above the white clay occur sand and gravel deposits continuous with those which overlie the black clay. The facts clearly establish the recentcy of the black clay as compared to the white Cretaceous clays.

The facts, as shown in the excavations, are supplemented by the records of over 50 borings, from which it appears that the black clay terminates rapidly to the south, partly by abutting against the underlying Cretaceous clay, and partly by thinning out and giving place to gravel and sand. It extends northeastward almost to Delair avenue, occurring on both sides of the river road, but its maximum known thickness (31½ feet) is apparently near the eastern portion of the present excavation. Towards its limits it diminishes greatly in thickness, contains lenses of sand or gravel, and is overlain by gravel which is unquestionably of Pensauken age. From northeast to southwest its length is about 3,800 feet, and its breadth, so far as known, 1,500 or 1,600 feet. It evidently occupies a somewhat circumscribed area, wherein during Pensauken submergence, unique conditions (for that epoch) favorable to the deposition of clay prevailed.

Fossils.[2]—Near the base of the clay there is a bed containing numerous casts of fresh-water mussels belonging to the genera

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[1] That is in such a way as to show that the white clay had been eroded and partly removed after it had been deposited and before the black clay was formed.

[2] N. J. Geol. Surv., Ann. Rep. for 1896, pp. 205-212.

Unio and *Anodonta,* which bear a close resemblance to living forms. Teeth and portions of the skull of an extinct horse have also been found, as well as a few other vertebrate remains and some plant forms. The fossil evidence is all indicative of the comparative late age of those clays, but is not sufficiently refined to do more than corroborate in a general way the evidence of age derived from the stratigraphy.

THE BRIDGETON FORMATION.[1]

The next older formation than the Pensauken recognized in New Jersey is the Bridgeton. Like the Pensauken, it represents a period when the State was depressed below its present level, so that areas now 200 feet and less above sea were for the most part submerged. Like the Pensauken, it is also chiefly gravel and sand; like the Pensauken, it occurs in a series of isolated patches, large and small, which are but remnants of what was once a continuous formation. These remnants are most extensive in the southeast parts of Burlington, Camden, Gloucester, and Salem counties and the northern portion of Cumberland. Here the formation in general caps the hills and forms considerable deposits on the broad interstream surfaces.

The formation locally contains a few thin seams of clay near its base, interbedded with coarse sands and even gravel. So far as known, however, these are never of commercial importance and are nowhere worked.

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[1] The exact age of the Bridgeton formation is not beyond question. It has not been positively determined whether it is Pleistocene or earlier, and, perhaps, never can be definitely settled. The weight of available evidence favors its correlation with the earlier or high-level Columbia of the District of Columbia.

CHAPTER VII.

CLAYS IN TERTIARY FORMATIONS.

CONTENTS.

The following subdivisions of the Tertiary beds are recognizable in New Jersey, beginning from the top downward.

8.	A coarse gravel member. Beacon Hill gravel,......	Pliocene or Miocene.
7.	A sand member. Cohansey sand,..................	
6.	A marl bed—Shiloh marl,........................	Miocene.
5.	A thick clay bed—Alloway clay,..................	
4.	A micaceous talc-like clayey sand (near Woodstown only),...	
3.	A fluffy sand,..................................	
2.	A clay bed—Asbury clay,........................	
1.	A marl bed—Blue marl,.........................	Eocene.

THE BEACON HILL AND COHANSEY FORMATIONS.

Definition of terms.—Under the term Beacon Hill, as used in the Annual Reports of the Survey from 1893 to 1900, there have been included two somewhat different beds; the upper, a bed of coarse gravel, chiefly quartz and chert, and the lower, a bed of coarse quartz sand, with occasional small pebbles. Locally, the sand is cemented into beds of sandstone. The lower member also contains lenses of clay, which are frequently of considerable economic importance. Whether these two members are a unit, or are really two separate formations, has been an unsettled question. Until recently they have, on the whole, been regarded as but one formation, but the other alternative has not been lost sight of. However, data now in the possession of the Survey, the result of recent field work by Mr. Knapp, apparently indicate that there is good ground for separating the two, and he proposes the term Cohansey for the sand member, thus restricting the term Beacon Hill to the upper gravel.

It has been impossible to fix definitely the age of these beds. No adequate stratigraphic ground for separating them from the underlying Miocene beds has been found, but it is quite possible that such a separation should be made, particularly since the scanty paleontological data at hand favor slightly their reference to the Pliocene, rather than the Miocene. The evidence, however, is not decisive, and the exact age of these formations must remain doubtful.

Fossils.—In the vicinity of Bridgeton numerous well-preserved plant remains have been found in the Cohansey sandstone. Mr. Hollick, who has studied these remains, makes the following statement:[1] "Probably about fifty species are represented in the collections which have been made—all of them angiosperms, many of them referable to living species, and some of them identical with species now growing in the vicinity of Bridgeton, such as *Ilex opaca, Nyssa sylvatica,* etc.

"A comparison between this fossil flora and the living flora of eastern North America indicates a close identity between the former and that now in existence at about the latitude of Virginia. In many of its elements it is unique and distinct from that of any other American Tertiary horizon. The collections of Eocene and Miocene plants which have been made in the West contain different species, and those from Bridgeton are

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[1] N. J. Geol. Surv., Report on Forests, 1899, pp. 197-198.

either rare or entirely wanting in them. As a whole, the flora is more nearly comparable with that of certain European Upper Miocene localities, and we may regard it as that which immediately preceded the close of the Tertiary period, and this conclusion is emphasized by the well-recognized fact that in Europe biologic evolution *was in advance* of America, so that the European Eocene flora is largely comparable with the American Miocene, European Miocene with American Pliocene, and European Pliocene with the American living flora."

Mr. Hollick also states[1] that the leaf-bearing formation could be referred either to the late Miocene or Pliocene on the basis of these fossil plants. Some obscure casts of Molluscan shells[2] have been found near Millville, but they are not decisive. The paleontological evidence, therefore, does not enable us to determine the age of the beds with any more certainty than does the stratigraphy, although it suggests their Pliocene age.

Clay Deposits.

Beds of clay, often of considerable extent, occur somewhat widely in the Cohansey sand. They range in thickness up to 24 feet, as reported, but in the great majority of cases they are only 8 or 10 feet thick, rarely exceeding 12, so far as known. Horizontally they vary from a few acres to several hundred in extent. In only those cases in which the deposit has been exhausted, or in which many borings have been made, is the size of these clay lenses known.

Distribution.—These clays occur in the southern portion of the State, for the most part southeast of the divide separating the tributaries of the Delaware from the streams which flow directly into the Atlantic. That is, they occur in Ocean and Atlantic counties, the southern portion of Burlington, Camden and Gloucester, and the central part of Cumberland. In other words, they occur in the sandy pines district of the State. This is, in a general way, the area southeast of the line on the map, Plate X, which

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[1] Letter to the writers.

[2] N. J. Geol. Surv., Ann. Rep. for 1896, p. 254.

represents the northwestern limit of the Miocene deposits. At present they are dug at Bridgeton (191), Rosenhayn (185), Millville (183), Mays Landing (195), Da Costa (197), Elwood (198), Winslow Junction (201), Woodmansie (213), Whitings (212), Toms River (206) and Herbertsville (218, 219). They have also been dug at Seven Stars, White Oak Bottom; north of Whitings, Wheatland, Union Clay works, Tuckerton (210, 211), Mayetta (209) and near Cedar Grove, all in Ocean county; at Mount Misery and Chatsworth, in Burlington county; near Atco, Williamstown Junction and Blue Anchor (202, 203, 204), in Camden county; at Egg Harbor City, and near Centre Grove, in Cumberland county. At Mayetta a tract over 700 acres in extent is reported to be underlain by clay, with a thickness of 24 feet.

Clay probably belonging to the same formation has been observed in the pines west of Toms River, near Davenport (208), and also north of Toms River and south of White Oak Bottom (207). It is also reported at South Park, Burlington county, and from many other places in the pines, as indicated on the map. It is entirely probable that similar lenses of clay exist at many other points within this district, but their location can be determined only by boring. In the absence of any natural exposures, such as stream bluffs, or of artificial excavations, such as road or railroad cuts, and in the presence of the widespread and continuous covering of sand and pine forest, their location is a matter of great difficulty.

Character.—These clay lenses vary considerably from place to place. They are usually somewhat sandy, particularly near their borders. The upper foot or two frequently contains scattered pebbles. In color they are white, yellow, chocolate and black. The latter clays contain much lignite, usually, however, in a finely broken condition. Many of these black clays, however, burn buff, Plate XVII, Fig. 1. The white clays are often more or less yellow mottled near the surface, owing to the infiltration of iron from the overlying yellow gravels.

The clay beds are underlain by coarse sand, into which they pass either by thin alternating layers of sand and clay or by a gradual transition, the clay becoming more and more sandy.

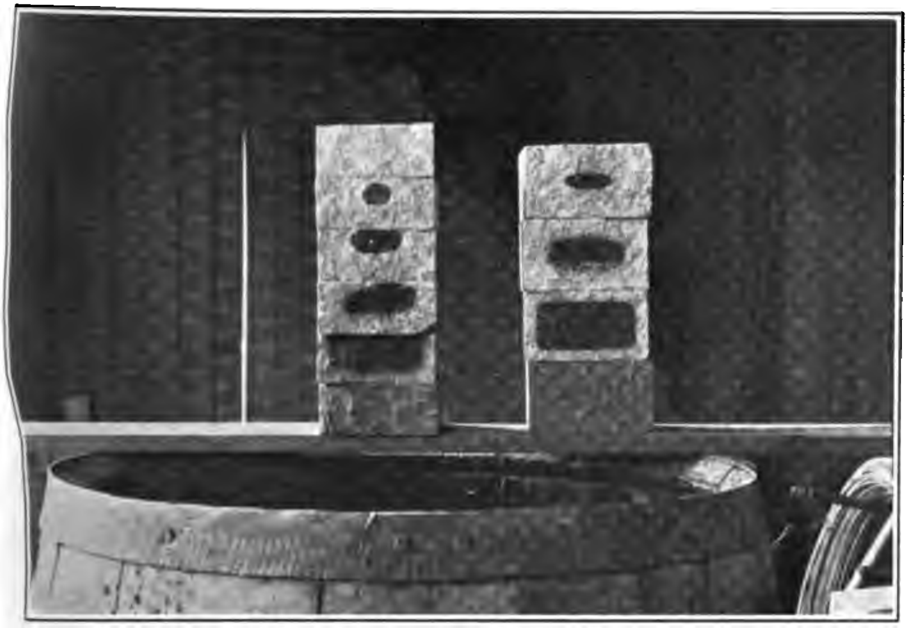

Fig. 1.

Showing the progressive changes in burning a black clay low in iron oxide to a buff-colored brick.

Fig. 2.

Showing the irregular surface of the clay under the bed of gravel. Rosenhayn.

The upper foot or two of the clay not infrequently contains scattered pebbles, and the whole is usually covered by several feet of sand or gravel or both. Locally, the change to the overlying sand or gravel is abrupt and sharply marked, and the upper limit of the clay is apparently an erosion surface on which the sand and gravel were later deposited (Plate XVII, Fig. 2). When this is the case, the upper part of the clay is without stones. Elsewhere, there is, for a space of a few inches or a foot or two, an alternation of sediments, laminæ of clay being contained in the overlying beds. In a few instances these clay laminæ continue for several feet above the main mass of the clay.

There seems little reason for doubting that the clay and the underlying sand were successive deposits, formed without interruption. In those cases, where the clay is somewhat sharply separated from the overlying sand and gravel, the former is best referred to the Cohansey, and the latter to the Bridgeton or Pensauken, or regarded as a secondary deposit derived from them by weathering and washing. Where the clay is apparently commingled in its upper part with the overlying gravel, the latter may still be a much later deposit, the commingling of the two being due to re-working of the upper portion of the clay as the gravel was deposited. In this case the bulk of the clay might be Cohansey, with its upper portion re-worked in Bridgeton or Pensauken time. In a few rare instances the clay, by its interlamination with the overlying sand and gravel, seems to be of the same age as the gravel, rather than older. Although in the light of our present knowledge it seems best to regard all these clay lenses as belonging in the Cohansey sand, yet the possibility that some of them may be later in age (perhaps Bridgeton) must be kept in mind.

THE SHILOH MARL.

A gray, highly fossiliferous marl is found in a limited area in Salem and Cumberland counties along the tributaries of Stow creek. In the region in which it occurs this formation next underlies the clay-bearing Cohansey sands. Since it contains fossils of undoubted Miocene age, the overlying sands and clays cannot be older than late Miocene, and, as above noted, they may be younger. It likewise enables us to fix the age of the thick bed of clay which occurs beneath it, so that, although it contains no clay itself, it is an important stratigraphical bed.

THE ALLOWAY CLAY.

Occurrence.—The clay bed, to which we have given this name, is continuously traceable from near Swans Mills, south of Mullica Hill, in Gloucester county, southwest to a point 2 miles south of Alloway, in Salem county. Isolated outcrops, where the overlying beds have been removed, have been observed as far south as Stow Creek township, in Cumberland county. The clay undoubtedly continues south of Quinton, towards Canton, and perhaps southeast to Bacons Neck, near Cohansey creek, but in this direction it is deeply buried beneath the later Cape May sand and gravel. Within the area between Alloway and Ewans Mills, its outcrop forms an exceedingly irregular belt, several miles in width. Within this belt, however, there are considerable areas where the overlying Bridgeton formation is so thick as to effectually conceal the clay which lies beneath. The map on Plate XIII (in pocket) shows the areas (1) in which this clay appears on the surface or is buried by not more than 5 or 6 feet of cover; (2) the areas in which it is so deeply buried as to be inaccessible, and (3) the areas from which it has been removed by erosion. Since the clay bed slopes gently towards the southeast, the northwestern border of this deposit is formed by the outcrop of underlying beds from which the clay has been eroded. Attempts to find this clay to the northwest of the area indicated on the map by boring or otherwise will, therefore, prove futile. On the southeast and south, however, the Alloway clay passes beneath younger formations of various ages. These rapidly attain considerable thickness, particularly to the southeast, owing to the rise of ground in that direction, so that, although the clay there continues an unknown distance to the south and southeast beyond the limits given on the map, yet it is discoverable only by deep borings.[1] Northeastward towards Ewan Mills the clay apparently thins out. At Haines & Son's brickyard, south of Yorktown, it has a thickness of 50 feet, as determined by boring. Along Salem creek it is exposed in frequent outcrops from Fox's mill, near Pittsgrove, nearly to Woodstown, a distance of 4 miles, in which the entire thickness of 75 or 80 feet is crossed. It is apparently a continuous bed of clay, without sand beds of sufficient extent to show themselves in outcrop. Northeast of Harrisonville, however, it rapidly thins out, giving place to sand, and towards Ewan Mills, a thick bed of sand apparently occupies its middle portion. A mile southwest of Five Points (Richwood) and one and one-half miles north of Ewan Mills a clay bed 4 to 6 feet thick apparently corresponds to the basal portion of the Alloway clay. No further trace of it has been found to the northeast.

At present this clay bed is being worked only in one locality—Haines & Son's brickyard—south of Yorktown. At Fenwick (169) a secondary surface clay derived largely from this clay bed was formerly utilized in a small way. This clay is available over wide areas, some of them advantageously located, as regards railroad facilities. It is finely developed on the lower slopes of Big Mannington hill, about a mile from the railroad, and also in the railroad cuts at Riddleton Junction and at Alloway.

Character.—It is usually a light-brown color, although some portions are white, yellow, or even black. Where weathered, it is traversed by many joints, breaking it up into small pieces, with conchoidal fractures. These joints are locally filled with iron crusts, Plate II, Fig. 2, which diminish greatly its value. The rich farming country underlain by this clay bed is shown in Plate V, Fig. 2. Samples of the clay were taken at many localities

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[1] At Glassboro it was penetrated at 90 feet from the surface, at an elevation of 50 feet A. T., where it was 55 feet thick (Ann. Rep. '93, p. 407); at Clayton, 98 feet from the surface at an elevation of 46 feet A. T. (Ann. Rep. '95, p. 89); at Williamstown 5 feet of black clay 66 feet below the surface between elevations of 84 feet and 79 feet A. T., may, perhaps represent it (Ann. Rep.., '97, p. 255); 1 mile south of Daretown it apparently occurs 80 feet below the surface from 60 feet A. T. to 35 feet A. T. (Ann. Rep. '97, p. 250).

and subjected to various physical tests, the results of which for locality are given in detail in Chapter XIX. A tabulation of the physical tests is given in Chapter XVIII.

THE MICACEOUS, TALC-LIKE CLAY.

Immediately below the Alloway clay there occurs, in the vicinity of Woodstown and towards Ewan Mills, a thin bed of white, micaceous, sandy clay, which is quite unique. Where pure, it is snow white in color, though it is not infrequently stained yellow by iron. It has a marked, soapy, talc-like feeling, so much so that in our notes it is referred to as a talc clay, although, strictly speaking, it is not talc at all. The bed is probably never more than 10 feet thick, but it is apparently quite constant in horizon. It is not very plastic and of doubtful value as clay. It is well exposed in the railroad cut just north of Woodstown (170) and at an old pit east of Harrisonville (173).

THE FLUFFY SAND.

Beneath the micaceous, talc-like clay there is a bed of fluffy sand, which, in Burlington county and southwest to Salem county, forms the lowest of the Miocene beds. At its very base there is not uncommonly a layer of pea-gravel a few inches in thickness, but this is not everywhere present. To the southwest, in the vicinity of Quinton and Alloway, its thickness is less than 10 feet, but it thickens to the northeast, having a thickness of 50 feet or more east of Mullica Hill. It extends much farther northeast, but beyond this point its exact limits cannot be determined, since the overlying Alloway clay is absent and the Cohansey sand, which lies above the Alloway clay, is brought into juxtaposition with the "fluffy" sand.

This sand is often, in fact usually, delicately colored in pale shades of pink and yellow, which frequently make a wavy banding, due not so much to stratification as to the irregularities of coloration. This sand contains some laminæ and thin beds of clay, but none in the southwestern part of the State that are anywhere worked, and none apparently of commerical importance.

THE ASBURY CLAY.

Stratigraphic relations.—In Burlington and Salem counties the fluffy sand apparently forms the base of the Miocene. In Monmouth county, however, the lowest portion of the Miocene contains numerous beds of clay underlying the fluffy sand and grading upward into it by interstratification. Locally, these clay beds attain considerable thickness, and, where not too deeply buried, form deposits of considerable economic importance. From their development just west of Asbury Park, they may be called the Asbury clay. It is believed that these clay beds lie below the great mass of "fluffy sand," and, therefore, at a lower horizon than the base of the Miocene farther southwest. In other words, it is believed that the successive Miocene formations overlap each other to the northwest, so that in Burlington, Gloucester, Camden and Salem counties its base, where exposed, lies farther up the dip of the formations than in Monmouth county, and consequently the basal beds, as exposed in the former counties, are not so low as those shown in Monmouth county. It is not certainly known whether the Asbury clay forms a single, well-defined bed of wide extent and varying thickness, or whether it is rather a series of overlapping clay lenses, some thin, some thick, separated by beds of fine, loose, light sand, all occupying about the same general horizon. On the whole, the evidence seems most to favor the latter view.

Occurrence.—Just west of Asbury Park the clay is well exposed in Drummond's pits (217), where 12 feet of dark clay, with thin laminæ of sand, underlie 8 feet of fluffy sand, with thin clay laminæ. Midway in these overlying beds there is a 6-inch layer of fine quartz gravel. The clay continues some depth below the present workings, a 2-foot bed of sand separating the worked from the unworked clay. The top of the clay is about 26 feet A. T., and its base cannot be less than 10 feet, since the underlying marl is found along the brook just north of the pit. Clay similar in appearance to this, but not so thick, outcrops at intervals for half a mile west along Asbury avenue. Its elevation increases westward. At Decker's pits (216), on the N. J. Southern R. R., 5 miles west by north of Drummond's, a thick black clay occurs at an elevation of 110 to 120 feet. Above it and interbedded in its upper portion is a light, fluffy, micaceous sand. At its base the clay is sandy, with some ironstone, beneath which is probably the marl. There is no question but that the clay at Decker's and Drummond's pits belongs to the same general horizon, which has a rise of about 18 feet per mile between the two points.

A mile north of Centreville, clay is known to underlie a considerable area on the property of Mr. D. H. Applegate (270). Numerous borings have shown that it rests upon a bed of marl, at an elevation of 90 feet. Its thickness, including 3 or 4 feet of a surface loam, which may be of somewhat later origin, is 14 to 17 feet. Most of this clay is light colored, but some borings have struck black clay.

On the west side of the Hominy Hills, east of Jerseyville, at Brockelbank's clay pits (214), a laminated sand and clay occurs at an elevation of about 115 feet, and borings have shown a marly sand at 95 feet A. T., the intervening beds being chiefly sand, with clay laminæ; a very sandy phase of the Asbury clay. Very similar deposits occur at the old brickyards, near Shark River station on the N. J. Southern R. R.

These data apparently indicate that the Asbury clay extends as far west as the west side of the Hominy Mills and underlies them, but that in the western portion of the area it becomes very sandy. Borings show that in the vicinity of Pine Brook, at the north, the clay has also thinned out. Sufficient data are not at hand to determine its southern extent. It is not known to occur south of the latitude of Shark river. Within the area thus roughly outlined, the clay is in general deeply buried by the overlying sands and gravels. It is only on the bordering slopes to the lower ground or along streams, which have cut into it deeply that the clay has been found. Further search for it should be controlled by the fact that the bed dips about 18 feet to the mile to the southeast from elevations of 115 feet on the northwest at Applegate's, Decker's and Brocklebank's to 25 feet at Drummond's, near Asbury Park.

THE EOCENE MARL.

This formation includes the upper portion of the Upper marl bed, which was designated as Blue marl by Prof. Cook. It is found in a limited area in Monmouth county along the valleys of the Shark and Manasquan rivers, where it is seen chiefly on the valley sides. It lies directly beneath the Asbury clay, being often separated from it by an indurated stony layer. It consists of very fine, dark-green sands, which have a slight bluish tinge, and it is quite fossiliferous. These fossils represent a fauna, which is generally regarded as Eocene in age. There is a slight unconformity between these marls and the overlying Miocene beds, indicated by the general overlapping of the Miocene beds upon the subjacent layers, so that towards the southwest the higher beds of Miocene rest directly upon beds lower than the Shark River marl. Since this formation contains no clay beds, it will be dismissed with these few words.

CHAPTER VIII.

THE CLAYS OF THE CRETACEOUS FORMATION.

CONTENTS.

The Cretaceous formations in New Jersey can be naturally grouped into three series, a glauconite Marl series at the top, a Clay series at the base, and a Clay Marl series in the middle. The Marl series and the Clay Marl series belong to the Upper Cretaceous; the Clay series to the Lower Cretaceous.

As is implied by the above names, each of these series is characterized by certain deposits of economic importance. The Marl series contains valuable beds of glauconite or greensand marl, which were very extensively dug for fertilizer in former years, and which are still in use to a more limited extent. The Clay series contains important beds of clay, some of great value. The Clay Marl series contains beds of clay and beds of marl, both of which have been utilized economically; but the clays are not so good as the best of those in the Clay series beneath, and the marls are inferior to the greensands of the Marl series. No marl occurs in the Clay series, nor has any workable clay been found in the Marl series.

Although the three divisions of the Cretaceous can thus be divided into a Marl, a Clay Marl and a Clay series, it must not be supposed that these divisions are composed exclusively of marl, clay marl and clay. This is far from the case. In each series there are several thick beds of sand, which make up probably more than half of each series. The Marl series is then a succession of interbedded layers of marl and sand; the Clay series, of clay and sand; the Clay Marl series, of more or less glauconitic clays, glauconitic sands and marls. In the case of the Marl series and of the Clay Marl series, these subdivisions are so distinctive, and so sharply marked from each other, and hold their characteristics so continuously, that they can be nearly all traced without difficulty across the State, and their limits accurately defined on a map. In the case of the Clay series, however, there is less regularity, and only in a comparatively narrow area between Woodbridge and South Amboy, where the beds have been exposed in many large openings, can definite horizons be made out and traced beyond the limits of individual exposures.

The three major subdivisions here outlined are the ones best suited to bring out the lithological and economic characteristics of the Cretaceous system in New Jersey. They are, moreover, the three subdivisions into which the Cretaceous in this State naturally falls. The lines separating them are more clearly defined lithologically and stratigraphically than any others which can be made, and their boundaries can be fixed in the field with greater accuracy than any of the lines between the individual members into which each series can be further divided.[1]

THE MARL SERIES.

The Marl series can be divided into the following formations, the essential characteristics of which are indicated by their names:

The Upper marl (in part).
The Limesand [including the Yellow (quartz) sand].
The Middle marl (Sewell).
The Red sand (Red Bank sand).
The Lower marl (Navesink marl).

Glauconite or greensand occurs in all five formations, but only as sparsely disseminated grains in the two sand members. The three marl formations are composed chiefly of glauconite, with small amounts of fine quartz sand and locally thin laminæ of clay or scattered clay pellets. These subdivisions are nearly everywhere readily recognizable in the field. Where their contacts are exposed they are seen to change from one to the other within reasonably narrow limits, usually 2 or 3 feet, and rarely more than 6 feet, so that their boundaries are sufficiently sharply marked to be accurately mapped. This definiteness is further enhanced in the case of the Limesand-Middle marl contact by a marked and persistent fossil bed 2 to 4 feet thick, which can readily be traced across the State.

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[1] Dr. W. B. Clark (Ann. Rep. State Geologist for 1897), has proposed a somewhat different classification for these beds, which on lithological and stratigraphical grounds seems inapplicable in several respects to New Jersey. Whether or not it is the one which should finally prevail for the Cretaceous of the Atlantic coastal plain is believed to be open to serious question, but this point is not here considered. For the purposes of this report, the above classification is more convenient, more accurate, and more readily understood by the non-professional reader.

The only exceptions to the above statement regarding the sharpness of contact are these. First, the top of the Upper marl (Cretaceous) passes into the Eocene marl without a break and with but little lithological change. The fossils, however, are decisive as to the age of the beds, although the division between the two formations can be made with difficulty in the field. Second, in Burlington, Camden, Gloucester and Salem counties, the Red sand, which separates the Lower from the Middle marl, is apparently absent, due to thinning out in the vicinity of Sykesville, Burlington county. The Middle marl is, therefore, in these counties superimposed upon the Lower marl, and it is impossible except in a general way to differentiate them. This is particularly the case the farther one passes southwest beyond the point of disappearance of the Red sand.

The location of the Marl series is shown in a general way on Plate X, where it lies immediately northwest of the line indicating the boundary of the Miocene. It extends in an ever-narrowing belt from Atlantic Highlands and Long Branch at the northeast, in Monmouth county, to Salem, Salem county, at the southwest. The narrowing outcrop to the southwest is due in part to a lesser thickness consequent on the disappearance of the Red sand, but more particularly to the overlap of the Miocene sands and clays. In the southwest these rest upon the Middle marl, save where the larger streams have eroded them back and exposed the Lime sand. In eastern Monmouth county, on the contrary, the Miocene rests upon the Eocene marls, and the whole of the Cretaceous marl series is exposed. Since the Marl series contains no beds of workable clay, it will not be further considered.

THE CLAY MARL SERIES.

The Clay Marl series includes beds of sand, marl, and clay which underlie the Marl series, described above, and overlie the Raritan or Clay series. Its base is marked by the contact of a black, glauconitic sandy clay upon a cross-bedded lignitic sand, containing laminæ and lenses of black, nonglauconitic, micaceous clay. The glauconitic clay at the base of the Clay Marl series weathers into a very characteristic cinnamon-brown, indurated earth, containing gunpowder-like specks of black or dark-green marl. This weathered phase is totally unlike the weathered phase of any of the underlying beds, and it is thoroughly characteristic of the Clay Marl series. The contact is usually a sharp one, easily identified and readily located in the field, wherever exposures are found from the Raritan river to Delaware bay.[1] The top of the Clay Marl series is likewise a definite line—the abrupt passage from a loose reddish sand often very coarse, with grains of quartz the size of small peas to a compact greenish marl. For much of the distance across the State the top of the Clay Marl series is also marked by a fossil bed 1 to 4 feet in thickness, which affords a definite and easily recognizable horizon.

The outcrop of the Clay Marls extends from the shores of Raritan bay across the State in a southwest direction to the Delaware river north of Salem. It forms a belt varying in width from 2½ to 8 miles. Since the beds dip about 35 feet per mile to the southeast, the belt of outcrop is widest where the slope of the surface is toward the southeast, and narrowest where it is steeply to the northwest. On Plate X the position of the two lower, or clay-bearing members, of this series is shown.

Subdivisions.—The Clay Marl series can be subdivided as follows, the divisions being numbered from base upward:[2]

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[1] In an earlier report of the Survey (1892), the base of the Clay Marls as mapped by Dr. W. B. Clark, include 90 or more feet of interbedded black clay and lignitic sand, exposed between Cheesequake creek and Matawan creek. These beds should more properly be classed with the Raritan formation for the following reasons: *a*) they are nonglauconitic; *b*) they are extremely variable and individual beds cannot be traced any distance; *c*) they contain a flora which connects them with the underlying rather than the overlying beds, and *d*) the clay layers, some of which are massive beds, thin out to the southwest and give place to sand, until in the vicinity of the head of Cheesequake creek the Clay Marl series is underlain by 90 feet of loose white sand with comparatively few beds of black clay. If the clays east of Cheesequake creek are included in the Clay Marl (Clark's Matawan series), the base of the latter is not drawn at a constant geological horizon, but rises or falls as the upper portion of the underlying series of beds is sandy or clayey.

[2] These subdivisions were first made out by Mr. Knapp and mapped by him in 1893-1895. The following names were at that time suggested by him for these divisions, beginning at the top (V) Wenonah sand, (IV) Marshalltown clay, (III) Columbus sand, (II) Woodbury clay, (I) Merchantville clay.

No. V. A reddish quartz sand.
No. IV. Black, laminated sand and clay, strongly glauconitic to the southwest, but less so to the northeast.
No. III. Vari-colored sands, locally with thin clay laminæ and lenses.
No. II. Black clay, weathering to a chocolate color, and non-glauconitic.
No. I. Black, sandy clay, notably glauconitic at top and bottom, weathering to a cinnamon brown.

The total thickness in Monmouth county is about 230 feet.

CLAY MARL V (WENONAH SAND).

This formation is in general a reddish-brown or black sand, sometimes strongly micaceous and often having a peculiar mixture of pinkish, brown and gray sand grains, which give it a characteristic color. Locally it is distinctly laminated with thin seams of black or chocolate-colored clay, but these are never, so far as seen, commercially important. It is somewhat ferruginous, and is not infrequently cemented to ironstone, but less commonly so than the lower sand bed, Clay Marl III. It contains a small amount of glauconite (greensand marl), but except near its top, this element is not apparent save upon close examination. Deep exposures, particularly in the upper portion of the formation, often show large pockets of white sand, which are sometimes clean sand, and sometimes contain pellets of a hard white clay giving the sand an arkose appearance. This phase is particularly characteristic of the upper 2 to 10 feet, and renders the sand quite compact. These upper layers generally contain very coarse grains of quartz sand, and are also not infrequently somewhat cemented by iron, which has been leached from the overlying marl beds.

At the very top of Clay Marl V, in the upper few feet of this "arkose" sand, there is generally found a fossil bed from 1 to 4 feet in thickness composed largely of the large shell *Gryphæa vesicularis*. The fossils are thickly imbedded in a matrix of clayey sand in which there is an increasing amount of marl towards the top of the shell layer. Immediately above the latter lie the workable greensand marl beds. The shells occur somewhat sparingly in the sand for some distance below the fossil bed and more rarely individuals occur in the marl above. Inasmuch as this layer is a very persistent feature and can be readily recognized at many localities across the State, and since the beds above and below are so different in character, the top of the Clay Marl series is a definite and easily recognizable horizon.

The Wenonah sand (Clay Marl V) outcrops along the southeastern side of the Clay Marl belt from Atlantic Highlands to Salem county. It is in part covered by areas of Pensauken gravel, but it forms the surface deposit over considerable tracts in the vicinity of Sharptown, Salem county; over a broad belt between Mullica Hill and Swedesboro, near Chew's Landing; Wenonah, east of Haddonfield, and near Evesboro, in Burlington county. In Monmouth county it forms the sandy belt on the northwest of the Lower Marl from Tennants, Robertsville, and Morganville to Atlantic Highlands. Its thickness is about 50 to 55 feet in Monmouth county, increasing to something over 60 feet in Salem county.

Although locally it contains thin seams of clay, yet these are nowhere of economic value.

CLAY MARL IV (MARSHALLTOWN BED).

This member of the Clay Marl series is more variable in its make up than either of the other four, but the variations are gradual, and there is no difficulty in tracing them from one phase to another. It ranges from a sandy clay to a clayey marl, which at one time was mistaken by all geological workers in the State for the Lower Marl.[1] In Monmouth county it is chiefly a laminated, micaceous clay with thin seams of sand, which locally may be of some commercial importance. In this region greensand grains are wanting in all save the upper portion, in which they are only

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[1] Mr. Knapp was the first to differentiate it from the Lower Marl and make out its true position, although he did not receive proper credit for it in the Annual Report for 1897.—H. B. K.

locally conspicuous. Towards the southwest, however, the marl content increases, and in the vicinity of Marshalltown, Salem county, the bed was once extensively dug for fertilizer. It has also been opened at many other points for the same purpose. The marly portions are abundantly fossiliferous.

This member of the Clay Marl series outcrops north and northwest of the Wenonah sand bed, into which it passes somewhat abruptly. In Monmouth county, where alone it is likely ever to prove of any value for clay, it occurs on the lower slopes of the Mount Pleasant hills from Atlantic Highlands westward through New Monmouth, Morganville, Robertsville and Englishtown. It lies between two thick sand beds, No. V above and No. III below, so that it can be readily identified. Its position for a portion of this distance above mentioned is shown upon the large scale of the Matawan district, Plate XII.

Clay Marl IV is not at present utilized for clay at any point, although a black laminated clay, belonging to this bed was formerly dug in a small pit near the railroad one and one-half miles west of Atlantic Highlands. At two small brickyards west of Mount Holly (Loc. 123) a loamy surface clay 2 or 3 feet thick may perhaps be the weathered portion of this formation, although it seems equally likely that it is a late Pleistocene deposit. The clay was, also, noted at Belmar (Loc. 148) and east of Rancocas (Loc. 124). Although not now used, there is no apparent reason, however, why portions of it might not be employed for common brick, equally as well as many of the black micaceous clays now utilized at many points. Its thickness is probably between 30 and 40 feet.

CLAY MARL III (COLUMBUS SAND).

The middle member of the Clay Marl series is a very conspicuous bed of quartz sand. It is white or yellow and sometimes marked by delicate lines of red, giving it a highly variegated appearance. Locally, the iron has cemented it into rather massive beds of stone. Although the bed for the most part is clean quartz sand, often closely resembling the sand on the present beaches, yet not infrequently it contains thin laminæ of firm brittle clay, which stand in sharp contrast to the adjoining sands, there being absolutely no gradation between the two. The clay laminæ contain no sand or grit, and the sand layers are entirely free from clay.

Towards the upper portion of the formation there is a horizon at which a bed of clay occurs locally. The clay is apparently not continuous, but has been seen at a number of widely separated points. At a few points this clay lense has been utilized for the manufacture of common brick, but nowhere extensively, and it is not likely ever to be of more than local importance. At the present time it is worked, in a small way, only at Thackara's pits, near Woodbury (155).

This member of the Clay Marl series is thickest at the northeast and decreases gradually towards the southwest. In Monmouth county it has a thickness of over 100 feet, on Crosswick's creek it has diminished to 30 or 35 feet, and at Swedesboro it hardly exceeds 20 feet. Farther southwest it seems to pinch out. Its characteristics, however, are the same where it is thin as where it is thick, and it retains its integrity as a distinct bed, so that it is readily recognizable everywhere from Atlantic Highlands to Salem county. It does not become more clayey to the southwest, as has been sometimes asserted,[1] but retains its characteristics unchanged.

It passes upward by a somewhat rapid transition into the overlying glauconitic or sandy clay, so that its upward limit can be well enough defined for purposes of mapping. It is underlain by a well-defined clay bed, into which it passes more or less sharply, so that as a formation it is distinct. It outcrops in approximately the middle of the Clay Marl belt, just to the southeast of the clays indicated on Plate X.

CLAY MARL II (WOODBURY).

Character.—The sand member just described is underlain by a thick bed of black clay, which we have designated as Clay Marl

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[1] Clark, W. B. Ann. Rep. 1897, p. 179.

II, or the Woodbury clay, from the fact that it was well exposed in the railway cut at that place.[1] The clay is somewhat micaceous, black in color, not sandy in the lower portion, but slightly so in the upper part, where it is locally distinctly laminated. It does not contain glauconite except perhaps at the very base, and in this respect it is to be distinguished from Clay Marl I, a glauconitic clay which underlies it. It weathers to a dove or light chocolate clay, which, when dry, breaks into innumerable blocks, large and small, frequently with a conchoidal fracture (Pl. XVIII, Fig. 1). In some localities, as at Dobbs' clay pit, near Camden (144), these joint faces are smoothed and polished in a striking manner. In its lower portion it is penetrated by numerous joints. Many of these are filled with crusts of limonite, which sometimes form huge honeycomb masses many feet in diameter and tons in weight. A most striking case of this sort was observed on the north bank of Rancocas creek west of Rancocas, where the clay was found to be so filled with these limonite masses as to render it necessary to abandon an extensive brickmaking plant.

Although the upper portion is more sandy than the lower, it is quite sharply set off from the sand bed above, the transition layer being only two or three feet in thickness at the most. Its base also is fairly distinct, although since the underlying member is also a clay bed, this line is not so sharp as at the top. This clay varies from 55 feet in Monmouth county to something less than that along the Delaware.

Although this member presents slight local variations, yet it can be readily traced across the State and is easily recognized by its characteristic features; *i. e.*, its dove or light-chocolate color when weathered, its many joints, its lack of marl and its position beneath the sand bed (Clay Marl III). Its characters are such that there is no question of its integrity as a definite and distinct bed at any point between the shores of Raritan bay and the Delaware river in Salem county.

Localities.—The position of this clay bed in the vicinity of Matawan is shown in detail on Plate XII. Within this area

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[1] This exposure has recently been obscured by grading, but numerous outcrops occur along the banks of the creek a mile west of Woodbury.

Fig. 1.

Showing the jointed structure of Clay Marl II. Dobb's clay bank, near Collingswood.

Fig. 2.

Clay bank at Budd's brickyard, Camden, showing the massive character of the Clay Marl I, and the drainage hole in the foreground into the Raritan sand. The vertical and horizontal marks on the clay are the impressions made by the spades in digging.

there are frequent exposures along roads and gullies. Farther southwest its outcrop is shown on Plate X where it has been combined with Clay Marl I. Over the greater portion of this belt, however, there is a mantle of Pensauken gravel or of displaced material of greater or less thickness, so that the presence of the clay is not always manifest on the surface. Except, however, where this mantle is of considerable thickness, the clay is commonly exposed along stream banks, gullies and road cuts.

Clay Marl II is utilized wholly or in part for brick and drain-tile at the following places: National Fireproofing Company, Lorillard works, Keyport (224); Edward Farry, Matawan (228); Dunlap & Lisk, Matawan (231) (for flower pots); Jamesburg Reform School (295); Reed Bros., Hightstown (194); John Braslin & Sons, Crosswicks (110); James C. Dobbs, Collingswood (144); Augustus Reeve, Maple Shade (149), and Theo. Saucelein & Son, Maple Shade (150). At many other localities the clay is equally as good as at these points. Numerous samples have been taken both from localities now worked and also from undeveloped parts of the bed. The tabulated results of these tests are given in Chapter XVIII; and in Chapter XIX the various localities in each county are described.

CLAY MARL I (MERCHANTVILLE CLAY).

Character.—The lowest member of the Clay Marl series is also a clay, but so different in its composition, in its mode of weathering and its lack of numerous joints that it has been found easy to differentiate it from Clay Marl II, and entirely practicable to map it as a separate bed. Clay Marl I is a black, glauconitic, micaceous clay, more sandy than Clay Marl II, and generally less brittle and more greasy. The upper and basal portions of this bed are commonly much more glauconitic than the middle part, and have been dug for marl at a number of points, but their use for this purpose has not been extensive. The lower half of the bed, both the marly and nonmarly portions, are usually massive and nonlaminated (Pl. XVIII, Fig. 2). The upper portion, however, particularly the nonmarly part, is more sandy and often distinctly laminated. Fossils are quite abundant, particularly in the glauconitic portions, and are more frequently found than in Clay Marl II.

The weathered portions of this bed are very characteristic. When marly they form an indurated, cinnamon-brown earth, in which the small black grains of marl are distinctly seen. When more sandy, the weathered portion has a peculiar "pepper and salt" aspect. The weathered part of the nonmarly portion is less characteristic, being sometimes a chocolate color and resembling the weathered portion of Clay Marl II. Where sections do not occur, the bed may be traced most readily by the rusty cinnamon brown color of the weathered basal and upper portions.

Stratigraphic relations.—The transition from Clay Marl I to Clay Marl II is generally accomplished within 1 to 3 feet. When exposed in section there is rarely any question as to where the division between the two formations should be made. The base of this bed is the base of the Clay Marl series. Wherever it has been seen it rests upon a loose, coarse, lignite-bearing sand or a sand with thin seams of black clay. Not infrequently the upper few inches or a foot of this sand is cemented into an ironstone. At some pits where this clay is dug it is only necessary to break through this crust to the loose sand beneath to secure perfect drainage (Pl. XVIII, Fig. 2).

The contact of the black marly clay or its rusty-brown weathered phase and the Raritan sand beneath is shown, 1) in the high bluff on the shore of Raritan bay northeast of Cliffwood; 2) at the clay pits on the west side of Matawan creek; 3) in several ravines between Morristown and Cheesequake (Jacksonville); 4) in the vicinity of Jamesburg; 5) at several points near Bordentown and Kinkora; 6) on Pensauken creek north of Maple Shade station; 7) at Budd Brothers' brickyard, Camden; 8) and at numerous other points southwest of Penns Grove. In Monmouth county heavy beds of black clay occur in the Raritan, not many feet below the contact with the Clay Marl. These beds have sometimes been included in the Clay Marl series, but that they do not belong there is at once apparent to anyone who makes a careful study of the two series. This is particularly the case if the contact between them is traced from the southwest, where the contrast is, if anything, more definite than in Monmouth county.

The thickness of Clay Marl I increases slightly from northeast to southwest. In Monmouth county its thickness is about 35 feet, at Bordentown it is 60 feet, and in Salem county about the same. Its outcrop across the State is shown on Plate X, and more in detail for the Matawan region on Plate XII.

Localities.—At the present time Clay Marl I is used wholly or in part at the following places: Edward Farry, Matawan (228); Pennsylvania Clay Company, Matawan (226); Dunlap & Lisk, Matawan (230); Reed Brothers, Hightstown (193); The Bordentown Brick Company, Bordentown (109); Murrill Dobbins, Kinkora (113); Augustus Reeve, Maple Shade (149), and Budd Brothers, Camden (143). The results of tests upon samples of this bed and those from other localities are given in Chapters XVIII and XIX.

THE RARITAN CLAY SERIES.

Character.—The Raritan or Plastic Clay series, as it was called by Dr. Cook, is the lowest and oldest of the three divisions of the Cretaceous in New Jersey. It consists of a number of beds of clay, sand, and locally, of gravel. The clays are of various kinds, from nearly white or steel-blue fire clay of the highest grade to black, sandy clay, containing varying amounts of pyrite and sulphur, and used only for common brick. Some of the sands are nearly pure quartz, sharp and angular in grain, suitable for a high grade of fire sand; others are highly micaceous, or lignitic, or arkose. Some of the latter, composed of coarse grains, or even pebbles of quartz and decomposed feldspar crystals, form the beds of so-called "feldspar" used in the manufacture of fire brick. Along the Delaware river, beds of gravel and cobble stones are known to occur locally, but in Middlesex county nothing larger than very coarse (pea) sand has been seen.

The Raritan series is characterized by the rapid alternation of strata, the abrupt transition both vertically and horizontally from one to another of these beds, and by the absence of any definite and orderly arrangement over extended areas. Individual beds of clay thin out rapidly or grade bodily into beds of sand within short distances. In not a few instances data have been observed, which indicate that beds after deposition were partially swept away by shifting currents, before the overlying layers were formed. Within comparatively short distances, also, sand and clay were being deposited simultaneously, so that rapid changes in the character of the deposit have resulted. In these respects the Clay series is in marked contrast to the Clay Marl or Marl series, during the deposition of which uniform conditions prevailed over wide areas, and successive deposits were formed, which can be traced as individual beds across the State.

Although it is impossible to establish any divisions in the Raritan series, which can be accurately identified at widely separated intervals, nevertheless, as was long ago pointed out by Cook and Smock,[1] in Middlesex county, in the vicinity of Woodbridge, Perth Amboy, South Amboy and South River, where the beds have been extensively opened in many localities, there are certain divisions, which in their general features persist from opening to opening, and so can be traced through all the region. Yet even here, not infrequently many of the minor beds seen in one pit are wanting in the next one a few rods away, showing that variable conditions prevailed, even in this area.

The degree, however, to which the Clay series has been subdivided in this part of Middlesex county is probably not due entirely to the distinctness and persistence of individual members. The great number of exposures, both natural and artificial, enable one to trace the beds with much greater detail than in any other portion of the State. Were the formation everywhere so well exposed as in this region, it is highly probable that some similar classification could be made in other districts, and that the formation would not prove to be such a varying complex of clay and sand, as seems to be the case. It is certain, however, that the classification which is applicable to Middlesex county would not apply to Burlington, and it is equally certain that no

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[1] Report on the Clay Deposits of Woodbridge, South Amboy, etc., 1878, pp. 33-75.

such definite subdivision would be possible in the case of the Raritan as has been made in the Clay Marls or Marl series.

Thickness.—The thickness of the Raritan series varies considerably, as is shown by numerous well borings which have penetrated to the older rocks beneath. Cook and Smock made an estimate of 347 feet from a detailed study and comparison of the various beds in Middlesex county. Our own estimates for this region give 380 to 390 feet. At Asbury Park, 20 miles down the dip from the outcrop, a well penetrated 367 feet of beds belonging to this series without reaching its base; whereas, at Bordentown, the entire thickness of the formation, from top to bottom, as shown by borings, does not exceed 250 feet. At Jobstown, southeast of Bordentown and 8 miles farther down the dip, the Raritan was penetrated for 409 feet, and bottom not reached. At Delair, north of Camden, the base of the Raritan is 162 below tide. Making due allowance for the upper part of the formation not present here, owing to post-Cretaceous erosion, the thickness is 275 to 300 feet. The greatest thickness, however, has been reached in a boring at Fort Dupont, Del. (opposite Fort Mott, N. J.), where 594 feet of the strata belonging to the Raritan were penetrated without reaching its base. These figures indicate that the formation is thinner along its outcrop than down the dip to the southeast. This conclusion is in accord with what is known of other formations of the coastal plain.

Stratigraphic relations.—As has already been stated, the contact of the Raritan and the Clay Marls above is sharp and easily recognized. Wherever seen, its top is a loose sand, or a sand with clay laminæ, whereas the base of the Clay Marl is a glauconitic clay, black when fresh, a rusty brown where weathered, and frequently fossiliferous. The contact is, moreover, frequently emphasized by a bed of ironstone due to cementation of the upper layer of sand.

The basal contact is less frequently shown. In Middlesex county, wherever exposed, the Raritan beds rest unconformably upon the eroded edges of the Triassic (Newark) shale, while some well borings show that locally they are underlain by trap rock. From Trenton, southwestward, they rest upon the Philadelphia gneiss and schist, as is shown by a few well borings. So far as known, the lowest layers are always derived from the subjacent formation. At Brinkman's clay pit, Piscataway (96), there is a gradual transition from the undecomposed Triassic red shale to a red and white plastic clay, which is undoubtedly Cretaceous. Since, however, the Triassic beds dip to the northwest, and the nearly horizontal Cretaceous beds lie upon their beveled edges, we know that there was a long period of erosion, accompanied by great crustal movements after the formation of the shale and before the deposition of the Cretaceous. Nevertheless, it is here impossible to draw a sharp line between them. The apparent transition is undoubtedly due to a partial re-working of the residuary red clay, which mantled the Triassic at the beginning of Cretaceous time. At other localities there is a distinct alternation of sediments derived from the shale, and from more distant sources.[1] In general, wherever the underlying rock is red shale, the lowest bed of the Raritan is a very sticky red clay, evidently derived in part, if not wholly, from it. Where the Raritan rests upon a micaceous schist or gneiss, as is the case at Delair, near Camden, borings have shown that the lowest beds of the Raritan are mica sands, such as would be derived from the subjacent formation.

Conditions of formation.—It has been generally considered that the Raritan formation was accumulated under broad estuarine conditions. The rapid alternation of layers, the horizontal variation in character of the beds, and their abrupt changes in thickness, have been interpreted to mean shifting currents and great variations in conditions within comparatively narrow limits. The cross-bedded structure of many of the sand beds, the billowy, eroded upper surface of some clay layers, the bits of lignite, and even trunks of trees and great masses of leaves, all indicate shallow water and proximity to a shore line, as well as shifting currents. The beds of extremely fine clay, however, indicate that still waters must have prevailed a portion of the time, even although the shore was not many miles distant. The few fossil shells which have been found are of brackish water, rather than marine types. In all these respects the Raritan beds stand in

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[1] Cook and Smock, loc. cit., pp. 169–170.

marked contrast to the Clay Marl and Marl series, which, by their constitution, indicate deeper water, uniform conditions over much wider areas, marine rather than brackish water, and a tendency to uniform, rather than strongly varying rates of accumulation.

Location.—The area occupied by the Raritan series is shown upon the accompanying map, Plate X. It forms a broad belt, extending from Raritan bay across the State to Trenton and Bordentown, and a much narrower strip along the Delaware river to Salem county. Its greatest width is something over 8 miles, while for a few miles below Bordentown it is limited in outcrop to the face of the bluff above the river, and the side slopes of the neighboring ravines, the greater part of the outcrop belt being beneath the bed of the river. Over most of its outcrop across the State its surface is more or less covered by later deposits of sand and gravel, the Pensauken or later formations. These are often so thick as to conceal effectually the beds beneath, and in not a few localities to hinder or entirely prevent digging or even prospecting for clay. This is particularly the case in the flat, low-lying portion of the State from Fresh Ponds and Spotswood to Trenton. Within this area it is not only impossible to make out any subdivisions in the Raritan, but it is a matter of some difficulty even to determine accurately its boundaries. Nevertheless, occasional well borings show that extensive beds of clay occur within this area, although not at horizons which render them economically valuable.

NORTHEASTERN MIDDLESEX COUNTY.

Within the region lying between Woodbridge, South River and Cliffwood, shown in detail on the maps, Plates XI and XII.[1] it has been possible to subdivide the Raritan formation into nine members, which can be differentiated and mapped with reasonable accuracy. These are as follows, beginning at the top:

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[1] These maps are described in detail in Appendix E.

Subdivisions of the Raritan formation in Middlesex County.

The Cliffwood lignitic sands and clays.
No. 4. Sand—laminated quartz sand.
The Amboy stoneware clay.
No. 3 Sand—chiefly quartz.
The South Amboy fire clay.
No. 2 Sand—including beds of so-called "feldspar" and "kaolin."
The Woodbridge clays—fire, stoneware and brick clays.
No. 1 Sand—in part, fire sand.
The Raritan clays—fire, and terra-cotta clays.

Locally, still more minute subdivisions can be recognized, but the above are the only ones which can be successfully mapped.

THE CLIFFWOOD LIGNITIC SANDS AND CLAYS.

These beds, the upper portion of the Raritan, are nowhere exposed in a continuous section, but are well shown, a) in the cliffs along the Raritan bay from the southeast side of Cheesequake creek to Prospect Grove, near Cliffwood; b) in the various clay pits about Cliffwood, and c) in the cuts of the Long Branch railroad, southeast of Cheesequake creek. Combining these various exposures, as well as possible, we have the following sequence of beds.

At Prospect Grove 40 feet of white sand, with seams of black lignite and thin beds of black clay (becoming thicker and more numerous in base of section), are exposed immediately beneath Clay Marl I. At tide level the top of a massive black clay is shown. These beds contain many sandstone concretions which have yielded numerous plant remains.[1] The lenses of clay in the sand thicken and thin out variously, as shown in the bluff along the shore. Apparently the basal portion of these alternating sands and clays are exposed in the higher beds at Geldhaus'

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[1] Hollick, Arthur—The Cretaceous Clay Marl exposure at Cliffwood, N. J Trans. N. Y. Acad. Sci., Vol. XXI, p. 124.

clay bank (223), at the south bank of the Cliffwood Brick Company (220), and at Gaston's pits (221). The massive black clay at sea level at Prospect Grove is probably the same as that at Furman's bank (222), at Gaston's, and at the more northerly exposures of the Cliffwood Brick Company. The thickness of this clay bed is not known, but it is probably at least 15-20 feet. One-fourth mile northwest of the Cliffwood Brick Company's bank there is a deep cut along the railroad, which shows

Weathered clay,	6 feet
Sand and clay,	14 feet
Clay with very much lignite,	10 feet

Beneath the lignite is a massive black clay, seen at the level of the track, which apparently extends down to tide level (20 feet) and borders the meadow east of Cheesequake creek. The weathered clay in the railroad cut is probably the basal portion of the more massive black clay dug in the Cliffwood Brick Company's banks. If so, the entire thickness of the lignitic sands and clays east of the Cheesequake meadows is about 104 feet. This corresponds closely with an estimate of the thickness (113 feet) a) based upon the dip of the base of the Clay Marls, 35 feet per mile, and b) on the distance from the appearance of the lowest bed bordering the Cheesequake meadows at the railroad cut to the Clay Marls near Cliffwood station.

The lignite bed exposed in the railroad cut has been struck at numerous points in this vicinity, and many years ago considerable exploring and mining work was done, particularly on the farm of George C. Thomas,[1] in the hope of opening a workable bed of coal. The material contains considerable pyrite ("sulphur"), which causes a disagreeable odor in burning, and it is always mixed with considerable quantities of sand and clay, so that these efforts were unsuccessful. A good specimen of it, analyzed some years ago in the laboratory of the Geological Survey, yielded

Gases,	50.2%
Coke,	34.6%
Ash,	15.2%

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[1] Report on Clay Deposits of New Jersey, 1878, p. 74.

Traced southwest towards the head of Cheesequake creek, these beds apparently become more sandy and less clayey. Black clays occur in the bluffs at the head of the creek, where they have been dug to some extent for brick clay, but they are not as thick as farther northeast, for here the greater part of the first 90 feet underlying the Clay Marls is sand. Black clays occur in the low ground southwest of Cheesequake (Jacksonville), but whether they belong to this horizon or to lower beds cannot be definitely asserted.

LAMINATED SANDS—NO. 4.

Below the lignitic clays and sands just described there occurs a great thickness of quartz sand which is usually distinctly laminated, often with very thin seams of more clayey material. These sands are well exposed in the bluff above the clay in H. C. Perrine's South Amboy pits (77), where there are 27 feet of yellow and white sand with thin laminæ of black clay in the lower portion. Southeast from here along the shore to Morgan station the same and higher beds are exposed. Here they are covered by a few feet of yellow gravel belonging to the Cape May formation. Locally these sands are lignitic, but on the whole they are light-colored and present a marked contrast to the dark-colored sands and clays east of Cheesequake creek, which lie above them. These same sands are also well exposed in the bluffs along the west side of Cheesequake creek, above the stoneware clay, which is dug at several points. At Perrine's bank (80) (formerly Ernst's), about 75 feet of sand with some thin clay seams are shown along the road leading down to the clay pits.

The thickness of this member was estimated by Cook and Smock to be about 40 feet, but this seems to be too small, in view of the above exposure. The maximum is probably not less than 75 feet.

THE AMBOY STONEWARE CLAY.

The next lower member of the Raritan series is the Amboy stoneware clay. This name was given by Cook and Smock, and is retained here, although only a part of the bed is a stoneware clay. It is best shown at present in H. C. Perrine & Son's pits southeast of South Amboy and the various banks at the base of the bluff on the west side of Cheesequake creek. It has, however, been opened at a number of other places, although most of these are no longer worked.

The upper portion of the bed is usually, but not always, a black, more or less sandy clay, with some lignite and pyrite ("sulphur"). It varies greatly in texture, being sometimes almost a sand, and elsewhere rather a tough, black clay. Locally, at least, its upper part was eroded by shifting tidal currents before the overlying sands were deposited. Moreover, this black clay in places rests upon the sharply undulating, eroded surface of the underlying stoneware clay proper, but this is not always the case. Owing to the inequalities in its top and bottom its thickness varies greatly, ranging from nothing up to 18 feet.

The stoneware clay proper, which underlies the black clay, is generally a light-blue or white clay, carrying from one-third to one-half its weight of fine quartz sand,[1] and very commonly containing minute specks of iron sulphide or pyrite, as a result of which it is often called "flyspeck" clay. In some pits a portion of the bed is red mottled, and is regarded as of less value than the light-blue or white clay.

The thickness of the stoneware clay varies greatly, owing to its partial erosion by tidal currents immediately after its formation, and probably also to differences in original deposition. In some banks, as in H. C. Perrine & Son's (77), the old Ernst banks (80), and in the old clay mines of Morgan & Furman, thicknesses of 30 or even 35 feet have been found. The average thickness, however, is much less.

In the bottom of the pits in the stoneware clay, there is found either a black, lignitic sandy clay or a loose quartz sand. Our knowledge of these beds, however, is limited to the information derived from borings, since they are nowhere exposed in a natural section. A boring made many years ago by Otto Ernst, at his pits near the mouth of Cheesequake creek, showed 22 feet of sand

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[1] Cook & Smock, loc. cit. p. 17.

below the stoneware clay proper, and then another bed of similar clay 15 feet thick. This lower clay was, however, extremely local in extent and could be followed only a few rods.

Extent.—The outcrop of the stoneware clay with the associated black, sandy clay is indicated on the map, Plate XI. At the pits of Perrine and of Whitehead (78) and (76), at the head of Henry street, South Amboy, a dark-bluish to black clay is dug. Similar clays occur beneath the sand in the neighboring cuts along the Raritan River R. R. Along the Pennsylvania R. R., south of the coal yards, the black, lignitic clay occurring in the bottom of the cut is probably just above the stoneware clay proper.

Farther southwest along the railroad, C. P. Rose digs a red and white-mottled, stoneware clay, while in pits at a somewhat greater elevation near Ernston station, a black, lignitic clay has been found. Since the base of the bed has here an elevation of about 67 to 70 feet, the northwestern extension of the clay in this vicinity is limited by the low ground west of the railroad. South and southwest of Ernston the country is high and the clay is buried, by the overlying Cretaceous sands and later gravels, to depths in some cases approximating 100 feet. It is impossible, therefore, to limit accurately the northwestern extension of the clay bed in this high area, but in the lower ground a mile and one-half south of Ernston, the clay outcrops again and is dug by H. C. Perrine & Son (81)—Poorhouse bank—one-half mile east of the railroad. Here the top of the stoneware clay has an elevation of 43 feet above sea level, varies in thickness from 4 to 10 feet, and is overlain by several feet of sandy, black or brown, weathered clay. South of this locality, the clay probably underlies considerable areas of the low ground about the headwaters of Tennant brook and its branches. A light-colored, sandy clay was formerly dug there by Charles Reynolds, and both black and white clays are found upon the farm of E. Z. Lambertson. Still farther southwest and a mile southeast of Old Bridge a black lignitic clay occurs at an elevation fairly well in accord with that of the black, sandy clay overlying the stoneware clay proper. So, also, clay has been observed at a number of points along the road southwest of Old Bridge, at the proper elevation for the stoneware bed. In default, however, of further knowledge of the character and extent of these deposits, it would not be safe to do more than suggest their correlation with this member.

From the pits at the head of Henry street, South Amboy, the clay bed can be traced along the bluffs by frequent exposures to Perrine's large banks (77) on Raritan bay. Most of these exposures are of the black clay, and the stoneware clay proper does not seem to be present, or, if present, is thin. Marked variations in thickness and local absence is a feature quite characteristic of the stoneware clay, but nevertheless the fact that it has been opened at many widely separated localities indicates that it was originally deposited over a considerable area.

Southeast of Perrine's bank, on Raritan bay, the clay descends below sea level, and the overlying sands are exposed along the shore to Morgan station. Since, however, the beds all rise towards the northwest, this clay horizon outcrops along the sides of Crossway brook valley, where the stream has cut through the clay bed into the sand beneath, except at its headwaters. The approximate line of outcrop is indicated on the map, but the old diggings and borings indicate that the clay is somewhat irregular in distribution and decidedly variable in thickness. It is not at present (1903) being dug along this valley.

Southwest from Morgan station the clay outcrop follows the sinuosities of the bluff bordering Cheesequake creek. Since the bluff rises steeply, the outcrop is in general a narrow one, even where the clay attains considerable thickness. For the most part, it lies at the foot of the bluff, and underlies the low ground just above the salt meadow. Locally, it extends out under the latter for some distance, but borings have shown that in some places the marsh mud extends down to depths below the level of the clay. This is not to be interpreted as indicating that the clay bed did not formerly extend across the Cheesequake valley to the southeast, but rather that in this direction it was worn away in the erosion of the valley, the bottom of which has since been partially filled with marsh mud.

As indicated on the map, the Amboy stoneware clay undoubtedly underlies the high ground west of the bluffs, and connects with the line of outcrops along the Pennsylvania railroad (Camden & Amboy Div.). Since, however, the overlying sand and gravel deposits are locally 135 feet thick, the great mass of the clay is unavailable.

At present the clay along Cheesequake creek is being dug only by Leonard Furman and H. C. Perrine & Son. The former mines his clay by shafts and drifts, the latter firm, controlling several banks, works in open pits. All in all, the stoneware bed is worked much less than was the case twenty-five years ago.

SAND BED, NO. 3.

Underlying the Amboy stoneware clay and overlying the fire clays, which are dug at Sayreville and Burt Creek (to be described below), there is a thick deposit of quartz sand. The lower portion of the bed is exposed in most of the excavations made to reach the underlying fire clay, while the upper part has been penetrated by a few borings made in the bottom of the overlying stoneware-clay beds. The entire bed is nowhere exposed in a continuous section.

In general the material is a loose, clean, quartz sand, often coarse and occasionally even approximating fine gravel. Much of it is sharp and angular and of value for fire, foundry, and building sand. The sand pits of Sayre & Fisher, Edward Furman, William Albert, Whitehead Brothers and J. R. Crossman, at Sayreville and Burt Creek, are located in this bed, which underlies the high ground south of the Raritan river and northwest of the Camden & Amboy Rwy., between Sayreville and South Amboy. A heavy bed of yellow gravel (Pensauken) forms the tops of the hills, but the sand underlies the gravel at an elevation of about 90 feet. Locally, however, it contains some thin lenses of clay, such as are seen in the upper part of Whitehead's bank (69), west of Burt Creek. The sandy clays formerly dug along the shore near George street, South Amboy, seem also to belong here, as they are too low for the Amboy stoneware clay.

As already noted in connection with the stoneware clay, the upper part of this sand member is, in some pits, a black, lignitic sand or sandy clay. This was reported to be the case at Perrine's poorhouse bank (81), one of the shafts at the old Ernst property

(80), and at several of the abandoned workings near the head of Crossway brook. At other points the Amboy stoneware clay rests upon clean, light-colored, quartz sand. So, also, the basal portion is variable. At some banks a clean, quartz sand rests upon the undulatory surface of the fire clay beneath. In other banks or even in other parts of the same bank, a black sand or sandy clay, or alternating layers of black sand and clay with a maximum thickness of 15 feet occur between the fire clay and the quartz sand. These beds are more or less lignitic, and Cook and Smock[1] report finding numerous well-preserved leaf impressions in some layers. Locally also, small masses of amber are found in these dark clays immediately above the fire clay. These dark, sandy clays are best exposed at the J. R. Crossman banks (65 and 66), J. R. Such's bank (67), and in several banks on the old E. F. & J. M. Roberts property, north of Burt Creek, now owned by Sayre & Fisher.

Judging from the width of outcrop of this sand bed, where its boundaries can be well determined, and assuming that its dip is the same as that of the adjoining beds, 35 to 40 feet per mile, it has a thickness of 45 to 50 feet. Exposures of 30 or even 40 feet are not uncommon in some of the fire-clay banks near Sayreville and Burt Creek. At Whitehead's clay pit (69) the base of the sand has an elevation of about 38 feet above tide. Thence the sand is apparently continuous to a height of 90 feet near the crest of the hill just east of the pit. This thickness (52 feet) agrees fairly well with that estimated from the dip, when the irregular character both of the upper and lower beds of clay are considered. Fifty feet seems a fair measure of the thickness of this member where both the adjoining clay beds are moderately well developed.

SOUTH AMBOY FIRE CLAY.

The South Amboy fire-clay bed lies beneath the quartz sand bed just described. Its main outcrop is on the northern and western slope of the high hills, which lie south of the Raritan river

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[1] Clay Report of 1878, p. 69.

between Sayreville and South Amboy. It is also found north of the Raritan, in the high ground north of Eagleswood and Florida Grove. It has not been recognized west of South river, although, if present at all, it should occur in the high slopes bordering the stream between South River village and Old Bridge. The upper part of these slopes are, however, gravel (Pensauken) and the lower are quartz sand, with some thin clay laminæ.

South of the Raritan and east of Sayreville the bed has a narrow outcrop along the lower slope of the hill. Since it dips gently to the southeast and the surface rises steeply in the same direction, the clay bed occupies but a narrow belt at the surface, and, when followed into the hill, is soon deeply buried by the overlying Cretaceous sands (No. 3) and the much more recent Pensauken gravel. North of the Raritan the surface is more nearly level, or slopes in the same direction as the dip of the clay bed, so that the latter occurs near the surface over a wider area. These facts are shown on Plate XI, where the zone of outcrop is shown, as well as the probable extension of the clay beneath the overlying beds.

The South Amboy fire-clay bed is in general a white, light-blue, or red-mottled clay. Locally some portions of the bed are quite dark and contain bits of lignite. The following succession has frequently been observed, beginning at the top: (a) Sandy white to buff-colored clay, (b) blue fire clay, (c) sandy red-mottled clay. These are not distinct layers, but gradations from top to bottom in the one bed, and similar horizontal variations frequently occur. The upper and lower portions are often more sandy than the middle part, but in at least two widely separated localities, McHose Brothers (45) and J. R. Such (67), one north and the other south of the Raritan, beds of loose quartz sand, varying from 2 to 12 feet in thickness, are known to occur in the middle of this bed, separating the fire clay into a top and bottom layer. Mr. Such also reports finding in one portion of his bank a lense of fine clay in the middle of this intermediate sand layer. It is apparent, therefore, that this clay bed shows considerable variation in different banks. " 'Sulphur balls,' or round ball-like aggregations of pyrite crystals, are found in many places in this bed. They occur irregularly in all parts of it in the rich white, or fine fire clays, just as in the inferior red clays. These are from

1 to 4 inches in diameter. Frequently the outer shell or periphery is completely changed to ferric oxide, while the interior is still unchanged sulphide of iron. Pyrite in smaller lumps and fragmentary pieces is also quite common, and diffused throughout the clay of the whole bed as worked in some places."[1]

In the banks of J. R. Crossman (65, 66), J. R. Such (67) and some of the old excavations on the Kearney tract, north of Burt Creek, a black, lignitic clay, or alternating bed of clay and sand occurs immediately above the fire clay proper and is included with the fire clay on the map. Small pieces of amber occur near the base of the black clay in some localities. The surface of the fire clay beneath this black clay is often sharply undulatory, so much so as to suggest some erosion of the fire clay previous to the deposition of the black clay. The interruption to continuous deposition was probably not long, and the erosion is no more than could have been accomplished by shifting tidal currents. At most exposures, however, the fire clay is overlain either by the quartz sand (No. 3), which belongs to the Raritan series, or by the much more recent Pensauken gravel or red glacial drift. In the latter case the overlying Cretaceous sand, and often the upper portion of the clay itself was removed in the long period of erosion, after the formation of the Cretaceous beds, and before the deposition of the Pensauken gravel or the still later glacial drift. But even where the clay is overlain directly by the quartz sand (No. 3), its upper surface is sharply irregular and the bed varies greatly in thickness, indicating that there was at least a brief interruption in sedimentation and some erosion of the clay, as a result of the changed conditions and swifter moving currents, which began the deposition of the sand.

As may be inferred from what has been said, the South Amboy fire-clay bed presents great variations in thickness. At Sayre & Fisher's bank (273) variations of 15 feet in the height of the surface in a horizontal distance of 30 feet have been observed, with corresponding variations in thickness. In a few banks a thickness of 30 feet is sometimes found, but the average is much less than this. In not a few localities the clay is absent entirely.

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[1] Report on the Clay Deposits of New Jersey, 1878, p. 67.

At Charles Edgar's pits (268) the average thickness is 15 feet; at Sayre & Fisher's (267) 8 feet, while in the adjoining railroad cut near Van Deventer's station, on the Raritan River railway, it is absent entirely or represented only by a sandy clay 1 or 2 feet thick. In Whitehead Brothers' banks, between Sayeville and Burt Creek, the thickness varies from 5 to 15 feet, but in the isolated hill just north of bank 69 (see map) quartz sand apparently occupies the horizon of the clay, which is absent. So, too, farther east, J. R. Crossman's and J. R. Such's clay (65, 66, 67) ranges from 8 to 30 feet, including all grades. In the various pits on the old Kearney tract (60, 61, 62) the clay has been found to run from 8 to 20 feet, but at Crossman's sand pit (63), and in the isolated hill just south of his dock, there is no sign of the fire clay, its horizon being occupied by coarse quartz sand. One-fourth mile east, however, in a new bank of the Sayre & Fisher Company (274), 12 to 15 feet of white and red-mottled clay is found at an elevation of between 70 and 58 feet above tide, while a few rods still farther east a dark-blue terra-cotta clay occurs at a corresponding elevation. For two-thirds of a mile farther north along the western face of the hills, a number of small openings have been made in search of the fire clay, but it is absent altogether, or is too thin to be worked profitably. Many years ago, however, it was found at an elevation (top) of 60 feet in considerable thickness about one-half mile southeast of Kearney's dock, where a large area was dug over. East of this point the clay cannot be traced continuously, but the sandy clay (4 to 7 feet thick) dug by George A. Thomas (56) at South Amboy apparently corresponds stratigraphically to the fire clay.

North of the Raritan river this clay bed is dug chiefly by McHose Brothers (45) north of Florida Grove, and by Henry Maurer & Son (42). At the McHose bank the clay varies greatly in thickness and quality. In one part of this bank there was found a black, lignitic clay, beneath which the fire clay was supposed to exist, but instead a boring penetrated between 30 and 40 feet of sand. At this depth 9 feet of blue and buff clay were found, but at too low a level to be correlated with the Amboy fire-clay bed. In adjoining portions of the bank 15 to 25 feet of clay of various grades are found, all belonging to the fire-clay horizon. Maurer's clay varies from 9 to 17 feet in thickness, and is mostly red or red-mottled, instead of white. The same bed has also been opened at other places, as indicated on the map, Plate XI.

Owing to the extreme variations in the thickness of this clay bed and its entire absence locally, it is difficult to map it accurately. Yet on the basis of its dip, which is about 40 feet per mile, its probable position has been approximately determined.

THE "FELDSPAR"—"KAOLIN" SAND BED.

Beneath the South Amboy fire-clay bed and above the Woodbridge clays, there is an assemblage of beds, mostly sand, of varying texture and order of stratification. Here are included the so-called "feldspar" and "kaolin," as well as beds of loose quartz sand, thin clay lenses and layers of fine, white, micaceous sand.

The upper portion of this member has been explored by a number of borings in the bottom of the Amboy fire-clay pits, while the middle and lower parts are shown at the top of some of the excavations in the higher portions of the Woodbridge clays and in the "feldspar" banks. That there is great variation in the order of stratification, and that the so-called "feldspar" and "kaolin" beds do not occupy definite stratigraphical horizons is soon apparent upon examination in the field, and may be readily seen from the following sections.

At McHose Brothers' pit (45) a boring gave the following section beneath the fire clay:

A Boring at McHose Brothers' Clay Pit.

a. Red sand,	6 ft.
b. "Feldspar,"	4 "
c. Fine sand, some clay seams,	20 "
	30 ft.

Another boring[1] made years ago in J. H. Manning's banks (38) showed below the fire clay:

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[1] Report on the Clays of New Jersey, 1878, p. 132.

A Boring at J. H. Manning's Clay Bank.

a. Black sandy clay,	2 ft.
b. Fire sand,	10 "
c. Buff-colored clay,	4 "
d. Fire sand,	4 "
e. "Feldspar,"	10 "
	30 "

In still another boring[1] in a pit east of McHose Brothers' bank, and formerly worked by E. F. Roberts, these beds were found beneath the fire clay.

A Boring at E. F. Roberts' Clay Bank.

a. White sand and kaolin,	10 ft.
b. "Feldspar,"	3-4 "
c. White sand,	......
d. Black clay at the bottom,	......

The black clay at the bottom is believed to be the top of the Woodbridge clays.

These three borings were in the area north of the Raritan river. Within the same region intermediate portions of this division are now exposed at the "feldspar" banks of E. W. Valentine & Bros. (40), Henry Maurer & Son (41), The Staten Island Clay Company (32), Remy & Son (242). Valentine's and Maurer's banks are close together, and by combining the sections there exposed the following sequence of strata can be made out:

Combined Sections at Valentine's and Maurer's Feldspar Banks.

a. Cross-bedded sands with thin clay lenses,	8 ft.
b. Quartz sand with thin clay laminæ,	13-8 "
c. "Feldspar," varying greatly in thickness, average,	4-9 "
d. Black micaceous sand,	8 "
Total,	33 "
e. Black clay, reported to be 35 feet thick.	

The underlying black clay (e), seen at the eastern end of Maurer's bank belongs to the Woodbridge beds; the other strata are included in the "feldspar-kaolin" sands.

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[1] Idem, p. 134.

West of Florida Grove at the sand pits of the Standard Fireproofing Company (47) there are, belonging to this bed:

Section at Standard Fireproofing Company's Sand Pits.

a. Cross-bedded white and yellow quartz sand,	30 ft.
b. "Feldspar" lenses up to	12 "
c. White mica sand,	2 "
Total,	44 "
d. Black clays and sands (Woodbridge beds).	

South of the Raritan river "kaolin" occurs immediately beneath the South Amboy fire clay in the banks of Sayre & Fisher (273), Whitehead Brothers (75), (69), J. R. Crossman (65), and some of the banks on the old Kearney tract. In other pits coarse quartz sand or a white micaceous sand is found beneath the fire clay.

In the cut on the Raritan River railroad near Van Deventer station, the following section occurs at the horizon of this member of the Raritan:

Section near Van Deventer Station, Raritan River R. R.

a. White sandy clay,	1–2 ft.
b. White quartz sand,	10 "
c. White micaceous clay,	2 "
d. "Kaolin,"	3 "
e. Micaceous sand (lignite),	3 "
f. White micaceous sand,	12 "
Total,	32 "
g. Woodbridge clays.	

In this exposure the Amboy fire clay is not present, unless represented by the white, sandy clay (a), which is overlain by quartz sand. The latter apparently extends to the top of the hill, and belongs to the sand bed overlying the fire clay.

Near Crossman's dock, north of Burt Creek, in a semi-isolated hill, the following beds occur:

Section near Crossman's dock, Burt Creek.

a. Quartz sand,	20 ft.
b. Chocolate sandy clay,	6 "
c. Quartz sand with lenses of "feldspar,"	14 "
d. Fine mica sand and "kaolin,"	6 "
Total,	46 "

f. Black laminated clays of the Woodbridge member.

No section is known in the State nor any boring embracing the whole of this subdivision, but it is believed that the total thickness does not greatly exceed the maximum given above. Probably a thickness from 40 to 45 feet would be not far from the average.

As was pointed out in the earlier clay report,[1] the terms "feldspar" and "kaolin," as used in the Woodbridge district are misapplied. The "feldspar" is a coarse, arkose sand or gravel, *i. e.*, a mixture of quartz, and more or less decomposed feldspar and pellets of white clay, together with extremely minute amounts of other minerals. Hornblende or pyroxene and undecomposed granitic pebbles occur very sparingly. In the most typical beds the quartz amounts to about 60 per cent. by weight and 50 per cent. by volume.[2]

The feldspar pebbles occur up to an inch and a half in diameter, but the bulk of the material is much finer. Nearly all the feldspar has been decomposed to a white clay, a nearly pure kaolinite, but occasionally pebbles of unaltered feldspar are found, which still show planes of cleavage on their fractured surfaces. Many of the kaolinized masses, however, are not pebble shaped, but are irregular in outline and are squeezed around the quartz pebbles. The quartz pebbles are generally rounded or at least subangular, and lack the sharp edges and corners of grains which have not been waterworn.

The "feldspar" beds occur as local lenses, which thicken and thin, pitch steeply or extend horizontally, and vary greatly in composition within narrow limits. The accompanying sands are

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[1] Report on Clays of New Jersey, 1878, p. 61.

[2] Loc. cit. p. 63.

Fig. 1.

"Feldspar" bank of M. D. Valentine & Bro., south of Woodbridge. The dark-colored upper portion of section is glacial drift.

Fig. 2.

Section showing black laminated sands and clay, and kaolin overlain by cross-stratified feldspar sands. Standard Works of the National Fireproofing Company, near Keasbey.

cross-bedded, and this, together with the irregularity of the "feldspar" lenses, indicates that the deposit was made in rapidly moving water, where shifting currents brought about constantly recurring conditions of deposition, erosion and re-deposition.

It has been stated [1] that the "feldspar" beds are entirely unstratified, and that in this respect they are in marked contrast to the other beds of the Raritan. It is true that in these lenses there is no stratification or lamination of such a nature as to separate the quartz pebbles from the decomposed feldspar masses. The two are most intimately mingled without a trace of the alternation of clay seams and sand layers, which is sometimes seen in other portions of the Cretaceous. Nevertheless, there are definite, though not always obtrusive, lines of stratification in the "feldspar" lenses, and there is plain evidence of its deposition in water. (Plate XX, particularly Fig. 1.)

As was noted above, the quartz pebbles are somewhat rounded, and hence have suffered at least a moderate amount of wear during transportation by streams or waves. The clayey or kaolinized material is now for the most part so soft that it is difficult to imagine how it could have been transported any distance in its present condition along with the hard quartz without complete disintegration. This difficulty is met, if it be assumed that the alteration of the feldspar pebbles to the clay masses has taken place subsequent to their deposition. The pebble-like form and incomplete alteration of a portion of them accords with this assumption, but the irregular shape and the manner in which much of the clayey material surrounds the quartz pebbles are apparently inconsistent with this hypothesis. It must be borne in mind, however, that, as the feldspar changes to kaolinite, water is absorbed and there is some increase in volume. This swelling may account in part for the irregular outlines of the clay particles. To some extent, also, settling of the beds since deposition may have squeezed the clayey material around and between the quartz pebbles, but these explanations do not seem wholly adequate. If the material were derived from a partially decomposed rock composed of quartz and large feldspar crystals, it may be assumed that some

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[1] Report on the Clays of New Jersey, 1878, p. 62.

of the feldspar would be hard enough to resist much wear, and be finally deposited in a firm condition. Part may have already been completely kaolinized and formed clay lumps, in which subangular quartz grains were already imbedded or became imbedded during transportation. The clay lumps would of course have been greatly diminished in size by transportation even a short distance only, but may still not have been completely worn away. But whatever may be the difficulties in determining the exact method in all details by which this material was formed, its ultimate derivation from a quartz-feldspar rock, and its deposition in its present position by water cannot be questioned.

The "feldspar" is used chiefly in the manufacture of fire brick, but it is not dug so much as formerly. The main workings at present are the banks of Valentine (40), Maurer (41), Staten Island Clay Company (32), and Remy (242), all north of the Raritan river. A few pits have been dug near the shore northwest of South Amboy, but they are not worked at present. Since the "feldspar" occurs as lenses, and not as a continuous bed, it is impossible to map it definitely. Its occurrence, however, is limited to the zone between the black clay of the Woodbridge bed and South Amboy fire clay, so that its general horizon can be definitely fixed.

The so-called "kaolin" is not in any sense of the term a kaolin, although always so named in this district. It "is a micaceous sand, consisting of very fine-grained, white quartz sand, mixed with a small and varying percentage of white mica, in small flakes or scales, and a very little white clay. The mica is, however, conspicuous, and gives the mass a glistening appearance and a somewhat soft and soapy feel, but the sand is largely in excess, constituting from 60 to 90 per cent. of the mass in the more clayey and micaceous specimens."

THE WOODBRIDGE CLAY.

General distribution.—Beneath the "Feldspar-Kaolin" sands, there occurs the Woodbridge clay bed, the most important and most widely worked of all the subdivisions of the Raritan formation. Its importance is due to its great thickness (50 to 80 feet where not eroded), to its wide outcrop, and to its character.

It has been opened in four somewhat distinct areas, a) south of Woodbridge, b) north of the Raritan river from Florida Grove to Bonhamtown, c) south of the Raritan from South Amboy to Sayreville and south to Jas. Bissetts' brickyard on South river, d) at South River village and west to Milltown. The four districts may be spoken of briefly as a) the Woodbridge area, b) the Sand Hills area, c) the Sayreville area, d) South River area. The Woodbridge and Sand Hills areas are separated from each other by a belt of hills, the tops of which are formed either by thick deposits of glacial drift or by the higher members of the Raritan formation, *i. e.*, the "Feldspar-Kaolin" sands, and the South Amboy fire clay. Whether or not the Woodbridge clays are continuous across the belt beneath these later deposits, or whether the core of the ridge of hills is formed by the Triassic red shale, as may be inferred from an isolated knoll of this formation between Eagleswood and Spa Spring is uncertain. The Sayreville and South River areas are separated from each other, and from the other two by the deep trenches of the Raritan river and of its tributary, South river. The clay bed was beyond a doubt formerly continuous between them, but the excavation of the river valleys has dissected it and removed a large part of the clay, so that, although these rivers, by affording navigable waterways and cheap means of transportation, have greatly enhanced the value of the clays along their valleys, yet their existence has been accomplished by the erosion and removal of much of the clay stratum.

Thickness.—The thickness of this member varies from about 50 feet in the vicinity of Woodbridge to 80 feet near Spa Spring and Maurer, as shown by borings, but this amount of clay is nowhere exposed in any one bank. At many of the banks near Woodbridge, particularly the more northwesterly openings, the upper part of the bed has been eroded away, and only the lower 15 or 20 feet remain. In fact, there has been a varying amount of erosion wherever the yellow Pensauken gravel or the red glacial drift lies upon the clay (Plate XXI, Fig. 1). In some cases also huge masses of the clay many feet in diameter have been included in the drift, as in Plate XXI, Fig. 2. But where the black, laminated clay at the top is overlain by a white, micaceous sand, that is by the next higher Cretaceous bed, there has been no erosion of the Woodbridge clay (Plate XX, Fig. 2). This is the case in most of the banks about Maurer and Keasbey, and at Sayreville. Here, however, the base of the clay lies so deep that it is below sea level and is reached only by borings. The thicknesses given above make due allowance for the upper layers where they have been eroded, or are based on the data furnished by borings where the base of the clay is not exposed.

The Woodbridge clays do not form a homogeneous bed, but are made up of many layers of varying quality. At the top there is a black, lignitic clay with alternating seams and layers of sand. These were called by Dr. Cook the "laminated clays and sands." At the base there is a bed of fire clay,—Cook's Woodbridge fire-clay bed. In some areas certain beds just above the fire clay have a marked individuality, and can be recognized in adjoining banks. Elsewhere the corresponding layers are not sharply separable from the laminated clays and are included with them.

The black laminated clays.—As above noted, the upper portion of the Woodbridge clay bed consists of a succession of beds of black clay carrying some lignite and pyrite, and alternating with thin seams of white quartz sand, which is often darkened by disseminated bits of lignite. There is no order or regularity in this alternation. Both the clay and the sand layers vary in every conceivable manner in thickness and position. Locally the clay beds are thick and the sand is reduced to leaf-like partings; elsewhere the reverse may be true, and the greater part of the section may be sand, although the clay predominates on the whole. Layers of clay from one-eighth to one-fourth of an inch in thickness, separated by seams of sand scarcely thicker than a sheet of stiff paper, are of common occurrence. It is utterly impossible to trace individual layers any distance, or to identify any particular portion of this member in a small exposure, except locally in the case of some beds just above the fire clay, as noted in the preceding paragraph. Lignite and pyrite are irregularly disseminated through the entire mass, occurring in nearly every layer in at least small quantities and forming a large part of some beds. Concretions

Fig. 1.

Clay pit near Woodbridge, showing irregular eroded surface of clay, capped by glacial drift.

Fig. 2.

Section of Raritan clay included in glacial drift. The lighter streaks and spots represent the clay. The upright rod is ten feet long.

or "ironstones" are not uncommon at some horizons, and are locally so abundant as to form an almost continuous layer of stone.

At many banks these layers have to be removed in order to get at the fire clay. They were formerly thrown away in great part, and this is to some extent the case at present, but most of them can be used in hollow brick, fireproofing, common brick, etc., and at many points, particularly near Maurer, Keasbey, Sayreville and South River, they are so used very extensively.

These clays, where uneroded, vary from 30 to 60 feet in thickness, according as it is possible to differentiate certain beds just above the fire clays, or as all beds down to the fire clays are included.

In the area about Woodbridge the black laminated clays are shown in the upper part of the banks worked by M. D. Valentine & Bros. (14), J. H. Leisen (16), Anness & Potter (6), Perth Amboy Terra Cotta Company (7), P. J. Ryan (8), W. H. Cutter (29, 30), and James P. Prall (28, 31), while the banks near Maurer Station, *i. e.*, of the Staten Island Clay Company (33, 43) and of Henry Maurer & Son (36, 34), are entirely in this member.

In the Sand Hills area, the black laminated clays are well exposed in the bluff west of Florida Grove and in the banks of the Perth Amboy Terra Cotta Company (241), the Standard Fireproofing Company (46, 47), the International Clay Company (48, 49), Henry Weber (52), Mrs. John Goodrich (51), Ostrander Fire Brick Company (53), R. N. & H. Valentine (55, 86), D. A. Brown (87), and Charles Edgar (94), near Bonhamtown. South of the Raritan river they occur along the shore from Kearney's dock southwest to Crossman's dock, where the upper beds are dug. At Sayreville, the black clays dug by the Sayre & Fisher Company (71), William F. Fisher (74), Edwin Furman (72), and Boehm & Kohlhepps (73), for common brick, belong to this member. In the vicinity of South River and Milltown, they are found in the banks of Jos. Bissett (85), Yates Brothers (82), Theodore Willets (83), John Whitehead (84), Pettit & Co. (247, 249), National Clay Manufacturing Company (244), N. A. Pyrogranite Company (246), M. A. Edgar (252), and the Sayre & Fisher Company (253, 254).

Fire-clay bed.—A thick, persistent bed of high-grade fire clay occurs at the base of the Woodbridge clay. It is usually a light-blue or gray color, although parts of it are red mottled, due to a larger percentage of iron oxide in these portions. The clay carries more or less white quartz sand, which is generally more abundant in the upper and lower portions of the bed. These are often called the "top-sandy" and "bottom-sandy" clay, respectively. Where not sandy, the clay is hard and brittle and of a high degree of refractoriness. Some of the No. 1 fire clay contains as low as 0.5 per cent. of quartz sand, but the average is 5 per cent., while some of the sandy portion runs over 50 per cent.[1] Some portions of the bed contain considerable pyrite in the form of "sulphur" balls or nodules which have to be carefully picked out and rejected in mining.

The best clay, the "fine clay," or "No. 1 fire clay," as it is variously called, is commonly in the central portion of the bed, but there are frequent exceptions to this. The spotted or red clays are an inferior grade, and most commonly, but not always, occur below the "fine clay." The line of demarkation is never a sharp one, and the two varieties are both parts of a single bed. In some pits the spotted clay does not occur and the whole bed is blue or bluish-white clay. In other pits the spotted clay overlies the blue, in still other localities it passes into the blue horizontally. As is shown in Chapter XVIII, there is considerable variation in the quality of even the "No. 1" clay dug in various banks.

The surface of the Woodbridge fire clay is in places strikingly irregular or wavy, just as was the case with the South Amboy fire clay. Many instances are known where the top of the clay undulates from 5 to 15 feet within a few rods. Where the top of the bed is exposed over considerable areas, this undulatory surface is apparent; "sometimes rising and falling quite gently, forming ridges or dome-like knobs or elevations and irregularly shaped depressions or hollows; at others, marked by exceedingly irregular 'bunks,' as the miners call them, and sink-like holes that succeed each other without any apparent order or system."[2] The irregu-

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[1] Cook & Smock, loc. cit. p. 51 and 53.

[2] Cook & Smock, loc. cit. p. 49.

larities are well shown in some of the banks west of Woodbridge. At other localities, on the contrary, the upper surface of the fire clay holds a constant level over somewhat wide areas. Nowhere is this better shown than in the long exposures in W. H. Cutter's banks (29, 30). (Compare Pl. XXI, Fig. 1, with Pl. I, Fig. 1.)

In general, the inequalities of the surface are most marked where the fire clay is immediately overlain by glacial drift or by the yellow gravel (Pensauken) formation (Fig. 35, B). In this case, the irregularities are due to erosion which removed the overlying Cretaceous beds before the much later drift was deposited. In those cases not only has a part of the fire clay been worn away, but also a great thickness of overlying Cretaceous beds, and perhaps a part of the Miocene.

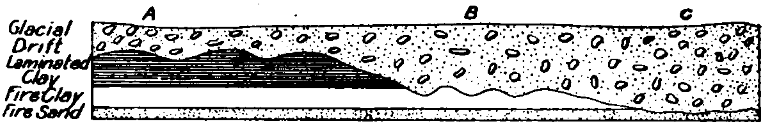

Fig. 35. A. Erosion and partial removal of the black laminated clay before the glacialdrift was deposited.

B. Complete removal of the black laminated clay, and erosion of the top of the fire clay, before the glacial drift was deposited.

C. Complete removal of the black laminated clay and of the fire clay before the drift was deposited.

Locally, erosion may have been so extensive as to remove the fire-clay bed itself. In such cases borings through the drift would strike not fire clay, but the underlying fire sand (Fig. 35 C). Erosion since the deposition of the drift will account for the absence of the fire clay along those streams such as Heard's brook near Woodbridge, where the stream has cut down its valley below the level of the fire clay. In such a case, the fire clay is found on either side the stream at a higher level (Fig. 36, A). In some cases, however, the undulatory upper surface of fire clay is followed immediately by beds of Cretaceous sand or sandy clay. In these cases the irregularities are apparently due to erosion by shifting currents, tidal or otherwise, during the deposition of the beds (Fig. 36, B). The few instances known where borings have shown that the fire clay is absent, although the overlying clays are present (Fig. 36, C), are due probably to this interdepositional erosion.

The base of the clay is somewhat undulatory, but less so than the top. Inasmuch as the basal undulations do not correspond with those of the top, the clay varies greatly in thickness. Instances of 40 feet have been reported, but the average is much less than that. Most commonly there is but 6 to 10 feet of the best clay, and 20 feet is a fair average thickness, including the sandy top and bottom. It is often much less than that.

The fire-clay bed is found in the bottom of all the banks about Woodbridge at present worked, except the Dixon banks (9, 10), which go down to a lower level, and the Perth Amboy Terra Cotta Company (7) which does not go deep enough. P. J. Ryan (1, 2, 8, 21), William Berry (11, 13), M. D. Valentine & Bros. Co. (14, 15, 23), J. H. Leisen (16), the Staten Island Clay Company (17, 18, 19), Albert Martin (20), Anness & Potter (6), Henry Maurer & Son (24), W. H. Cutter (29, 30), and J. P. Prall (31), are the principal miners of this clay about Woodbridge, and the various phases of the bed are shown in their banks.

Fig 36. A. Erosion along a valley through the drift laminated clay and fire clay. Borings in bottom of the valley show only fire sand while those on the valley sides strike the clay.
B Partial erosion and removal of the fire clay before the overlying laminated black clays were deposited.
C. Erosion and removal of the fire clay before the deposition of the laminated clay which is here thicker than usual. Borings here pass directly from the laminated clay into the fire sand.

None of the banks near Spa Spring and Maurer Station now go deep enough to reach the fire clay, its surface lying 10 feet or more below sea level near Maurer Station. The same thing is true of the banks between Florida Grove and Keasbey, wells along the water-front between these places showing the fire clay to occur far below sea level.

Just north of Keasbey Station, however, the fire clay rises to about sea level, and is reached in the lowest pits of the International Clay Company (48, 49). In Goodrich's bank (51), Ostrander's bank (53, 54), R. N. & H. Valentine's (55, 86), and also D. A. Brown's (87) at Sand Hills, the fire clay is well above sea level and is extensively dug. Nearer Bonhamtown the very base of the Woodbridge fire clay is shown in a small opening on the hillside over J. Pfeiffer's bank (90), but the greater part of the hill above is of Pensauken gravel. A number of shallow pits between Brown's bank and Pfeiffer's are in the weathered basal portion of the fire clay. South of Bonhamtown are the banks of Charles Edgar (94, 98), and the Raritan Ridge Clay Company, formerly Augustine Campbell (99). A fire clay is dug at the former, but at Campbell's banks a terra-cotta clay is found in the same stratigraphical position as the fire clay, so that there seems here to be a marked local variation in the quality of the clay. Campbell has, however, recently opened a new bank in the fire clay on the north side of the ridge near Bonhamtown.

South of the Raritan river the fire-clay bed lies far below sea level in the Sayreville area, and only the black laminated clays are dug, but a white clay, probably the fire clay, was penetrated in a boring at Furman's brickyard 35 feet below sea level.[1]

North of South River village, the fire clay occurs in the lowest pits of the N. A. Pyrogranite Company (245), and of the National Clay Manufacturing Company (244). Between Milltown and South River, M. A. Edgar (232, 252), the Sayre & Fisher Company (233, 237, 259), and the American Enamel Brick and Tile Company (256), have opened the Woodbridge clay bed at the horizon of the fire clay, but the clay is reported not to be so refractory as that of the same bed farther east, a sample from the American Enamel Brick and Tile Company's bank melting to a glass at cone 30, whereas the No. 1 fire clay of the banks near Woodbridge do not melt under cone 35. In addition to these localities where this bed has been opened, a white and red-mottled clay, said to be 20 feet thick, outcrops along the road southeast of Hoey's schoolhouse, on the property of George Hardenberg. Its

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[1] Cook & Smock, loc. cit., 1878, p. 183.

position and elevation, as well as its general appearance, indicate that it belongs to this horizon.

Intermediate beds.—Although the black laminated clays and sands at the top and the fire clay at the bottom are the only two subdivisions of the Woodbridge clays which can be generally recognized, yet between them there are a few beds which locally become somewhat conspicuous.

The fire clay is often, but not always, overlain by a bed of dark sand or sandy clay, which is usually rejected by the miners. This bed was somewhat fully described by Cook and Smock in the Clay Report of 1878,[1] from which the following sentences are quoted:

"Lignite or, as it is more commonly termed, wood, and pyrite (sometimes known as 'sulphur balls') are also common in this bed, and the dark color of the sandy mass is often due to the amount of carbonaceous material disseminated in small fragments and particles through it. This is sometimes so abundant that the bed appears made up of many thin layers of compressed woody matter in the form of flattened limbs and trunks of trees and leaf impressions packed so closely together that it is difficult to get good specimens or well marked prints. These all lie with the stratification, that is, with their longer axes conformable to the plane of bedding. In the banks of H. Cutter & Sons [now W. H. Cutter], and at Sayreville, the bed seems like a great herbarium, with its specimens nicely pressed and preserved in the sandy layers."

The leaf-bed has been recognized at seven or eight different banks, but our studies have failed to convince us that the bed is well enough characterized or persistent enough to be recognized over the whole district.

In a number of banks north of Keasbey, a white or light-colored, sandy clay occurs a little way above the fire clay and stands in somewhat marked contrast to the lignitic clays or sands between it and the fire clay. It varies in thickness from 2 to 10 feet, with an average of 3 or 4. This clay has been called the "top-white" clay, and is used for retorts, stoneware, etc. In other banks a well-marked black or dark-blue plastic clay of generally greater thickness than the top-white occurs at about the same

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[1] pp. 53-54.

horizon. Locally there are several such layers separated by thin beds of sand. In the latter case they might very well be classed with the laminated clays and sands. The best of these black clay beds were formerly much used for pipe, and are now in demand for conduits, speckled brick, front brick, etc. At Cutter's and Prall's banks a thin bed (2 to 3 feet) of buff-colored clay—known as rockingham clay—occupies about the same relative position respecting the fire clay as did the "top-white" clay in the banks near Keasbey.

Where best developed these various beds—the sandy leaf-bearing clay, the top-white, pipe and rockingham clays—do not exceed 15 feet in thickness. They are nowhere so sharply marked in their contacts and so distinctive in their characteristics that they can not be regarded as parts of the laminated clays and sands, which form the upper half of the Woodbridge clay. The varying orders of stratification of the Woodbridge clays is shown by several detailed sections which are given in Chapter XIX, in connection with the discussion of the clays from Middlesex county.

FIRE SAND, NO. I.

Below the Woodbridge clays there occurs a bed of quartz sand, much of which is so angular in grain and so free from other minerals as to be dug extensively for foundry and fire sand, as well as for building purposes. Locally it contains thin beds of gravel, and towards its base it carries lenses or seams of clay. The upper portion of this sand bed is occasionally penetrated in the deepest pits in the Woodbridge fire clay, but it is best exposed at the numerous localities south of Bonhamtown, and south and east of Milltown, where it is extensively dug. It is, also, well exposed in the upper part of many of the clay banks near Bonhamtown, which go down to the underlying fire and terra-cotta clays. North of the Raritan river it outcrops somewhat extensively east of Mill brook and south Bonhamtown. It also forms a well-defined belt south of the Raritan from the "Island farm," near the mouth of Lawrence brook, southwest past Milltown and Hoey's schoolhouse. The numerous localities at which this sand bed has been opened are indicated on the map, Plate XI.

Its thickness varies from 15 to over 35 feet. North of the Raritan river its average thickness is between 15 and 20 feet, but south of the river it is known to exceed 35 feet at several localities.

THE RARITAN FIRE AND TERRA-COTTA (POTTER'S) CLAY.

In the Report upon the Clays of New Jersey, 1878, the terms "Raritan potter's clay" and "Raritan fire clay" were used by Dr. Cook to indicate the two lowest subdivisions of the Plastic clay series. Inasmuch as the whole series is now known as the Raritan formation, these names are not now so appropriate, and yet, since they have been used in the earlier clay report, and are to some extent used locally by the clay workers, it seems best to retain them, in spite of the possibility of confusion.

Inasmuch, however, as the evidence is not conclusive that the fire clay and the potter's clay form coextensive distinct beds, and since it is not easy to separate the two in mapping, they are here considered together.

This clay underlies the fire sand described above. Wherever its base has been seen it rests upon the red shale, into which it apparently grades without a break. This is the case at Brinckman's pit (96), on the Mill brook, and at the abandoned pits of Calvin Pardee (237) a little to the east. The apparent transition from the Triassic shale, which dips 15 degrees to 20 degrees northwest, to the Cretaceous clay, which dips very gently southeast, is interpreted to mean, not that the clay was deposited immediately after the shale, but that the tilted and eroded edges of the shale were, at the beginning of Cretaceous time, covered by a residuary clay formed from the decay of the shale itself, and that, as the land was submerged prior to the deposition of the Cretaceous beds, this clay layer was in many places gently re-worked in its upper portion and re-deposited. With the gradual influx of other material, the deposit passed upward into the more typical Cretaceous clay, which was evidently not derived from the red shale. So gradual is this transition that even where the section is freshly exposed, it is frequently impossible to say within several feet, where the Triassic shale ends and the Cretaceous clay begins.

Excavations and borings indicate that this clay bed, at least its lower part, rests in hollows in the shale, and that it is more or less discontinuous. This was clearly shown a number of years ago in exposures near Silver lake, Piscataway,[1] where the clay, with a maximum thickness of 18 feet, was pinched out within a few yards to the south between the underlying shale and overlying drift, by the ascent of the shale. The same thing is indicated by borings in the vicinity of Bonhamtown. At the trolley barns a well penetrated 65 feet of gravel and then struck red shale; at the road fork, a few rods east and at an elevation 10 feet lower, a fire clay was reached beneath 40 feet of gravel,[2] and a third boring in the bottom of the gravel pit just north of these localities revealed a white clay beneath the gravel at about the same elevation.

The top of the clay bed beneath the fire sand is, also, very uneven, undulating sharply within comparatively narrow limits. This was well shown (1901) at Bloomfield's and Pfeiffer's banks (92, 90). It is evident that with the changed conditions, which brought about the deposition of the coarse fire sand on the clay, the surface of the latter was somewhat eroded by the estuary currents.

Owing to these variations in the top and bottom of the clay, its thickness is extremely variable. Locally, the fire sand seems to rest upon the shale and so cut out the clay entirely. More commonly, however, the clay is present in thicknesses varying from a few feet up to 35 feet. The latter thickness is said to occur at Bloomfield's bank (92), 15 to 20 feet of it being merchantable clay.

The fire clay.—The upper portion of this clay bed is a fire clay—the Raritan fire clay of Cook's report. It is a drab or light-blue clay, sometimes red mottled and sometimes almost black. It is usually quite sandy, much more so than the better portions of the Woodbridge fire clay, specimens showing from 29 per cent. to 50 per cent. of fine-grained quartz sand.[3] At present it is dug by C. A. Bloomfield (92), John Pfeiffer (90), C. A. Edgar (89),

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[1] Cook & Smock, Report on the Clays of N. J., p. 171.
[2] Cook & Smock, loc. cit. p. 162.
[3] Cook & Smock, loc. cit. p. 45.

and at the Dixon bank in Woodbridge by M. D. Valentine & Bros. (9). It was also formerly dug on the Ellison property, southeast of Edgar's banks (94). Here a pit passed through the following section:[1]

Section in a pit on the Ellison property.

(1)	Sand, coarse, and in part a fire sand,	7	ft.
(2)	"Hard pan" of sand, cemented by oxide of iron,	1	"
(3)	Clay,	8	"
(4)	Clay and lignite,	2	"
(5)	"Hard pan" layer (cemented sand),	1½	"
(6)	Clay,	4-4½	"

The upper clay (3) was a fire clay; the lower clay a potter's or terra-cotta clay. The sand bed between them separates the fire clay above, from the potter's clay below, so that here they apparently occur in two well-defined beds.

The potter's clay.—The Raritan potter's clay of the earlier report, which at Ellison's bank underlies the fire clay and apparently constitutes the lower part of this clay member, is extremely variable in color and in composition. It is often a white or white-blue clay; elsewhere it is a red-spotted clay, and its basal portion is usually a deep chocolate red, closely resembling the decomposed shale from which it was doubtless in part derived.

It has been found beneath the fire clay only on the old Ellison property; elsewhere, so far as exposed, it occurs without the fire clay, being directly overlaid, either by the much later Pleistocene deposits (glacial drift, or Cape May sand and gravel) or less frequently by the fire sand (Sand No. 1). In the former case the absence of the fire clay may be assumed to be due to erosion in the long interval between Cretaceous and Pleistocene times. In the latter case, it may be that the fire clay was never deposited, or that it was eroded away by the swifter currents, which attended deposition of the overlying fire sand. Over the larger part of the area mapped as the *Raritan fire and potter's clay,* Plate XI, only the potter's clay occurs, so far as present data show.

At the present time it is dug only by the Brinckman Terra Cotta Company (96) east of Martin's dock, and by Augustine

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[1] Idem, p. 167.

Campbell at several pits south of Metuchen. In addition to these, it has been dug by Calvin Pardee (237), on the John Conger farm (97), and by N. Lorensen (238), since the publication of the 1878 Clay Report. In some of the pits mentioned in that report, but long since abandoned, samples of the clay can still be seen. In addition to these localities, where there is no question as to the stratigraphical position of the clay, a red-spotted, terra-cotta clay has been dug by Joshua Little and George Cutter a mile north of Fords and 2 miles southwest of Woodbridge. The clay resembles very closely that of the Brinckman Terra Cotta Company, so far as color and feeling goes, but the altitude of its top in the two pits, 135 feet and 145 feet respectively, is much greater than the Raritan potter's clay bed should have in this vicinity, unless the underlying shale rises very rapidly at this point. The clay was reported to have a thickness of 37 feet, which would make the altitude of its base 108 feet. In spite of the discrepancy in elevation, this clay is tentatively referred to the Raritan potter's clay.

South of the Raritan river, and within the area shown on Plate XI, the outcrop of this clay bed is a very narrow one, being limited to a ribbon-like strip along the sides of Lawrence brook and its tributaries. A black clay grading downward into a white clay, and exposed to a depth of 7 feet, is seen in the bottom of one of Whitehead Brothers' sand pits, a mile southeast of Weston's mills. The same dark clay has also been found in the bottom of the sand pits on the Island farm, just east of this locality. For the most part, the exposures along Lawrence brook are of a red-spotted clay occurring directly above the shale, and overlaid by a great thickness of Pensauken or by the next higher member of the Cretaceous, the fire sand. Owing to the thickness of this covering, these localities are not, for the most part, favorable for the economic development of the clay. Beyond the limits of the map and southwest of Parson's mills, a white and mottled clay is reported to occur in considerable thickness on the property of Mrs. Eva Van Deventer (264). It is conveniently located in respect to the Trenton & New Brunswick trolley and is not deeply covered by drift. A mile farther southwest, on the property of T. W. Buckalew (263) (Plate X), 18 feet of gray-white clay—a low-grade fire clay—were found in digging a well. There is here no overburden. A considerable thickness of white clay (14 feet) was also reported from a well at Franklin Park station, 4 miles southwest of New Brunswick, but the overburden of gravel is here considerable.

THE RARITAN FORMATION SOUTHWEST OF THE WOODBRIDGE-SOUTH RIVER DISTRICT.

From the Woodbridge-South River area, represented on Plate XI, the Raritan formation extends across the State to the Delaware river between Trenton and Bordentown, but over most of this area it is somewhat deeply buried by the Pensauken gravel. Nevertheless, at a few localities plastic clays have been noted and borings at other points have demonstrated the extension of the clays in this direction.

The occurrence of clay just above the red shale along the valley of Lawrence brook has been mentioned in the previous section, as well as its occurrence in a thick bed on the Buckalew farm (263) and on the Van Deventer property (264). This clay is at the base of the Raritan formation in the *Raritan potter's and fire-clay bed*. Two miles west of south of Monmouth Junction a dark-gray clay is exposed in the bottom of a cut along the Trenton and New Brunswick trolley at an elevation of 95 feet. The overburden is very slight and the clay is favorably located as regards shipment. Clay has also been found by boring along the Millstone river midway between Hightstown and Princeton Junction, but it is not exposed at the surface and the overburden of gravel is heavy. Still farther southwest sandy clays are reported to occur along the Pennsylvania railroad (a) a mile southwest of Princeton Junction (b), near the Clarksville road, and (c) near Lawrence station, but very little is known of them.[1]

TEN-MILE RUN.

An isolated area of the Raritan formation is found on the hills north of Monmouth Junction and near Ten-Mile Run. The Rar-

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[1] Cook & Smock, loc. cit. p. 233.

itan potter's clay resting on red shale has been worked in times past at several points, and at present is dug by the Excelsior Terra Cotta Company for use in their works at Rocky Hill. An analysis of this clay is given in Chapter XIX, under clays of Somerset county.

Overlying the clay bed, which is said to reach a thickness of 14 feet in places, is a quartz sand, which is undoubtedly to be correlated with the fire-sand bed near Woodbridge.

TRENTON CLAYS.

Two miles east of Trenton clays are dug in a number of pits along Pond run. These are locally known as Dogtown clays. The stripping, chiefly Pensauken gravel, varies from 5 to 12 feet in thickness. The clay is commonly red or red-spotted, grading into a blue at the bottom of the pits. In some places the upper layer is a white clay, and locally a black lignitic clay occurs beneath the blue clay. Elsewhere a sand bed underlies the clay. The most extensive diggings are those of James Moon (101) (Plate VI). The general section as reported by Mr. Moon is as follows:

Section at pits of J. J. Moon, Dogtown, near Trenton.

Stripping, chiefly gravel,	5–12 ft.
White clay (where stripping is thin),	2–3 ft.
Red clay, grading down into a red-spotted and thence to a blue clay,	14–28 ft.
Sand,	3–4 ft.
Hard, tough, blue clay, called "hard-pan,"	3–4 ft.
Loose, white sand, more than	8 ft.

Somewhat similar clays are dug on the J. Priest farm (100), by D. South (102), by A. Lattimer (105), by J. Kuhn adjoining Lattimer's pits, and on the A. Worthington property (104). Priest's clay is reported to range from 16 to 22 feet in thickness, Moore's 18 to 32, South's 10 to 14 feet, and Lattimer's 15 to 22 feet. They are used chiefly for saggers and wad, and are hauled by wagon to the Trenton potteries. Clay has also been found at other points in this neighborhood, but the pits are no longer worked. It is not possible to correlate these clays with any of the beds in the Woodbridge area.

In addition to the Dogtown clays, pits have been opened in the Raritan formation at other points near Trenton, but they are no longer worked. Clay occurs in the bluff along the Delaware river south of Trenton and north of Crosswicks creek, particularly on the property of Dr. C. C. Abbott and P. E. De Cou. Some of this clay was at one time taken out by tunneling into the hillside, some drifts being 200 feet long, but owing to the cost of timbering it was abandoned. A black sandy clay, 6 to 7 feet thick, is exposed beneath 10 or 15 feet of Pensauken gravel in a ravine west of Yardville (107), but it has not been worked.

BORDENTOWN.

From Bordentown to Kinkora the base of the Clay Marl I is found at the top of the bluff along the river, and black lignitic clays and interbedded sands of the Raritan formation form the basal portion. Landslides and washes have very generally obscured the section, but occasionally fresh faces are visible. About one-half mile south of the Bordentown depot the following section was reported by Drs. Cook and Smock.[1]

Section near the Bordentown Depot.

(1) Yellow sand and gravel,	8–10 ft.
(2) Clay marl (greensand),	5 ft.
(3) Black, sandy clay full of pyrite and lignite, alternating with layers of white quartz sands,	35–40 ft.
(4) White quartz sand at the level of the track (10 feet A. T.)	

At White Hill, at the north end of the forge building, they reported the following[2]:

Section near White Hill.

(1) Yellow earth and gravel,	8–10 ft.
(2) Clay Marl,	6 ft.
(3) White sand containing red oxide of iron crusts,	12 ft.
(4) Black, sandy clay alternating with thin layers of sand,	12 ft.
(5) White sand from railroad track level to tide level,	10 ft.

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[1] Cook & Smock, loc. cit. p. 239.

[2] Idem, p. 240.

Forty distinct layers were counted in a vertical section of 3 feet in No. 4, while above them was a single bed of clay 3 feet thick. This illustrates the great variation in thickness of the clay and sand layers.

At S. Graham & Co.'s brickyard (112), the same thin-bedded, black clay, with fine laminæ of white sand is dug in pits east of the wagon road, while along the railroad more sandy beds are exposed. The horizontal variation from clay to sand is well brought out in these banks (Plate II, Fig. 1). At Dobbin's bank, Kinkora (113), a few feet of the same black laminated clays are shown, but the greater portion of the clay there dug belongs to the overlying Clay Marl series.

FLORENCE.

Below Kinkora the course of the river is more to the west and it crosses obliquely the outcrop of the Raritan formation towards the base. The immediate consequence of this is that, in the bluff below Kinkora, lower beds of the formation are exposed, so that at Martin's brickyard (115) a tough, white and red-spotted plastic clay is found in pits in the lowest portion of the yard. This clay belongs below the black laminated clays of S. Graham & Co.'s bank, but the interval between them is unknown. A black clay is also dug in another part of Martin's yard at a higher level. It does not, however, belong to the Raritan formation, but is of much later age, being a Pleistocene clay similar to that found at Fish House (p. 133). For a mile or more above Florence the river flows at the foot of a high bluff, in the lower portion of which white and red clays outcrop at numerous points. They were somewhat extensively worked twenty-five or thirty years ago, and the following sections are given in the Clay Report of 1878.

Section at Joshua Eayre's clay banks.

(1) Yellow sand, in undulating wavy lines,	16 ft.
(2) Gravel,	2 ft.
(3) Reddish and variegated clay,	18 ft.
(4) White clay,	4 ft.
(5) Clay and sandy earths,	2 ft.
(6) White sand (called *kaolin*),	6 ft.
(7) Sand at mean tide level.	

In other portions of the bank, however, the section was quite different.

Section at Henry I. Tinsman's clay bank—300 yards from Eayre's.

(1)	Sand,	15 ft.
(2)	Black clay with lignite,	5-8 ft.
(3)	Bluish white clay with some included masses of red clay in it, down to tidewater,	12 ft.

These pits are no longer worked, but E. M. Haedrich has made extensive excavations in the bluff a mile northwest of Florence station, where both Pensauken and Cretaceous gravel and sand are worked. Several feet of Clay Marl I are here exposed beneath the Pensauken and above the sands of the Raritan formation. Incidentally some beds of white and red clay are also taken. A black sandy clay, probably corresponding to the laminated clay at S. Graham & Co.'s brickyard, is reported in wells around Florence and Florence station at depths of 15 to 25 feet.

BURLINGTON.

White and red plastic clay occurs 2 miles east of Burlington, along Assiscunk creek, on both banks of the river, on property belonging to Mr. Joseph P. Scott (120) and Mr. Hays (121). On the north bank it occurs in low ground covered by a few feet of sand; on the south bank it is seen at the base of the creek bluff, overlain by yellow sand at an elevation of 12 or 14 feet above the creek. Stripping of 20 to 25 feet will be encountered in working back into the bank for any distance, but considerable clay can be dug along the creek without much stripping. Samples of these clays have been tested, the results being given in Chapter XIX, under the clays of Burlington county.

BRIDGEBORO.

The clay dug by J. W. Paxon & Co., at Bridgeboro, on the south bank of Rancocas creek (132), belongs to the Raritan formation. At the western openings a red-mottled clay, with some yellow and some white masses, was exposed to a depth of 10 feet, below 8 or 10 feet of Pleistocene sand and gravel. The

Fig. 1.
General view of a portion of H. Hylton's sand and clay pit, near Palmyra.

Fig. 2.
Raritan clay overlain by Pensauken sand in H. Hylton's pits, near Palmyra.

clay was reported to be 14 feet thick and to be underlain by a white, water-bearing sand. Traced southeast 200 yards, the red clay grades into white clay, in the upper portion of which is a 6-inch layer containing lignite. A hundred feet farther east the lignitic clay layer passes rapidly into a lignite-bearing sand bed. These facts illustrate the constant variation in color and texture of the Raritan beds in this part of the State.

PENSAUKEN CREEK.

The Raritan clay has been dug at three points along Pensauken creek (133, 134, 135). At Parry (North Pennsville), excavations no longer worked, show a loose, white sand, with some beds of sticky clay, as well as intermediate grades. These Cretaceous beds are overlain with Pensauken gravel from 10 to 35 feet thick.

A mile west there is the enormous Hylton opening, which has been worked for gravel, sand and clay for many years, Plate XXII. Here an almost continuous section is shown for nearly three-fourths of a mile, but much of it is obscured by wash. In the eastern part 40 to 50 feet of Pensauken sand and gravel occurs above the clay, the top of which is about 12 feet above the meadow bordering Pensauken creek. The clay is white or red spotted, varying locally. When seen in 1902, it averaged 6 or 7 feet in thickness and was underlain by a fine white clayey sand, the so-called "kaolin." In the western portion of the bank the Pensauken gravel is thinner, and a white and yellow Cretaceous sand occurs below the gravel and above the clay. Locally this sand bed contains thin lenses of white clay, which often vary in thickness or pass into sand within the space of a few rods. The clay bed is reported to be 20 or 25 feet thick in places. In previous years great quantities of fire clay have been dug here, but at the present time sand and gravel constitute a larger part of the material handled. Above the Pensauken gravel there is a clay loam 4 or 5 feet thick over much of the surface. In general appearance it resembles the clay loams used at many points for brick (p. 121).

Just west of Hylton's bank the same beds of gravel, sand and clay are dug by P. Erato, along the Pennsylvania R. R. at Morris station (Pl. XXIII, Figs. 1 and 2). Here the lense-like character of the clay beds are strikingly shown. In the middle of the bank, where it is highest, the section in 1902 showed:

Pensauken gravel,	10 ft.
Raritan white sand, with thin clay lenses,	30 ft.

Much of the sand is sold for fire sand, and some of the clay is said to be a fire clay.

The variable character of the Raritan formation in this part of the State and the impossibility of separating it into persistent horizons is well brought out by the record of 2 wells at Jordantown, 1 mile northeast of Merchantville, drilled for the water supply of the latter place. The wells are located along the swampy flood plain of the South Branch of Pensauken creek at an elevation of less than 5 feet A. T. and 100 yards apart.

Sections in Wells at Jordantown, near Merchantville.

Well No. 1.

Gritty white clay, from	41 to 52 ft.
Gritty white clay "	57 to 63 "
Sandy clay, "	70 to 73 "
White clay, "	78 to 80 "
Sandy clay, "	84 to 86 "
Sandy clay "	95 to 97 "

Well No. 2.

Thin sandy clay, at	46 ft.
Smooth clay, from	56-58 "
Three-inch seam of clay, at	73 "
Sand, from	73 to 111 "
Gritty clay, from	111 to 115 "
Smooth white clay, from	136 to 146 "
Blue clay, from	183 to 205+ ft.

Between the clay beds loose sand, ranging in some cases up to small gravel, was found. The above sections show that the first three clay beds in Well No. 1 are represented by only thin seams in No. 2, while the last three clay beds in No. 1 are absent entirely in No. 2, or were so thin as not to have been recognized at all in drilling. The deeper clays in Well No. 2 were not reached by Well No. 1, so we cannot compare that part of the section.

Fig. 1.
General view of Erato's clay and sand bank in the Raritan formation, Morris station.

Fig. 2.
Pensauken gravel, Raritan cross-bedded sand and Raritan clay, in Erato's bank, Morris station.

CAMDEN AND SOUTHWARD.

At Fish House, north of Camden, white clay belonging to the Raritan formation has been found under the black Pensauken clay (p. 133). Beds of similar clay are exposed intercalated in sands along the ravines south of Fish House (135, 136), but the clay layers are apparently not thick. So, too, thin beds of sandy clay were noted along the banks of a small stream north of Dudley station at East Camden, but the Raritan formation in this vicinity is chiefly sand. Raritan clay is also reported to occur on the United States government land at Red Bank, below Gloucester; on property of B. A. Lodge, near Billingsport, and of James Kirby, near Raccoon creek, a mile south of Bridgeport.[1] At none of these localities is the clay dug at present. From Bridgeport southwestward the country is low and flat. The Raritan formation is nearly everywhere covered by the later Cape May sand and gravel, and, although there is no reason to doubt the existence of clay beds at various horizons beneath this later cover, yet their exact location, as well as their nature are unknown.

From this brief summary it is evident that the Raritan formation, outside of the Woodbridge-South River area of Middlesex county, is not a great clay producer. Although clay is dug in a few localities, as at Dogtown (near Trenton), at Kinkora, and on Pensauken creek, the formation, as a whole, is not so important as some of the higher members. This is in part due to the fact that from Trenton southwestward the channel of the Delaware river covers a considerable portion of the formation, and in part to the fact that across the central part of the State, as well as farther southwest, the later Pleistocene sands and gravels are quite thick and so conceal the clay. But it is also true that in this part of the State the formation, so far as we know it, contains more sand and gravel and less clay than farther northeast, and that the clay beds are more local and discontinuous.

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[1] Cook & Smock, loc. cit. pp. 251, 252.

CHAPTER IX.

CLAY DEPOSITS IN SYSTEMS OLDER THAN THE CRETACEOUS.

CONTENTS.

TRIASSIC.

The Triassic or Newark series in New Jersey consists chiefly of red shales and sandstones with some masses of trap rock. It has been described in detail in the Annual Reports of the State Geologist for 1896 and 1897. It forms a belt across the State between the Highlands on the northwest and the Cretaceous strata on the southeast, extending from the New York State line between Suffern and the Hudson river, to the Delaware river between Trenton and Holland. The red shale where disintegrated forms a sandy, clayey soil of shallow depth. Locally this may accumulate in hollows as the result of wash from surrounding slopes and form clay beds of no great depth and limited extent, but so far as known beds of this description are nowhere used. The shale itself is for the most part rather gritty and not favorable for use in clay products, but locally it is fine grained and suitable for brick. It is so utilized at Kingsland, Bergen county, with apparent success. A few experiments on shale from other localities were made in the course of these studies, and although unfavorable and decisive so far as they went, they were not sufficiently numerous to test the formation thoroughly. Beds suitable for brick or draintile are more likely to occur in the Brunswick shales, rather than in the Lockatong or Stockton subdivisions,[1] and in the Brunswick shales rather to the south of a line from Passaic to Morristown than to the north of it, but there may be local exceptions to this rule.

At Pedrick's brickyard, Flemington, the basal portion of the clay used has been formed by the disintegration of the red shale beneath, and it is expected to use the less disintegrated material as soon as suitable machinery for crushing it can be installed.

The trap rock, where deeply weathered, gives rise to a yellow, more or less stony clay, usually containing many fragments of the less disintegrated portions of the rock. South of the drift-covered area, *i. e.*, southwest of a line from Morristown to Perth Amboy, this residuary deposit often attains a thickness of several feet. Locally, it has been utilized for clay, as at Daniel's brickyard, on Sourland mountain, southeast of Lambertville (277), but it is full of bowlders, which are left in the pit (Pl. XXIV, Fig. 1).

DEVONIAN.

The Devonian formations of New Jersey are limestones, shales, sandstones and conglomerates. They occur in Sussex county along the Delaware river from Wallpack bend northward to the State line, and also in the Green Pond-Bearfort mountain region. In the former region they are chiefly limestones with some shales; in the latter, gritty shales, sandstones and conglomerates. In some states the Devonian shales are a source of valuable materials for paving brick, sewer pipe, drain and roofing tile, terra cotta, etc. In New Jersey, however, they are nowhere used, and in view of the unfavorable nature of most of the Devonian rocks, as well as the present inaccessibility by railroad transportation of much of the region covered by them, it is doubtful whether they will prove of any immediate importance.

SILURIAN.

The Silurian formations in New Jersey consist chiefly of sandstones, with a few limestone and shale strata. They occur in

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[1] Annual Report of the State Geologist, 1897.

Fig. 1.

Shallow bed of clay formed by disintegration of trap rock. Daniel's clay pit, Lambertville.

Fig. 2.

Rolls for disintegrating clay before putting it through stiff-mud machines. E. Farry's yard, Matawan.

Warren and Sussex counties in Kittatinny mountain and the lower country on the west, and also in the Green Pond-Bearfort mountain region. The shales are nowhere utilized, and no tests have been made of them in this investigation. They are for the most part sandy and unpromising.

CAMBRIAN AND ORDOVICIAN.

The Cambrian and Ordovician rocks are limestones and shales with some beds of sandstone and quartzite. They occur chiefly in Warren and Sussex counties in the great Kittatinny valley, between the Kittatinny mountain on the northwest and the Highlands on the southeast. They also occur within the Highland area in the valleys of the Musconetcong and Pohatcong, the South Branch of the Raritan northeast of Califon, and in the Green Pond mountain region. They also are found in a few small areas southeast of the Highlands between the crystallines and the Trias red shale, the largest of these isolated areas being in the vicinity of Clinton and Pattenburg.

Southwest of the terminal moraine, which marks the southward border of the region covered by the ice of the last Glacial epoch, the rocks are in places somewhat deeply weathered and buried beneath the products of their own disintegration. The limestone commonly weathers into a yellow sticky clay, containing more or less abundantly the insoluble black cherts or flints, which occur in it. Locally beds of clay may thus be formed, partly by the decay of the rock beneath and partly by the wash from similar material on higher slopes. The smooth clay on the property of L. T. Labar, near Beattystown (Loc. 283), has probably originated in this way,[1] although some of it may belong to a very early glacial drift.

At Alpha (Loc. 278), near Phillipsburg, the Portland cement rock (Trenton age) is covered by 3 or 4 feet of yellow sticky clay, with a soapy feeling, which contains occasional small masses of vein quartz, etc., and which was derived from the cement rock

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[1] See Chapter XIX for physical tests of these clays.

by the solution and removal of the calcium carbonate. It is used in the manufacture of common brick.

Outside of the moraine the shale also is deeply weathered, as is well shown in several railroad cuts between Hackettstown and Washington. At Port Murray (Loc. 282) it is utilized by the Natural Fireproofing Company in the manufacture of fireproofing (Plate LVI). Similar weathered material occurs abundantly in this vicinity and in the shale belt west of Clinton along the line of the Central R. R. of New Jersey.

North of the moraine the shale is covered by the glacial drift, or if exposed, is in general but slightly weathered. The fresh shale, when ground up and mixed with water, is lacking in plasticity and tensile strength and, therefore, does not give such good results as that which has been deeply weathered. This being so, it is doubtful whether the great shale deposits within the glacial area will ever prove of value for these purposes.

PRE-CAMBRIAN ROCKS.

The pre-Cambrian rocks occur in the Highlands. They are chiefly gneisses, schists and granites. Some of the latter are coarse feldspathic rocks, although by far the greater part are not. Under favorable conditions the decay of a coarse-grained granite will give rise to a mass of kaolin, with some mica and quartz. Such deposits are known to occur in New Jersey, but they are of small extent and unworked at the present time.

In the Annual Report for 1874 such a deposit is noted as occurring in a narrow valley one and one-half miles southwest of Bethlehem, Hunterdon county, on lands owned by Mr. Willever, and later by S. L. Shimer, of Phillipsburg. A shaft 33 feet deep is reported to have been sunk in it without reaching its bottom. The bed was a mixture of white clay, with a large percentage of very fine white quartz and partially decomposed feldspar. Analyses of the crude material show a large amount of potash, with some lime and magnesia and a little oxide of iron, the latter giving it a dark color in burning.

A somewhat similar appearing deposit has also been observed near Amsterdam, Hunterdon county, on the property of Mr. Rapp. It lies in a little hollow, near the road from Amsterdam to the Delaware river. A small opening was made here some years ago, and a little clay shipped. An analysis of this clay is given in Chapter XIX, under the head of Hunterdon county.

Within the region which was covered by the ice sheet of the last Glacial epoch, the surface of the Highlands was in general severely eroded and all residuary material removed. The rocks there, where outcropping on the surface, as well as where exposed beneath their covering of glacial drift, are generally hard and unweathered. Under these circumstances it is extremely doubtful whether any workable residuary kaolin deposits will ever be found in that area.

PART III.

THE MANUFACTURE OF CLAY PRODUCTS, WITH ESPECIAL REFERENCE TO THE NEW JERSEY INDUSTRY.

By HEINRICH RIES.

INTRODUCTORY STATEMENT.

Probably few persons have any conception of the many different applications of clay in either its raw or burned condition. These varied uses can be best shown by the following table, compiled originally by R. T. Hill [1] and amplified by the writer:

Domestic.—Porcelain, white earthenware, stoneware, yellow ware and Rockingham ware for table service and for cooking; majolica stoves; polishing brick, bath brick, fire kindlers.

Structural.—Brick: common, front, pressed, ornamental, hollow, glazed, adobe; terra cotta; roofing tile; glazed and encaustic tile; draintile; paving brick; chimney flues; chimney pots; doorknobs; fireproofing; terra-cotta lumber; copings; fence posts.

Hygenic.—Urinals, closet bowls, sinks, washtubs, bathtubs, pitchers, sewer pipe, ventilating flues, foundation blocks, vitrified bricks.

Decorative.—Ornamental pottery, terra cotta, majolica, garden furniture, tombstones.

Minor uses.—Food adulterant; paint fillers; paper filling; electric insulators; pumps; fulling cloth; scouring soap; packing for horses' feet; chemical apparatus; condensing worms; ink bottles; ultramarine manufacture; emery wheels; playing marbles; battery cups; pins, stilts and spurs for potters' use; shuttle eyes and thread guides; smoking pipes; umbrella stands; pedestals; filter tubes; caster wheels; pump wheels; electrical porcelain; foot rules; plaster; alum.

Refractory wares.—Crucibles and other assaying apparatus; gas retorts; fire bricks; glass pots; blocks for tank furnaces; saggers; stove and furnace bricks; blocks for fire boxes; tuyeres; cupola bricks; mold linings for steel castings.

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[1] Mineral Resources U. S., 1891, p. 475, Washington.

Engineering works.—Puddle; Portland cement; railroad ballast; water conduits; turbine wheels; electrical conduits; road metal.

Nearly all of the more important products are made in New Jersey, and these branches of the industry are treated in some detail in the following pages.

Classification of clays based on uses.—Clays are sometimes classified according to their uses into the following groups:

Kaolins or China clays.—Those burning white and used in manufacture of white earthenware or porcelain.

Fire clays.—Buff-burning clays of refractory character used chiefly for fire brick.

Stoneware clays.—Semirefractory clays, which burn to a dense body and possess good plasticity and tensile strength.

Pipe clays.—Nonrefractory clays, of good plasticity, and which are vitrifiable.

Brick clays.—Impure clays, usually red-burning.

These do not by any means represent all the names commonly met with in the clay-working industries. For this reason it may be well to give at least the more important ones below.

Kaolins.—A term applied to white-burning residual clays, used in the manufacture of white earthenware, porcelain, wall tiles, white floor tiles, paper making, etc.

Ball clays.—White-burning, plastic, sedimentary clays, used chiefly in the manufacture of the fine grades of pottery, viz.: those having a white body.

Ware clay.—A term applied to ball clays mined near Woodbridge.

Fire clay.—A term loosely applied to clays considered suitable for making fire brick. No standard of refractoriness has been adopted in this county, and many clays are called fire clays which have absolutely no right to the name. Fire clays are often classed as No. 1 and No. 2 grades. Since the term is so loosely used, and, furthermore, as even in New Jersey there is no uniform usage of the name, in this report the fire clays have been grouped as highly refractory, refractory, semirefractory (p. 100), and no clay fusing below cone 27 is considered a fire clay. The terms No. 1 and No. 2, when used, refer to the designations given by the clay miner, and often mean no more than that the clay is the best or second best dug by him.

Stoneware clays.—Under this term are included such clays as are adapted to the manufacture of stoneware. They must, therefore, possess good plasticity, dense-burning qualities and preferably good tensile strength. The lower grades of stoneware are often made from a nonrefractory clay, but the better grades, and in New Jersey even the common ones, are generally made from a No. 2 fire clay.

Sagger clay.—This is a term applied to clays which are used in a mixture for making the saggers, in which the white ware and other high grades of pottery are burned. They are commonly rather siliceous in their character, although some may be used on account of their bonding power and freedom from grit to hold the more porous grades together. As far as the physical properties go, the sagger clays are not, therefore, represented by any one type. Their refractoriness varies from that of a refractory to a semirefractory clay.

Wad clay.—This is a low grade of fire clay, which is used for grouting the joints between the saggers, when they are set up in bungs in the kilns. It is dug at several localities in Middlesex and Mercer counties.

Terra-cotta clay.—This term does not mean very much and is used rather indiscriminately to indicate different beds of clays, which are being dug for the manufacture of terra cotta. In the majority of cases they are semirefractory clays of buff-burning character, sometimes sandy, at other times dense-burning. At one or two places a red-burning clay is dug for terra-cotta manufacture. The wide difference in character between two of them is shown elsewhere in this report.

Retort clay.—A dense-burning, plastic, semirefractory clay, used chiefly in the manufacture of stoneware. In New Jersey the term is restricted to the Woodbridge district.

Pipe clay.—This is a term applied to almost any fine-grained plastic clay. Strictly speaking, it would refer to a clay used for making sewer pipe.

Brick clay.—This includes all impure, nonrefractory clays suitable for the manufacture of common brick.

Pot clay.—A clay used for the manufacture of glass pots, and consequently representing a very dense-burning fire clay. In refractoriness it ranges from a highly refractory to a refractory clay.

Paper clay.—This term is generally applied to fine-grained white clays that can be used in paper manufacture.

CHAPTER X.

THE MANUFACTURE OF BUILDING BRICK.

CONTENTS.

Building brick include common brick, face and pressed brick, enamel brick and glazed brick. Common brick include all those used for ordinary structural work, and are employed commonly for side and rear walls of buildings, or, indeed, for any portion of the structure where appearance is of minor importance, although for the sake of economy they are often used for front walls. They are usually made without much regard to color, smoothness of surface, or sharpness of edges.

Face, front or pressed brick include those made with greater care, and usually from a better grade of clay, much consideration being given to their uniformity of color, even surface and straightness of outline. Enamel brick are those which have a coating of enamel on one or sometimes two sides. Glazed brick differ from enamel brick in being coated with a transparent glaze instead of an opaque enamel.

RAW MATERIALS.

Clays for common brick.—The clays used for common brick are usually of a low grade, and in most cases red-burning. The main requisites are that they shall mold easily and burn hard at as low a temperature as possible, with a minimum loss from cracking and warping. Since most common clays when used alone show a higher air and fire shrinkage than is desirable, it is customary to decrease this by mixing some sand with the clay, or by mixing a loamy or sandy clay with a more plastic one.

Measurements made at 29 yards manufacturing common brick showed, however, that in practice there is apparently no uniformity in the air shrinkage of the brick, the linear air shrinkage ranging from 0.7 per cent. to 10.9 per cent., with an average of 5.41 per cent. This variation in the air shrinkage is due to the character of the clay and the process of manufacture. Common-brick clays are mostly nonrefractory, for this insures their hardening at a low temperature, whereas when No. 2 fire clays are employed, they must be burned at higher temperatures to prevent the brick from being soft and porous. Some common-brick clays of the Cohansey formation found in Monmouth county are a good example of this, for they remain porous even when fired up to cone 8, and for use these are mixed with more fusible clays. The plasticity of common-brick clays is usually good, although it is possible to employ some very lean ones, and the tensile strength of those employed in New Jersey ranges from 60 lbs. per square inch up to 300 lbs. or more.

The general variation in the physical characters of New Jersey common-brick clays can be seen from the following table:

Table showing physical characteristics of New Jersey brick clays.

LOCALITY.	Air-shrinkage per cent.	Fire shrinkage at cone .05.	Fire shrinkage at cone 1.	Color when burned.	Tensile strength of raw clay in lbs. per sq. in.
Kinkora,	7.	....	5.6	Buff	168
Cliffwood,	6.5	1.5	3.	Red	88
Matawan,	6.3	1.	3.7	Red	197
Bordentown,	8.8	8.2	11.8	Red	251
Toms River,	4.3	....	2.3	Red	68
Somerville,	5.0	....	6.6	Red	297
Herbertsville,	2.5	0.5	1.5	Red	49
Yorktown,	7.6	1.	2.8	Red	229
Flemington,	3.	1.6	7.6	Red	159
Buckshutem,	7.	3.3	6.	Red	291

The above figures refer to laboratory tests made on the raw clay. In the case of some, such as the clay from Bordentown, it will be seen that both the air and fire shrinkage are high, and too great, in fact, to permit their being used alone. It is, therefore, necessary to mix some sandy clay with them.

Common-brick clays vary widely in their composition, but most of them contain a rather high percentage of fluxing impurities.

The following table gives the maximum, minimum and average percentage of the different constituents in a brick clay, compiled from a number of analyses[1]:

Chemical Composition of Common-brick Clays.[2]

Constituent.	*Range.*	*Average.*
Silica,	34.35 –90.877%	49.27%
Alumina,	22.14 –44.00%	22.774%
Ferric oxide,	0.126–33.12%	5.311%
Lime,	0.024–15.38%	1.513%
Magnesia,	0.02 – 7.29%	1.052%
Alkalies,	0.17 –15.32%	2.768%
Water,	0.05 –13.60%	5.749%
Moisture,	0.17 – 9.64%	2.502%

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[1] H. Ries, The Clays of New York, Bull. N. Y. State Museum, No. 35, p. 639.

[2] The lime and magnesia of this table represent new calculations, and, hence, differ from the original.

Analyses of New Jersey Common-brick Clays.

	1	2	3	4	5	6
Silica (SiO_2), ...	66.67	66.66	65.53	72.37	60.18	68.96
Alumina (Al_2O_3), ...	18.27	14.15	17.21	14.40	23.23	17.87
Ferric oxide (Fe_2O_3), ...	3.11	3.43	5.23	3.43	3.27	3.27
Lime (CaO), ...	1.18	2.15	0.95	0.75	1.00	0.25
Magnesia (MgO), ...	1.09	0.38	0.31	0.49	0.67	0.25
Potash (K_2O), ...	2.92	2.32	2.84	1.60	2.58	2.10
Soda (Na_2O), ...	1.30	1.38	0.96		0.80	
Titanic acid (TiO_2), ...	0.85	....	....	....	....	....
Water (H_2O), ...	4.03	8.40	4.54	6.70	8.54	6.95
Organic matter, ...	....					....

1. Pleistocene clay from Little Ferry.
2. Clay Marl I and loam, Budd Brothers' yard, City Line Station.
3. Black clay and loam mixture, used for common brick, Fish House.
4. Cape May clay. Buckshutem (Loc. 180).
5. Raritan clay. Sayreville (Loc. 71).
6. Mixture of Alloway clay and some surface loam, used for brick near Yorktown.

Clays suitable for common brick are found at many localities in New Jersey and in many formations. Those obtained in the northern part of the State are chiefly of glacial origin and occur at many points, as mentioned under Bergen, Warren, Sussex, Union and Hunterdon counties (Chap. XIX). Farther south the Raritan formation contains an inexhaustible supply of good brick clay, as described under Middlesex and Burlington counties. The Clay Marls I and II can be drawn upon for an abundance of clay in the counties of Monmouth, Mercer, Burlington and Camden. The Alloway clay is of value for common brickmaking in Salem county, and the Cape May formation, together with the clay loams, likewise carry brick materials in Cumberland, Camden, Mercer and Cape May counties. In Monmouth county the Asbury clay is drawn upon, and in Atlantic and Ocean counties the Cohansey clays can be easily used when the deposits are red burning.

In the selection and preparation of raw materials there is sometimes a tendency on the part of the clayworker to overload his mixture with sand, especially if the soft-mud process of molding is used. This has a bad effect since it produces a soft, porous product, unless the materials are burned harder than is usually done. In the southern half of the State the extensive mantle of loamy clay found on the surface at so many localities forms a desirable material to add to the more plastic clay beneath.

Pressed brick.—Pressed brick call for a much higher grade of clay than is necessary for common brick. The kinds now in use fall in three groups, viz, 1) red-burning clays, 2) white-burning clays, 3) buff-burning clays, usually semirefractory. The composition of a sample of each of these three types is given below:

Analyses of clays used for making pressed brick.

	Shale—Kansas City, Mo.	*White clay—Grover, N. C.*	*Front brick clay—Sayreville, N. J.*
Silica (SiO_2),	55.75	68.28	56.10
Alumina (Al_2O_3),	21.16	18.83	27.42
Ferric oxide (Fe_2O_3),	5.69	2.60	2.68
Lime (CaO),	3.25	0.70	....
Magnesia (MgO),	2.84	0.13	0.18
Alkalies (Na_2O, K_2O),	3.02	2.29	2.71
Water (H_2O),	8.45	6.47	6.00
Moisture,	....	0.76	2.90
Titanium oxide (TiO_2),	....	0.27	1.00

The physical requirements of a clay for pressed brick are 1) uniformity of color in burning, 2) freedom from warping or splitting, 3) absence of soluble salts, and 4) sufficient hardness and low absorption when burned at a moderate temperature. The air shrinkage and fire shrinkage, as well as tensile strength, vary within the same limits as common bricks.

Red-burning clays were formerly much used, and, indeed, are still employed to some extent around Trenton and Philadelphia, but in recent years other colors have found greater favor, and the demand for the former has greatly fallen off. Buff-burning, semirefractory or refractory clays are, therefore, much employed now, partly on account of their color and partly because coloring materials can be effectively added to them, for since the range of natural colors that can be produced in burning is limited, artificial coloring agents are sometimes used. Manganese is the one most employed.

The clays must necessarily burn hard at a moderate temperature, and in the case of red-burning clays the temperature reached is usually the fusing-point of cone 1 or 2, while for buff-burning clays it is commonly necessary to go to cone 7 or 8 to make the brick steel-hard.

The following table gives the physical characters of several clays used for pressed brick in New Jersey.

Physical properties of some New Jersey clays used for front brick.

Formation.	Locality number.	Water required, per cent.	Air shrinkage, per cent.	Aver. tensile strength, lbs. per sq. in.		Fire shrinkage.	Absorption.	Color.
Raritan, ...	45	32.00	5.0	65	cone 1			Buff
					cone 5	5.0%	11.68%	
					cone 8	6.6%	11.34%	
Cohansey, ..	195	23.17	7.5	282	cone 1	2.8%	8.09%	Buff
					cone 5	4.5%	3.08%	
					cone 8	6.5%	0.84%	
Cohansey, ..	201	37.50	5.5	196	cone 8	9.1%	4.01%	Buff

In New Jersey the Raritan, Pleistocene and Cohansey formations supply materials for the manufacture of pressed brick. The Raritan clays found around Perth Amboy were formerly much used for making pressed brick, but at the present time comparatively few are manufactured in this district, although much Raritan clay is shipped to other States to be used for this purpose. They are commonly molded in stiff-mud machines and re-pressed. The Pleistocene (post-Glacial?) clay loams were much used in former years for making red pressed brick, and are still employed to some extent. They cover large areas around Trenton, in Mercer county, but, owing to their shallowness, much of the material has been removed. Similar loams are found in western Burlington and Camden counties. The Cohansey clay is often found to make a good buff-burning brick, with either the stiff-mud re-pressed, or dry-press process, but trouble is experienced now and then in making the bricks flash well. These Cohansey clays are available in Burlington, Camden, Atlantic, Cumberland, and Ocean counties. They are not fire clays, and can barely be classed as semirefractory, but burn to a good hard buff brick at cones 6 to 8. They are utilized for this purpose at present at Winslow Junction, Mays Landing and Rosenhayn.

Enameled brick.—The clays used for these are similar to those employed in the manufacture of pressed brick. There are two factories in the State making enameled brick, and both employ a mixture of fire clays from the Middlesex county district.

Glazed brick are made only to a slight extent in New Jersey. The clays used are similar to those employed for enameled brick.

METHODS OF MANUFACTURE.

The methods employed in the manufacture of common and pressed brick are usually very similar, the differences lying chiefly in selection of material, the degree of preparation, and the amount of care taken in burning. The manufacture of bricks may be separated into the following steps: preparation, molding, drying and burning.

PREPARATION.

In brickmaking some preparation of the clay is commonly necessary, since few clays can be sent direct from the bank to the molding machine, although some common brick manufacturers in New Jersey reduce the preparation process to a minimum.

Weathering.—Many clays are prepared by weathering, especially if they are to be used in the manufacture of pressed brick. This is done by distributing the clay in a thin layer over some flat surface not more than 2 or 3 feet in thickness and allowing it to lie there exposed to frost, rain, wind, and sun. This results in a slow but thorough disintegration or slacking. Iron nodules, if present, tend to rust, and are thus more easily seen and rejected, while pyrite, if present, may also decompose and give rise to soluble compounds, which form a white crust on the surface of the clay. Although some clays are weathered, yet in great part their preparation is done by artificial means.

Dry crushing.—When the clay or shale is to be disintegrated or crushed, it is commonly done dry, and the machine employed varies with the character of the material. Hard shale is usually disintegrated in a jaw crusher, which consists of two movable jaws that interact, and are set closer together at their lower than at their upper ends. Where a soft shale, or a hard, tough, dry clay is to be used, dry pans are often employed. These consist of a circular pan, in which there revolve two iron wheels on a horizontal axis. The wheels turn because of the friction against the bottom of the pan, the latter being rotated by steam power, and in turning they grind by reason of their weight, which ranges from 2000 to 5000 pounds. The bottom of the pan is made of removable, perforated plates, so that the material falls through as soon as it is ground fine enough. Two scrapers are placed in front of the rollers to throw the material in their path. The diameter of a dry-pan may range from 6 to 9 feet. For a 9-foot pan with rollers 48 inches in diameter and 12 inches face, the total weight would be about 20 tons, while the weight of the two rollers with their shafts and boxes is about 6½ tons. From 12 to 16 horsepower are required to operate the pan. The capacity of such a machine will depend on the size of the screen meshes, and character of raw material, whether hard or soft, dry or moist. For a medium shale, it is possible to grind 8 tons per hour through a ⅛-inch screen and about 12 tons through a ¼-inch screen.

Disintegrators represent a third type of machine used for breaking up clay or shale, and, where used, are commonly found to be quite effective. Their capacity is large, but much power is also required to drive them. A disintegrator has several drums, or knives on axles, revolving rapidly within a case, and in opposite directions. As the lumps of clay are dropped into the machine they are thrown violently about between the drums and also strike against each other, thus pulverizing the material completely and rapidly. Such machines can pulverize from 8,000 to 28,000 pounds of material, such as shale or gypsum, in one hour, and require from two and one-half to four horsepower per ton per hour.

Rolls (Pl. XXIV, Fig. 2) are often employed for breaking up clay and pebbles, and, where dry material is used, they are quite effective, but if damp clay is put through them, as is done at some yards, the lumps are simply flattened out. Rolls are also supposed to break up any stones that may be present in the clay. The surface of the rolls is smooth, corrugated or toothed, or tapering. The two rolls revolve in opposite directions and with differential velocities of 500 to 700 revolutions per minute.

Fig. 1.

Ring pit for tempering clay. Steam power. Standard Brick Co., Mountain View.

Fig. 2.

Ring pit, operated by horsepower. Newton.

All the machines mentioned above are used on dry or nearly dry clay, but there are several other types which are employed for wet clays only, and these in addition to breaking up the clay may also be used to mix it. The process is sometimes termed tempering.

Soak pits.—These are the simplest of the different types of machinery used for tempering, and are employed at a number of common brickyards. Their construction is simple, consisting merely of a pit lined with planking and usually set immediately behind the molding machine. The clay or mixture of clays, with possibly some sand, is dumped into the pit, water poured on, and the whole allowed to soak over night. This process softens the clay, but does no mixing, which is done entirely within the molding machine. The soaked clay is shoveled directly into the machine.

Ring pits.—Ring pits (Pl. XXV, Figs. 1 and 2) are employed at many yards where common brick are manufactured and give much better results than soak pits, for the clay receives a more thorough mixing. They are of circular form, 20 to 25 feet in diameter, about 3 feet deep and lined with boards or brick. Revolving in this pit is an iron wheel, 6 feet in diameter and geared so as to travel around the pit, and at the same time move back and forth between the centre and circumference, thus thoroughly mixing the mass. Before starting the wheel, the mixture of clays or clay and sand is dumped into the pit and sufficient water added. The tempering is accomplished usually in 5 or 6 hours, and one pit commonly holds enough clay for 25,000 to 30,000 brick. Two ring pits are often operated in conjunction with one molding machine, so that while the clay is being shoveled out of one pit, the second is tempering the clay for the next day's supply. Ring pits are cheaper than pug mills, but have a lower capacity and require more room. They are operated by either steam or horsepower.

Pug mills.—These are semicylindrical troughs, varying in length from 3 to 14 feet, with 6 feet as a fair average. In this trough there revolves a horizontal shaft, bearing knives set spirally around it and having a variable pitch. The clay and water are charged at one end, and the blades on the shaft not only cut up the clay lumps, but mix the mass, at the same time pushing it towards the discharge end. The speed of the clay through the machine varies with the angle of the blades on the shaft. It will be seen at once that the thoroughness of the mixing depends to a large degree on the length of the pug mill, as well as the angle at which the blades are set. For some clays, therefore, it is very inadvisable to use a short mill, one not more than 3 or 4 feet long.

Pug mills are thorough and continuous in their action, take up less space than ring pits and do not require much power to operate. They are nearly always used in connection with stiff-mud machines, and at the present day are often used with the soft-mud process.

Wet pans.—These are similar to dry pans, but differ from them in having a solid bottom. The material and water are put into the pan and the clay is crushed and tempered at the same time. Where the clay contains hard lumps of limonite or pyrite nodules, a wet pan is superior to a pug mill or disintegrator, for the charge is crushed and tempered in a few minutes, and can then be replaced by another one.

MOLDING.

Bricks are molded by one of four methods, viz., soft-mud, stiff-mud, dry-press, and semidry-press, although in reality there is not much difference between the last two methods.

Soft-mud process.—In this method the clay, or clay and sand, are mixed with water to the consistency of a soft mud or paste and pressed into wooden molds. Since, however, the wet clay is sticky and likely to adhere to a wooden surface, the molds are sanded each time before being filled. Soft-mud bricks, therefore, show five sanded surfaces, and the sixth surface will be somewhat rough, due to the excess of clay being wiped off even with the top of the mold. They are also slightly convex on one side and slightly concave on the other, due to the sides of the soft brick dragging slightly as it is dumped from the mold to the drying floor.

Soft-mud bricks are molded either by hand or in machines.

In hand molding, the clay is tempered quite soft. A lump more than sufficient to fill the mold is taken and forced into the wooden mold by the molder, who then, by means of a wire, cuts off the excess of clay from the top of the mold box. The latter is then turned over on the drying floor and the brick dumped out (Pl. XXVI, Fig. 1). With such an outfit one man is able to mold about 2,500 bricks in ten hours. Hand molding is in most cases confined to small yards, where the production is small and the capital invested of corresponding size. The hand-molded bricks are usually more porous than the machine-molded variety.

The soft-mud machine consists usually of an upright box of wood or iron, in which there revolves a vertical shaft, bearing several blades or arms. Attached to the bottom of the shaft is a curved arm, which forces the clay into the press box. The molds, after being sanded, are shoved underneath the press box from the rear side of the machine. Each mold has six divisions, and as it comes under the press box the plunger descends and forces the soft clay into it. The filled mold is then pushed forward automatically upon the delivery table, while an empty one moves into its place. As soon as the mold is delivered its upper surface is "struck" off by means of an iron scraper. Under favorable conditions soft-mud machines have a capacity of about 40,000 brick per day of ten hours, although they rarely attain this. Four men are commonly required to tend a machine which is operated by steam or horsepower.

The molds are sometimes sanded by hand, but more frequently by a machine consisting of a barrel on which the molds are fastened to form the sides. Sand is then put inside and as the barrel revolves on its horizontal axis, the sand falls into the compartments of the molds. As soon as one mold is removed, another requiring sanding is put into its place.

The soft-mud process was the first method of molding employed, and is still largely used at many localities. It is adaptable to a wider range of clays than any of the others, and possesses the advantage of not only producing a brick of very homogeneous structure, but one that is rarely affected by frost action. Its cost is small, but the capacity is limited, as compared with a good stiff-mud machine, and a large number of men are also required. It does not produce a product with smooth faces and sharp edges, but this defect can be overcome by re-pressing the product.

Stiff-mud process.—In this method of molding (Pl. XXVI, Fig. 2), the clay is tempered with less water and consequently is much stiffer. The principle of the process consists in taking the clay thus prepared and forcing it through a die in the form of a rectangular bar, which is then cut up into bricks. The machine now most used is known as the "auger" type, the "plunger" type having nearly disappeared from use. Its general form is that of a cylinder closed at one end, but at the other end tapering off into a rectangular die, whose cross section is the same as either the end or the largest side of a brick. Within this cylinder, which is set in a horizontal position, there is a shaft, carrying blades similar to those of a pug mill, but at the end of the shaft nearest the die there is a tapering screw. The internal shape of the die is variable, depending on the make of the machine. It is heated by steam or lubricated by oil on its inner side, in order to facilitate the flow of the clay through it.

The tempered clay is charged into the cylinder at the end farthest from the die, is mixed up by the revolving blades, and at the same time it is moved forward until seized by the screw and pushed through the die. Since this involves considerable power, it results in a marked compression of the clay. With such conditions, there will naturally be more or less friction between the sides of the bar and the interior of the die, causing the centre of the stream of clay to move faster than the outer portion. Much attention has, therefore, been given to the construction of the die, in order to overcome this and facilitate the flow of the clay as much as possible. In case the amount of friction between die surface and clay is greater than the cohesion in the plastic mass, the bar of clay is likely to tear on the edges, producing serrations like the teeth of a saw. The effect of the screw at the end of the shaft, together with the differential velocities within the stream of clay, also produces a laminated structure in the brick, which is often greatest in highly plastic clays, but is sometimes marked in clays of only moderate plasticity when machines

Fig. 1.

Molding soft-mud brick by hand. Thackara's yard, Woodbury.

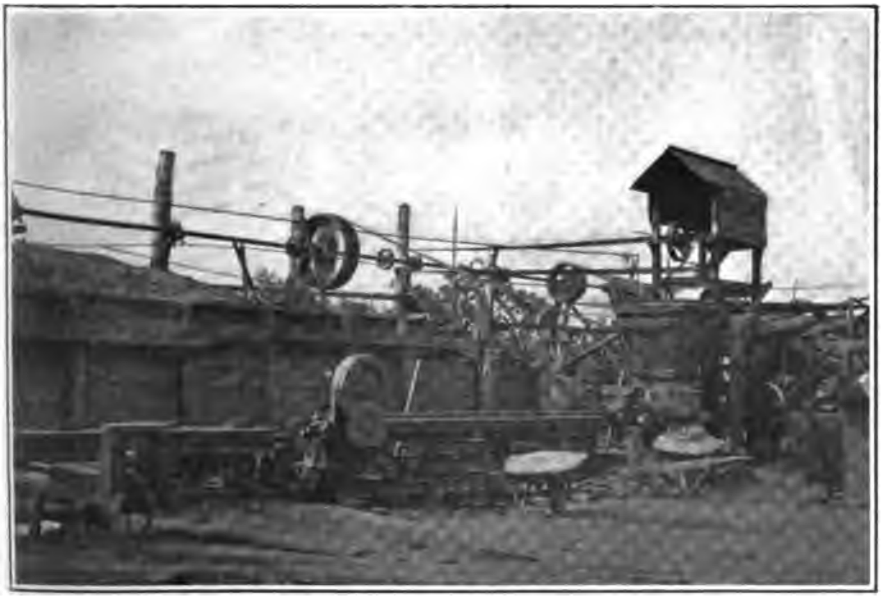

Fig. 2.

Stiff-mud machine with automatic cut-off for making end-cut brick. E. Farry's, Matawan. The bar of clay is seen issuing on the cutting table, and the separate bricks are seen on the second belt to the left of the revolving cutter.

of a particular structure are used. Irregularity of clay supply may also cause laminations.

Laminations are sometimes quite noticeable in brick made from many of the New Jersey Clay Marl beds. These are molded at many localities by the stiff-mud process, and while the clays themselves do not show wide variation, the structure of the bricks often exhibit considerable irregularity, due apparently either to improper mixing or to the machine. The laminated structure is less harmful, however, in common brick than in paving brick, and may at times be considerably diminished by re-pressing or thorough burning. In some instances, however, the shells shrink away from each other during the burning, and the laminated appearance of the product is increased. Judging from the tests made on the New Jersey brick, the presence of these shells did not much affect the strength when the product was hard burned.[1]

The brick made in auger machines are either end cut or side cut, depending on whether the area of the cross sections of the bar of clay corresponds to the end or side of a brick, and consequently the mouth of the die varies in size and shape. The auger machine is probably used more extensively at the present day than either the soft-mud or dry-press machine, especially for making paving brick. It has a large capacity and can produce 45,000 or even 60,000 brick in ten hours, the output of the machine being sometimes increased by the use of double or even triple dies, but this is not a desirable practice. When a triple die is employed, the middle stream of clay flows faster than the two side ones.

As the bar of clay issues from the machine it is received on the cutting table, where it is cut up into bricks. This may be done in several ways, as follows:

1. Attached to the cutting table is a framework carrying a number of parallel steel wires. When a bar of clay has issued to a sufficient distance, these wires are drawn through it to cut it up. In some machines it is necessary to stop the machines while this is being done; in others the construction is such that the cutting frame moves forward with the stream of clay as it cuts through

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[1] See Tests of New Jersey Brick, Chap. XI, p. 256.

it. As soon as the bar is cut up the bricks are removed. This style of cutter is used for side-cut brick.

2. At the end of the delivery table there is a revolving automatic cutter (Pl. XXVI, Fig. 2), carrying a number of short transverse wires, each borne on a fork-like frame at the end of a series of arms corresponding to the spokes of a wheel. This cutter revolves as the bar of clay issues from the die, so that each wire, as it descends, cuts through the bar. The wheel is so geared that the wire moves with the same velocity as the clay, thus producing a vertical cut. This cutting device is used for end-cut bricks. In New Jersey this type of cutter is used much more than it is in most other states, but its action is not found to be as satisfactory as the preceding one.

3. Some side-cut machines have the cutting table provided with a wheel carrying several wires in the position of spokes. The centre of the wheel is to one side of the delivery belt, and the plane of it at right angles to the same. As the clay bar issues from the die, the wheel revolves, the wires cutting the clay and moving forward at the same time. One cut is made at a time.

The stiff-mud process is adapted mainly to clays of moderate plasticity. It does not work well with stony clays, for the cutting wire is liable to be broken by contact with the stones, necessitating the frequent stoppage of the machine for repairs. These are not difficult to make, but frequent delays are in the long run expensive. The stiff-mud brick, like the soft-mud ones, can be re-pressed, and many face brick are now made by this process.

The stiff-mud process is a good one, if properly used, but the clays should be thoroughly tempered before molding, and the elimination of a pug mill for reasons of economy is bad. Small molding machines having a short cylinder have been put on the market, and some small manufacturers, tempted by their cheapness, have used them, usually with poor results, for a pug mill is rarely used in connection with them, although a pair of rolls is sometimes substituted for it. This does not, in most cases, do more than break up occasional pebbles.

Dry-press and semidry-press process.—This process in New Jersey is restricted to the production of front brick. The clay is powdered and then pressed into steel molds in a dry or nearly dry condition. In order to prepare the clay for disintegration, it is usually stored in sheds for some time before being used, and is then broken up either in a disintegrator or dry pan before passing to the screen. The latter is commonly from 12 to 16 mesh. The molding machine consists of a steel frame of varying height and heaviness, with a delivery table about three feet above the ground, and a press box sunk into the rear of it. The charger is connected with the clay hopper by means of a canvas tube, and consists of a framework which slides back and forth over the molds. It is filled on the backward stroke, and on its forward stroke lets the clay fall into the mold box. As the charger recedes to be refilled, a plunger descends, pressing the clay into the mold, but at the same time the bottom of the mold, which is movable, rises slightly, and the clay is thus subjected to great pressure. The plunger then rises, while the bottom of the mold ascends with the freshly molded bricks to a level with the delivery table. These are then pushed forward by the charger as it advances to refill the molds.

The faces of the mold are of hard steel and heated by steam to prevent adherence of the clay. Air holes are also made in the dies to permit the air, which becomes imprisoned between the clay particles, to escape. If this were not done, the air in the clay would be compressed, and when the pressure was released, its expansion would tend to split the brick. The great pressure necessary to form the clay is generally applied by means of a toggle joint, and 1 to 6 bricks are molded at a time, according to the size of the machine. At Winslow Junction, N. J., and at several localities in other states, an hydraulic dry-press machine is used. In this the pressure is produced by a pair of hydraulic rams acting from both above and below and is applied gradually.

The advantages claimed for the dry-press process are, that in one operation it produces a brick with sharp edges and smooth faces. There is practically no water to be driven off, as the clay has been pressed in a nearly dry condition, hence drying tunnels can be dispensed with, although sometimes used. When hard burned, dry-pressed bricks are as hard as others, as can be seen from tests of New Jersey brick given on later pages. On account of the method of molding, dry-press bricks usually show a granular structure.

The capacity of a dry-press machine is about the same as that of a soft-mud one, provided six bricks are molded at a time. Two and four-mold machines are, however, also made. The initial cost of the machinery is considerable, although this may be more than offset by the saving in dryers.

RE-PRESSING.

Many soft-mud and stiff-mud brick that are to be used for fronts are improved in appearance and often in density by re-pressing. This smoothens the surface and straightens and sharpens the edges of the product, as well as sometimes increasing the strength.[1]

The re-press consists essentially of a steel mold box, having both bottom and top movable. The green brick are placed in this mold box, and pressure applied to it by the vertical motion of the top or bottom of the mold, the effect of this being to re-form the brick to a slight degree. Re-pressing machines are operated either by hand or steam power. In the hand power machines, the bottom of the mold is moved upwards by means of a lever and applies the pressure. With such a machine, one man and two boys can re-press 2,500 to 3,000 per day. In steam power re-presses, both the top and bottom of the mold box move. They are commonly constructed with two compartments, and their capacity is about 25,000 per day of ten hours. In both types of re-presses the dies have to be liberally oiled. Soft-mud brick are allowed to dry for a few hours before re-pressing, but stiff-mud brick can be re-pressed as soon as molded.

The change in volume that occurs in a brick in re-pressing can be seen from the following measurements of a paving brick.

Before re-pressing, 8¾ by 4⅜ by 3⅛ inches, . . . 119⅝ cubic inches.
After re-pressing, 8$\frac{11}{16}$ by 4⅜ by 2⅞ inches, . . . 109¼ cubic inches.

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[1] See Table of Brick Tests, Chap. XI.

Fig. 1.

Drying soft-mud brick in an open yard.

Fig. 2.

"Hacks" of partially dried soft-mud brick. The men are placing freshly molded brick on the drying floor. The Sayre & Fisher Company, Sayreville.

DRYING.

Bricks made by either the stiff-mud or soft-mud process have to be freed from most of their water of tempering before they can be burned. This is done by drying them in 1) open yards, 2) covered yards, 3) on pallet racks, 4) tunnel driers, or 5) floors.

Open yards.—These are used at most soft-mud brick plants, and are simply smooth flat floors of earth or brick, on which the bricks are dumped as soon as molded, and allowed to dry in the sunlight. (Pl. XXVII, Fig. 1.) They are cheap, but require much space, and in case of a sudden shower the green bricks are washed from lack of cover. After being spread out for a day the bricks are generally piled in double rows several courses high along the sides of the yard. These rows, called "hacks," are often covered with planking as protection from rain (Plate XXVII, Fig. 2).

Covered yards.—Covered yards differ from the preceding in having a sectioned roof that can be opened in fair weather. They are not used to any great extent, for when some form of protection against weather is desired, the type of drier next mentioned is more commonly used.

Pallet driers.—These are covered frames for holding the boards or "pallets," on which the bricks are dumped from the mold at the machine. They are used at many soft-mud yards and even some stiff-mud plants, and possess the advantage of cheapness, large capacity, economy of space and protection against rain.

One disadvantage common to all three of the above methods is that they cannot be used in cold weather. Dampness in summer may also interfere with them, and therefore sunlight and wind are the most favorable weather conditions in most cases. Some clays are quite susceptible to air currents, however, and crack easily when exposed to them.

Drying tunnels.—Many brickyards dry their product by this method, especially if they continue in operation throughout the year. With this system the bricks, after molding, are piled on cars, which are run into a tunnel heated artificially. Several of these tunnels are generally constructed side by side, and the green bricks are run in at the cooler end, and pushed along slowly to the warmer end, where they are removed. This passage through the tunnel requires commonly from 24 to 48 hours. If the bricks are soft-mud, it is necessary that the cars be provided with pallet racks, but if stiff-mud, they can usually be piled on top of each other, a car holding about 350 brick. The tunnel dryers used at different localities differ chiefly in the manner in which they are heated, the following methods being employed.

1. Parallel flues underneath and heated by fire placed at one end.

2. By steam heat, the pipes being laid on the floor or sides of the tunnel or both.

3. By hot air, the latter being supplied from cooling kilns and drawn through the tunnel by natural draft or fan. If the air is too hot, cooler air is mixed with it before it enters the dryer. The temperature to which tunnels are heated varies, and in most cases is not over 100° C. (212° F.)

Floor driers.—Floor driers are used at some brick works, although their application is more extended at fire-brick works. They are made of brick, and have flues passing underneath their entire length, from the fireplace at one end to the chimney at the other. Such floors are cheap to construct, but the distribution of the heat under them is rather unequal, and a large amount of labor is required to handle the material dried on them.

In rare cases, drying racks are set up on the top of the kiln, and in at least one instance in the State, brick are dried by being placed on steam pipes not enclosed in tunnels, but merely roofed over to afford protection from the rain.

BURNING.

This stage of the process of manufacture is an important one, and although the clay may have passed safely through the preceding stages, much loss may occur at this very point. The imperfect bricks thus obtained may be due 1) to mistakes of the burner, 2) to the clay, 3) to the fuel, 4) to the construction of the kiln. In burning, certain changes, partly physical and partly chemical, take place in all clays, as a result of which the brick is converted into a solid mass, which is hard and rock-like when cool. Other changes, due to the presence of certain ingredients or certain physical characteristics of the clay, occur in specific cases.

The amount of heat required for burning brick will vary with the clay, and the color, density and degree of hardness desired, the same clay giving different results, when burned at different temperatures. Common bricks are rarely burned higher than cone 05 or 03, while pressed brick are frequently fired to cone 7 or 8, because the clays generally used have to be burned to that point to render them hard.

General effects.—In burning, the last traces of moisture are driven off. This vapor, which is termed water-smoke or steam by the brickmaker, is simply the moisture which has been retained in the pores of the clay. Its expulsion results in a slight loss of weight. With further heating to very dull redness the chemically combined water disappears.

If the clay contains considerable carbonaceous matter, this will burn off at a low red heat, provided in the first place sufficient air is present to insure an oxidizing atmosphere. In this case carbon in the clay uniting with the oxygen of the kiln atmosphere, burns off as carbon dioxide. If the heat is raised too rapidly the clay contracts before all the carbonaceous matter has burned off, and the result is a black centre to the brick, which may also be accompanied by a swelling of the clay. In calcareous clays the carbonate of lime present also loses its carbon dioxide. The driving off of all these substances will, therefore, tend to make the brick very porous. Further heating, however, after the volatilization of these substances, causes a drawing together of the clay particles, or shrinkage, and this is accompanied by an increase in density and hardness, the maximum density and shrinkage being reached when the brick is vitrified.

These effects of heating a clay can be summarized as follows:

1. Loss of volatile substances present, such as water, carbon dioxide and sulphur trioxide, the volatilization of these leaving the clay more or less porous.
2. A shrinkage of the mass, by further heating.
3. Hardening of the clay due to fusion, of some at least, of the particles.

4. Increasing density with rising temperature, the maximum being reached at the vitrifying point of the clay.

Effects due to variation in the clay.—Burned clays may be of many different colors. Although the majority of clays contain sufficient iron oxide to burn red, nevertheless it is not safe to predict, from the color of the clay, the shade that it will burn, since some bright red or yellow clays may yield a buff brick. If considerable iron oxide is present, 4 to 5 per cent., the brick burns red, unless much lime is also present. If only 2 to 3 per cent. are present, a buff product is obtained, whereas, with 1 per cent., or under, the clay burns white, or nearly so. An excess of lime in the clay will, however, counteract the effect of the iron oxide and yield a buff brick, but a brick owing its buff color to this cause will not stand as much fire as one which owes its buff color simply to a low percentage of iron oxide.

Where a clay is mottled, as red and white, for instance, the colors of the different spots will retain their individuality most plainly after burning, unless the clay is thoroughly mixed. Some clays of South Jersey contain lumps of whitish clay, much tougher than the rest of the mass. These resist disintegration in the tempering machines, so that after burning they can be plainly seen, as white spots in the red ground of the brick.

The normal iron coloration may often be destroyed by the effects of the fire gases. When these are reducing in their action (i. e., taking a part of the oxygen from the ferric compounds and reducing them to ferrous compounds, pp. 57-59), the red color may be converted to gray, or even bluish black, if the reduction is sufficient, so that in some districts the bricks, on account of lack of air in the kilns and carbonaceous matter in the clay, do not burn a very bright red. Moreover, other things being equal, the higher the temperature at which a clay is burned, the deeper will be its color.

The surface coloration of a burned brick may often be different from the interior. This is due to several causes. 1) Soluble salts may accumulate on the surface, sometimes causing a white coating, because they have been drawn out by the evaporation of the water during the drying of the brick.[1] 2) The deposition

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[1] See "Soluble Salts in Clays," pp. 75, *et seq.*

of foreign substances by the fire gases may cause a colored glaze. This is especially seen on the ends of arch brick, and on the bag walls of a down-draft kiln, where the particles of ash carried up from the fires stick to the surface of the hot brick and cause a fluxing action. 3) If the clay contains much lime carbonate, and there is much sulphur in the coal, the latter may unite with the lime, forming sulphate of lime, and thereby prevent the combination of the lime and iron. In this case the centre of the brick, not being thus affected by the gases, may show a buff color, whereas the outside has another tint.

Flashing.[1]—Many bricks used for fronts are often darkened on the edges by special treatment in firing, caused chiefly by setting them so that the surfaces to be flashed are exposed to reducing conditions, either at the end of the firing or during the entire period of burning. This color is superficial and may range from a light gold to a rich, reddish brown. The principle of the operation depends on the formation of ferrous silicate and ferrous oxide, and their subsequent partial oxidation to the red or ferric form. This oxidation probably takes place during cooling, for if the kiln be closed so as to shut off the supply of oxygen, the brick are found to be a light grayish tint.

The degree of flashing is affected, 1) by the composition and physical condition of the clay, 2) the temperature of burning, 3) the degree of reduction, and 4) the rate of cooling and the amount of air then admitted to the kiln.

1. The percentage of iron oxide should not be large enough to make the brick burn red, but to produce buff coloration, and the clay should have sufficient fluxes to reduce the point of vitrification to within reasonable limits, thus facilitating the flashing. Clays high in silica are apparently better adapted to flashing than those low in silica and high in alumina. The condition in which the iron is present in the clay probably exerts some influence, that is, whether it is there as ferric oxide, ferrous silicate, concretionary iron, ferrous sulphide or perhaps ferrous carbonate. Bleininger's experiments showed that of three clays, which were used for flashing, all contained considerable

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[1] A. V. Bleininger. Notes on Flashing. Trans. Amer. Ceramic Soc. II:74.

quantities of iron soluble in acid. Some eastern manufacturers are obliged to add magnetite ores to their clays, which are low in combined iron, and No. 2 fire clays, which contain more iron that the finer grades, seem to give the best results. As to the effect of the physical condition of the clay, finer grinding seems to give more uniform flashing effects, and the reason that stiff-mud brick flash better than dry-press ones is claimed by some to be due to vitrification taking place more easily in the former.

The following analysis gives the composition of a No. 2 fire clay from Ohio used for flashed brick:

Analysis of an Ohio No. 2 fire clay.

Silica (SiO_2),	67.14
Alumina (Al_2O_3),	19.74
Ferric oxide (Fe_2O_3),	2.46
Lime (CaO),	0.53
Magnesia (MgO),	0.71
Potash (K_2O),	2.80
Soda (Na_2O),	0.43
Water (H_2O),	7.01
Total,	100.82

In one case the green clay showed a total of 2.15 per cent. of ferric oxide, of which 0.88 per cent. was soluble in acid. The flashed surface of a brick made from this clay gave, on analysis, a total of 2.31 per cent. of ferric oxide, of which 0.14 per cent. was soluble in nitrohydrochloric acid, thus indicating that during the burning most of the iron oxide had combined with silica, forming a ferrous silicate.

2. The temperature reached must be sufficient to cause a combination of the iron and silica, and, therefore, it varies with different clays, the combination being aided by the presence of fluxes.

If the kiln atmosphere is oxidizing during nearly the entire burning, with only a small period of reduction at the end, the temperature reached must be comparatively high in order to insure union of the iron and silica by fusion. If, however, a reducing fire is maintained during most of the burning, then the temperature need not be as high, because the clay will vitrify sooner. (See Fusibility, pp. 97-106.)

At one factory it had formerly been the practice to burn with an oxidizing fire to a high temperature,[1] viz., from cone 11-12, and then to cause reducing conditions to take place in the kiln during the last 5 or 6 hours of the burn. This practice, however, was changed, it being found that by maintaining a reducing fire during the entire period following water smoking, a lower temperature was sufficient.

3. The oxidation which causes the flashing probably takes place in the first twelve hours after closing the kiln, and can be regulated by a proper handling of the dampers.

In the experiments of Bleininger already referred to, it was found that a reduction of air, equal to 20 per cent. below that required for ideal oxidation, and considered as 100, is usually sufficient to produce flashing.

By this is meant that "100 per cent. of air represents theoretically ideal conditions, in which just enough air is present to consume all the combustible gases forming CO_2; less than 100 per cent. of air corresponds to reducing conditions. For instance, if an analysis on calculation represents 90 per cent. of air, it tells us that the gases are reducing to the extent of 10 per cent. of air; similarly 110 per cent. shows an excess of air to the amount of 10 per cent."

While 100 per cent. represents theoretically the amount of air required for perfect combustion, still in actual practice with coal fuel, the mixture of gases is not perfect, and it may be necessary to have more than 100 per cent. of air present to bring about thorough oxidation.

4. As regards the rate of cooling, it was found that the longer the period of cooling from the maximum temperature down to approximately 700° C., the darker the flash under given conditions.

Kilns.—Bricks are burned in a variety of kilns, ranging from temporary structures, which are torn down after each lot of brick is burned, to patented or other permanent forms of complicated design. They are built on one of two principles, either up-draft or down-draft. In the former the heat from the fire boxes at the

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[1] Ibid., p. 79.

bottom passes directly into the body of the kiln and up through the wares, escaping from suitable chimneys or openings at the top. In the latter the heat from the fire boxes is conducted first to the top of the kiln chamber by means of suitable flues, and then down through the wares, being carried off through flues in the bottom of the kiln to the stack. The down-draft system is growing in favor, as the burning can be regulated better. Furthermore, since the bricks at the top receive the greatest heat, and those at the bottom the least, there is less danger of the bricks in the lower courses being crushed out of shape.

Up-draft kilns.—The simplest type of kiln with rising draft is known as the "scove kiln" (Pl. XXVIII, Figs. 1 and 2), which is in use at many yards making common brick, and is of a temporary character. The bricks are set in large rectangular masses from 38 to 54 courses high, depending on the kind of clay. In building up the mass a series of parallel arches is left running through the mass from side to side, and with their centres about two feet apart. After the bricks are set up they are surrounded by a wall two courses deep of "double-coal" brick, and the whole outside of the mass daubed with wet clay to prevent the entrance of cold air during burning. The top of the kiln is then closed by a layer of bricks laid close together and termed the platting (Pl. XXIX, Fig. 2). Kilns of this type involve little cost except the labor of building. They are, however, adapted only to common brick, and are not capable of being heated to a high temperature, so that in some parts of the State, where they are used to burn bricks made from the sandy Miocene clays, which need a high temperature, the product is not hard.

The so-called Dutch kilns (Pl. XXIX, Fig. 1) are a slight improvement over the scove kilns, since they have permanent side walls, and so yield somewhat better results, for they heat up better and admit less cold air.

Many common brick and nearly all front brick, however, are burned in kilns that are walled and roofed, with a door at each end for filling and emptying. They are, therefore, far more reliable, capable of better regulation, attain higher temperatures, and are both up-draft and down-draft. The fuel used is sometimes wood, but mostly coal, not a few manufacturers employing

Fig. 1.

Side view of a scove kiln for burning common brick, exterior daubed over with mud. The fire places are shown at the bottom of one side.

Fig. 2.

View of a partly finished scove kiln.

Fig. 1.

End view of an updraft common-brick kiln with permanent side and end walls. Bordentown Brick Company, Bordentown.

Fig. 2.

View of the top of same type of kiln, the uneven surface of the brick platting representing the settling that has occurred during burning.

anthracite in part. With coal, the fuel is sometimes placed on grate bars, or on the floor of the hearth.

Continuous kilns.—These were originally designed to utilize the waste heat from burning. Many types have appeared, some of which are patented, but the principle of all is the same. It consists essentially in having a series of chambers, arranged in a line, circle or oval, and connected with each other and also with a central stack by means of flues. Each chamber holds about 22,000 bricks. In starting the kiln, a chamber full of bricks is first fired by means of exterior fire boxes, and while the water-smoke or steam is passing off, the vapors are conducted to the stack, but as soon as this ceases the heat from the chamber first fired is conducted through several other chambers ahead of it, before it finally passes to the stack. In this manner the waste heat from any chamber is used to heat the others. When any one compartment becomes red hot, fuel in the form of coal slack is added through small openings in the roof, which are kept covered by iron caps.

As soon as one chamber has reached its maximum temperature, the next two or three ahead of it are being heated up while those behind it are cooling down. A wave of maximum temperature is therefore continually passing around the kiln. It is thus possible to be burning brick in certain chambers, filling others, and emptying still others, all at the same time, making the process a continuous one. Continuous kilns are employed in many States for burning common brick, and with considerable success, but only three are in use in New Jersey, and none of these are employed in burning building brick.

CHAPTER XI.

THE NEW JERSEY BRICKMAKING INDUSTRY.

CONTENTS.

HISTORY.

The brick industry in New Jersey dates back to a very early period, and I am indebted to Mr. Geo. E. Fell, of Trenton, for much of the following information regarding the early periods of its development.

At the time of the Revolution, when Trenton was but a small village, the few brick buildings then erected were constructed chiefly of brick brought from England, and until a few years ago two such stood on Warren street, about 100 feet north of W. Hanover street. About the time of the Revolution, however, a few bricks were made on the north bank of Assanpink creek, between Broad street and Montgomery street, although it is very doubtful whether these were the first bricks made in the State.

Between 1780 and 1800, brick were also made between White Horse Tavern and Hamilton Square, and still a little later at Maiden Head, now Lawrenceville.

About 1826 a man named Embly came to Trenton from Connecticut and began making brick in the square bounded by Princeton and Brunswick avenues and Sandford and Bond streets. Again in 1831 Joseph Himer and Peter Grim, of Philadelphia, established a yard on the Hedden farm, now owned by the S. K. Wilson estate, about halfway between the two city reservoirs, the brick used in the original part of the present State Prison being made by them. This yard was abandoned by Grim in 1839, and another started on the present site of the Fell & Roberts yard, while a yard was established in 1845 by James Taylor on the site abandoned by Grim. Between this year and 1856 a number of yards were started around Trenton and served as the nucleus of a thriving brick industry, which has continued up to the present. The pressed-brick business of Trenton commenced about 1865, and increased steadily up to about 1894, since which time it has declined. The explanation of this decline is to be found chiefly in the fact that the demand for red pressed brick has greatly decreased in late years, owing to the introduction of buff, mottled, speckled and other types of fancy front brick. Since the clay found at Trenton burns red, it cannot be utilized for these newer styles.

Brick were first made in Middlesex county in 1851, at Roundabout (now Sayreville), by James Wood, and in the fall of that year Peter Fisher and James Sayre purchased a small property of 23 acres and commenced the manufacture of common brick, but gradually branched out into the manufacture of other grades. In 1887 this copartnership merged into a corporation known as the Sayre & Fisher Company, which is now by far the largest individual brick-making firm in the State. The inexhaustible supplies of brick clay in this region early led to the establishment of other yards, and at the present time there are 11 large brickyards at South River and Sayreville.

In the Hackensack region, brick have also been made for many years, but although the New York market is only 7 miles distant in a straight line, yet the water route via Newark bay is 31 miles long. As the Hackensack river is obstructed by numerous low drawbridges, shipping has to be done almost entirely by barges and steam-tugs, and as the cost of towage is high, the otherwise cheap facilities for shipping are minimized and the nearness to the New York market is more apparent than real.

Some of the smaller yards scattered over the State have likewise been in operation for a long time, as is indicated in the table below, which shows the date of establishment of a number of yards.

1816, T. O. Daniel, Lambertville.
1840, G. C. Pedrick, Flemington.
1866, D. F. Haines, Yorktown.
1869, J. A. Hobart, Millville.
1887, Kilborn & Gibson, Rosenhayn.
1890, B. H. Reed & Bro., Hightstown.
1890, Eastern Hydraulic Press Brick Company, Winslow Junction.
1900, Somers Brick Company, Bakersville.

METHODS OF MANUFACTURE EMPLOYED IN NEW JERSEY.

The methods of brick manufacture employed in New Jersey do not differ materially from those of other States. The different stages in the process, as followed out in New Jersey, can perhaps be best discussed individually, and this is done below, the discussion including yards making common and front brick, but not enameled wares. Statistics were collected at 69 yards.

Preparation.—Crushers are not commonly used, but since some of the clays are tough, rolls, disintegrators, or dry-pans are employed at several yards. Out of 69 yards from which statistics of manufacture were collected, only 12 used machines for breaking up the raw clay, their number being distributed as follows:

Number of yards,	12	100 %
Using rolls,	6	50 %
screen,	3	25 %
disintegrators,	1	8.3%
dry pans,	2	16.7%

Tempering.—In the machinery used for tempering, it was noticed that the use of the ring pit predominates, because it is commonly associated with the soft-mud method of manufacture, but at some yards the clay does not go through any tempering process whatever. The statistics are as follows:

Number of yards reported,	69	100 %
Using ring pit,	34	49.2%
pug mill,	20	29 %
soak pit,	8	11.5%
no tempering machinery,	7	10.1%

At those where no tempering machinery is employed, the clay is sufficiently moist as mined to be fed into a stiff-mud machine. This is chiefly true of the Clay Marl belt along the Delaware river in Burlington and Camden counties.

Molding.—Reports of the molding methods in use were obtained from the same number of yards, as below:

Number of yards reporting,	69[1]	100 %
Using soft-mud process—		
steam power,	37	48.7%
hand power,	9	11.8%
horsepower,	6	7.8%
Using stiff-mud process—		
end cut,	14	18.4%
side cut,	8	10.5%
dry press,	2	2.6%

This indicates the prevalence of the soft-mud method throughout the State. The percentage of these would be still larger if all the yards were included, since there are several others in the northern and northwestern part of the State making soft-mud brick.

The use of the stiff-mud process is confined chiefly to yards along the Delaware river and the neighboring region, many of which employ the Clay Marls I and II wholly or in part for brickmaking.

Drying.—Here again the method employed is closely related to the molding processes, but the system of drying by tunnels is

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[1] Several yards use two or more methods in molding brick.

not as extensively used for stiff-mud brick as it is in some other States, pallet racks being more often employed instead. Sometimes the bricks are piled up at once in "hacks" or long rows (Pl. XXVII, Fig. 2) in the open air until ready for the kiln. The details are given herewith:

Number of yards reported,	68	100 %
Open yards,	37	55.2%
Hacks,	12	17.6%
Tunnels,	10	14.9%
Pallet racks,	5	7.4%
Covered sheds,	2	2.9%
No dryers used (dry press),	1	1.6%

Burning.—Since the product is chiefly common brick, few improved kilns are employed. As will be seen from the statistics given below, only about one-sixth of the yards use down-draft kilns, and not one brick works in New Jersey is using continuous kilns. Indeed, so far as the writer is aware, there are only three continuous kilns in use in the State, one being used for fireproofing, a second for conduits, and a third for fire bricks. The kiln statistics are as follows:

Number of firms reported,	70	100 %
Up-draft permanent walls,	36	51.4%
Up-draft scove kilns,	22	31.4%
Down-draft,	12	17.2%

In setting common brick in scove kilns, the number of courses built varies considerably, but is the same usually in any one district. Thus, around Matawan, the bricks are set from 50 to 52 courses high, and the settle in burning (see Pl. XXIX, Fig. 2) is claimed to be about 12 inches. Along the Delaware river, from Trenton to Camden, and eastward towards Moorestown, the bricks are set from 37 to 39 courses high, and settle is said to be from 9 to 15 inches. Where the soft-mud process predominates, scove kilns are commonly employed, but at the stiff-mud works dutch kilns and even those of the down-draft type are usually built.

The temperatures reached in burning common brick are usually low, and while no cone measurements were made in any scove kilns, the majority are probably burned at about cone 05 to 03, except in the Hackensack district, where the heat probably does not exceed the melting point of cone 08. Measurements made in some down-draft kilns showed that a temperature sufficient to fuse cones 1-2 was reached. In the burning of pressed brick a much higher temperature is reached, the buff brick manufactured in New Jersey being burned at cones 7 to 9. Measurements made with cones in some down-draft kilns showed a difference of as much as two cone numbers between the temperature of the top and bottom. Such a difference is sufficient to make the brick in the top considerably harder than those in the bottom.

SHRINKAGE MEASUREMENTS OF NEW JERSEY BRICKS.

At many of the brickyards measurements of all three dimensions were made of the freshly molded and burned bricks, and from these both the linear and cubical air and fire shrinkages were calculated, the former being measured on the greatest length of the brick.

If a brick is burned by itself the shrinkage will probably be equal in all directions, but if the same brick is placed under considerable weight, it seems probable that the percentage of shrinkage will be greater in a vertical direction than a horizontal one. This becomes quite apparent when the tables of shrinkage given below are examined, for in these it will be noticed that the linear fire shrinkage in some cases is zero, while the cubical fire shrinkage is several per cent. For purposes of comparison, therefore, it would seem more desirable to use the latter rather than the former. The results obtained are given in the following tables, the first one representing the stiff-mud bricks, and the second the soft-mud ones.[1]

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[1] In calculating the air and fire shrinkage, the freshly molded brick is used as basis of length. Figures show the per cent. of shrinkage. Those preceded by a dash (—) show expansion.

Shrinkage measurements of stiff-mud bricks.

Locality.	Linear shrinkage			Cubical shrinkage.		
	Air.	Fire.	Total.	Air.	Fire.	Total.
Cliffwood,	0.7	0.0	0.7	0.7	—5.2	....
Sayreville,	1.3	4.2	5.5	10.5	12.2	22.7
Sayreville,	1.4	4.3	5.7	14.4	11.7	26.1
Kinkora,	1.4	5.9	7.3	14.7	4.1	18.8
South River,	1.9	3.4	5.3	9.9	15.8	25.7
City Line Station,	2.0	3.9	5.9	5.7	21.0	26.7
Maple Shade,	2.1	5.6	7.7	11.2	15.8	27.0
Asbury Park,	3.3	4.8	8.1	5.5	14.1	19.6
Woodbine,	4.3	1.5	5.8	7.2	8.9	16.1
Florence,	4.3	4.4	8.7	9.7	15.1	24.8
Maple Shade,	4.9	4.7	9.6	4.7	12.3	17.0
Rosenhayn,	4.9	2.1	7.0	19.2	5.2	24.4
Whippany,	5.2	7.9	13.1	17.3	19.4	36.7
Yorktown,	5.3	4.7	10.0	19.3	14.8	34.1
Collingwood,	5.4	0.0	5.4	10.8	8.9	19.7
Crosswicks,	5.5	7.0	12.5	26.5	—0.3	26.2
Hightstown,	5.6	0.7	6.3	14.6	3.1	17.7
Bordentown,	6.2	2.8	9.0	5.9	9.2	15.1
Buckshutem,	8.4	1.5	9.9	19.1	2.4	21.5

Shrinkage measurements of soft-mud bricks.

Locality.	Linear shrinkage.			Cubical shrinkage.		
	Air.	Fire.	Total.	Air.	Fire.	Total.
Plainfield,	1.4	5.8	7.2	11.5	7.3	18.8
Morristown,	2.8	4.3	7.1	18.6	8.0	26.6
Trenton (re-pressed),	3.5	—0.7	2.8	19.9	0.6	20.5
Matawan,	5.4	5.4	10.8	29.6	—0.9	28.7
Flemington,	5.7	0.0	5.7	11.6	2.3	13.9
Sayreville,	5.7	....	....	23.1	....	....
Farmingdale,	5.9	0.0	5.9	21.9	4.0	25.9
Dunellen,	5.9	1.4	7.3	21.5	4.1	25.6
Woodbury,	6.9	0.0	6.9	14.5	8.5	23.0
Somerville,	7.3	3.0	10.3	11.8	10.9	22.7
Cliffwood,	8.2	2.1	10.3	26.2	7.3	33.5
Cliffwood,	8.3	2.8	11.1	25.2	4.8	30.0
Belle Plain,	9.8	0.0	9.8	38.3	0.7	39.0
Bridgeton,	10.8	2.7	13.5	26.4	8.2	34.6
Farmingdale,	10.9	4.1	15.0	28.6	9.3	37.9

An examination of these figures shows considerable variation, in fact, larger than one expects. The measurements given show no direct relation between linear and cubical shrinkage, which may be due to two causes, viz., (1) difference in the three linear shrinkages, and 2) differences in the degree of burning.

The air shrinkage of the soft-mud bricks varies between slightly wider limits than the stiff-mud, but the average air shrinkage of the stiff-mud bricks is slightly lower than that of the soft-mud ones. In both the stiff-mud and soft-mud the linear fire shrinkage is rarely high, while in the soft-mud ones the fire shrinkage is lower than the air shrinkage in most of those measured. Again, in the stiff-mud bricks, the number showing a fire shrinkage greater than the air shrinkage is about equal to those showing the reverse.

The low fire shrinkage of the soft-mud brick is due partly to the sandy character of the clay mixture, and partly because of the low temperature of burning. A difference of two or three cone numbers in burning may make considerable difference in the shrinkage of a plastic clay, as can be seen by reference to the tables of physical tests given in Chap. XVIII.

TESTS OF NEW JERSEY BRICKS.

In order to test the qualities of the bricks made in New Jersey, a number of samples were collected from different localities. Where several yards were in operation at the same locality, and using the same clay, samples were taken from only one, the object being to show the character of the product obtainable from different clays, or by different methods from the same clay. A number of samples were in every case collected at each locality, and always by members of the New Jersey Geological Survey. They were taken at random either from the stock pile or kiln, and, unless otherwise stated, were normally burned brick.

The samples thus obtained were subjected to several different tests in order to determine, 1) their crushing strength; 2) their transverse strength, and 3) their absorptive capacity. The first two tests were carried out by Prof. I. H. Woolson, of the Department of Mechanical Engineering, Columbia University, assisted by Mr. R. H. Waters. The absorption tests were made by the writer. In nearly every test from 5 to 7 bricks were broken or crushed, so as to give a reliable average, and the results are given in condensed form in the table on page 256. Each manufacturer has been furnished with a copy of the tests made on his own brick, although in this report no names are published in connection with these tests, even though, in the majority of cases, the results are very creditable.

Explanation of Tests.

Crushing test.—This test was made in order to determine the number of pounds pressure per square inch that a brick will stand before it crushes under a load. This strength will vary with the density of the brick, degree of hardness to which it has been burned, character of the raw materials and freedom from flaws. In most bricks it rarely falls below 2,000 pounds per square inch, and may reach 15,000 or more pounds, although in actual use (that is when set in the wall), the bricks are seldom compelled to stand the weight that they are capable of resisting.

The test to determine a brick's crushing strength is commonly made in a specially constructed machine. Half bricks are usually tested, because a whole brick has so large a surface area that it might resist a greater pressure than could be applied by the machine. Before crushing, the two opposite surfaces of the brick (in this case the top and bottom) must either be ground perfectly smooth and parallel, or else they must be built up to this condition by the application of a layer of plaster of paris. The reason for this is that in the testing machine the brick is set between two steel surfaces, and unless its surface fits perfectly against these, the pressure will not be evenly distributed.

Before crushing, the area of the brick's surface is measured, and, the total load necessary to crush the brick, divided by this area, gives the crushing strength in pounds per square inch. It will be seen from the table that the average crushing strength of the 174 New Jersey bricks which were tested was 5,104 pounds per square inch, ranging from an average of 661 pounds for those of one manufacturer up to 13,873 pounds for those of another, while the minimum and maximum for individual bricks was 555 pounds and 16,675 pounds, respectively. For a brick measuring 8 inches in length by 4 in width, this would mean a crushing strength for the whole brick of from 21,152 to 443,936 pounds.

Transverse strength.—This is more important even than the crushing strength, for while a brick is rarely loaded to its crushing limit, it is sometimes exposed to its limit of elasticity and cracked. This can perhaps be better understood if the manner of making the test is first explained. In the cross-breaking test a whole brick was placed on two rounded knife-edge bearings (Fig. 37), which in the tests made on the New Jersey brick were 6 inches apart. Pressure was then applied from above, as indicated by the arrow, until the brick broke in two, and the number of pounds pressure at which this occurred was noted. It is evident that in two bricks of exactly the same degree of strength, the amount of pressure necessary to break them will depend upon, 1) the distance between the supports, and 2) the cross section of the brick. The farther apart the supports the less the pressure necessary to break the brick, and the greater the cross section, the greater the pressure necessary. Since this is so, it is necessary that for purposes of comparison all results of the breaking strength be reduced to some uniform expression, which shall take account of the differences in length, width and thickness of the brick. The most accurate expression is that

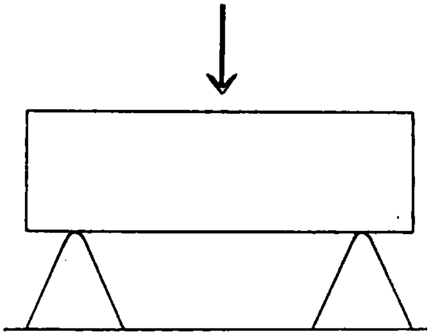

Fig. 37.

Diagram showing method of testing the breaking strength of brick.

termed the ***modulus of rupture,*** which is calculated from the following formula:

$$R = \frac{3\,W\,l}{2\,b\,h^2}$$

in which R = Modulus of Rupture.
W = Pressure necessary to break the brick.
l = Distance between the supporting knife-edges.
b = Breadth of the brick.
h = Thickness of the brick.

That is, three times the pressure in pounds multiplied by the distance between the supports is divided by twice the breadth of the brick, multiplied by the square of the thickness. If the pressure necessary to break a brick was 2,000 pounds, distance between supports 6 inches, width of brick 4 inches, and thickness 2 inches, the modulus of rupture would be calculated as follows:

$$\frac{3 \times 2000 \times 6}{2 \times 4 \times 2^2} = 1125 \text{ pounds.}$$

Absorption tests.—An absorption test is made for determining how much water a brick is capable of absorbing. This indicates the degree of porosity which it possesses. Vitrified brick which are impervious, or nearly so, will absorb little or no water. Many common brick may absorb an amount of water equal to 15 per cent., or even 20 per cent. of their dry weight. It is easily understood that if a brick of high porosity is exposed to a freezing temperature when its pores are filled with water, the expansion of the latter, when changing to ice, may be sufficient to disrupt the brick, either after one freezing, or after repeating freezings following periods of thawing. A moderate or low absorption is therefore desirable.

In making the absorption determinations on New Jersey brick, the test was carried out on a half brick. The advantage of doing this is that the surface of the brick is sometimes slightly denser than the interior and acts as a protective skin against percolating water. If, therefore, a whole brick is tested, we do not always get its true absorptive capacity. In use, this outer skin may get worn off wholly, or in part, especially if the brick is exposed to abrasive action, as in pavements.

The samples tested were first thoroughly dried, then weighed, and soaked in water for 48 hours, after which they were weighed again. The increase in weight gave the amount of water absorbed, and this, divided by the original weight, gave the percentage of water absorbed. The percentage of absorption is, therefore, based upon the weight of the dried brick.

The absorption on 8 different kinds of soft-mud bricks was determined. The lowest of these was 5.36 per cent. and the highest 18.64 per cent., but 6 ranged between 12.09 per cent and 14.87 per cent. The average of the 8 was 13.39 per cent., or, omitting the two extremes, it was 13.86 per cent. Curiously enough, the highest and lowest figures belong to bricks from the same yard, but represent two different banks of clay. The one with the high absorption was red, but lacked in hardness; the other was hard, but its color was yellowish white with iron specks, and on account of its poorer color it did not command so good a market. The effect of re-pressing is seen in the lower absorption of brick from Trenton in the series given below.

Absorption tests on 14 kinds of stiff-mud brick from 14 localities ranged from 1.34 per cent. to 14.29 per cent., with an average of 10.19 per cent., which is somewhat lower than the absorption of the soft-mud samples. The following are the figures obtained:

Table showing absorption of New Jersey brick.

SOFT-MUD BRICKS.

Locality.	*Absorption, percentage.*
Herbertsville,	5.36
Trenton (re-pressed),	9.75
Trenton (not re-pressed),	12.09
Farmingdale,	12.97
Little Ferry,	13.79
Cliffwood,	14.52
Herbertsville,	14.87
Sayreville,	14.91
Herbertsville,	18.64

STIFF-MUD BRICKS.

Locality.	*Absorption, percentage.*
Whippany,	1.34
South River,	5.63
Cliffwood,	7.52
Rosenhayn,	8.61

Locality.	*Absorption, percentage.*
Yorktown,	8.80
Collingswood,	9.23
Sayreville,	10.34
Camden,	11.08
Maple Shade,	12.76
Asbury Park,	13.01
Fish House,	13.58
Kinkora,	13.65
Hightstown,	13.78
Buckshutem,	14.02
Kinkora,	14.29

The absorption tests are given separately because they include some samples which were not subjected to crushing tests.

Explanation of table.—The following table gives the crushing and transverse tests made on New Jersey bricks. The first column gives the number of the brick, corresponding to the records kept in the Survey office. Each manufacturer has been informed which number represents his brick, and no firm names are published, as some brickmakers preferred not to have this done for business reasons, and their wishes are respected. The second column gives the character of material, and the third column gives the methods of manufacture, although aside from this the bricks are separated into the stiff-mud, soft-mud, and dry-press groups. In the fourth column the color of the brick is given, and in the fifth the character of the product. In the sixth, seventh, eighth and ninth columns there are data referring to the crushing tests. The sixth column gives the lowest test of those made, the seventh the highest, the eighth the average, and the ninth the number of bricks tested. In the next three columns the transverse tests are shown, the minimum, maximum and average being given, as in the crushing tests. The fourteenth represents the percentage of absorption, and the fifteenth, or last, column indicates the geological formation from which the clay or mixture of clays was obtained.

Table of transverse and crushing tests.

Number.	MATERIAL.	METHOD OF MAN'F'R.	COLOR.	CHARACTER.	CRUSHING STRENGTH, LBS. PER SQ. IN.			No. Tested.	TRANSVERSE STREN TH, MODULUS OF RUPTURE.			No.	ABSORPTION, PER CENT.	GEOLOGICAL FORMATION.
					Min.	Max.	Aver.		Min.	Max.	Aver.			
					STIFF-MUD.									
1	Clay,	Side cut, re-pressed,	Buff,	Hard burn,	13,260	15,590	13,873	7	828	1,471	1,145	5	1.61	Cohansey.
2	Black clay & loam,	Stiff mud, end cut,	Dark red,	Normal burn,	1,845	2,760	2,124	7	455	1,394	874	5	11.08	Clay Marl I.
3	Clay,	End cut,	Light red,	Normal burn,	3,410	4,620	3,820	4	608	922	755	4	14.02	Cape May.
4	Clay and loam,	End cut,	Red,	Normal burn,	1,277	2,740	2,012	7	271	784	513	5	7 52	Upper Raritan.
5	Clay,	End cut,	Red,	Normal burn,	580	2,280	1,694	6	622	1,350	1,003	5	9.23	Clay Marl II.
6	3 clays run of bank,	Side cut,	Red,	Normal burn,	3,250	5,880	4,543	6	558	739	659	5	13 01	Asbury clay.
7	Clay and loam,	End cut,	Dark red,	Normal burn,	1,680	2,070	1,823	5	416	725	559	5	14.29	Raritan.
8	Clay and loam,	End cut,	Red,	Normal burn,	3,315	4,965	4,163	6	674	1,047	912	5	13.58	Pleistocene—Pensauken.
9	Clay and loam,	Side cut,	Light red,	Normal burn,	4,930	6,330	5,538	4	553	951	700	4	8 80	Alloway clay.
10	Clay and loam,	End cut,	Dark red,	Normal burn,	3,080	4,775	3,908	5	537	1,035	752	5	8.11	Raritan and Cape May.
11	Clay and loam,	End cut,	Light red,	Normal burn,	4,390	6,280	4,933	5	674	1,007	913	5	13.78	Clay Marl I and II and loam.
12	Clay and loam,	End cut,	Dark red,	Same as 11, hard burn	8,995	12,770	11,058	3	1,463	2,042	1,750	3	13.78	Clay Marl I and II and loam.
13	Clay and loam,	End cut,	Dark red,	Normal burn,	1,395	2,650	2,108	5	748	1,407	1,038	5	12.76	Clay Marl I and II and loam.
14	Clay,	Side cut, re-pressed,	Buff,	Normal burn,	6,525	8,670	7,931	4	1,074	1,812	1.394	4	8.61	Cohansey.
15	Clay,	Side cut,	Dark red,	Normal burn,	2,655	4.398	3,751	5	424	720	632	5	13 04	Clay Marl II.
16	Clay,	Side cut, re-pressed,	Buff,	Hard burn,	4,740	6,975	5,858	6	912	1,232	1,094	5	5.26	Raritan.
17	Clay,	Side cut, re-pressed,	White,	Hard burn,	6,820	7,925	7,429	5	922	1,205	1,060	5	....	Raritan.
18	Clay and loam,	End cut,	Dark red,	Normal burn,	1,955	2,890	2,482	5	519	1,003	743	5	6.89	Clay Marl I and loam.
19	Clay,	Side cut,	Dark red,	Hard burn,	3,550	9,260	6,288	3	1,272	1,735	1,459	3	1.34	Pleistocene—Glacial lake.
					SOFT-MUD.									
20	Clay and sand,		Light red,	Normal,	1,270	2,955	1,980	6	235	574	336	5	14 87	Cohansey.
21	Clay and loam,		Light red,	Normal,	555	748	661	5	124	155	141	5	15.38	Cohansey.
22	Clay mixture,		Red,	Normal,	3,340	4,625	3,940	5	354	633	500	5	14.52	Raritan.
23a	Clay and sand,	Same yard, different pits,	Light red,	Normal,	3,246	3,665	3,456	2	615	651	633	2	14.28	Pleistocene—a Secondary clay.
24b			Dark red,	Normal,	1,705	1,805	1,755	2	210	314	262	2	....	Pleistocene—a Secondary clay.
25c			Gray,	Normal,	....	....	5,280	1	....	....	782	1	....	Pleistocene—a Secondary clay.
26	Clay and sand,	Hand molded,	Dark red,	Normal same yard,	2,205	3,760	3,107	5	328	492	440	4	12.09	Clay loam.
27	Clay and sand,	Hand molded, re-pressed	Dark red,	Normal	3,830	4,850	4,304	5	420	780	613	5	9.75	Clay loam.
28	Clay and sand,		Red,	Normal,	4,180	6,630	5,270	6	563	868	686	6	13.79	Pleistocene—Glacial lake.
29	Clay and sand,		Red,	Normal,	....	....	5,730	1	....	....	943	1	....	Pleistocene—Glacial lake.
30	Clay,		Dark red,	Normal same yard,	2,120	3,840	3,051	5	673	870	781	5	10.34	Raritan.
31	Clay,	Re-pressed,	Dark red,	Hard	5,535	6,470	5,909	5	1,046	1,323	1,042	5	....	Raritan.
					DRY-PRESSED.									
32	Clay,		Reddish brown	Hard,	9,125	16,675	13,535	4	1,338	1,455	1,397	4	....	Cohansey.
33	Clay,		Speckled buff,		11,360	14,430	12,989	4	1,288	1,448	1,367	4	....	Cohansey.
34	Clay,		Buff,		6,140	7,300	6,760	4	852	1,162	985	4	....	Cohansey.
35	Clay,		Buff speckled,	Hard,	4,370	7,050	5,583	4	752	883	831	4	....	Cohansey.

Comments on brick tests.—In studying the above tests a number of interesting points are to be noted.

1. Taking the two largest groups of bricks as a whole, that is, the stiff-mud brick and the soft-mud brick, we find that the crushing strength in the former ranges between 1,694 and 13,873 pounds per square inch, with an average of 4,856 pounds, while the latter range from 661 pounds to 5,909 pounds per square inch, with an average of 3,703 pounds. Even if the two exceptionally high tests, Nos. 1 and 12, are deducted, the average of the stiff-mud crushing tests still remains higher, being 4,055 pounds.

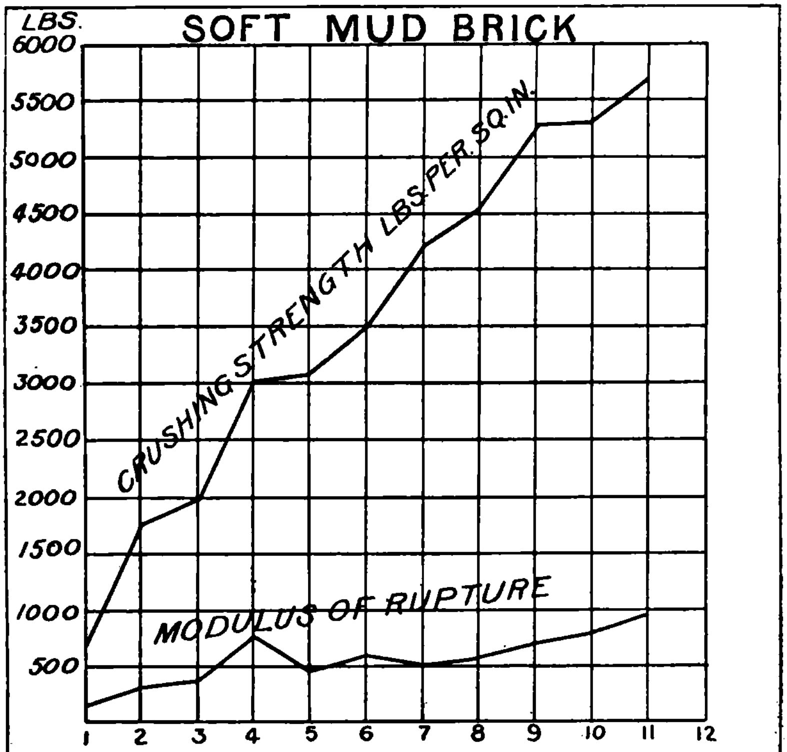

Fig. 38. Diagram showing lack of close agreement between crushing strength and transverse strength.

2. Comparing the transverse tests in the same manner, we find

that the modulus of rupture in the stiff-mud bricks ranges from 513 to 1,750 pounds, with an average of 950 pounds, while in the soft-mud the variation lies between 141 pounds and 1,042 pounds,

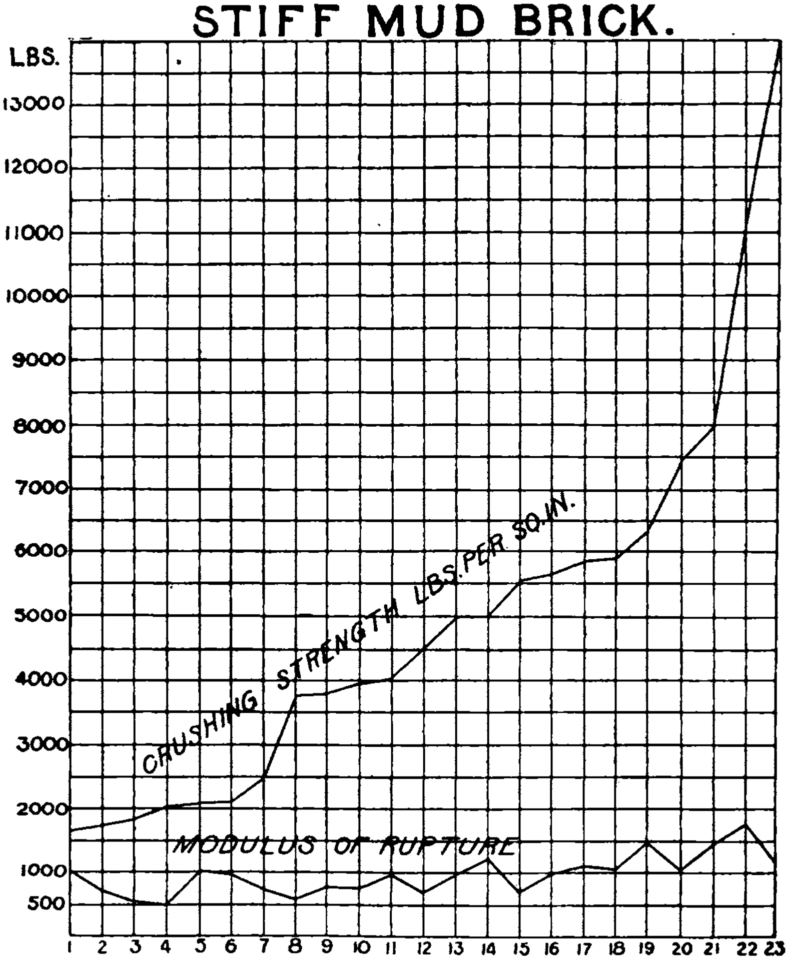

Fig. 39.

Diagram showing lack of close agreement between crushing strength and transverse strength of stiff-mud brick.

with an average of 571 pounds, or nearly 50 per cent. less than that of the stiff-mud.

3. If the crushing and transverse tests are shown graphically, as in Figures 38 and 39, it will be seen that the transverse breaks

do not seem to stand in direct relation to the crushing resistance, bricks of high crushing strength in some cases showing a low strength on the transverse test, and vice versa. This is notably true of the stiff-mud bricks tested.

4. In testing the individual bricks it will be noticed that there is sometimes a great difference between the maximum and minimum figures, as in tests Nos. 5 and 19. The lower breaks are in many cases due to carelessness in the manufacture, and wherever a low break occurred, it was found in the majority of instances to be due to pebbles in the brick three-fourths of an inch or an inch in diameter. These come from the loam that is mixed with the clay, and could be removed by a proper preliminary screening.

5. The hardness of the brick and porosity as shown by the absorption test are not necessarily an index to its crushing strength, except within very wide limits. Thus No. 1 is of low porosity and great hardness, but its crushing strength is very high, whereas No. 19, which is also of low porosity and great hardness, has a crushing strength of only about one-half that of No. 1, due perhaps to the fact that it is made of a much more plastic clay, which tends to warp and split somewhat in burning. Again, No. 12 is extremely porous, and hard burned, but has a crushing strength almost equal to No. 1. On the other hand, examples of high porosity and low crushing strength are shown in Nos. 2, 3, 7, 8, 13, 15, so that, while it is perhaps safe to say that high porosity is more frequently accompanied by low crushing strength, and vice versa, nevertheless, these tests prove that there are many striking exceptions to this generalization.

If we compare the transverse strengths with the porosity, we find the same lack of any close accord, although generally speaking the least porous brick shows the higher transverse strength, and vice versa. Thus, No. 21 has the least strength and the greatest porosity, and No. 19 has the least porosity and next to the greatest transverse strength, which accords well with our generalization. A striking exception is to be noted in the case of No. 12, which stands first in point of strength and is, also, one of the most porous, standing eighth in a list of 26, instead of last, as the generalization demands. So, too, No. 4 stands low in strength, and also low in porosity, contrary to what we might expect.

6. Re-pressing increases the strength of the brick so far as the New Jersey experiments go; it also increases the density and, therefore, decreases the absorption. As an example of this, we may take samples 26 and 27, representing the red brick made around Trenton. In this case the re-pressing has increased the crushing strength about 40 per cent. and the transverse strength nearly 30 per cent., while the absorption has decreased 2.24 per cent. A similar difference is observable in specimens 30 and 31, where the difference is still greater, but in this case it has been increased somewhat by harder burning.

7. The material added to decrease the shrinkage may seriously affect the strength of the brick. Thus Nos. 20 and 21 are common bricks made from the same clay bed, at two different, but not widely, separated points. No. 20 contains clean, sharp sand as an anti-shrinkage ingredient, while No. 21 has a sandy loam added to it in tempering. The latter has evidently made the brick more porous, softer, and less ringing. It also lowers its crushing strength more than 66 per cent. and its transverse strength over a half.

8. In one instance the same yard was found to be using both the stiff-mud and the soft-mud process; the clays used were obtained from the same bed, and the mixtures used differed but little. No. 4 represents the stiff-mud, and No. 22 the soft-mud brick. The greater crushing strength of the latter is probably due to its more homogeneous character, for the former contains many small cracks.

9. The effect of hard burning is seen in Nos. 11 and 12. Both lots came from the same down-draft kiln, but No. 12 was taken from the top, where it had been subjected to greater heat. Its strength is more than double that of No. 11.

For the sake of completeness of data, and also to indicate the character of the clays used, the conditions surrounding the manufacture of each brick are given here in detail, the numbers corresponding to those given in the first column of the table of tests.

STIFF-MUD BRICKS.

1. A front brick, made from a plastic, gritty clay, having a high tensile strength, and vitrifying at above cone 12. The bricks are burned in down-draft kilns, at about cone 6 or 7. The crushing tests ran quite uniform, and the lower figures of the transverse tests were due to fine cracks in the bricks.

2. A common brick made from a mixture of black clay and loam, in the proportion of about two-thirds of the former and one-third of the latter. Little or no water is added to the clay in the stiff-mud machine. The bricks are dried on pallets and burned in up-draft kilns. The brick are all fine grained, but some showed a laminated structure. The minimum modulus of rupture was caused by a one-inch pebble in one sample.

3. Common brick made from Cape May clay. The raw material is a highly plastic, gritty and sometimes pebbly clay, with an average tensile strength of 289 pounds per square inch. The linear air shrinkage was 8.4 per cent. and the fire shrinkage 1.5 per cent. The bricks are dried on pallets and burned in scove kilns. On the fracture they showed a coarse grain, with small clay nodules and gravel, and also slight laminations.

4. A common brick made from a mixture of Raritan clay and surface loam. The mixture is gritty, moderately plastic and not of high tensile strength. No temperature or cone measurements were made on the kiln, but the laboratory bricklet at cone 05 shows about the same absorption as the large brick. The linear air shrinkage is 0.7 per cent. and the fire shrinkage 0 per cent. The cubical air shrinkage 0.7, and fire shrinkage 5.2. The bricks show numerous fused specks of limonite, and the centres are sometimes black and shelly. The minimum transverse break was caused by a one-inch pebble.

5. Common brick made from a dense-burning clay of high tensile strength and red-burning if fired slowly. The clay was molded as taken from the bank in a small stiff-mud machine, stacked up to dry under sheds, and burned in up-draft Dutch kilns. The linear air shrinkage in drying is 5.4 per cent. and the fire shrinkage, as measured on the greatest length, is 0 per cent., but

the cubical fire shrinkage is 8.9 per cent., since the decrease in size occurs in the other two dimensions. The bricks were fine-grained, laminated, with a black centre, showing many fragments of burned lignite or coal. Their surface was rather rough. The average modulus of rupture is much better proportionately than the average crushing strength. The absorption is low.

6. Common brick made of a mixture of loam, black sandy clay, and yellow sandy laminated clay. None of the three individually have very high tensile strength (although that of the black clay is good) nor high fire shrinkage. The last two contain scattered limonite nodules. The bricks are molded in a stiff-mud machine, with little or no water added to the clay, and hacked up in the sun to dry. They are burned in Dutch kilns. The cubic air shrinkage is 5.5 per cent. and the cubic fire shrinkage 14.1 per cent. Many of the bricks showed fire cracks, which seemed to have affected the modulus of rupture rather than the crushing strength. The former was also no doubt lowered by the pebbles of one-fourth to one inch in size, which were visible on the fracture.

7. Common brick made from a mixture of black laminated clay, separated by thin layers of white sand and surface loam. The clay burns fairly dense and has good tensile strength. The bricks are dried in tunnels and burned in up-draft kilns. They are fine-grained, but slightly laminated and with few lumps or pebbles. The cubic air shrinkage is 9.7 per cent. and the cubic fire shrinkage 15.1 per cent.

8. Common brick made from a mixture of black, plastic Pleistocene clay, and loamy clay, with some loam. The clays have a high tensile strength and burn quite dense at a temperature but a few cones higher than that at which the bricks are burned. The product is fine-grained, but those with low fracture showed many clay nodules ranging up to one-half an inch in size.

9. Common bricks, made from a mixture of slightly weathered Alloway clay, and about one-third surface loam. The bricks, after molding, are hacked up to dry under sheds, then burned in a down-draft kiln, and are somewhat harder than the general run of common brick. The clays used are very plastic, have a high tensile strength and burn to a good red color. The crushing

strength is excellent for a common brick and the transverse strength is very fair. The bricks have a cubic air shrinkage of 19.3 per cent. and a cubic fire shrinkage of 14.8 per cent.

10. Common brick made from a mixture of light gray sandy Raritan clay, a black sandy clay of late Pleistocene age, and Cape May sandy loam in the proportion of one to one and one-half. The clays are put through a short pug mill, without previous disintegration, and after molding are hacked up to dry and burned in Dutch kilns. The cubic air shrinkage is 9.7 per cent. and the cubic fire shrinkage 15.1 per cent; the bricks are commonly even and fine-grained, with little trace of lamination. If the Raritan clay does not get thoroughly broken up in the pug mill it shows as white spots in the brick.

11 and 12. Common brick made from a mixture of Clay Marls I and II, with a small amount of surface clay added. The clays are charged directly into the stiff-mud machine and the drying is done either on racks or in tunnels. They are burned in circular down-draft kilns to about cone 1. In the normally burned brick the cubic air shrinkage is 14.6 per cent. and the cubic fire shrinkage 3.1 per cent. The bricks are fine-grained and dense, although some showed scattered pebbles on the fracture. No. 12 shows an increased strength due to harder burning.

13. Common brick made from a mixture of Clay Marls I and II and loam. The loam is first screened through a sieve with one-inch mesh, but this fails to remove many pebbles. The bricks are dried in tunnels and burned in up-draft kilns. They show few laminations. The cubic air shrinkage is 4.7 per cent. and the cubic fire shrinkage 12.3 per cent. The modulus of rupture is rather high as compared with the crushing strength.

14. Front bricks made from a gritty, plastic clay of moderate tensile strength. The brick, after molding are re-pressed and dried in tunnels. They are burned in down-draft kilns at about cone 1. The cubic air shrinkage is 19.2 per cent and the cubic fire shrinkage 5.2 per cent. The strength is good and absorption not high.

15. Common bricks made from more or less weathered beds of Clay Marl II. After molding they are hacked under sheds to dry, and burned in up-draft scove kilns. The bricks are

slightly laminated, with black centres at times. The brick showing the lowest transverse test broke off the centre and contained numerous sandstone fragments. Nearly all were dotted with pebbles on the broken surface.

16. Front bricks, made from Raritan clay of only moderate tensile strength, but dense burning and of semirefractory character. They are dried in tunnels and burned at about cone 9 in down-draft kilns. The grain of the brick is fine, and somewhat brittle, with no laminations.

17. Made in same manner as 16, but from different clay. Strength is similar.

18. Common bricks made from a black, dense-burning clay, of high tensile strength and shrinkage, to which is added a surface loam of opposite physical characters from the clay. The bricks are dried on pallets and burned in Dutch kilns. The cubic air shrinkage of the bricks is 5.9 per cent., and the cubic fire shrinkage is 9.2 per cent.

19. A dense, nearly vitrified brick made from a plastic, dense-burning surface clay. The cubic air shrinkage is 17.3 per cent., and the cubic fire shrinkage 19.4 per cent. The bricks have a smooth, dense fracture, and fine grain, with scattered angular quartz fragments. The surface shows some cracks.

SOFT-MUD BRICKS.

20. Common bricks made from a mixture of sandy clay and clean sand. The clay was tempered in ring pits and molded in a horsepower soft-mud machine. It was dried on an open yard and burned in a scove kiln, at a cone number probably not higher than 05. The mixture used has a low tensile strength and air shrinkage. The bricks are moderately hard, have a slight ring, and on the fracture show numerous pebbles and ash fragments up to one-half inch diameter.

21. Common brick made from a mixture of sandy clay and loam; tempered in a soak pit, molded in a soft-mud horsepower machine, dried on open yards, and burned in a scove kiln probably at a low temperature. The product is rather porous, lacks a

ring and shows many ash fragments on the broken surface. Its strength is the lowest of any tested, due to the loam used to temper the clay. Better results would be obtained by the use of sand.

22. Common bricks made from a mixture of lignitic clay and surface loam. The clay mixture is moderately plastic, has moderate tensile strength and low shrinkage. The bricks are dried on open yards and burned in scove kilns. The cubic air shrinkage is 26.2 per cent., and the cubic fire shrinkage 7.3 per cent. The bricks show a somewhat coarse grain, and some have a black centre.

23, 24, 25. Common bricks made from a sandy, open-burning, Pleistocene surface clay. They were molded in a horsepower machine, dried on an open yard and burned in a scove kiln. The three samples represent different mixtures and banks.

26. A machine-molded common brick made from the clay loam used so extensively about Trenton. It was dried in the sun and burned in an up-draft Dutch kiln. The fracture shows numerous small pebbles.

27. The same clay, with the addition of some more plastic material, but brick re-pressed after molding. It shows a more even grain. The cubic air shrinkage was 19.9 per cent. and the cubic fire shrinkage 0.6 per cent.

28. Common bricks from the Hackensack district, made of a mixture of clay and sand. The clay has a moderate tensile strength and burns dense at a low temperature, viz., cone 01. The mixture is tempered in ring pits, dried on open yards and burned in scove kilns. The fracture is moderately fine-grained and homogeneous and showed few pebbles.

29. Common bricks made from sandy glacial clay. It is tempered in ring pits, dried on open yards and burned in scove kilns. Only one sample was tested, which represented a normally burned brick.

30 and 31. Two common bricks from the same yard, the second one re-pressed. They were made from a red-burning, laminated Raritan clay, of moderate tensile strength. The re-pressed bricks show higher strength, due in large part to harder burning.

DRY-PRESSED BRICKS.

32, 33, 34 and 35 are all dry-pressed bricks made from Cohansey clays. The raw materials are of moderate tensile strength and are buff-burning at cone 6 to 8.

Value of New Jersey Brick.

The value of the different kinds of brick produced in New Jersey in 1902[1] was as follows:

Kind.	*Quantity. Thousands.*	*Value.*	*Average price per thousand.*
Common,	300,583	$1,506,224	$5.01
Front,	42,926	552,000	12.86
Vitrified,	1,014	10,437	10.29
Fancy or ornamental brick,	......	11,407	....

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[1] Mineral Resources, U. S. Geol. Survey, 1902, Chapter on Clay-working Industries.

DIRECTORY OF FIRMS MAKING BRICK.

C = common. F = front. E = enameled.

John Hoffman,	Alpha,	C.
Drummond Brothers,	Asbury Park,	C.
Somers Brick Company,	Bakersville,	C.
R. T. Greenlee,	Belleplain,	C.
Kresner & Holland,	Berkeley Heights,	C.
Bordentown Brick Company,	Bordentown,	C.
S. Graham & Company,	Bordentown,	C.
J. C. Benward,	Brass Castle,	C.
B. Erickson,	Bridgeton,	C.
Budd Brothers,	Camden,	C.
Cliffwood Brick Company,	Cliffwood,	C.
A. Gaston,	Cliffwood,	C.
O. Gehlhaus,	Cliffwood,	C.
J. C. Dobbs,	Collingswood,	C.
J. Braislin & Son,	Crosswicks,	C.
D. Doerr,	Da Costa,	C.
—. Rajotte,	Dunellen,	C.
H. C. Adams,	Edgewater Park,	C.
J. Einsiedel,	Egg Harbor City,	C.
Rupp & Sawyer,	Elmwood,	C.

Edwin Lippincott,	Farmingdale,	C.
Hatch & Son,	Fish House,	C.
G. C. Pedrick,	Flemington,	C.
Passaic Brick Company,	Garfield,	C.
E. Schmults,	Hackensack,	C.
I. H. Tilton,	Herbertsville,	C.
Herbertsville Brick Company,	Herbertsville,	C.
Wm. Sculthorp,	Herbertsville,	C.
B. H. Reed & Brother,	Hightstown,	C.
A. B. Brocklebank,	Howell,	C.
David E. Cole,	Karrsville,	C.
Kingsland Brick Company,	Kingsland,	C. F.
M. Dobbins,	Kinkora,	C.
T. O. Daniel,	Lambertville,	C.
C. E. Walsh,	Little Ferry,	C.
J. & W. Felter,	Little Ferry,	C.
M. B. & L. B. Gardner,	Little Ferry,	C.
M. & I. E. Gardner,	Little Ferry,	C.
J. W. Gillies,	Little Ferry,	C.
Mehrhof Brick Company,	Little Ferry,	C.
N. Mehrhof & Company,	Little Ferry,	C.
P. Mehrhof,	Little Ferry,	C.
C. E. Walsh,	Little Ferry,	C.
A. W. Leonard,	Loganville,	C.
T. Sauselein,	Maple Shade,	C.
Maple Shade Brick Works, A. Reeve,	Maple Shade,	C.
E. Farry,	Matawan,	C.
Pennsylvania Clay Company,	Matawan,	C.
Atlantic Brick Manufacturing Company,	Mays Landing,	F.
South Jersey Brick and Drain Tile Works,	Millville,	C.
F. L. Armstrong,	Morristown,	C.
Standard Brick Company,	Mountain View,	C.
Uschwold & Ulrich,	Mountain View,	C.
F. Dubell,	Mount Holly,	C.
F. E. Losee,	Newton,	C.
D. Hand & Son,	Plainfield,	C.
S. B. Sickler,	Pentonville,	C.
W. W. Scattergood,	Rancocas,	C.
Geo. B. Decker,	Red Bank,	C.
Kilborn & Gibson,	Rosenhayn,	C. F.
Boehm & Kohlhepps,	Sayreville,	C.
W. F. Fisher & Company,	Sayreville,	C.
E. Furman Company,	Sayreville,	C.
Sayre & Fisher Company,	Sayreville,	C.
Geo. Conners,	Singac,	C.
Singac Brick Company,	Singac,	C.
J. C. Ross,	Somerville,	C.
American Enameled Brick & Tile Company,	South River,	E.
J. & M. Bissert,	South River,	C.

Pettit & Company,	South River,	C.
National Pyrogranite Company,	South River,	F.
Pettit & Cook Company,	South River,	C.
J. Whitehead,	South River,	C.
S. J. Willett,	South River,	C.
Yates Brick Works,	South River,	C.
E. R. Tilton,	Toms River,	C.
Applegate & Company,	Trenton,	C.
Donahue & Nolan,	Trenton,	C.
New Jersey Brick Company,	Trenton,	C.
R. M. Drake & Company,	Trenton,	C.
Fell & Roberts,	Trenton,	C.
J. F. Heath,	Trenton,	C.
Kafer & Ivins,	Trenton,	C. F.
Wm. Mushet,	Trenton,	C.
Trenton Red Front Brick Works,	Trenton,	C.
B. F. Walton,	Trenton,	C.
J. A. Hobart,	Vineland,	C.
J. M. Hulme,	Westhampton,	C. ?
A. H. Furman,	Whale Creek,	C.
Moore Brick Manufacturing Company,	Whippany,	C.
Eastern Hydraulic Press Brick Company,	Winslow,	F
Bushnell & Westcott,	Woodbine,	C.
C. B. Thackera,	Woodbury,	C.
D. F. Haines,	Yorktown,	C.

CHAPTER XII.

TERRA-COTTA MANUFACTURE AND THE NEW JERSEY TERRA-COTTA INDUSTRY.

CONTENTS.

The term terra cotta is applied to those clay products used for structural decorative work which cannot be formed by machinery, and therefore have to be molded by hand.

RAW MATERIALS.

It rarely happens that one clay alone can be used for terra cotta, and consequently a mixture of several clays is employed. Most of the clays chosen are No. 2 fire clays, and are, therefore, buff-burning, but in their other physical properties they vary widely. Some are used because of their dense-burning character and bonding power, others because of a low shrinkage and freedom from warping, while absence of soluble salts is an important as well as desirable property in all.

Buff-burning clays are commonly chosen, partly because they burn to a hard body at the desired temperature, and there is no danger of overburning. The color of the body is of no great importance, since the final color is applied superficially. Very few terra-cotta manufacturers at the present day employ a low grade clay.

The soluble salts are undesirable because in drying they may come out through the color slip. In order, therefore, to render them insoluble, if necessary, the clay is usually treated with barium chloride or carbonate.

Properties.—To give a tabulated statement of the properties of clay used for terra-cotta manufacture would involve listing 40 per cent. or 50 per cent. of all the clays mined in the Woodbridge district. It may be of interest, however, to give the properties of a terra-cotta mixture, the tests being made on a soft green mass as tempered at the works. Its physical properties were as follows:

Air shrinkage, 4½ per cent. Tensile strength, 97.5 pounds per square inch. Its behavior in burning was as follows:

Physical qualities of a terra-cotta mixture.

	Cone 01	*Cone 5*	*Cone 10*
Fire shrinkage, ...	1.5%	4.8%	5%
Hardness, ...	not steel-hard.	nearly steel-hard.	
Absorption, ...	very absorbent.	slightly absorbent.	nearly impervious.
Color, ...	pale buff.	grey buff.	grey buff.

In making terra cotta, the clay is not carried to the temperature last given, as there would be danger of its warping, but it is fired between cone 6 and cone 8, at which point this danger is greatly, if not entirely, diminished.

In the following table are given the physical characters of some of the New Jersey clays used for terra-cotta manufacture:

Table showing physical characteristics of some New Jersey terra-cotta clays.

Field No.	Labratory No.	LOCALITY.	Water required in tempering—per cent.	Air shrinkage—per cent.	Tensile strength—lbs. per sq. inch.		Fire shrinkage—per cent.	COLOR.	HARDNESS.
5	376	G. H. Cutter, Woodbridge,	26	4.6	57	Cone 05 Cone 1 Cone 5 Cone 14	4 9.4 12	Clay-red, Deep red, Very deep red, ...	Nearly steel-hard. Nearly impervious. Impervious. Viscous.
7	385	Perth Amboy Terra Cotta Co., tendency to warp,	34	6.6	142	Cone 8 Cone 26	7.4	Buff, ...	 Vitrifies thoroughly.
77	395	Clay from Perrine's Pit, known as a stoneware clay,	37	7	109	Cone 01 Cone 1 Cone 3 Cone 10 Cone 27	6 6 7.6 9	Yellowish white, Light buff, Buff, Gray buff, ...	Absorbent. Steel-hard. Very dense. Incipient fusion.
132	622	J. W. Paxson & Co., Bridgeboro,	22	5 3	104	Cone 05 Cone 3 Cone 5 Cone 8	1.3 2.7 4.7 6.7	Pale red, Light red, Dark red, Gray,	Barely steel-hard, absorbent. Steel-hard, but absorbent. Absorbent. Vitrified.
134	621	Hylton's Pits, Palmyra,	20	5.3	65	Cone 05 Cone 5 Cone 8 Cone 27	1.3 1.3 2	Buff, Buff, Buff, ...	Absorbent, not steel-hard. Absorbent, not steel-hard. Steel-hard, absorbent. Well vitrified.
213	656	Adams Clay Mining Co, east of Woodmansie,	23.3	5	73	Cone 5 Cone 8 Cone 10	2 7 2.7	Dirty white, Dirty white, Gray buff,	Steel-hard, absorbent. Steel-hard, absorbent. Small fused specks of iron silicate.

It will be seen from the above table that the clays used are mostly of low tensile strength, and that when burned at the cone number (8) at which terra cotta is usually fired some burned quite hard, while others were still porous. The latter kind, it will be seen, show a low shrinkage.

Distribution.—Clays for the manufacture of terra cotta are obtained from several districts in New Jersey, but only from two formations, viz., the Raritan and the Cohansey. The Raritan supplies the greatest quantity of terra-cotta clay, large amounts being dug in the Woodbridge and Perth Amboy districts, much of it for use in other States. Clays of the same age are also dug to some extent from the pits that have been opened along the Delaware near Palmyra and Bridgeboro.

The Cohansey clays mined extensively near Woodmansie are employed to a considerable extent for terra cotta, and others dug near Blue Anchor have been used for this same purpose, but in most cases where the Cohansey and Delaware river clays are used, they are mixed with a certain amount from the Woodbridge district.

TERRA-COTTA MANUFACTURE.

The manufacture of terra cotta stands on a much higher plane in ceramic technology than it did a few years ago. The grades of clay employed have improved, and the progress that has been made in the number of colors producible and the complex and original designs which can be executed, have called for the employment of highly skilled labor in the execution of the architect's wishes. Indeed, the use of terra cotta for exterior decoration has met with such success, that few modern buildings of large size are erected at the present day without the use of a large quantity of this product. The high development of this branch of the clay-working industry is due no doubt in part to the competition between different manufacturers to meet the demands of the architect.

It will be easily seen, therefore, that in the manufacture of terra cotta, the labor forms a large portion of the expense. Furthermore, with an increase in the intricacy of design, much greater care has been necessary in the mixing of the clays, for a thorough preparation aids much in the prevention of warping or cracks in burning. Some terra-cotta manufacturers even store their clay in bins for some time after tempering it.

There are several reasons why terra cotta has taken the place of stone to such a large extent during the last few years. These are 1) its durability, which in some cases is equal to, if not greater than stone; 2) the many shades and colors which can be produced; 3) the almost endless variety of designs; 4) the possibility of producing more delicate outlines than are often obtainable in stone, and 5) the combination of lightness and durability.

In the manufacture of terra cotta, the clay is usually ground first in a dry pan, having sometimes been previously exposed to the weather, partly for the purpose of disintegrating the clay and thereby increasing its plasticity, and partly for allowing any iron nodules or concretions present to weather out or rust, so that they can be readily seen and removed. The ground clays are sometimes tempered in a wet pan, and may then be subjected to still further mixing in a pug mill of either vertical or horizontal type. The clay issues from this in a bar about eight inches square, and is cut up into square lumps which are piled away in bins until used.

Terra-cotta objects are always formed by hand, either in plaster molds or by modeling. The former method is employed for all simple forms, but for intricate undercut designs, it is necessary to model the object free-hand, and every terra-cotta factory, therefore, has its corps of skilled laborers for this purpose. In making a mold, it is first necessary to make a plaster model around which the mold can be cast. Small simple designs can be molded in one piece, but larger objects or special shapes have to be formed in several pieces which are joined together after burning.

In filling a plaster mold the tempered clay is pushed into all the corners and crevices and spread over the interior of the mold to a depth of about an inch or an inch and a half. After this the mold is set aside for several hours in order to permit the clay to shrink sufficiently to allow of its being removed from the plaster form. Any rough or uneven edges are then usually trimmed off with a knife.

Terra cotta is usually dried on steam-heated floors, and this process must be carried on slowly and carefully with large pieces.

The latter are turned around or over during the drying, to facilitate shrinkage and drying in all directions. After thorough air drying the green ware is taken to the spraying room, where the slip which is to form the surface coating is sprayed on it, thus forming a thin layer over all the surface, and also being somewhat absorbed by the body. The slip, which is commonly a mixture of kaolin, quartz and feldspar, to which the proper coloring ingredients are added, forms an impervious layer on the surface of the terra cotta, and also produces the color effect on the ware. It is sometimes made so as to burn to a dull enamel.

Terra cotta is commonly burned in circular down-draft kilns, whose diameter ranges from 15 to 25 feet; the kilns are often of the muffle type.[1] The different objects are set in the kiln surrounded by a framework of quarries (slabs of fire brick) so that during the burning no object has to bear any weight other than its own. The total shrinkage in drying and burning is commonly about 8 per cent., and the temperature reached is commonly between cones 6 and 8 where No. 2 fire clays, or a mixture of these with No. 1 clay is employed. If the terra cotta is made from lower grades of clay, as is seldom the case now except at a few small factories, much lower temperatures are of course used, such as cone 1 or 2.

NEW JERSEY TERRA-COTTA INDUSTRY.

Although a number of large terra-cotta works in surrounding states are dependent on New Jersey for their raw materials, there are comparatively few terra-cotta factories in the State itself. The most important centre is Perth Amboy, where 3 factories are located, and there are 4 others in the State respectively at Beverly, Moorestown and Rocky Hill.

The terra-cotta industry in New Jersey was established first at Perth Amboy, in 1849, the first works being known as the Hall

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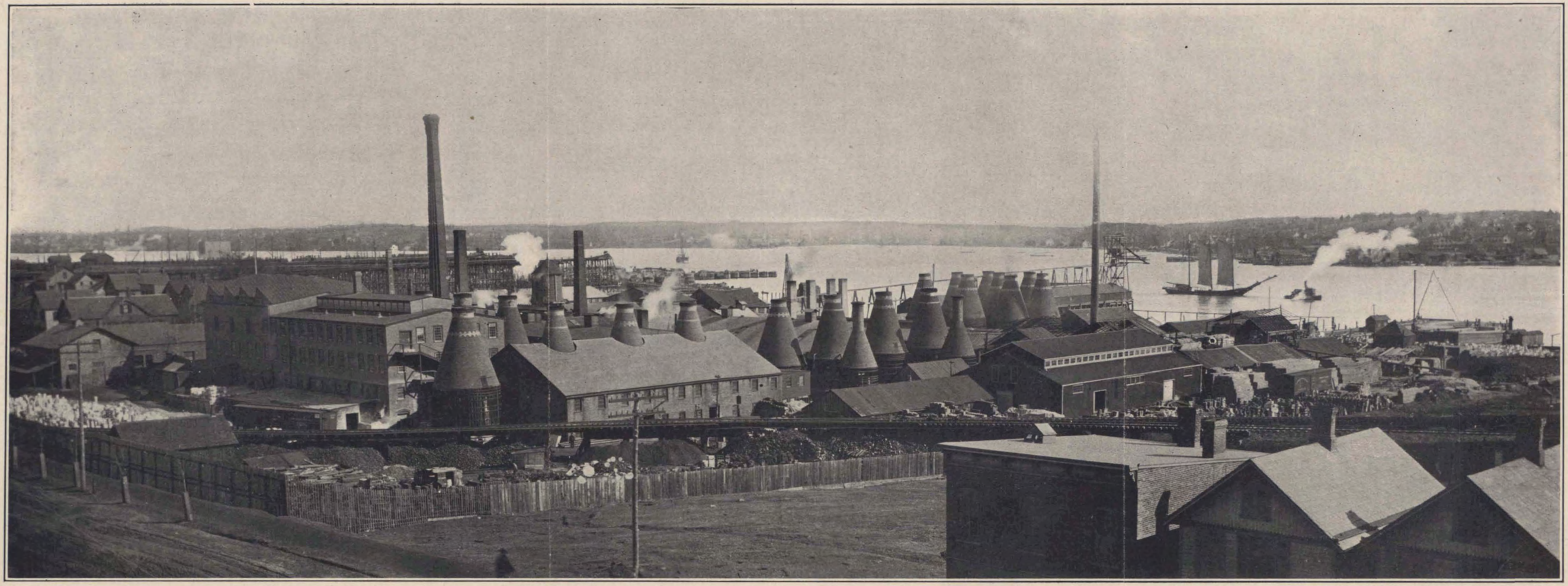
[1] A muffle kiln is one in which the flames do not come in contact with the ware, but pass upwards through double walls, and then sometimes down through a flue in the center of the kiln.



Plant of the Perth Amboy Terra Cotta Company. Perth Amboy.

Terra-cotta Works, and in 1879 changed to the Perth Amboy Terra-cotta Company. (Plate XXXI.) This was followed in 1888 by the establishment of the New Jersey Terra-cotta Works. The present Standard Terra-cotta Works was organized in 1890 under the name of the Architectural Terra-cotta Works, and the others are of still more recent date. One plant at Matawan has been converted into a floor-tile works.

The value of the terra cotta produced in New Jersey in 1902 was \$861,730.[1]

List of producers of terra cotta in New Jersey.

Perth Amboy Terra-cotta Company, Perth Amboy.
New Jersey Terra-cotta Company, Perth Amboy.
Standard Terra-cotta Company, Perth Amboy.
Excelsior Terra-cotta Company, Rocky Hill.
Burlington Terra-cotta Company, Beverly and Moorestown.
South Amboy Terra-cotta Company, South Amboy.

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[1] Mineral Resources, U. S. Geol. Survey, 1902. Chap. on Clay-working Industries.

CHAPTER XIII.

HOLLOW WARE FOR STRUCTURAL WORK AND CONDUITS.

CONTENTS.

HOLLOW WARE FOR STRUCTURAL WORK.

Character.—Under this heading are included fireproofing, terra-cotta lumber, hollow blocks and hollow bricks. These are all hollow, being molded through a stiff-mud die (see Pl. XXXII, Fig. 1), and may contain one or more cross webs or partitions to give them strength. *Fireproofing* is the term applied to those forms used in the construction of floor arches, partitions and wall furring for columns, girders and other purposes in fireproof buildings. *Terra-cotta lumber* is a form of fireproofing that is soft and porous, owing to the addition of a large percentage of sawdust to the clay. The former burns off in the kiln, thus leaving the material so soft and porous that nails can be driven into it. It is used chiefly for partitions. *Hollow blocks* are used for exterior walls, in both fireproof and nonfireproof buildings. They are of rectangular outline. *Hollow brick* are like hollow blocks in form, but no larger than ordinary building bricks.

A number of different shapes and sizes of fireproofing are made, and while the majority of them agree in being 12 inches long, the other two dimensions may vary. Thus, of the blocks which are 12 inches long, the other dimensions may be 6 by 3 in., 6 by 4 in., 6 by 5 in., 6 by 6 in., 6 by 7 in., etc., or perhaps 3 by 8 or 3 by 12 in., etc. A large number of the fireproof shapes made are for floor arches, and in such cases the architect commonly specifies the depth of the arch while the width of the blocks is governed by the width of the span. The weight of the arch will depend on its depth.

Thus, 6-inch	floor	arches	weigh	about	25	pounds	per	square	foot.
7 do.	do.	do.	do.	do.	28	do.	do.	do.	do.
10 do.	do.	do.	do.	do.	35	do.	do.	do.	do.
12 do.	do.	do.	do.	do.	42	do.	do.	do.	do.
3-inch	book	tile	do.	do.	15	do.	do.	do.	do.
3-inch	partition	tile	do.	do.	15	do.	do.	do.	do.
6 do.	do.	do.	do.	do.	21	do.	do.	do.	do.
8 do.	do.	do.	do.	do.	28	do.	do.	do.	do.
2 do.	wall	furring	do.	do.	8.5	do.	do.	do.	do.
3 do.	do.	do.	do.	do.	10.5	do.	do.	do.	do.
2 do.	column	covering	do.	do.	13	do.	do.	do.	do.
3 do.	do.	do.	do.	do.	15	do.	do.	do.	do.

The cost of fireproofing is commonly figured by the ton.

Hollow blocks are usually made in 8-inch lengths, but vary in their other two dimensions, being 4 by 16, 6 by 16, 8 by 16, 10 by 16, 12 by 16, etc. They are used quite extensively in the central States, but not so much in the eastern ones. Hollow blocks are made with either smooth, corrugated or ornamented surfaces.

Sizes 8 by 4 by 16 in. are sold for about $0.07 each, and 8 by 8 by 16 in. at $0.10 each. Hollow bricks are often used for the interior course of exterior walls, and the plaster can be laid directly on them without the use of lathing.

Raw materials.—The clays used for making fireproofing and hollow bricks are often a grade of fire clay, but those manufactured in New Jersey are made from a mixture of an impure red-burning clay, to which a certain proportion of fire clay is sometimes added. The former is obtained in great abundance from the laminated clay in the upper part of the Woodbridge clay bed, as well as from Clay Marl II. While the different classes of

Fig. 1.

Making fireproofing. The man grasps with his left hand the frame with piano wires for cutting the clay into proper lengths.

Fig. 2.

Large excavation made in digging clay for fireproofing. National Fireproofing Company, Standard plant.

material vary somewhat in their character, many of them are dark, bluish-black clays, often strongly laminated and containing much organic matter, mica, and scattered nodules of pyrite and limonite. They are red-burning, usually of low refractoriness, and their fusion point lies not uncommonly between cone 12 and 15, or even lower. To these a certain proportion of a No. 2 fire clay is sometimes added. Shale is used at one locality. The mixtures used burn steel-hard at cone 01 to cone 1. The general physical characters of the clays can best be judged from the tabulated statement given below.

Tests of New Jersey clays used for fireproofing.

Locality No.	Laboratory No.	LOCALITY.	Water required to temper—per cent.	Air shrinkage—per cent.	Average tensile strength.		Fire shrinkage—per cent.	COLOR.	HARDNESS.
47	447	Perth Amboy, black clay, small lumps pyrite and lignite,	. . .	5	145	Cone 05	1.6	Gray-red,	Not hard.
						Cone 01	2	Red,	Hard.
						Cone 3	2.9	Red,	Hard.
						Cone 15 to 16	. . . .	. . .	Viscous at 1,440 °C.
46	451	Perth Amboy district, similar to the preceding,	. . .	5.5	112	Cone 05	2.5	Reddish,	Not hard.
						Cone 01	3	Red,	Hard.
. .	449	Lorillard,	. . .	6	238	Cone 05	2.6	Red,	Fairly hard.
						Cone 01	4	Red,	Hard
						Cone 1	5	. . .	
						Cone 13 to 14	. . . .	. . .	Viscous at 1,400 °C.
93	396	Spa Spring, gritty clay, moderate plasticity,	. . .	5.5	50	Cone 05	2.5	Red,	Not hard.
						Cone 1	2.5	Red,	Hard.
						Cone 3	3.4	Red,	Hard.
						Cone 10	11.5	Speckled gray-brown,	Nearly vitrified.
96	408	Piscataway red clay, quite plastic,	36	7	129	Cone 05	4	Deep red,	Hard.
						Cone 01	10	Red,	Vitrified.
						Cone 3	10.7	Deep red,	Well vitrified.
71	371	South River, dark gray clay, mica scales and organic matter,	25	.	84	Cone 1	8	Red,	Hard.
						Cone 5	10.7	. . .	Vitrified
282	728	Shale from Port Murray,	18.5	2	51	Cone 05	1.6	Pale red,	Easily scratched.
						Cone 01	2.4	Deep pink,	Scratched.
						Cone 1	4.6	Red,	Scratched.

The above tabulation is not without interest, and shows a considerable variation in certain directions. The air shrinkage shows little variation, but the tensile strength shows a great range. Of these different samples, Nos. 447, 451 and 371 are practically from the same bed. No. 408 is from the base of the Raritan series and is one of the most dense-burning clays to be found in that section, or even in the State. Most of these clays have to be burned to cone 01 before becoming steel-hard, the one exception being No. 408, which burns very hard at cone 05. They all burn red. The pyrite and limonite nodules are abundant in some of the layers, and in burning often swell and spall off pieces of the ware.

The black laminated clay which forms the upper part of the Woodbridge clay bed (pp. 184-5) is the most important source of the terra-cotta lumber and fireproofing clays in New Jersey. As shown on the map, Plate XI, they are found in the region bordering the Raritan river, that is at Perth Amboy, Keasbey, South River and Sayreville, as well as in the vicinity of Woodbridge and Spa Springs. At Lorillard, east of Keyport, Clay Marl II is also extensively utilized. On account of the enormous quantity of fireproofing manufactured, a great amount of clay is dug, and the excavations are very large. In some pits the clay is dug with a steam shovel (Pl. XXXII, Fig. 2) and loaded onto tram cars, which are hauled to the works either by horsepower or a small engine.

The following analyses are representative of the general chemical composition of the New Jersey fireproofing clays:

Compositions of two New Jersey fireproofing clays.

	1	2
Silica (SiO_2),	52.22	60.18
Alumina (Al_2O_3),	29.43	23.23
Ferric oxide (Fe_2O_3),	2.78	3.27
Lime (CaO),	0.88	1.00
Magnesia (MgO),	0.72	0.67
Potash (K_2O),	2.10	2.58
Soda (Na_2O),	0.75	0.80
Loss on ignition,	11.10	8.54
	99.98	100.27

1. Clay from bank of National Fireproofing Company, Keasbey (Lab. No. 399).
2. Clay from Sayre & Fisher's pits, Sayreville (Lab. No. 393).

Method of manufacture.—Hollow blocks and fireproofing are molded on stiff-mud machines, with either a single or double die. The material is previously tempered in a wet pan, as this crushes up the pyrite and sandstone lumps found in many of the clays. Some firms use drying tunnels, while others employ slatted floors, and the burning is done mostly in circular down-draft kilns, although one firm uses a continuous kiln. Most of the factories do not burn higher than cone 01, and as the clays used contain much organic matter, the burning has to be done slowly.

Many of the clays also contain considerable soluble salts, which come to the surface during drying, but this is of little consequence, as the product is covered up when in the building. The range of shrinkage in drying and burning, as determined at several works, is as follows:

Shrinkage in drying and burning fireproofing.

Linear.		Cubic.	
Air.	*Fire.*	*Air.*	*Fire.*
3.4%–4.3%	3.9%–5.2%	11.1%–15.4%	9.9%–13.2%

New Jersey industry.—One of the most interesting statements to be found in the New Jersey Clay Report of 1878, and one which serves well by comparison to show the great strides that have been made in the clay industry of New Jersey, is the following: "They (the hollow brick) have not been much used in this country. Henry Maurer, of Perth Amboy, has begun their manufacture, and there is now an opportunity to make a trial of this promising improvement in building materials."

At the present day there are nine factories in New Jersey whose product consists *largely or entirely* of fireproofing, hollow blocks, etc., with an output in 1901 valued at $611,864 and in 1902 at $965,047. Of these the firm of Henry Maurer & Son was the first to begin this manufacture as above noted (Pl. XXXIII, Fig. 1). Four of the other factories are operated by the National

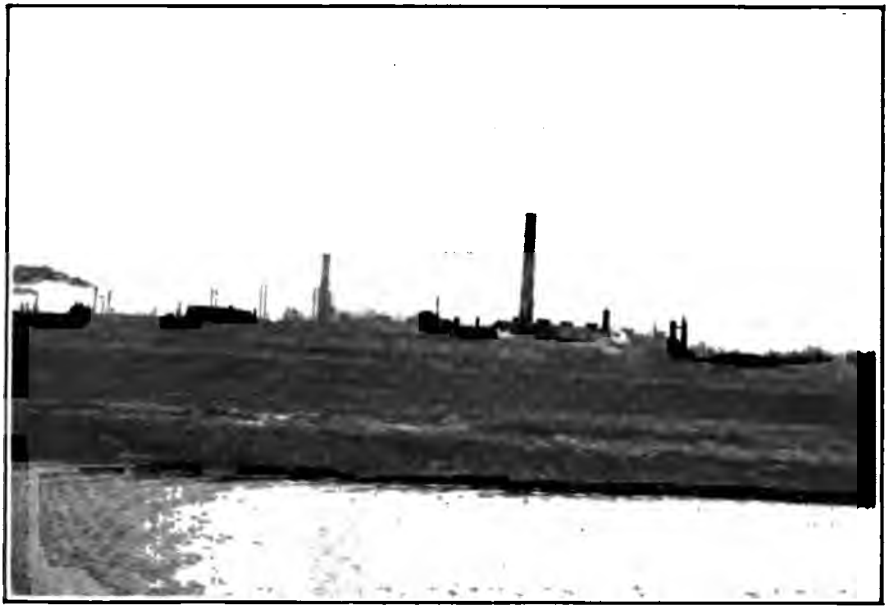

Fig. 1.
General view of works of Henry Maurer & Son, taken from Sewaren.

Fig. 2.
General view of the fireproofing works of National Fireproofing Company, Port Murray.

Fireproofing Company, which has its headquarters at Pittsburgh, and whose original plant in New Jersey was the factory at Port Murray, Warren county, which uses Hudson shale (Pl. XXXIII, Fig. 2). In 1900 this company acquired the Perth Amboy Works, known as the Old Pardee Works; in January, 1901, the fireproofing factory at Lorillard was taken over, and in July, 1901, the Raritan Hollow & Porous-Brick Company at Keasbey. Other factories are those of C. W. Boynton, Sewaren, and one located at Spa Springs, which began in 1869 as the Anness Pottery, and was subsequently known as Anness & Lyle, Staten Island Terra-Cotta Lumber Company, and is now the Staten Island Clay Company.

In addition to the nine factories above mentioned, fireproofing is now manufactured by the Brinkman Terra-Cotta Company, near Piscataway, and by the National Clay Manufacturing Company, of South River, which purchased the old Edgar Brick Works in 1902, and has more or less re-modeled them. Anness & Potter, at Woodbridge, also began the manufacture of fireproofing during 1902, and some hollow brick are made at Crosswicks by John Braislin & Son (Pl. XXXIV, Fig. 2).

The rapid growth of this industry in New Jersey is due to several causes. It is for the most part due to an inexhaustible supply of clay, which in former years had little or no value, and even at the present day would probably not be put to any use other than that for which it is now dug. Furthermore, these clay deposits are in general close to tide water, so that the product can be shipped either by boat or rail to the large eastern markets. Cheap fuel is also an important factor.

CONDUITS.

Clays and manufacture.—Conduits form a line of clay products, the use of which has greatly increased in the last few years. These are hollow blocks of varying length, having sometimes several cross partitions and rounded edges, and are used for pipes for electrical cables and wires below ground. On this account they have to be hard-burned, with dense body, and are salt-glazed.

The clays used are similar to those employed for making fireproofing, although they are somewhat more carefully selected with regard to plasticity and freedom from pyrite and limonite lumps. They must also burn dense at a moderate temperature.

The conduits are molded in auger stiff-mud machines. They are then removed from the cutting table on a pallet, and placed on a stand (Pl. XXXIV, Fig. 1), where the ends are trimmed smooth before the pieces are taken to the drying floor or drying tunnel. In drying the conduits are stood on end. The burning is commonly done in down-draft kilns, between cone 8 and 9, although some manufacturers burn lower than this. The average shrinkage that takes place in a long conduit is about as follows: Length freshly molded, 39 inches; length air dried, 37½ inches; length burned, 35 inches.

New Jersey conduit industry.—There has been a great demand for conduits in the large eastern cities during the last two years, many being used in New York city especially, in the construction of the rapid transit subway, so that the following large plants have been running almost exclusively on this line of work:

The National Fireproofing Company, Standard plant, Perth Amboy;
The National Clay Manufacturing Company, at South River;
The Globe Fireproofing Company, at Clayville.

Conduits are also occasionally made at the fireproofing factories.

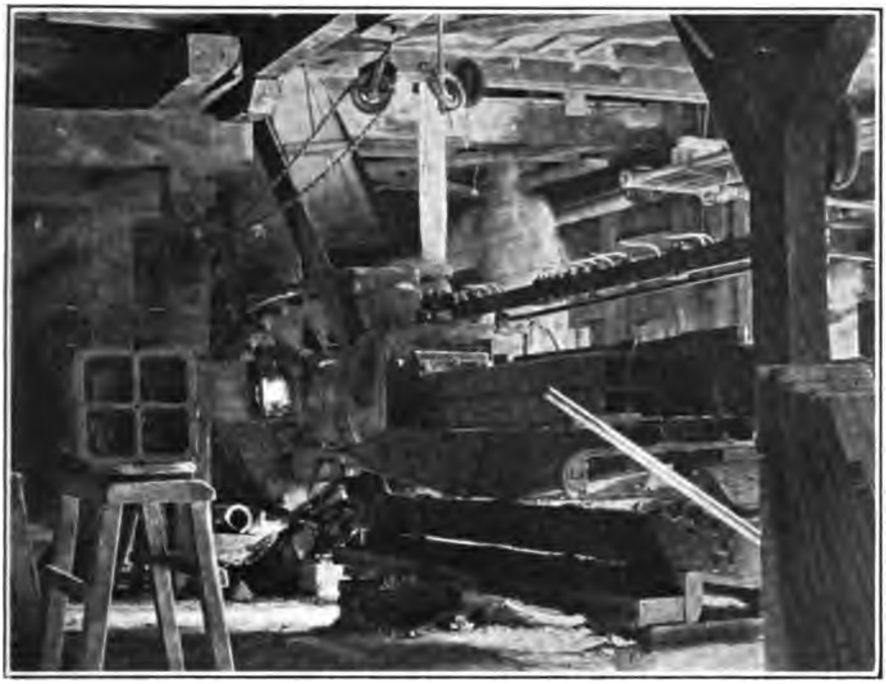

Fig. 1.

Stiff-mud machine for molding conduits. Globe Fireproofing Company, Clayville. Conduit, after molding, is placed on the stand at the left to have its edges trimmed smooth.

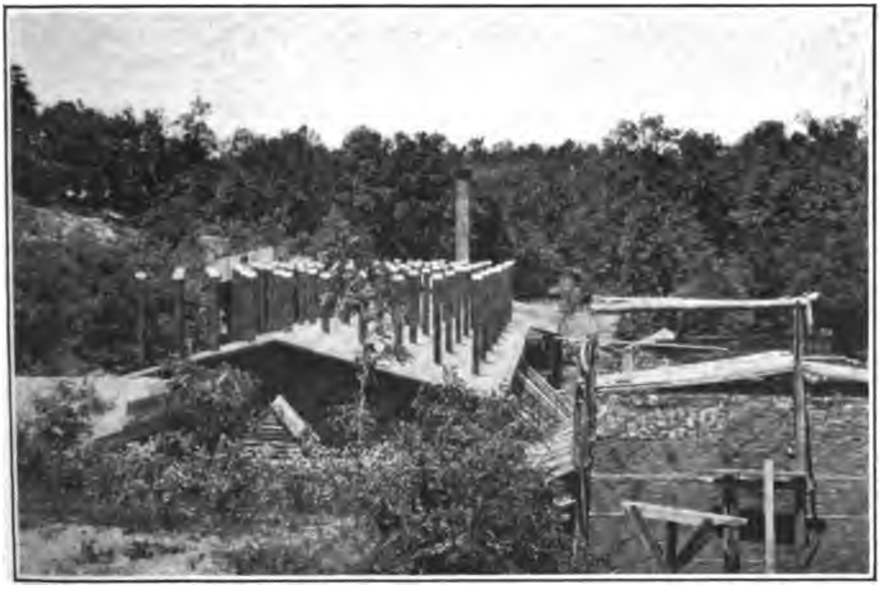

Fig. 2.

General view of hollow-brick works of John Braislin & Son, Crosswicks.

CHAPTER XIV.

FLOOR TILE, WALL TILE AND DRAIN TILE.

CONTENTS.

FLOOR TILE.

This includes those forms of tile, of varying colors and design, which are used for floors and pavements. Two kinds are distinguished, viz., unicolored tile, in which the entire piece is of uniform color, and encaustic tiles in which the colors of the design extend inward from the surface to a depth of about one-eighth inch, the rest of the tile being usually buff.

Raw materials.—Great care is necessary in the selection of the raw materials, for the clays used must be such that they will not form surface cracks after being dry pressed. These cracks are caused by the escape of the air compressed between the clay particles during the process of molding. The clay should also be free from any tendency to warp, or split in burning, and furthermore, the manufacturer must aim to adjust his mixtures, or select his clays, so that the greatest number of colors can be burned at one temperature. Clays used for floor tile should also be as free from soluble salts, as is the case with those employed for the manufacture of pressed brick or terra cotta, although, as pointed out by Langenbeck,[1] soluble lime salts may come from the coloring materials used. Thus the manganese and umber used for chocolates, browns or black is seldom free from gypsum.

Floor tile when white are commonly made of a mixture of white-burning clays, flint and feldspar. Buff-colored tiles and artificially colored ones are usually made from fire clays, while red tiles are often made from a red-burning clay or shale. A certain amount of flint and feldspar is usually added to the clay to regulate the shrinkage or degree of vitrification in burning.

Method of manufacture.—Floor tiles are always molded by the dry-press process in hand-power machines, the raw materials being first carefully ground and mixed. In making encaustic tile, the design is produced by using a framework of brass strips, arranged so as to form the outline of the colors making the pattern. This framework is placed in the mold and the colored clays sifted into their proper divisions to the depth of about one-fourth inch. The brass framework is then removed and the rest of the mold filled up with a buff-burning clay which forms the "backing." It is necessary that the backing should be as dense as the clays forming the upper surface or face of the tile, otherwise the latter may split in freezing weather due to the expansion of the water absorbed.

In burning the tile they are placed in saggers and burned in down-draft kilns. Those made in New Jersey are burned at from cone 9 to 12, depending on the character of the body and degree of vitrification to be obtained. The burning is regulated in some factories by cones and in others by trial pieces.

Character of product.—Owing to the conditions under which they are used, floor tile should possess sufficient hardness to resist abrasive action, sufficient transverse strength to resist knocks, and sufficient density to prevent excessive absorption of water. Many floor tiles, especially the white ones, show little or no absorption, but most of the other colors soak up from 1 per cent. to 5 per cent. of moisture or perhaps even more.

The absorption tests were made of a number of single-colored

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[1] Chemistry of Pottery, p. 155.

tile, part from New Jersey and part from other localities, with the following results:

Table showing absorption of floor tile.

Color.	*Per cent. of Absorption.*
White,	0 –0.031
Gray,	0 –0.5
Green,	1.6 –6.63
Red,	1.30–3.11
Blue,	0 –3.59
Light blue,	0.34–2.5
Black,	0 –5.39
Pink,	0.80–3.70
Light green,	0.86–4.44
Slate,	0.03–1.5
Red brown,	3.8 –4.7
Buff,	1.7 –3.3

Langenbeck[1] claims that floor tile should not take up more than 3 or 4 per cent. by weight of water, as otherwise it is difficult to keep the dirt from grinding into their pores.

New Jersey floor tile industry.—Floor tile are manufactured by the following firms in New Jersey:

Trent Tile Company, Trenton;
Old Bridge Enameled Tile Works, Old Bridge;
Eagle Tile Company, Keyport;
Mosaic Tiling Company, Matawan.

The clays used are mined only in part in New Jersey, some being obtained from Pennsylvania, Florida, North Carolina, and England. The products are shipped not only to various states but also to foreign countries.

WALL TILE.

These are quite different from floor tile in character of body and style of decoration. The body is made of white-burning clay, and is not burned to vitrification, but on the contrary is usually just hard enough to resist scratching with a knife. It is, therefore,

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[1] Chemistry of Pottery, p. 156.

very porous, and a series of tests showed an absorption ranging from 15.59 per cent. to 20.62 per cent.

Wall tile are molded in dry-press machines and burned first in saggers in a biscuit kiln. They are then glazed and fired in a muffle kiln at a much lower temperature. Many different shapes, colors and styles of decoration are now produced. In some cases the decoration is supplied by a relief design impressed on the surface of the clay during molding, in others different colored glazes are used, or a considerable variation may be obtained in the shades of one color by varying the thickness of the glaze over different parts of the tile. Print work and hand painting are also employed at times to ornament the ware.

The defects which wall tiles may show are warping, crazing or peeling of the glaze, as well as pin holes, bubbles or spots in latter. Imperfect tile are of course sorted out before shipment. The crazing may, however, sometimes appear after the tile has been in use for some time.

Glazed wall tiles are much used for interior decoration in hall ways, bathrooms, mantel pieces and other surfaces where cleanliness, brightness and ornament are desired.

The New Jersey wall tile industry.—Wall tiles are made in New Jersey by six different firms, but the clays used are obtained chiefly from other states.

The list of producers is as follows:

Trent Tile Company, Trenton;
Providential Tile Company, Trenton;
Pardee Tile Works, Perth Amboy;
Old Bridge Enameled Tile Works, Old Bridge;
Menlo Ceramic Tile Works, Menlo Park;
Maywood Art Tile Company, Maywood.

The value of tile produced in New Jersey in 1902 was $795.153.[1] This included all grades except draintile.

DRAINTILE.

A plastic clay capable of making a good dense building brick is generally adapted to the manufacture of draintile, and they are

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[1] Mineral Resources, U. S. Geol. Surv., 1902. Loc. cit.

made at many brickyards, the more plastic layers of the bank being used. Draintile are usually molded on stiff-mud machines, although at some of the smaller yards a handpower press is employed with satisfactory results.

The clays employed are the Alloway, Asbury, Cohansey, Cape May, and sometimes Clay Marl II. The tiles are commonly dried on pallet racks and set in the same kiln with the bricks for burning. Those made in New Jersey are mostly pipe tile, having a circular cross section. Among the firms making them are the following:

J. C. Dobbs, Collingswood.
D. F. Haines, Yorktown.
Everett Tilton, Toms River.
A. Brocklebank, Howell.
Dunlop & Lisk, Matawan.

The value of the draintile produced in New Jersey in 1902 was $33,020.[1]

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[1] Mineral Resources, U. S. Geol. Surv., 1902. Loc. cit.

CHAPTER XV.

THE POTTERY INDUSTRY.

CONTENTS.

INTRODUCTION.

Under the term of pottery there is included a great series of products for ornamental or domestic use ranging from the common red earthenware flowerpot to the highly artistic and delicate porcelain vase. The technology of the lower grades is comparatively simple, but for the manufacture of white earthenware or porcelain, the successful completion of the product calls for skill, intelligence and good materials.

There was a time when white-ware mixtures and glazes of the proper quality could be obtained only after long and tedious experimenting and the expenditure of much time and money. The day of this, however, cannot be said to be altogether past, for many potters are still groping in the dark. Modern ceramic technology, however, has worked wonders, and a knowledge of it proves invaluable to the progressive potter in aiding him to work out the proper combinations of body and glaze. It enables him to adjust them if they do not agree, or to find out in a comparatively short time where the trouble lies when failures occur.

To take advantage of the facts and principles of ceramic technology does not require a very profound knowledge of chemistry, and the potter who seeks and grasps them will advance rapidly, while, on the other hand, he who rejects them and carefully guards some elementary facts, as imaginary secrets of great value, does himself a positive injury. Freedom of discussion has proven an invaluable aid in other technical branches, and there is no apparent reason why it should not do the same for the pottery industry. The subject of ceramic technology in America has been behind that of Europe for many years, although it is now coming forward with rapid strides. The annual meetings of the American Ceramic Society form a centre where clay workers can gather, and both give and receive information without the necessity of disclosing any business secrets. Indeed, so successful have these meetings become that the printed transactions of the society form a most valuable series of works dealing in a technical and scientific way with clays and clay products.

In addition to this, ceramic schools have been established in several States, New Jersey among them, and provision thereby made for instruction in modern ceramic technology and investigation of allied subjects. The following statement regarding the Department of Ceramics at the State College, New Brunswick (Pl. XXXV), has been kindly prepared by Prof. C. W. Parmelee, head of the department.

Laboratory of the New Jersey School of Clay Working and Ceramics, New Brunswick, N. J.

THE DEPARTMENT OF CLAY WORKING AND CERAMICS AT THE STATE COLLEGE, NEW BRUNSWICK, N. J.

This school of clay working and ceramics was established by Legislative enactment in 1902 for the benefit of the clay-working industry of New Jersey, and it is maintained by an annual appropriation. Similar schools are numerous in Germany, and their usefulness has repeatedly been demonstrated. In the work of the department provision has been made for a careful study of the clays of the State and the methods of manufacture employed.

The equipment is housed in a commodious laboratory especially adapted and arranged for the purpose. This building is located on College property adjacent to the campus. The front of the main portion is of the Colonial style, plainly but well executed in buff brick.

The workshop contains nearly 1,700 square feet of floor space, which provides an admirable place for the machinery installed. Here is located the 30 horsepower electric motor. The power is distributed by two lines of shafting furnished with split steel pulleys. The brickmaking outfit (Pl. XXXVI) consists of an auger brick machine of a capacity of 20,000 brick a day, a horizontal pug mill and a down-cut board delivery table. Appliances for the potter and the tile maker also find place in this shop. The machinery for that purpose consists in part of the following articles: A dry pan or grog mill arranged for wet and dry grinding, a clay-mixing and preparing machine or a combined blunger, agitator, lawn screen, filter press and slip pump with a capacity of 500 to 1,000 pounds a day, a four-jar glaze mill, a large size ball mill, a combination pull-down and jigger combined, a potter's pug mill, a wad machine, a hand jigger, sieving machinery, a tile press and other necessary appliances, all of the latest design and representative of the chief types used in the manufacture of a wide range of wares.

In an adjacent room is a wet closet built of porous brick with a terra-cotta lumber ceiling. The outside is covered with a coat of cement. In this room may be stored unfinished clay wares which may be kept damp for a long period.

A kiln has been provided which is sufficiently large to hold a quantity of wares of various sorts. It is so constructed as to be used either as an updraft or a downdraft, thus representing the two chief types. Frit furnaces and an improved Seger furnace are also at hand. A Le Chatelier pyrometer and Seger cones have been purchased for use in study of the phenomena associated with high temperatures.

In an upper room is placed an extensive library containing the most important literature on clays and clay working. This literature represents the best thought of French, German, English and American investigators.

A collection of ceramic ware is in process of installation. Suitable cabinets have been arranged for containing this collection.

Inasmuch as this department is required to perform the twofold function of a school for instruction and a laboratory for investigation, a room has been set apart for the use of the director. It is furnished with the usual fixtures and scientific apparatus.

Two courses of instruction have been arranged, that of four years, leading to the degree of B.Sc.; a short course of two years, which is designed for young men who have had practical experience in clay working and are unable to take the longer term. A certificate is awarded for work done in the short course.

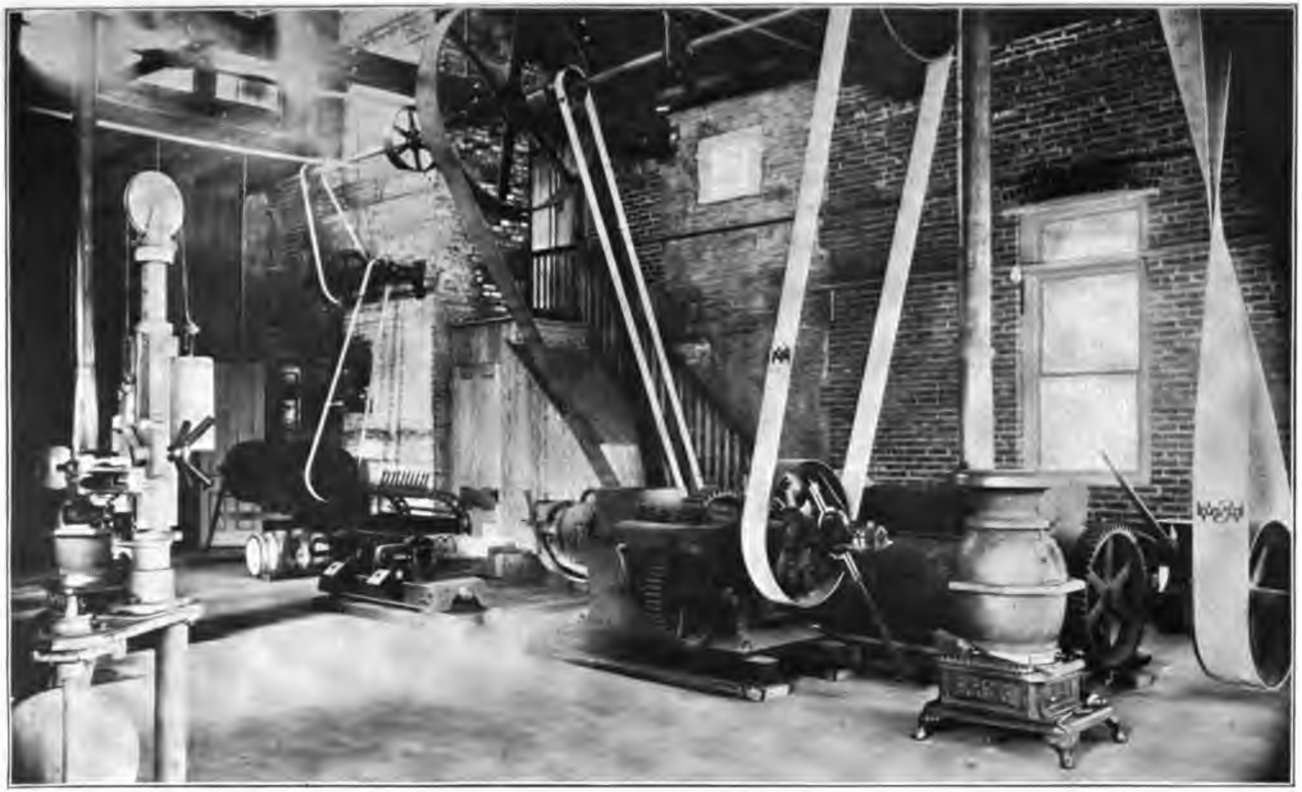
The instruction will be given in lectures and recitations on clay materials, clay products, bodies, glazes, fuels, kilns, etc., and is supplemented by practical work in the laboratory.

RAW MATERIALS.

New Jersey contains a number of grades of pottery clay, although not enough to supply all branches of the industry. It may not be out of place, therefore, to mention the characters of the different grades of clay required in pottery making, and to refer briefly to their distribution so far as they are found in the State.

Clays for common earthenware.—Red earthenware forms the lowest grade of pottery and is usually made from medium or poorer grades of clay. Those used are commonly red-burning,

PLATE XXXVI.



A portion of the clay-working machinery, New Jersey School of Ceramics.

of good plasticity, free from grit and burn porous but steel-hard at cone 05-03.

Clays of this grade are not at all scarce and they occur widely distributed over the State. In the northern counties many of the Pleistocene and post-Pleistocene clays found in the valleys are of the proper quality for flowerpots, and other earthenware vessels. A number of small potteries are supplied from deposits around Linden, near Elizabeth, and some of the red-burning Raritan clays are also adapted to earthenware work. In the central part of the State, the Clay Marl beds I and II are locally sufficiently free from grit to be used, but the Cohansey and Cape May clays are not as a rule sufficiently fusible to burn dense at a low cone. The Alloway clays, however, in the southern part of the State might also be used with success.

Stoneware clays.—Those commonly employed are semirefractory clays burning to a nearly impervious body at cones 5 to 7, but fusing at about cone 27, although some, dug about Woodbridge and South Amboy, do not fuse lower than cone 33 and can be classed as refractory clays. They should possess good plasticity, and a tensile strength of not less than 150 pounds per square inch, although many of the New Jersey stoneware clays do not much exceed 100 pounds per square inch. Freedom from soluble salts which will form a scum on the green ware, and freedom from warping and cracking in burning are also essential characters. The clay should not shrink excessively in burning, and should be of a degree of refractoriness to vitrify at the temperature necessary to melt the glaze. Sulphur in any form is an undesirable ingredient. The better grades of stoneware are commonly made of a mixture of two or more clays.

The Raritan beds around South Amboy form the main source of stoneware clay in the State, and large quantities are shipped from there to potteries in neighboring states. Aside from these, few stoneware clays are found in any of the other formations except the Alloway clay. Some of the Pleistocene clays may be found suitable for stoneware manufacture, but they would be much less refractory than those of the Raritan formation. None of the Cohansey clays examined, if used alone burn dense enough for stoneware manufacture. That from Loc. 207 (Toms River), might do for stoneware if mixed with a tighter burning clay.

Clays for white ware, porcelain and sanitary ware.—Two kinds of clay are used in the manufacture of these grades of ware, viz., kaolin and ball clay. No kaolin of suitable quality has ever been found in New Jersey, nor is there much chance of finding any—indeed, it is extremely doubtful whether any exists, the so-called "kaolin" of the Woodbridge district not being a kaolin at all but a micaceous sand.

Ball clay is found only in the Raritan formation especially near South River, and there is no likelihood of its being found in other formations in the State. Since the New Jersey ball clays show a tendency to crack in burning they cannot be used in large quantities in a pottery body. A ball clay should be plastic, burn white, and not warp or crack in drying or burning, and should burn steel-hard at cone 8 or lower.

The other raw materials used in white-ware bodies are ground flint and spar, but neither of these is found in commercial quantity in New Jersey, although veins of them may possibly occur in the Highland region. The crude materials are brought to Trenton in large quantities from other states and milled there.

The following table gives the composition of several American ball clays and kaolins, as well as of foreign clays, these latter being added for the purpose of comparison:

Analyses of ball clays.

	1.	*2.*	*3.*	*4.*	*5.*	*6.*
Silica (SiO_2),	46.11	44.40	44.89	56.40	48.99	59.61
Alumina (Al_2O_3),	39.55	38.34	37.269	30.00	32.11	26.81
Ferrous oxide (FeO),	....	....	.....	....	2.34	2.03
Ferric oxide (Fe_2O_3),	0.35	0.86	0.97	....	....	....
Lime, (CaO),	....	....	0.41	0.40	0.43	0.82
Magnesia (MgO),	0.13	....	0.19	Tr.	0.22	0.44
Soda (Na_2O),	....	0.18	1.124	2.01	....	....
Potash (K_2O),	....	0.26	0.317	3.26	3.31	3.57
Water (H_2O),	13.78	13.50	14.47	7.93	9.63	7.46
Sulphur trioxide (SO_3),	0.07	....	.....	....	....	....
Titanium oxide (TiO_2),	1.20	....	.....	....	....	....
Moisture,	....	1.10	.....	....	....	2.33

1, Edgar, Fla.; 2, Burt Creek, N. J.; 3, South Amboy, N. J.; 4, Mayfield, Ky.; 5 and 6, "Poole" clay from Wareham, England.

Analyses of washed Kaolins.

	1.	2.	3.	4.	5.	6.	7.	8.
Silica (SiO_2), ...	46.278	45.70	46.50	50.96	48.26	47.71	46.87	59.42
Alumina (Al_2O_3), ...	36.25	40.61	37.40	33.30	37.64	36.78	38.00	27.15
Ferric oxide (Fe_2O_3),	1.644	1.39	0.80	0.82	0.46	....	0.89	1.77
Lime (CaO), ...	0.192	0.45	Tr.	....	0.06	....	Tr.	....
Magnesia (MgO), ...	0.321	0.09	....	2.42	Tr.	....	0.35	0.52
Alkalies (Na_2O, K_2O),	2.536	2.82	1.1	....	1.56	2.58	1.22	[a]1.50
Water (H_2O), ...	13.535	8.98	12.49	8.95	12.02	13.03	12.70	9.85

[a] All potash (K_2O.)

1, Brandywine Summit, Pa.; 2, Harris Clay Company, near Webster, N. C.; 3, West Cornwall, Conn.; 4, Glen Loch, Pa.; 5, Cornwall, England; 6, Coussac-Bonneval, France; 7, Zettlitz, Bohemia; 8, Pilsen, Bohemia.

MANUFACTURE OF POTTERY.

In making pottery there are certain steps that are common to all grades of ware, but the care of preparation, and the number of steps is increased in the manufacture of the higher grades.

The different steps may be grouped as follows:

- Preparation,
  - Washing.
  - Weathering.
- Tempering,
  - Chaser mills.
  - Pug mills.
  - Tables.
- Molding,
  - Turning.
  - Jollying or jigging.
  - Casting.
  - Pressing.
- Drying.
- Burning.
- Glazing.
- Decorating.

Clay is sometimes exposed to the weather as a preliminary means of preparation, but the custom is not a widespread one. High-grade clays are usually freed from grit and sand by a washing process (see Chap. I).

Tempering.

Chaser mills are sometimes used at stoneware factories, but none are in operation in New Jersey. They consist of a circular iron pan in which there revolves a frame bearing 2 narrow iron wheels, 30 to 36 inches in diameter. As this frame revolves, the wheels by means of a gearing, travel from the centre to the circumference of the pan and then back. The clay and water are placed in the pan and the action of the wheels grinds and cuts it up, the tempering taking from one to two hours. The action of such a machine is quite thorough, but considerable power is required to operate it.

Pug mills.—The principle of these is similar to those used in brick manufacture (p. 225), but they differ in being upright or vertical. The clay and water are added at the top and slowly mixed, being at the same time forced down to the opening at the bottom of the box.

Tables.—Kneading tables are used at some factories for working the clay by machine instead of wedging it by hand. Although much used abroad, their introduction into this country has been rather restricted. The machine consists of a circular table about 6 feet in diameter, the upper surface of which slopes outward. On this are 2 conical rolls, 20 to 30 inches in diameter and about 8 inches wide. These rolls have corrugated rims, and are attached to opposite ends of a horizontal axis, having a slight vertical play. The clay is laid on the table and as the rolls travel around on it, the clay is spread out into a broad band. A second axle carries 2 other pairs of rolls of the same shape but smaller size, which travel around in a horizontal plane. These rolls press the band of clay together again. In this way the clay is subjected to alternating vertical and lateral pressure and all air spaces are thus closed. The rolls make 10 to 12 revolutions per minute, and the machine kneads 2 to 3 charges of 350 pounds per hour.

Molding.

After the clay has been properly tempered, the next step in the process of manufacture is molding. As indicated above this is done in four different ways, the clay having first been thoroughly kneaded, usually by hand, in order to insure its complete homogeneity and freedom from all air bubbles.

Turning.—This is done on a rapidly revolving horizontal wheel, the potter taking a lump of clay and placing it on a rapidly revolving disk. Wetting the surface with a slip of clay and water, he gradually works the revolving mass into the desired form. After being shaped, the object is then detached from the wheel by running a thin wire underneath it, and it is set aside to dry. Crocks, jugs and similar articles are turned, this method being often employed for molding common stoneware, and sometimes for earthenware.

Jollying or jigging.—This is a more rapid method than turning, and the clay to be used for this purpose is tempered to a much softer consistency. The jolly is a wheel fitted with a hollow head to receive the plaster mold, the interior of which is the same shape as the exterior of the object to be molded. A lump of clay is placed in the revolving mold and is gradually forced up around the sides of the latter. In the beginning of the operation this is done by the fingers, but finally a metallic arm or templet is used, which is brought down into the mold and serves to shape the interior of the object. Cups, crocks, jugs, pitchers and even wash basins can be molded in this manner. Articles with tapering necks are generally jollied in two parts, which are subsequently cemented together with slip, while handles are stamped out separately and afterwards fastened on the article.

A modification of jollying, used for making plates and saucers, consists in having a plaster mold, the surface of which has the same shape as the interior or upper surface of the plate to be formed. The potter's assistant takes a piece of clay of the desired size, and pounds it to a flat cake, called a "bat," which is laid on the mold; he then shapes the other side or bottom of the plate by pressing a wooden templet of the proper profile against it as it revolves. A modification of this machine is one used for flower pots, in which the mold is of steel, and instead of a templet, a solid piece, also of metal, and fitting the interior surface of the pot, is brought down into the mold.

Pressing.—Ewers and vessels of oval or elliptical section are usually made by means of sectional molds, consisting of two or three pieces, the inner surface of which conforms to the outer surface of the object to be molded. A slab of clay is laid in each section and carefully pressed in, the mold put together, and all seams smoothed with a wet sponge. After drying for a few hours the parts of the mold are lifted off. Clocks, lamps, water pitchers and similar articles are made in this manner.

Casting.—This consists in pouring a slip of clay into a porous mold, which absorbs some of the water, and causes a thin layer of the clay to adhere to the interior surface of the mold. In order to produce a slip with less water, some alkaline salt is added to the mixture. When the layer on the inner surface of the mold is sufficiently thick, the mold is inverted and the remaining slip is poured out, the mold being removed in a few hours. This method is extensively used in making thin porcelain ornaments, as well as many white earthenware objects. It is also used for making belleek.

Subsequent Steps.

Drying.—The ware after it has been molded is usually set on shelves in steam-heated rooms to dry.

From this point on, the method of manufacture varies somewhat, depending on the kind of ware that is to be produced.

Burning.—Common earthenware and stoneware are usually burned in round kilns, or more rarely in rectangular ones. For common earthenware up-draft kilns are mostly employed, but for stoneware the down-draft type predominates. The wares are piled in the kiln on top of each other, and also nested whenever possible. Red earthenware is not burned above cone 05, but the stoneware in New Jersey is burned from cones 5 to 8. The time of burning depends partly on the size of the kiln, and partly on the clay, ranging from 30 to 90 hours.

White earthenware and china, on account of their color, have to be burned in saggers, which are oval or cylindrical receptacles with a flat bottom, about 20 inches in diameter and a height usually of about 8 inches.

The saggers are filled with unburned ware and set one on top of the other, so that the bottom of one forms a cover for the one below it, the joint between the two being closed by a strip of "wad" clay. The use of these saggers is to protect the ware from the smoke and gases of the kiln fire. The chief requisite of a sagger clay is that it shall stand slightly more heat than the ware placed in it, repeated firing and cooling, as well as handling without breaking. Saggers are generally made from a plastic, refractory clay, with the maximum admixture of grog, *i. e.*, a powder made of old saggers, broken fire brick, etc. The kilns are generally circular down-draft, having a diameter of from 15 to 25 feet. The temperature reached in burning varies. White earthenware is commonly burned at from cone 8 to 9, while porcelain may be fired as high as cone 12 or 13. Since the color of ferrous iron is less noticeable than ferric iron, the fires should be reducing during at least the last part of the firing, and the kiln is then cooled down as rapidly as possible to prevent the oxidation of whatever iron may be in the clay.

Glazing pottery.—Common red earthenware is rarely glazed, but if this is done, the glaze consists of an easily fusible mixture of metallic oxides, such as lead, together with quartz, and sometimes boracic acid.

Stoneware is usually slip glazed or salt glazed. A slip glaze consists of an easily fusible clay, which will melt to a colored glaze at the temperature reached in burning the stoneware. This is stirred up in water to a slip and the green ware dipped into it, or if the articles are very large, the slip may be applied with a brush. When placed in the kiln and burned, the slip melts to an enamel over the surface of the ware. One of the slip clays most used is that from Albany, N. Y., which has been found suited to a wide range of clays. It melts to an enamel at about cone 6. Another slip clay is dug near Rowley, Mich., and a third near Seneca Falls, N. Y.

When the wares are to be salt glazed, they are placed in the kiln, unprotected from the flames. As soon as the kiln has reached its highest temperature, the salt is put in the fire places, one or two shovels full at a time, at regular intervals, so that the addition of the salt may extend over several hours. When the salt is placed in the fires the heat volatilizes it, and the vapors in passing up through the kiln unite with the clay, forming a glaze on the surface of the ware. Many clays are capable of taking a good salt glaze, some take a poor one, and others do not glaze at all.

From experiments recently made by L. E. Barringer[1] it seems that a clay may be either too aluminous or too siliceous to be successfully salt glazed, but that if the process of salt glazing is properly carried out, clays in which the proportion[2] of silica to alumina is more than 4.6 to 1 and less than 12.5 to 1, are capable of receiving a glaze. The degree of fineness of the free silica in the clay makes a little difference. The finer the sand the lighter the color of the glaze.

Barringer also found that, contrary to what was usually supposed, a considerable quantity of soluble salts, as much as 3 per cent., could be present in a clay without seriously interfering with the salt glazing, when conducted at cone 8.

Glazing white earthenware and china.—In this grade of ware the glazing and burning are not done in one operation, as in stoneware, but the ware is first burned to steel hardness, then dipped in the glaze, and burned a second time. In the case of white earthenware, the second burning is done at a lower temperature, and in the case of china it is done at a higher temperature than the first. The glazes for white earthenware and porcelain are complex compounds of an artificial character. They consist of a mixture of acids and bases combined according to a definite formula, in such proportions that they will melt to a glass at the temperature reached in burning. A glaze thus produced must furthermore agree with the body in its shrinkage, and coefficient of expansion, in order to prevent various defects, such as crazing, peeling, etc. A discussion of the composition and methods of calculating glaze formulas hardly lies within the province of this report, and those wishing to become acquainted with this subject, are referred to a most excellent little manual of Ceramic Calculations issued by the American Ceramic Society.[3]

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[1] Trans. Amer. Ceramic Society, Vol. IV, p. 223.

[2] Molecular ratio.

[3] Purchasable for $1.00 from S. G. Burt, Rookwood Pottery, Cincinnati, O.

Decoration.—Common earthenware is rarely decorated, but stoneware for domestic use, if salt glazed, may sometimes be decorated by tracing designs in the green clay and filling these in with cobalt or other coloring matter.

White earthenware and porcelain are often elaborately decorated, either under or over the glaze. The form of decoration most often seen is print work. This is done by printing a copper-plate design on special paper, and applying this to the surface of the ware. After being allowed to stand for a few hours the paper is washed off, but the ink of the design is retained on the surface of the ware. The colors are then fixed by firing in a muffle kiln at a dull red heat. The print work is sometimes "filled in" and elaborated by brush work, or on better grades of ware the entire design may be hand painted. The more delicate colors as well as gold have to be applied over the glaze as they are destroyed by hard firing. With chromolithography a soft and ornamental multicolored design can be produced at one operation, but it is but little used in this country, although productive of beautiful effects.

Electrical porcelain.—This forms a separate branch of the clay-working industry. These insulating materials are made of a mixture of white-burning clays and molded by the dry-press process. It is necessary to burn them to vitrification, and none are probably burned below cone 10 and some at cone 12. They are usually glazed.

Sanitary ware is made sometimes from the same classes of clay as white earthenware, but the body is usually vitrified or nearly so, and is glazed. The ware is formed by hand in plaster molds, and great care has to be exercised in drying and burning.

Bath tubs and washtubs.—These are commonly made from buff-burning clays, such as fire clays and retort clays, and covered with both a white slip and a glaze. The lining is usually vitrified, but not the body, and they are termed porcelain lined. The molding, drying and burning of such a large object as a bath tub requires much care and time. The molding is done by hand in large plaster molds. The wares are burned commonly at from cones 9 to 10, or perhaps slightly higher. A finished bath tub may weigh as much as 1,100 pounds.

THE NEW JERSEY POTTERY INDUSTRY.

Early history.—The State of New Jersey can probably lay claim to having one of the oldest potteries in the country, for E. A. Barber, in his work on the Pottery and Porcelain of the United States, notes that the remains of an old kiln fire hole were found a mile or two below South Amboy, and that it is probably a relic of the earlier pottery ware made on this continent, "and most probably built by the Dutch to make stewpans and pots."

Dr. Daniel Coxe, a former governor of West New Jersey, was probably the first to make white ware in the Colonies, for he erected a pottery at Burlington, N. J., before 1685. Barber gives the following "quaint and interesting reference to it as copied from an inventory of property offered for sale in 1688":

"I have erected a pottery att Burlington for white and chiney ware a greate quantity to ye value of 1200li have already been made and vended in ye Country, neighbour Colonies and ye Islands of Barbadoes and Jamaica, where they are in great request. I have two houses and kills with all necessary implements, diverse workmen, and other servants. Have expended thereon about 2000£."

Later, about 1800, a stoneware potter by the name of Van Wickle, located at Old Bridge, now Herbertsville, and in 1820 J. H. Remmey established a pottery at South Amboy, N. J. Similar ware was also made at Roundabout (now Sayreville), on the Raritan, about 1802. Another stoneware pottery was started in Elizabeth, N. J., in 1816, and operated later as a yellow and rockingham ware factory.[1] Still later it passed into the hands of L. B. Beerbauer & Company, and was used for making ironstone china.

In 1825 the Jersey Porcelain & Earthenware Company was incorporated in the town of Jersey, Bergen county, and succeeded in the following year in taking a silver medal at the exhibition of the Franklin Institute, in Philadelphia, for "the best china from American materials." These works passed into the hands of

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[1] E. A. Barber, Pottery and Porcelain of the United States, p. 117.

Messrs. D. & J. Henderson about 1829, who in 1830 exhibited a "flint stoneware." Three years later, or in 1833, David Henderson organized the American Pottery Manufacturing Company, "for the purpose of manufacturing the various kinds of pottery at the works already erected." This factory during the next seven years produced ware with a buff or cream-colored body, which was much used. It is interesting to note that these works were the first in America to use the English method of transfer printing in decoration.

About 1843 the name of the factory was changed to the Jersey City Pottery Company, and it is stated by Mr. Barber,[1] from whose book the above description is taken, that many of the "best potters of the old school in the United States learned their trade at this factory." The pottery subsequently passed into other hands, and in 1892 the old buildings, which had stood for 65 years and from which many fine pieces of work had been turned out, were finally demolished.

At Trenton.—The pottery industry at Trenton, which at the present day has assumed such vast proportions, had its birth probably about 1852, at which time Hattersly's pottery was in operation with one small kiln 6 feet in diameter. Since that time the increase has been steady, but sure, and the events can perhaps be best listed chronologically as follows:

1852. Taylor & Speeler began manufacture of yellow and rockingham ware, adding white granite in 1856.
1853. Millington & Astbury organized first sanitary ware pottery in America.
1853. Wm. Young's Sons began manufacture of C. C. ware in leased pottery located on present site of City Pottery Company works.
1857. Wm. Young leased Hattersly pottery for a term of five years, but later built his own pottery.
1859. Rhodes & Yates. First pottery to make white granite and C. C. ware exclusively.
1859-1891. Trenton China Company.

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[1] E. A. Barber, Pottery and Porcelain of the United States, p. 117.

1862. Greenwood Pottery Company organized, started by W. Tams and W. Barnard, and operated in turn under name of Stephens, Tams & Co., and Breasley & Co., the present name being adopted in 1868.

1863. Etruria pottery built by Bloor, Ott & Booth; succeeded by Bloor, Ott & Brewer in 1864. Shortly after changed to Ott & Brown. Later it became the Cook pottery.

1863. Coxon & Co. started the Empire pottery.

1863. John Moses founded a pottery.

1869. James Moses bought the Mercer pottery from Mr. Thompson.

1869-1889. Union Pottery Company.

1869. James Mayer founded the Arsenal pottery.

1873. East Trenton Pottery Company.

1879. International Pottery Company began operations on site of Speeler's old pottery.

1879. New Jersey pottery organized, but re-organized in 1883 under name of Union Pottery Company.

1879. Burroughs & Mountford pottery established in what was formerly the Eagle pottery.

1879. The Willets Manufacturing Company bought the Wm. Young's Sons' pottery.

1880. Prospect Hill pottery started by Dale & Davis.

1881. Trenton China Company established.

1881. Enterprise Pottery Company established.

1881. Crescent pottery established.

1882. Harris Manufacturing Company began manufacture of porous tile.

1882. Thos. Maddock & Sons took the old Millington & Astbury pottery.

1884. Delaware pottery started.

1889. Ceramic Art Company organized.

1890. Greenwood China Company started.

1890. Crown Porcelain Works established by Barlow & Marsh.

1891. Imperial Porcelain Company organized.

1892. Keystone Pottery Company began operations.

1892. Trenton Potteries Company began operations and purchased the Crescent, Delaware, Empire and Equitable potteries. Also built the Ideal.
1893. Maddock Pottery Company organized and purchased plant formerly owned by the Trenton China Company.
1894. Bellmark Pottery Company.
1894. Hart Brewer Pottery Company, started originally as Isaac Davis pottery, and passed in turn into the hands of Fell & Throp and then of the present owners.
1895. Electrical Porcelain & Manufacturing Company.
1895. Economy Pottery Company.
1895. John Maddock & Sons.
1896. Monument Pottery Company.
1896. Artistic Porcelain Company.
1897. Cook Pottery Company.
1897. Sanitary & Earthenware Specialty Company.
1899. Star Porcelain Company.
1900. Diamond Porcelain Company.
1901. Elite Pottery Company.
1901. Acme Sanitary Pottery Company.
1902. Fidelity Pottery Company, successors to the Egyptian pottery.
1902. Hudson Porcelain Company.
1903. Morris & Wilmore Company.

In 1852 there was one pottery with one kiln. In 1879 there were 19 potteries with 57 kilns, producing about $2,000,000 worth of wares annually. In 1883 the number of potteries had increased to 23 with 110 kilns and in 1903 there are 41 with 258 kilns.

Up to 1863 the products included white, sanitary, yellow, and rockingham ware; in 1903 they include china, C. C. ware, white granite ware, sanitary ware, belleek, and porcelain.

The technical advances that have taken place in the pottery industry at Trenton have been well summarized recently by Mr. E. C. Stover.[1] One of the early improvements was the production of a ware that would not craze, following which came the

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[1] Transactions American Ceramic Society, Vol. II, p. 147.

introduction of Belleek porcelain by Messrs. Ott & Brewer. Later a superior quality of hotel china was introduced by the Greenwood Pottery Company which at the present day has secured a wide and enviable reputation. The production of a good quality of sanitary ware was another important development, and the manufacture of this has grown, so that at the present day, Trenton is without question at the head of this branch of the pottery industry. The Trenton potter has not stopped, however, at a satisfactory body, but makes successfully the most complicated forms of sanitary appliances, much of this ware being exported.

Still another important advance has been made in the manufacture of fire-clay bath tubs and sinks which are made in one firing. In this line of work Trenton also leads, having the largest single pottery in the world, devoted exclusively to the manufacture of these goods. The product comes into successful competition with foreign wares.

Trenton is the most important potting centre in New Jersey, and in fact is one of the two great pottery centres of the United States, East Liverpool, Ohio, being the other. The wares produced at Trenton include table and toilet wares, sanitary wares, ornamental articles, druggist supplies, door knobs, electrical goods, hardware trimmings, washtubs, bath tubs, sinks, etc. The statistics of production are given on another page.

Trenton has assumed its importance as a pottery centre, not because of a wealth of raw materials in the immediate neighborhood, but rather because of its central location as regards transportation facilities, for probably the only New Jersey raw materials used by most of the Trenton potters are sagger and wad clays. The others, such as kaolin, flint and spar, are all brought from other states, as is also most of the ball clay. The sanitary ware branch of the potting trade is the one that has developed most rapidly in Trenton, so that more of this class of ware is now produced there than at any other locality in the United States.

At other localities.—Outside of Trenton the manufacture of pottery is carried on at scattered points in the State, the product consisting usually of either red earthenware or stoneware. Sanitary ware is made by the Camden Pottery Company, at Camden, and washtubs and sinks are produced by the Perth Amboy Ceramic Company, of Perth Amboy.

The clays used by these other potteries outside of Trenton are in most cases obtained from the Middlesex district.

The following list includes all of the potteries outside of Trenton, so far as the Survey could determine them:

Ironside pottery, Bordentown—Sanitary ware;
Smith & Son, Bridgeton—Earthenware;
Camden Pottery Company, Camden—Sanitary ware;
Julius Einsiedel, Egg Harbor City—Earthenware;
The Fulper Pottery Company, at Flemington, established in 1805 as an earthenware factory, but now making stoneware exclusively;
Chas. Wingender & Bro., Haddonfield—Stoneware and Earthenware;
Marion Pottery Works, Jersey City—Porous cups for batteries;
Dunlop & Lisk, Matawan—Stoneware and earthenware;
Belmont Avenue pottery, Belmont Ave., Newark—Stoneware and earthenware;
Excelsior Pottery Works, Newark—Earthenware;
Union Pottery & Drainpipe Works, Newark—Earthenware;
Perth Amboy Ceramic Company, Perth Amboy—Sinks and tubs;
C. L. & H. A. Poillion, Woodbridge;
Rahway Pottery Works, Rahway.

The value of the pottery manufactured in New Jersey in 1902 is as follows:[1]

Value of New Jersey Pottery in 1902.

Earthenware and stoneware,	$59,820
C. C. ware,	581,267
White granite and semivitreous porcelain ware,	1,431,270
China,	680,368
Bone china, Delft and belleek ware,	90,840
Sanitary ware,	2,807,322
Porcelain electrical supplies,	358,496
Total,	$6,009,383

Of this amount Trenton produced $5,545,580, which, together with $151,831 of miscellaneous pottery products not enumerated in the above table, was 23.61 per cent. of the entire production for the United States.

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[1] Mineral Resources, U. S. Geol. Surv., 1902, Chap. on the Clay-working Industry.

CHAPTER XVI.

THE FIRE CLAYS AND FIRE-BRICK INDUSTRY.

CONTENTS.

PROPERTIES OF FIRE CLAY.

Definition.—Strictly speaking a fire clay is one whose fusion point lies at least above that of cone 27, but the term is somewhat loosely used and often applied to clays of even low refractoriness. Aside from refractoriness, which is the most important property of a fire clay and the one possessed by all true ones, they vary widely, showing great differences in plasticity, density, shrinkage, tensile strength and color. Since the resistance of a fire clay to heat is governed primarily by its chemical composition, and secondarily by its fineness of grain, it may be well to consider first the former property.

Chemical composition.—Fire clays (see Appendix C., Middlesex county), contain practically all the substances usually determined by the ultimate analysis,[1] but in every good fire clay the

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[1] See p. 49; also, pp. 315, 319, 320.

total percentage of certain fluxing impurities such as ferric oxide, lime, magnesia and alkalies, is small. This is necessarily the case, since, if the fluxing impurities were present in large quantities, the clay would fuse at comparatively low temperatures and could not be classed as refractory.

Effect of silica.—It is found, however, that clays running low in fluxes, but high in silica, may also show poor refractoriness. If we compare two fire clays of low-flux contents, but high silica in one case, and low silica in the other, it is found that, other things being equal, the high silica clay is less refractory than the other. This indicates that a high percentage of silica, as well as a high percentage of the fluxes mentioned above, diminishes the refractoriness of the clay. We might therefore term the iron oxide, lime, magnesia and alkalies low-temperature fluxes and the silica a high-temperature flux.

In any fire clay, some of the silica is combined chemically with the alumina in the form of the mineral kaolinite (p. 47), while the balance is probably there in the form of quartz.[1] If kaolinite alone is heated, its refractoriness is found to be high, for its fusion point is the same as cone 36 of the Seger series (see p. 102), and the refractoriness of quartz or silica alone is nearly as high, but if these two minerals are mixed together in varying proportions, then the fusion point of the mixtures will in every case be lower than that of either silica or kaolinite alone.

This fact was pointed out some years ago by Herman Seger, the German ceramic technologist, who made up a series of mixtures of alumina and silica, and kaolin and silica. In the former series of mixtures the quantity of alumina in each case was the same, but the amount of silica was increased. Starting with 1 part of alumina[2] to one of silica by volume (91.5 of alumina to

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[1] There cannot be many silicate minerals such as feldspar, mica, etc., in a fire clay, otherwise the percentage of alkalies, magnesia, lime and iron oxide would be higher than it usually is, so that the balance of the silica must be quartz.

[2] What is meant here is parts by volume, which would not be the same as parts by weight, because the 2 substances have different specific weights, hence 1 alumina to 1 silica per volume would be 91.5 per cent. alumina to 8.5 silica by weight.

8.5 of silica by weight), a mixture the fusion point of which was the same as that of cone 37, he found that the refractoriness decreased until a mixture of 1 part alumina to 17 parts of silica (10 alumina to 90 silica by weight) was reached. The fusing point of this mixture was cone 29. A further increase in the amount of silica began to increase steadily the refractoriness. This shows that silica added to alumina in certain proportions acts as a flux at high temperatures.

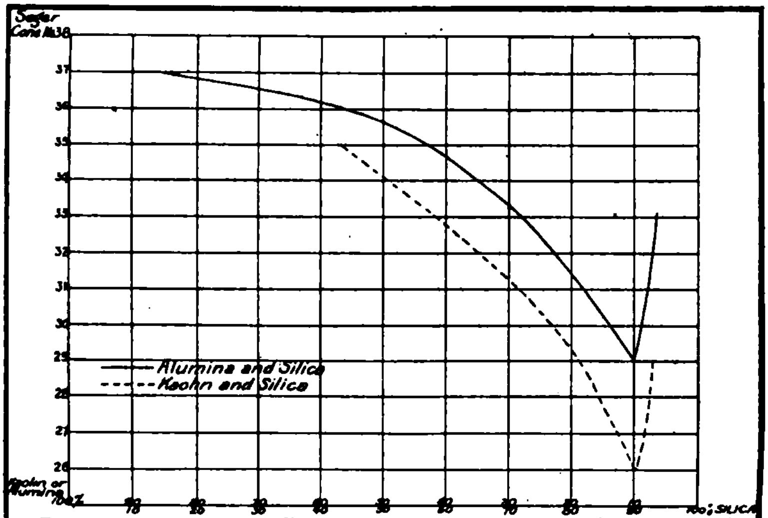

Fig 40. Diagram showing effect of Silica on the fusion point, when mixed with Alumina and Kaolin, from Seger's experiments.

If now silica is mixed with kaolinite in the same manner, a similar lowering of the refractoriness of the mass takes place down to a certain point beyond which the fusion point again rises. These experiments of Seger are shown graphically in Fig. 40, in which the horizontal lines represent the different cone numbers from 26 to 38 inclusive. The divisions on the lower line represent percentages of alumina or kaolin measured above the line, 100 per cent. being at the left end, and percentages of silica measured below the line, 100 per cent. being at the right end. The solid curve represents the mixture of silica and alumina, while the dotted curve represents mixtures of kaolin and silica. An inspection of these curves, shows quite clearly how an increase in the percentage of silica up to a certain point causes a dropping of the fusion point, but that a further increase in the silica contents raises it again, although not quite as high as it originally was.

It will be seen from a comparison of these two curves that the kaolinite-silica mixtures have lower refractoriness than the pure silica-alumina mixtures. This effect of silica will no doubt be at first accepted with doubt by many brick manufacturers, who have considered that silica or sand adds to the refractoriness of clay in burning, but it should be remembered that common bricks are burned at a much lower temperature than that at which the alumina and silica unite.

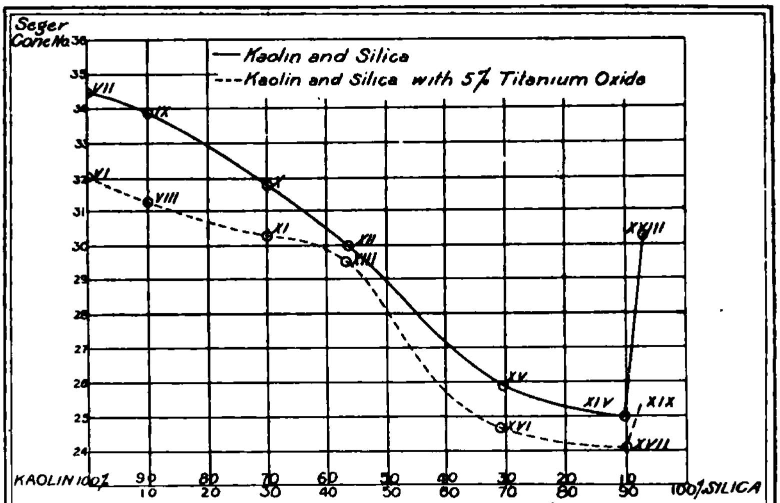

Fig. 41. Diagram showing the effects of silica and titanium on the fusibility of kaolin.

In testing the New Jersey fire clays in the Deville furnace, the results obtained seemed to bear out Seger's experiments, but did not agree with them very closely, and in fact the fusion points were usually lower than would be expected from his curve. Accordingly a series of mixtures of a white-burning clay[1] and finely-

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[1] This clay was practically free from fluxes, and, hence, had very nearly the composition of kaolinite.

ground quartz were made up and their fusion points tested in the Deville furnace. These results were plotted in a curve (Fig. 41), which in its general form agrees with that of Seger, but shows lower cones of fusion for corresponding mixtures. The results obtained with New Jersey clays seem to agree more closely with this curve than they did with Seger's (Fig. 40).

Applying the facts obtained from these experiments to a study of fire clays it would seem that, other things being equal, those fire clays will be the most refractory which contain the lowest percentage of fluxing impurities such as iron, lime, magnesia and alkalies, and the smallest quantity of sand or silica not in combination with the alumina of kaolinite.

Let us see how these facts apply to some New Jersey clays, analyses and fusion points of which are given below.

Analyses of some New Jersey fire clays.

1	2 Silica (SiO_2)	3 Alumina (Al_2O_3)	4 Ferric oxide (Fe_2O_3)	5 Lime (CaO)	6 Magnesia (MgO)	7 Alkalies (Na_2O, K_2O)	8 Titanic oxide (TiO_2)	9 Water (H_2O)	10 Clay base.	11 Silica (free).	12 Total fluxes.[1]	13 Cone of fusion.
1	50.60	34.35	0.78	tr.	tr.	tr.	1.62	12.90	87.20	10.65	0.78	34+
2	51.56	33.13	0.78		0.12		1.91	12.50	83.94	13.25	0.90	34+
3	68.67	21.46	0.78		1.35		1.34	6.40	52.82	43.71	2.13	27
4	67.26	23.36	1.63	0.25	. . .	0.65	with Al_2O_3	6.94	57.47	40.09	2.53	27
5	45.76	39.05	tr.	0.95	0.04	. . .	with Al_2O_3	14.46	98.93	0.24	0.99	34+
6	69.78	19.86	0.62		1.24		1.96	6.54	49.50	46.68	1.86	30
7	40.64	41.19	3.27	0.65	. . .	. . .	with Al_2O_3	14.74	96.57	. . . .	3.92	29

[1] Exclusive of titanium. This probably stands intermediate between silica, and the other fluxes, in its fluxing power, but nearest to silica.

No. 1. No. 1 fire clay, M. D. Valentine & Bro. (Loc. 14), Woodbridge.
2. No. 1 fire clay, Anness & Potter (Loc. 6), Woodbridge.
3. Top-sandy clay, Anness & Potter (Loc. 6), Woodbridge.
4. Fire-mortar clay, Maurer & Son (Loc. 24), Woodbridge.
5. Ware clay, W. H. Cutter (Loc. 29), Woodbridge.
6. No. 1 sandy clay, McHose Bros. (Loc. 45), Florida Grove.
7. No. 1 blue fire clay, J. R. Crossman (Loc. 65), Burt Creek.

In this table the second to ninth columns inclusive represent the determinations made in the ultimate analysis. A partial analysis, only, of some of the samples was available, and in these cases the difference between the sum of the substances determined and 100 was taken as representing the sum of the lime, magnesia and alkalies. The clay base given in the tenth column was obtained by considering the alumina to be contained in kaolinite, figuring the amount of silica necessary to unite with it, and adding the combined water to it; the total of the three then represents the clay base.[1] The difference between the silica necessary to combine with the alumina and form the clay base and the total silica, was considered as representing the free silica. The twelfth column represents the sum of the iron oxide, lime, magnesia and alkalies. The last column gives the cone of fusion.

Examining the percentages given we see that in the first analysis the percentage of clay base is 87.20 per cent. and silica 10.65 per cent., while the total fluxes are 0.78 per cent. Comparing these percentages with the curve (Fig. 41), we see that a mixture of 90 per cent. kaolinite and 10 per cent. silica (IX), which is close to the composition of clay No. 1 of the table, melted at cone 34, so that the 0.78 per cent. fluxes probably exert little influence.

Again in the third analysis, the percentage of clay base or kaolinite is 52.82 per cent. and that of the silica 43.71 per cent.; from the curve in Fig. 41 such a mixture would fuse at approximately cone 29. But we have here in addition to the silica 2.13 per cent. total fluxes, so that we should expect the clay to fuse at a still lower cone. By actual test the fusion point was found to be cone 27, so that evidently both the free silica and fluxes present force down the fusing point and the facts correspond to the theory.

No. 4 of the table of analyses behaves similarly to No. 3, and No. 5 has a high fusing point on account of its high percentage of clay substance and low amount of fluxes.

In the case of No. 6 we find that, leaving the fluxes out of consideration, a mixture of kaolinite and silica in the proportions

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[1] The amount of water present as an ingredient of limonite is so small in these cases that it can be neglected.

shown in this clay should fuse at about cone 30, and the amount of lime, magnesia, alkalies and titanium oxide given in the analysis should lower the fusion point to at least cone 29 or even 28. As it is, the fusion point as determined is cone 30, and there is an apparent disagreement between theory and the facts. This is probably explainable by the fact that the clay is a very sandy one, and, therefore, since much of the silica is in the form of coarse grains, it is not able to enter into active chemical union with the clay base. In any event this sample illustrates the fact that the fusion point of a clay cannot be determined solely from a chemical analysis. No. 7 owes its low refractoriness to a high content of total fluxes, and not to high-silica contents. Were it not for nearly 4 per cent. of fluxes, its refractoriness would be quite high. These few examples, will, however, serve to show the practical application of the facts mentioned above.

Many manufacturers of fire brick consider that ferric oxide is one of the most important fluxing elements, and that an analysis of a No. 2 brick for example should necessarily show a higher content of ferric oxide than a No. 1 brick. From what has been said above, however, it is easily conceivable that two fire bricks or fire clays may show the same per cent. of ferric oxide and yet differ in their refractoriness by several cones owing to the difference in the amount of free silica, or the No. 2 brick might show even less ferric oxide than the No. 1 although this is not likely.

Effect of titanium.—It will be noticed that the percentage of titanium oxide has been determined separately in several of the above analyses, and from the quantity present it is believed to exert some influence. As has been mentioned under *Titanium* (p. 70), the presence of 2 per cent. of titanium seems to lower the refractoriness a whole cone number, while 0.5 per cent. lowered it half a cone, when it was mixed with kaolin alone.

If we compare the curve in Fig. 25 with the one in Fig. 41 it will be seen that the fluxing effect of 1 per cent. of titanium is equal to 10 per cent. silica.[1]

In fire clays the titanium oxide and kaolinite are not usually

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[1] Compare No. II and VII, Fig. 25, with No. VII and IX, Fig. 41.

present alone, but are accompanied by silica, and the question arises what possible effect this combination may have.

In order to throw some light on this problem, the same series of mixtures represented by the upper curve in Fig. 41 was made up, but 5 per cent. of the silica was replaced in each case by 5 per cent. of very finely ground titanium oxide as follows:

Table showing composition of various kaolin-silica-titanium mixtures.

	Kaolin.	*Silica.*	*Titanium oxide.*
VIII,	90%	5%	5%
XI,	70	25	5
XIII,	56.6	38.4	5
XVI,	30	65	5
XVII,	10	85	5
XIX,	7	88	5

The fusion point of these mixtures was then determined in the Deville furnace and plotted as a dotted curve, Fig. 41. On comparing this curve with that of kaolin and silica alone it is evident that the substitution of 5 per cent. titanium oxide in place of a part of the silica rendered all the samples more fusible. For example, No. IX (kaolin 90, silica 10) fused slightly below cone 34, whereas No. VIII (in which 5 per cent. titanium oxide had been substituted for an equal amount of silica) fused 2½ cones lower. So, too, No. XV (kaolin 30, silica 70) fused about cone 26, while No. XVI (kaolin 30, silica 65, titanium oxide 5) fused between cones 24 and 25. The addition, therefore, of titanium oxide to a mixture of kaolin and silica lowers the fusion point materially. The reason for the irregularity of the curve at No. XIII is not quite apparent, for no doubt was felt regarding the determination of the fusion point.

This curve can be combined with that of Fig. 25, since No. VI (kaolin 95, titanium oxide 5) on the latter is the same as No. VI on the former. If this is done we have a graphic illustration, first, of the effect upon the fusion point of kaolin of the addition of from 1 to 5 per cent. of titanium oxide, and second, the further effect of adding silica to this mixture with a corresponding decrease in the amount of kaolin. For example, when no silica was present, 5 or 6 per cent. of titanium oxide colored the clay deep blue on vitrification, but the addition of 5 per cent. silica in place of some kaolin exerted a bleaching influence on the color. Not only so, but, as shown by the curves, it reduced the fusion point. Thus, No. VI (Fig. 25) (kaolin 95, titanium oxide 5) fused just above cone 32, whereas No. VIII (kaolin 90, silica 5, titanium oxide 5) fused above cone 31, and a still further increase in the silica lowered the fusing point still more. It seems evident, therefore, not only that silica and titanium oxide each act as a flux at high temperatures when mixed with kaolin, but that their combined action when both are present is greater than of either singly. Since titanium acts so strongly, when present in small amounts, it certainly seems necessary to determine it in the analysis of a fire clay or fire brick.

For purposes of comparison, and as further illustration of the facts given above, some additional analyses are given of both American and foreign clays..

The analyses of the native clays are taken from a paper by H. O. Hofman.[1]

Analyses of some American fire clays.

LOCALITY.	Sand.	Combined silica.	Alumina.	Ferric oxide.	Lime.	Magnesia.	Potash.	Soda.	Water.	Fluxes	Cone of fusion.
Athens, Tex, . .	37.06	31.82	20.71	1.01	0.22	0.39	0.69	0.39	7.17	2.70	29
St. Louis, Mo., . .	38.32	26.03	21.16	2.72	0.61	0.30	0.86	0.88	8.94	5.37	30-31
Golden, Colo., . .	5.22	45.99	31.72	0.75	0.36	0.23	0.48	0.45	13.30	2.27	31-32
Mineral Point, O.,	7.13 1.68 TiO^2	35.39	31.84	0.67	0.50	0.19	0.59	. . .	11.68	1.95	33
Sayreville, N. J., .	3.10 1.20 TiO_2	41.10	38.66	0.74	. . .	. . .	0.28	0.18	13.55	1.20	35

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[1] Trans. Amer. Inst. Min. Engrs. Vol. 24, p. 42, and Vol. 25, p. 3.

Analyses of some foreign fire clays.

Number.	Silica, SiO_2	Alumina, Al_2O_3	Ferric oxide, Fe_2O_3	Lime, CaO	Magnesia, MgO	Alkalies,		Miscellaneous.	Loss on ignition.	Cone of fusion.	Total fluxes	Total alkaline earths.	Total alkalies.
						K_2O	Na_2O						
	Sand 5.15										In burned condition		
1	40.53	38.54	0.90	0.08	0.38	0.66	. . .	. . .	13.00	35	2.28	0.49	0.76
2	44.76	39.25	0.48	0.26	0.36	1.55	. . .	. . .	13.41	. . .	. . .	. . .	. . .
3	51.45	45.23	0.55	0.30	0.41	1.78	. . .	. . .	. . . .	35	3.04	0.71	1.78
4	59.15	35.64	1.04	0.36	0.33	3.46		. . .	. . . .	32–33	5.19	0.69	3.46
5	56.03	37.22	3.10	tr.	0.30	3.32		. . .	. . . .	33	6.72	0.30	3.32
6	43.93 8.99	39.16	2.57	0.18	1.24	3.55		. . .	10.51	30	7.54	1.42	3.55
7	65.77 3.72	33.20	1.12	0.25	0.70	2.43		. . .	(9.99)	32–33	4.50	0.95	2.43

1. Washed kaolin Zettlitz, Bohemia.
2. Clay, green, from Buessen.
3. Clay, burned, from Buessen.
4. Burned clay from Ebernhahn, Westerwald district. Seger & Cramer, analyst.
5. Hettenleidelheim. Seger & Cramer, analyst.
6. Grünstadt, Ger., clay.
7. Grünstadt, Ger., Pipe clay.

In looking over the fusibility tests of fire clays, given above, it is observable that the clays listed range in fusibility from cones 27 to 35. The question, therefore, arises as to what the standard of refractoriness of a fire clay should be, for none has been adopted by fire-brick manufacturers in this country. In Europe a clay is not considered refractory unless it becomes viscous above cone 27, although it may vitrify at a lower cone, and there has been some discussion among foreign fire-brick producers regarding the advisability of raising this standard. It is certainly reasonable to set cone 27 as the lower limit of refractoriness, and in the case of No. 1 fire clays it would seem desirable to demand that they have a fusing point above cone 33. Unfortunately, many clays are put on the market as fire clays which have absolutely no claim to the name, and the same is sometimes true of fire brick. In Chapter IV, under *Fusibility,* several arbitrary limits have been suggested.

Other properties of fire clays.—As mentioned at the beginning of this chapter the term *fire clay* does not signify the presence of any other character than refractoriness. Fire clays may vary widely in their plasticity, shrinkage, texture, color, tensile strength and other physical properties, all of which affect the behavior of the clay during the process of manufacture, but none of which can be used as a guide in determining its probable refractoriness. Color may be an aid under certain conditions, since pure white clays and light-yellowish clays are often at least semi-refractory, and sometimes highly refractory. Some fire clays are tinged a deep yellow, or yellowish red, as though they contained considerable ferric oxide, and yet they possess considerable heat-resisting power. If the clay is black or bluish black, there is no means of telling from mere inspection what its heat-resisting qualities are, for under these conditions both a clay with very little iron oxide and one with much iron oxide will sometimes outwardly appear the same. There is consequently no sure means of determining the refractory character of a clay without testing it in a furnace or making a chemical analysis of it.

Two kinds of fire clay are recognized in the field, viz., plastic fire clays and flint clays. The former are plastic when wet, the latter are hard and flint-like, with a smooth, shell-like fracture and dense texture. They develop no plasticity, even when ground very fine, but are usually highly refractory and show little air or fire shrinkage; none are found in New Jersey.

Plasticity has little or no direct relation to refractoriness, although H. Seger has pointed out that of two clays of unequal refractoriness, the one of lower fire-resisting qualities may withstand the action of molten materials better, if it is of high plasticity, as this makes it burn to a very dense body at a comparatively low temperature. The result of this is that the pores are closed and the clay resists the corrosive action of a fused mass better than the more refractory clay, which does not burn dense at as low a temperature as the first one, and which, therefore, permits the fused mass to enter the pore spaces between its grains.

Fire clays are of variable tensile strength, and some of the highest grades mined in New Jersey have so little tensile strength and crack so badly in burning, when used alone, that it is necessary to add a certain quantity of more plastic clay as a binder, even though it may be of less refractory character.

MINERAL IMPURITIES.

The analysis of a true fire clay shows but a small percentage of injurious substances or mineral impurities. This is not due always to their absence from the deposit, but because they are frequently segregated in lumps which can be thrown out in the mining of the clay, and consequently an analysis of the marketable clay does not show them. One of the most abundant of these is pyrite, the compound of sulphur and iron already referred to (p. 46). This forms lumps which are more or less widely distributed through the clay, but not uncommonly predominate in certain layers, or in certain parts only of one or several layers. In these cases they can be avoided or separated in mining. In New Jersey pyrite is not uncommon in the Woodbridge fire clay, but is more abundant in the South Amboy fire clay. Layers of iron-stained sands, or sandstone layers cemented by iron, may also occur here and there in the bank, or again nodules of iron oxide are sometimes found. Lignite or carbonized wood is often seen in the New Jersey fire clays, and is an almost invariable accompaniment of pyrite, the latter having been usually deposited on or around the former. Pyrite, as mentioned on a previous page (75), may on weathering yield alum, which forms whitish spots or coatings in the clay, and in some stoneware clays of the Amboy district causes considerable trouble. Where the impurities are scattered throughout the deposit, hand sorting may not always eliminate them, and washing is necessary.

USES OF FIRE CLAY.

The main use of fire clay is for the manufacture of fire brick. These are made in many different shapes and sizes, the density and composition of the brick being varied to suit the conditions under which it is to be used. The wide and varied use of refractory bricks therefore necessitates the making of many different and special forms and mixtures, some of which are only produced for special orders. The fire bricks made in New Jersey are used for blast furnaces, rolling mills, pottery and brickkilns, boiler settings, gas houses, heating chambers, cupolas, etc.

Among the other products of this nature may be mentioned glass pots and glass furnace blocks, zinc muffles and gas retorts. Of these the last mentioned are made to some extent from New Jersey clays, but not as much as formerly. Glass pots require a special dense-burning fire clay, which has not been found in New Jersey. Zinc muffles have to be made from clays similar to those required for glass pots, but a small amount of New Jersey clay can be sometimes used in the mixture. Clay of a semirefractory character is used in the manufacture of emery and carborundum wheels for the purpose of binding the grains of the abrasive together, when the wheels are burned. A semirefractory, or refractory grade of sandy fire clay is used for making fire mortar in which to set fire bricks. Quite a little fire clay is also consumed by foundries and blast furnaces, but here sandiness combined with plasticity are of more importance than high refractoriness. Steel manufacturers, also, demand several grades of fire clay for making mixtures for mold linings. A clay of high-bonding power and dense character, but not necessarily high refractoriness, is called for by graphite manufacturers. The materials used for graphite crucibles are, however, chiefly imported ones. Aside from their use in making refractory wares, fire clays of either first or second grade are used in the manufacture of front brick, terra cotta, stove linings, saggers, stoneware, floor tiles, etc.

HISTORY OF THE FIRE-BRICK INDUSTRY.

The manufacture of fire brick represents one of the oldest branches of the clay-working industry in New Jersey, and is of more importance than is commonly imagined. The New Jersey clays were first used for fire brick after the war of 1812, and one of the earliest records, according to Dr. Cook, shows that clay was taken from Woodbridge to Boston in 1816, and used for manufacturing fire brick. The value of the clays of the Woodbridge district does not seem to have been widely recognized for some years, however, although in 1855 the statistics, given in the Report on Clays in 1878, show that clay for making 50,000,000 fire bricks was then being taken annually from the pits at Woodbridge, Perth Amboy and South Amboy.

Perhaps the oldest factory in the State was that known as the Salamander works (no longer in existence), where brick were made as early as 1825. A little later, in 1836, John R. Watson established a factory at Perth Amboy, and in 1868 Sayre & Fisher commenced making fire brick at Sayreville. The works of W. H. Berry, at Woodbridge, began operations in 1845, and have continued up to the present day, although in 1896 the name was changed to J. E. Berry.

Henry Maurer & Son established a fire-brick factory in 1856, and M. D. Valentine & Bro. in 1865. The latter were started for making "Bath brick," later sewer pipe, and finally fire brick and other refractory forms. A branch works, located at Valentine, on the Lehigh Valley R. R., was started in 1887. Within the last two years several other firms have begun the manufacture of fire brick, including the factories erected by the Mutton Hollow Fire-Brick Company, and Anness & Potter, at Woodbridge, and The Superior Fire-Lining Company, at Trenton.

Other firms manufacturing fire brick are:

Adam Weber's Sons.
Trenton Fire Brick Company, Trenton.
The Pyrogranite Company, South River.
Ostrander Brick Company, Ostrander.
National Fireproofing Company, Keasbey works, Keasbey.
Staten Island Clay Company, Spa Springs.
J. H. Gautier & Co., Jersey City.

METHOD OF MANUFACTURE OF FIRE BRICK.

All fire-brick makers in New Jersey use a mixture of several grades of clay, to which there is added a certain percentage of grog, and occasionally some of the so-called "feldspar" found in connection with the fire clay. These ingredients are commonly tempered in ring pits, but sometimes in pug mills, and then molded either by hand or machine. If the former is used, the bricks are molded very soft; if the latter is employed, a soft-mud machine is favored, although a stiff-mud machine is used at a few works. In every case the brick are re-pressed, and after re-pressing they are commonly hacked up to dry, and are then placed in the kilns. Hand- or machine-molded bricks are usually spread out on brick drying floors, warmed by flues passing underneath, and after remaining there a short time are re-pressed. This not only compresses the brick, but smoothens the sides and straightens the edges. The following dimensions, given in inches, indicate the amount of compression that takes place in re-pressing.

Before re-pressing, 9½ by 4½ by 2⅞.

After re-pressing, 9⅜ by 4⅝ by 2⅝.

The loss in weight and decrease in size of a stiff-mud fire brick is shown by the following figures, obtained at another works:

Conditions.	*Dimensions in inches.*	*Weight.*	
Freshly molded, ...	$9\frac{11}{16}$ by $2\frac{11}{16}$ by $4\frac{13}{16}$	9 pounds.	
Re-pressed, ...	$9\frac{3}{8}$ by $2\frac{5}{16}$ by $4\frac{7}{8}$	8 do	12 ounces.
Dried, ...	$9\frac{3}{8}$ by $2\frac{5}{8}$ by $4\frac{5}{8}$	7 do	2 do
Burned, ...	9 by $2\frac{1}{4}$ by $4\frac{1}{2}$	6 do	2 do

Most of the fire-brick manufacturers burn their product in circular down-draft kilns, although one factory has a continuous kiln, and a few works have rectangular kilns. A few of the fire-brick makers in New Jersey use Seger cones as a guide in burning, but the majority do not. A number of cones were, therefore, distributed among the different fire-brick manufacturers for placing in their kilns. From these, and those used regularly at some of the works, it was found that the New Jersey fire brick were burned at from cone 9 to cone 12. There is no reason to believe that those manufacturers whole kilns were not tested, burn at a much higher cone, although it is probable that in the hottest parts of the kiln a slightly higher cone may sometimes be melted. At one factory cone 16 has been melted when placed opposite the flue leading from the fireplace. The firing commonly takes three to four days, depending on the heat to be reached, size of kiln and the weather, and after this several days are required for cooling.

The absorption of the New Jersey fire bricks ranges in most cases between 11 per cent. and 14 per cent. One sample of stiff-mud manufacture showed 5.37 per cent., but other stiff-mud bricks ran as high as 13.00 per cent.

Their refractoriness is not as high as Ohio and Pennsylvania bricks, and yet they have the reputation of standing changes of temperatures much better. Each manufacturer commonly makes three or four brands, which are adapted to special uses.

TESTS OF NEW JERSEY FIRE BRICK.

In order to test the refractoriness of the New Jersey fire bricks and to determine its relation to their chemical composition and texture, samples of their different brands were requested from all the fire-brick manufacturers in the State. All except three readily agreed to the proposition, and samples of the different brands were taken from the stock piles or kilns by a member of the Survey staff. The fusing point of the bricks was tested in the Deville furnace and a partial analysis made to determine the quantity of silica, alumina, ferric oxide and titanium oxide, the balance being considered as lime, magnesia and alkalies.

These tests are tabulated in the accompanying table. The various samples are indicated by number (column at the extreme left), and the name of the manufacturer is not published, but a record has been kept in the Geological Survey office of the source of each sample, and each maker has been supplied with a copy of the tests made on his brick.

Each column is properly headed and needs no explanation, except, perhaps, the last two. The absorption represents the percentage of water absorbed by the brick when soaked for 48 hours, and is, therefore, an indication of its porosity. The column headed "Grade" represents the rank or quality of the brick as compared with others made at the same works. Thus, all those marked "1" come from different factories, and represent in each case the best brick made at the factory from which they were taken. They are not always branded No. 1, for the best brick made at any one works may be branded XX, Special A1, or possibly something else. It will be seen from a comparison even of those marked No. 1 that they vary in their refractoriness, from cone 33 down to cone 27, and that there is as great a difference between the highest grades of different manufacturers as there is between some No. 1's and some No. 4's. In other words, the lowest grade brick of some manufacturers fuse at a higher temperature than the best grade of other makers.

Chemical composition and fusion point of New Jersey fire brick.

No.	*Silica.*	*Alumina.*	*Ferric oxide.*	*Titanium oxide.*	*Total.*	*Cone of fusion.*	*Absorption.*	*Grade.*
1	78.24	19.24	0.68	1.66	99.82	33	13.39	1
2	82.45	14.86	1.54	0.90	99.75	32	12.92	1
3	68.70	25.80	3.35	1.25	99.10	27	11.25	2
4	77.15	19.46	1.99	0.95	99.55	27	14.33	1
5	75.20	21.09	1.37	1.72	99.38	33	12.72	1
6	81.10	15.81	2.19	*	99.10	27	13.92	1
7	68.90	28.21	0.78	1.69	99.38	32	13.39	1
8	54.68	39.35	2.42	2.53	....	32	....	1
9	85.15	12.22	1.48	1.10	99.95	33	....	1
10	74.01	19.13	1.76	4.30	....	31–32	....	2
11	77.50	20.40	1.00	*	98.90	33	....	1
12	81.20	14.98	0.92	1.43	98.53	30	11.90	2
13	72.37	24.67	0.98	1.79	99.93	32	11.97	2
14	82.30	14.84	1.70	0.71	99.55	31	12.48	2
15	74.10	21.72	1.37	1.91	99.10	32	11.70	2
16	84.99	13.20	1.75	*	99.94	30–31 ?	13.39	2
17	79.10	18.30	0.70	*	98.10	......	12.52	2
18	78.84	18.06	0.65	1.53	99.08	31	....	2
19	74.54	22.23	1.63	1.43	99.83	30	....	1
20	75.05	20.06	1.74	1.50	98.35	31–32	14.45	3
21	77.55	17.82	3.48	1.20	100.05	27?	....	3
22	77.32	19.51	1.11	1.86	99.80	28–29	5.37	3
23	77.80	18.29	1.50	1.61	99.20	31 ?	12.96	3
24	73.48	22.35	1.07	1.73	98.63	30	....	3
25	78.50	19.20	0.80	*	98.50	30	....	3
26	77.30	18.99	2.06	1.05	99.40	31–32	11.64	4
27	74.70	20.86	0.98	1.62	98.16	28	11.42	4

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* Titanium oxide is included with the Alumina in these analyses.

The above table shows that there is considerable variation both in the chemical composition and fusibility of the New Jersey fire brick, and a careful study of the table together with some supplementary experiments brings out some interesting facts in the relationship between the two.

If from these analyses, the ratio of kaolinite to free silica be calculated, as can be done approximately by assuming that all of the alumina is present as kaolinite, it will be possible to compare the actual fusion point of the brick with that of the kaolin-silica mixtures in Fig. 41.

For example let us take No. 1 of the above series. If we assume that the 19.24 per cent. alumina was present in the clay as kaolinite (and probably most of it was), then the amount of silica necessary to combine with it is 22.38 per cent., because in kaolinite the ratio of silica to alumina is as 46.3 to 39.8, and the brick would consequently contain 41.62 per cent. of dehydrated kaolinite and 55.86 per cent. free silica. If we recalculate this on the basis of 100 per cent. and add in the amount of water necessary to the kaolinite it gives us 53.61 per cent. silica, and 46.39 per cent. kaolinite. Such a mixture according to the upper curve in Fig. 41 should fuse at cone 28 if the silica and kaolin are finely divided and thoroughly mixed.

As shown by the table, however, brick No. 1 fused in the Deville furnace at cone 33, six cones higher than we should expect it to fuse, if we figured its refractoriness from the silica-kaolinite ratio mentioned above, and it therefore becomes necessary for us to find the reason for this discrepancy. The explanation of these apparently contradictory results is to be found in the texture of the brick. If we examine a piece of this brick that has been fused in the Deville furnace, we find that scattered through the fused scraps there are white grains that seem to have resisted fusion, and an examination of the brick shows that probably 15 per cent. or 20 per cent. of it is composed of angular quartz grains, some of them $\frac{1}{16}$ or $\frac{1}{8}$ of an inch in diameter. We have, therefore, an explanation of the disagreement between the theoretical fusion point of the brick based on the kaolin and silica ratio, and the actual fusion point of the brick, for as was pointed out in discussing the fusibility of clays (p. 99) the size of grain exerts a strong influence on the fusing point.

The above theory is not new, and is well understood, but in order to make it perfectly clear a portion of the brick was ground sufficiently fine in a mortar to pass through a sieve of 100 meshes to the linear inch so as to greatly reduce the size of the grains, especially the quartz ones. This ground mixture when tested, in the Deville begins to get viscous at cone 28, which is the point we should expect it to fuse at if the silica and kaolinite were exceedingly fine. Owing to the fact that the quartz grains are only ground so as not to exceed one-hundredth of an inch, it would tend to fuse a little higher, were it not for the fluxing action of the .68 per cent. of ferric oxide and 1.66 per cent. of titanium oxide which the brick contains.[1]

We see from this therefore that much of the silica in the above described brick is bound up in grains and fluxing action can only proceed from the surface of the grain inward, and, therefore, this brick has the ability to resist a higher heat than its chemical composition would indicate. The refractoriness in this case is not determined by the chemical composition of the whole brick, but rather by the composition of the body in which coarse silica grains are held.

In No. 2 of the list of tests, the silica and kaolinite percentages recalculated to 100 would be 63.59 and 36.41 respectively. Theoretically a mixture of this composition should fuse between cone 26 and 27, and a sample of it ground to 100-mesh, and tested in the Deville furnace was thoroughly viscous at cone 27, so that viscosity must have begun at least as low as cone 26 and probably lower, the ferric oxide and titanium oxide having helped depress the fusion point. The unground brick, however, in which the silica is largely in coarse grains did not fuse lower than cone 32, as shown by the table. The results from this test therefore corroborate the conclusions drawn from No. 1.

In No. 14 the fusion point of the calculated mixture of kaolinite and silica should lie a little below cone 27, but when ground to

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[1] In the case of fine-grained clays, free from fluxes the theoretic and actual fusion points agree very closely. (See p. 315.)

100-mesh it fuses at cone 26, whereas the brick fused at cone 31, due to the presence of the silica in coarse quartz grains.

In No. 20, the actual fusion point of the brick was cone 31-32, but when ground to 100-mesh its fusion point was cone 28, while the theoretic fusion point of the silica-kaolinite ratio in the analysis of this brick would be cone 29 according to the curve in Fig. 41. The ferric oxide and titanium oxide aided in lowering it.

Again in No. 23, a calculation of the silica-kaolinite ratio would lead us to expect a fusion point of cone 28, if the brick were fine grained and free from iron oxide or titanic oxide. The fusion point of the brick when ground to 100-mesh is cone 26, owing to over 3 per cent. of iron and titanic oxide. The actual fusing point with the silica present in coarse grains is cone 31.

For the sake of clearness it may be well to tabulate the facts given above.

No. of brick.	*Silica percentage.*	*Kaolinite percentage.*	*Theoretic fusion point.*	*Fusion point ground.*	*Actual fusion point.*
1	53.61	46.39	28	28	33
2	63.59	36.41	26–27	26	32
14	63.52	36.48	27	26	31
20	50.65	49.35	29	28	31–32
23	55.22	44.78	28	26	31

The first column refers to the number in the table of tests. The second and third gives the percentage of silica and kaolinite recalculated to 100. The fourth gives the theoretic fusion point of such a mixture according to the curve in Fig. 41, the fifth the fusion point when ground to 100-mesh, and the sixth one the fusion point of the brick.

We see here that those mixtures, such as numbers 2 and 14, having the highest percentage of free silica, show the lowest fusion point theoretically, and that this was true practically when the material was finely ground, the fact that ground bricks in such cases fused lower than the silica-kaolinite mixture being due to the presence of fluxes, such as ferric and titanium oxide, as well as to a small total quantity of lime, magnesia and alkalies, represented by the difference between the sum of the substances determined and 100.

As can be seen, however, from the difference in the fusing points between the fire brick in a ground and unground condition, the presence of quartz in coarse grains can offset to some extent at least the presence of a high percentage of free silica. This is seen in the case of all five bricks tested. In No. 1, for instance, there was a difference of 5 cones, that is, the fire brick in its normal condition fused at cone 33, while if ground it fused at cone 28.

Both ferric oxide and titanium oxide will lower the fusing point in proportion to the quantity present.

No. 8 is perhaps a good example of this. This brick contains so little free silica that its condition, whether coarse or fine, would affect the fusion point but little. Even assuming that the silica was all finely divided, the fusing point of the silica-kaolinite mixture contained in the brick would be as high as cone 34, as shown by the upper curve, Fig. 41, but the brick fuses at cone 32, evidently because of nearly 5 per cent. of ferric oxide and titanium combined.

From what has gone before the following conclusions seem warranted:

Chemical analyses alone can not be entirely relied on for judging the refractoriness of a fire brick, although it is true that they indicate in a general way whether the brick is likely to be of low or high refractoriness. Large percentages of ferric oxide, or titanium oxide, indicate low refractoriness. So, too, a large percentage of free silica suggests a low refractoriness under certain conditions. The chemical analyses, however, give no clue regarding the texture of the brick, and, as seen in the case of the several numbers of the above table, which were discussed in detail, this may be a very important factor.

It follows, therefore, that if silica in excess must be added to a fire brick it is more desirable to add it in the form of coarse grains rather than fine sand. It is not, however, a desirable ingredient of fire clay at all, and the most refractory brick made in this country and also in Europe contain a lower percentage of it than those from New Jersey.

For purposes of comparison, a number of analyses and fusion points of foreign brick are given below, and it will be seen that those of high refractoriness run comparatively low in silica and other fluxes. Those having a fusion point similar to many of the New Jersey brick have a similar composition.

Table of analyses of foreign fire bricks together with their fusibility.

	NAME OF BRICK.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Loss Ign.	Cone No. fusion.	Total fluxes.	Total Alk. earths		Alkalies.
	German Bricks—												
1	Marked A (Hecht, analyst),	51.15	45.72	0 80	1.77	....	0.34	0.28	35-36	2.01	1.77		0.34
2	Marked B,	57.55	40 56	1.36	....	..	Undet.	0.56	—35	2.33		0.97	
3	Marked C,	59.76	35.36	2.42	0.45	0.48	0.61	1 30	—35	3.96	0.93		0.61
4	Marked D,	58.84	38 71	1.20	0.30	0.20	0.74	0 33	34-35	2.44	0 50		0.74
5	Marked E,	50.00	46 21	1.62	0.55	0.35	1.21	0.12	35-36	3.73	0.90		1.21
6	Palatina (Seger & Cramer),	54 28	42.52	1.92		2.28		....	—35	4.20		2.28	
7	Saarau XXI (Seger & Cramer),	52.20	45.90	1.00		0.90		....	35-36	1 90		0.90	
8	Saarau XX,	52.50	43.60	1.60		2.30		....	34	3.90		2.30	
9	Saarau A,	62.50	35 30	1.60		0.60		...	33	2.20		0.60	
10	Saarau O (Stolber, Prag),	69.65	28 71	1.20		0.44		....	33	1.64		0.44	
	English Bricks—												
11	Walbottle,	58.74	35 09	2.80	0 27	0.80	2.11	0.40	31-32	5.98	1.07		2.11
12	Svan,	58 02	36.84	2.64	0.45	0.52	1.54	0.22	31-32	5 15	0 97		1.54
13	Preston Grange,	58 50	31 41	6.00	0 70	0.64	2 41	0.50	28-29	9.75	1.34		2 41
14	Lucas,	61.24	30 48	3.20	0.45	0 54	3.90	0.54	—31	8.09	0 99		3.90
15	Ramsay,	58 41	32.80	4 94	0 40	tr.	3.01	0 83	30-31	9 18	0.40		3.01
16	Glenboig,	62.06	32.81	4 30		0.83		...	30-31	5.13		0.83	
17	Glenboig,	62 50	34.00	2.70		0.80		....	31	3.10		0.80	
18	Glenboig, sample from market,	58.58	34.13	4.22		3.07		....	30-31	7.29		3.07	
19	Stourbridge (Iron Jour.),	58 48	35 78	3.02		2.72		...	31-32	5.74		2.72	
20	Stourbridge,	63.40	31.70	3 00		1.90		...	30-31	4.90		1.90	

For purposes of comparison, a number of analyses and fusion points of foreign brick are given below, and it will be seen that those of high refractoriness run comparatively low in silica and other fluxes. Those having a fusion point similar to many of the New Jersey brick have a similar composition.

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17	Glenboig,	62 50	34.00	2.70		0.80		. . . .	31	3.10		0.80	
18	Glenboig, sample from market,	58 58	34.13	4.22		3.07		. . . .	30-31	7.29		3.07	
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20	Stourbridge,	63.40	31.70	3 00		1.90		. . .	30-31	4.90		1.90	

CHAPTER XVII.

THE CLAY-MINING INDUSTRY.

CONTENTS.

INTRODUCTORY STATEMENT.

Under this heading is considered only the clay dug and sold by miners, and not that dug by manufacturers for their own use. In most States, as well as in many parts of New Jersey, each factory, except those producing white ware, floor tiles, wall tiles and other grades of ware, requiring a No. 2 fire clay or something better, digs clay from its own pits, located near the works. But in New Jersey, owing to the variations which are to be found in any one pit, it is often impossible to get a large amount of one kind of fire clay from a small area, and it is therefore more practicable for the factories requiring clays of medium or high refractoriness, to buy their materials from a number of clay miners.

Furthermore, the terra-cotta, fire-brick, and tile factories and potteries located in adjoining States are often not able to obtain their raw materials near the works, and draw upon New Jersey for a large portion of their supply.

The result of this has been that in several areas of New Jersey, chiefly within the Raritan clay belt, a thriving clay-mining industry has been developed. These areas are, 1) the Middlesex county area, including the region around Woodbridge and South Amboy; 2) the Trenton area; 3) the Delaware river area; 4) the Woodmansie area.

MIDDLESEX COUNTY.

In the northeastern portion of Middlesex county, especially around the towns of Woodbridge, Perth Amboy, South Amboy, Sand Hills, etc., there is developed the most important clay mining area in the State, the deposits in this region having been worked for a number of years. The importance of this area is due in large degree to the vast quantities of the higher grades of clay which have been obtained there,[1] ease of extraction and good transportation facilities by water or rail.

The output from this region is contributed by between twenty and thirty firms or individuals. Around Woodbridge and Perth Amboy, especially, many acres of clay land have been dug over and the operations carried on since the early part of the nineteenth century. In the earlier years of the clay-mining industry, it was chiefly the better grades of clay that were sought for, and in order to obtain these, many beds that were then of no commercial value, but for which there would now often be a call, were thrown aside or mixed with overburden, so that through these wasteful methods much good material was lost. At the present day more care is exercised, and in some cases even filled pits are being re-excavated to get the clay that was left at the bottom.

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[1] See description of Middlesex county, Chap. XIX.

The Middlesex district supplies a greater variety of clays than any of the other three. Among these certain well-marked types are recognized, but the names of these are of little significance in indicating the use of the material. The most important varieties obtained in the Middlesex district are the following:

No. 1 fire clay.—This term refers to the most refractory clay to be found in any fire-clay pit, and in some cases indicates a material of high refractoriness, fusing at cone 34 or 35. The term does not refer to any standard type, but is used by each clay miner to indicate his best grade of clay, and therefore it does not follow that the No. 1 fire clays obtained in the different pits of Middlesex county are all of the same degree of refractoriness. On the contrary, they exhibit as much variation, as there is among the different No. 1 fire bricks made at different works. In some cases the term *No. 1 fine* or *No. 1 blue* is used. Around Woodbridge some of the better grades of fire clay are often quite sandy in their character, and consequently the terms *No. 1 sandy, top* or *bottom sandy,* or *extra sandy* are employed.

No. 2 fire clay.—This refers to the second grade of fire clay found in any given bank.

The chemical composition and fusibility of many of these Middlesex county fire clays will be found in Chapter XIX, but since the term No. 1 and No. 2 fire clay is so loosely used, they are grouped there as highly refractory, refractory and semirefractory clays.

Retort clays.—This type of clay is recognized only in the Woodbridge district. As there recognized it is very plastic clay, burning dense, usually at cone 3 or even lower, but it is not as refractory as the No. 1 fire clay. It was probably extensively used in former years in the manufacture of gas retorts, and in this manner has obtained its name. At the present day, however, its chief use is in the manufacture of stoneware, especially of the sanitary variety and of other objects where a dense-burning clay of good bonding power is required.

Stoneware clay.—This term is applied in some pits to a dense-burning plastic clay of less refractoriness than the ball clay, which is used to some extent in stoneware manufacture as well as for terra cotta. A small amount is obtained near Woodbridge, but the greatest quantity of it is dug from pits around South Amboy. It is sometimes divided into No. 1 and No. 2 grades.

Ball clay.—The material dug under this name conforms to the usually accepted definition of the term. It is dug near South Amboy (Loc. 67) and Sayreville (Loc. 273), and south of Woodbridge (Loc. 29, Lab. No. 378). The clay from the first two localities is put through a washing process (Pl. IX), but that from the third locality is sold crude and goes under the name of ware clay.

Sagger clays are dug in many parts of the Middlesex district. Their refractoriness varies from medium to low.

Wad clay is dug at several localities.

Terra-cotta clay.—Two types are mined in Middlesex county, one a fine clay of medium or low refractoriness, and the other a red-burning clay. The former kind, which is the most important, is obtained from all parts of the Middlesex district, and is not always sold under the name of terra-cotta clay. The latter type is mined west of Woodbridge.

Pipe clays.—Most of those mined and sold under this name from the Middlesex area are nonrefractory. In former years sewer pipe were manufactured in New Jersey in much greater quantity than they are at present, and the name pipe clay no doubt originated in this manner. Certain plastic layers of dark-gray clay mined around Keasbey and used in conduits are also designated by this name.

Hollow-ware clay.—Under this term is included a great series of thinly laminated black and bluish-black, sandy, micaceous clays, which are found above the Woodbridge fire clay around Woodbridge, as well as along the Raritan river from Perth Amboy to Keasbey and also at South River. They are extensively used for the manufacture of fireproofing, hollow brick, hollow blocks, conduits and common brick. The conduits are made from the smoother and more plastic beds. Some No. 2 fire clays are also used in the manufacture of these hollow wares, but on the market they are spoken of as No. 2 fire clays rather than as hollow-brick clays.

TRENTON AREA.

Sagger, wad and fire clays of Raritan age are dug in a number of pits at Dogtown, east of Trenton. Most of the product is hauled by wagon to Trenton for use in the potteries there. The number of firms or individuals actively and permanently in operation does not exceed three, but the clay is sporadically dug by others. Detailed tests of the Dogtown clays are given under Mercer county, Chapter XIX.

DELAWARE RIVER AREA.

Semirefractory fire clays are dug in several pits near Palmyra. These are shipped chiefly to Philadelphia and other nearby towns for terra cotta and foundry use. The deposits are overlain by a great thickness of sand, which is the chief product of the pits, the clay being excavated in but comparatively small quantities from the bottom.

WOODMANSIE AREA.

This represents a small area of Cohansey clay mined near Old Half Way, in Ocean county, and shipped mostly to Philadelphia for terra-cotta manufacture.

METHODS OF MINING.

The methods used for mining the clay by square pits, as practiced in the Middlesex and Trenton districts, have already been referred to in Chapter II. It may appear to some that this system of mining, as extensively practiced in the Woodbridge district, is not the best that can be adopted, and yet, under the conditions, it is probably the most practicable, since the frequent change in character of the beds both vertically and laterally prohibits any methods involving the digging of the clay on a larger scale. This is one of the reasons why steam shovels could not be used for excavating purposes. The pit method, described in Chapter II, has certain advantages, for in digging through the section each time, to or nearly to the bottom of the deposit, it is possible for the clay miner to supply a number of kinds of clay at one time, whereas, if a large excavation were made working over a large area at one level, only one kind of clay might be extracted at a time. Unless, however, a number of pits are worked at once the output from any one property is restricted. One of the finest appearing banks in the Woodbridge district is that of W. H. Cutter, located south of the village (Pl. XXXVII).

AMOUNT OF CLAY MINED IN NEW JERSEY.

The total quantity and value of the clay mined in New Jersey in 1902 was as follows:[1]

Clay mined in New Jersey, 1902.

Kaolin (so called),	1,576	short tons,	$1,761
Fire clay, raw,	281,508	do.	327,580
Ball clay, raw,	697	do.	3,991
Stoneware clay, raw,	34,397	do.	59,270
Miscellaneous clay, raw,	157,225	do.	136,471
do. prepared,	6,765	do.	15,586
	494,800	do.	$612,721

New Jersey is the largest producer of clay in the country, the total quantity of clay mined in the United States in 1901 being 1,367,170 short tons, valued at $2,576,932. It must be understood, however, that these figures refer only to the clay, which was sold by the miner in the raw state, and does not include the much larger amount of clay which was dug directly by the manufacturers of fire brick, fireproofing, hollow ware and all the various grades of building brick, most of whom own their clay banks and utilize themselves nearly all, if not all, the clay they dig. Even in the Woodbridge-Perth Amboy district, where the clay miner as

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[1] The figures are taken from the Mineral Resources, U. S. Geol. Surv., 1902.

distinct from the clay manufacturer is most prominent, the clay dug and sold raw is probably not more than one-half the total amount dug, and the total amount of clay dug in the entire State must be many times these figures.

SHIPMENTS TO OTHER STATES.

The most interesting feature of the New Jersey clay-mining industry, however, is its important relation to the production of clay products in the other States, many of the largest firms in New York, Pennsylvania, and adjoining States drawing on the New Jersey pits for their supply of raw materials. In order to determine the quantity of clay shipped to points outside the State in 1902, a letter of inquiry was sent to the different clay-mining firms, and replies were received from all those active in that year with the exception of a few small ones. The results received from twenty-four miners when tabulated gave the following:

Amount of clay shipped from New Jersey to other states in 1902.

State.	*Long tons.*	*Number of firms shipping.*
Pennsylvania,	56,482	15
New York,	27,636	18
Ohio,	24,039	8
Maine,	20,266	3
Connecticut,	9,985	8
Massachusetts,	5,405	14
Maryland,	2,727	5
New Hampshire,	1,557	3
Canada,	1,676	3
West Virginia,	897	4
Rhode Island and Wisconsin,	1,343	4
	152,013	

This amount, as can be seen by reference to the statistics preceding it, represents about 30 per cent. of the clay mined in New Jersey and sold raw. At the time the statistics were collected inquiries were also made regarding the uses of the materials shipped. These as far as ascertainable were as follows: stoneware, saggers, white brick, terra cotta, gas works, forges, steel works, sanitary ware, abrasive wheels, tiles, crucibles, fire bricks, zinc works, fire mortar, sewer pipe, boiler covering, puddling in dams, hollow brick, white earthenware, electrical porcelain.

DIRECTORY OF CLAY MINERS[1] IN NEW JERSEY.

Adams, A. A., Woodmansie;
Anness & Potter Fire Clay Company, Woodbridge;
Berry, James E., Woodbridge;
Bloomfield, Chas. Metuchen;
Brown, David, Woodbridge;
Clayville Mining & Brick Company, South Vineland;
Crossman, J. R., South Amboy;
Cutter, William H., Woodbridge;
Drummond, Warren, Woodbridge;
Edgar Brothers, Metuchen;
Erickson, Benjamin, Bridgeton;
Erato, P., Palmyra;
Furman, G., South Amboy;
Guest, Thos., Metuchen;
Hillman, F. A., South Amboy;
Hylton, H., Palmyra;
La Rue, G. A., South Amboy;
Leisen Clay Mining Company, John H., Woodbridge;
Liddle, J., & Sons, Woodbridge;
McHose Brothers, Perth Amboy;
Moon, J. J., Trenton;
Ostrander Fire Brick Company, Ostrander, Main Office, Troy, N. Y.;
Paxon Company, The J. W., Philadelphia, Pa.;
Perrine, H. C., & Son, South Amboy;
Pettit & Co., New Brunswick;
Prall, James P., Woodbridge;
Raritan Ridge Clay Company, Metuchen;
Ryan, P. J. & J. F., Woodbridge;
Ryan, P. L., Woodbridge;
South, Jos., Trenton;
Such, J. R., South Amboy;
Valentine, M. D., & Bros. Company, Woodbridge;
Valentine, R. N. & H., Woodbridge;
Weber, Adam, Sons., Weber;
Whitehead Brothers Company, 537 W. 27th St., New York City;
Worthington & Son., 135 E. State St., Trenton.

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[1] Individuals and firms which manufacture all the clay which they dig are not included.

PART IV.

THE ECONOMIC GEOLOGY OF THE NEW JERSEY CLAYS.

By HEINRICH RIES.

CHAPTER XVIII.

ECONOMIC DESCRIPTION OF THE CLAY-BEARING FORMATIONS.

CONTENTS.

The extent, thickness and distribution of the clay-bearing formations of New Jersey have been described in detail in Part II of the present report, so that in this chapter only a brief summary of their economic characters will be given, leaving the detailed discussion of the individual occurrences to be taken up in the county descriptions which follow. At the end of the description of each formation, in the present chapter, there is given a table containing all the determinations of water absorption in mixing, air shrinkage, tensile strength, fire shrinkage and absorption of burned bricklets that have been made.

PLEISTOCENE AND RECENT CLAYS.

Twenty-one samples of Pleistocene and post-Pleistocene clays have been examined in the laboratory. Those from the northern part of the State were deposited in connection with the melting ice of the last Glacial epoch or have resulted from wash at the foot of steep slopes or in swampy depressions. They are therefore glacial or colluvial clays (pp. 7, 13, 120, 124). Those from the southern part of the State were deposited in sheltered bays or estuaries[1] when the land stood somewhat lower in respect to sea level than at present. They were not, however, all formed simultaneously since there are known to have been at least two periods of submergence during the Pleistocene, and some of the clays belong to the earlier or Pensauken and others to the later or Cape May (pp. 130-135). Included in this group are also the clay loams (p. 121), which are so widely distributed at levels below 240 feet, and which are believed to belong to the closing stages of the Cape May submergence.

Both groups of clays are commonly of local occurrence and show a variable depth. They are for the most part shallow, but those of northern New Jersey occurring in the basin of the extinct Lake Passaic and along the Hackensack river attain very considerable thicknesses, 50 feet being reported for the depth near Hackensack, and still greater depths for the clays in Lake Passaic. In the southern portion of the State the thickness is never great. It varies commonly from 2 to 5 feet around Trenton, and 4 to 6 feet in southeastern New Jersey, although south of Bridgeton (Loc. 190), a section of at least 8 feet of clay was seen, and at Belle Plain 7 feet of clay is said to occur; at Buckshutem (Loc. 180), 9 feet of clay is found, but only the upper 6 feet are dug. The overburden rarely exceeds 2 to 3 feet, and may be sandy loam, or gravelly loam.

The extreme shallowness of the deposits around Trenton (Pl. XV, Fig. 1), has necessitated digging over large areas, in order to keep up a sufficient supply.

As can be seen from what has been stated above the two groups of clays occur in more or less separated areas. More than this they are rather distinct in their physical properties, those of the first group being invariably red burning, sometimes fine grained and of low fusibility, while those of the second group are predominatingly gritty, and of higher fusing point.

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[1] The clay from Hobart's pit, north of Vineland (Loc. 184), is, perhaps, an exception, as it may be due to surface wash.

It therefore seems to be desirable to discuss their physical properties separately.

First group of Glacial and Colluvial Clays.

Texture.—The clays of this group range from coarsely gritty clays, to fine-grained laminated ones. They are often more markedly stratified than those of the second group.

Slaking.—They vary in their slaking qualities, but those which have been formed in ponds and are thinly laminated, break up first along the thin laminæ of sand and then slake completely.

Air shrinkage.—The clays tested varied from 3.5 per cent. to 8 per cent. in their air shrinkage with an average of 6.3 per cent. The lowest was a gritty clay loam from Flemington (Loc. 276), and the two highest were fine-grained clays from Murray Hill and Schooley's mountain, respectively.

Water for tempering.—The percentage required ranged from 20.5 to 35.4, with an average of 26.4 per cent. Owing to the abundance of fine grit, many of the Pleistocene and post-Pleistocene clays absorb as much water as some of the more plastic ones. Thus a loamy clay from Flemington took 23.9 per cent. of water although its air shrinkage was only 3.5 per cent., and one from Washington, derived by hillside wash from disintegrating gneiss, with a shrinkage of 6.3 per cent., required 26.2 per cent. water.

Tensile strength.—None of the samples tested except one (Loc. 292) showed a low strength, and one from Somerville (Loc. 234) had a high strength. These two represented the extremes of 65 pounds and 297 pounds per square inch, respectively.

Burning.—Many of the clays included in this section burn steel-hard at a lower temperature than the majority of clays found in the other formations with the exception of the Alloway clays. Those from localities 234, 276, 280, 290, 291 and 292 all burned steel-hard at cone 05. Most of them burn to a good red color at this cone. The fire shrinkage at cone 05 is usually low, although one from Murray Hill (Loc. 290) had a fire shrinkage of 11 per cent. at this cone. On account of their low fire shrinkage none of the samples tested burned dense at cone 05, but one from the Hackensack district (Loc. 291) was well vitrified at cone 01. No refractory clays are found in this group, for in fact most of them fuse quite readily.

Uses.—These clays are worked at a number of localities in the northern part of the State, including Somerville, Plainfield, Berkeley Heights, Singac, Mountain View, Morristown, Whippany, Hackensack, etc. Many of them could be worked into draintile, and the finer grained layers used for common red earthenware. One deposit near Linden is extensively drawn upon for the last mentioned purpose. Vitrified brick have been made at Whippany.

Second group, chiefly of Cape May age.

Texture.—Most of the clays of this series are gritty, loamy or even very sandy. Those around Trenton also contain scattered pebbles and cobbles. Those underlying the terraces along the lower Delaware are commonly loamy. When the pebbles are abundant it becomes necessary to remove them either by screening the clay or else by crushing in rolls. Judging from the tests obtained, clays in adjoining pits may show some difference in their behavior when fired, as for example the clays from localities 180 and 181, near Millville, which represent pits on opposite sides of the river not over 1,000 feet apart.

Slaking.—Many of these clays fall to pieces rapidly when thrown into water, but others even though sandy, slake slowly because the clay particles in them are evenly distributed and hold the sand grains together. These same ones will usually dry to a hard mass.

Air shrinkage.—In the 14 samples measured the air shrinkage was found to range from 3.6 per cent. up to 10 per cent., with an average of 6.04 per cent. The air shrinkage of 9 of the 14 lay between 5 and 7 per cent.

Water for tempering.—The amount of water required to mix the material to a plastic mass ranged from 21.4 per cent. to 37.1 per cent. with an average of 27.3 per cent. Unlike Clay Marls I and II none of these clays can be molded as taken from the bank, and the one showing the highest water absorption did not show the highest air shrinkage.

Tensile strength.—The tensile strength was determined in 10 samples of this group, and was high in the majority. It ranged from 90 pounds per square inch to 291 pounds per square inch.

Burning.—As will be seen by reference to the table, p. 348, the different clays of this group show a great variation in their fire shrinkages. Thus, for example, at cone 1 we find fire shrinkages ranging from 1 per cent. up to 7.6 per cent., while the absorption varies from 14.49 per cent. to 3.08 per cent. The greater number of the samples tested burned red and moderately hard at cone 1. Those from Buckshutem (Loc. 180) and south of Millville (Loc. 181) became steel-hard at cone 03. The mixture of Fish House clays was the most dense burning of the series, even though its fire shrinkage was not high.

In some deposits, clays of quite dissimilar character are obtainable, as for example at Woodbine (Loc. 189), where both a red-burning and buff-burning clay are found in the same bed. The former gives a good hard brick at cone 1, but the latter does not become steel-hard until above cone 3, burning to a light-buff product at cone 5, and to a buff of slightly grayish shade at cone 8. There is not much difference in the fire shrinkage of the two. The difference in color of the two clays after burning is seen in the bricks made of these clays, the more refractory clay showing as whitish spots.

At cone 5, several samples, viz., those from localities 190, 181 and 188, gave good hard bricklets, two of which had a low absorption.

The one showing the highest heat-resisting power, viz., sample No. 678 from locality 189 (Woodbine), may be a clay of low refractoriness, as at cone 15 it was not vitrified. Two samples were burned to cone 10 and one to cone 12. Of the former, one (Loc. 190) softened sufficiently to lose its shape. The one heated to cone 12 (Loc. 178) burned gray buff, and was nearly vitrified but showed no warping or twisting.

Uses. — The clays of this group are worked chiefly around Trenton for making common and some pressed brick. East and southeast of the Delaware the clay loams are much used to mix with the underlying clays. The sample from Bordentown (Loc. 109, Lab. No. 171) is an example of this type of material. Other localities at which these clays are being worked are Edgewater Park, Woodbine, Buckshutem and Belle Plain.

At several localities the stiff-mud process of molding is used, and while a good marketable brick is obtained, a better product could no doubt be turned out with the use of more care in tempering and molding or by re-pressing. As can be seen by reference to the table of brick tests (p. 256) the products made from these clays show a crushing strength equal to that of the other common building bricks. Layers are occasionally found of sufficient fineness and plasticity to make common red earthenware, some clay for this purpose having been dug in Hatch & Sons' pit at Fish House. Many of the less gritty clays could also be used for draintile.

COHANSEY CLAYS.

The Cohansey clays represent an important group of deposits whose value has become prominently known since the issuance of the first New Jersey Clay Report, in 1878.

The deposits show considerable variation in thickness. Many openings were seen, showing from 6 to 8 feet of clay; 12 feet were also observed, and in one instance, viz., at Clayville, the bed of clay is said to be 24 feet thick. At some localities the bank may be fairly uniform from top to bottom, while at others there may be several layers, varying in character, and in the latter case, if the run of the bank is to be used, thorough mixing is necessary.

In mining the clay the deposit is sometimes large enough to be worked with a steam shovel, especially if much clay is to be dug and shipped daily. This method is not commonly used, however, but instead the clay is usually dug with mattocks, and loaded either onto tram cars or two-wheeled horse carts. (Pl. VII, Figs. 1 and 2.)

The amount of overburden ranges from 4 to 6 feet at most localities, but in one or two instances 12 to 15 feet of stripping

Pleistocene and Post-Pleistocene Clays (chiefly Cape May Age).

Loc. No.	Lab. No.	LOCALITY.	CHARACTER OF MATERIAL.	Tempering—H_2O req., per cent.	Air shrinkage.	TENSILE STRENGTH. Lbs. per sq. in.				Cone 05.		Cone 03.		Cone 1.		Cone 3.		Cone 5.		Cone 8.		Cone 10.		REMARKS.
						Minimum.	Maximum.	Average.	Number tested.	Fire shr.	Absorption.	Fire shr.	Absorption.	Fire shr.	Absorption.	Fire shr.	Absorption.	Fire shr.	Absorption.	Fire shr.	Absorption.	Fire shr.	Absorption.	
127	651	Edgewater Park—H. Adams,	Gritty clay, common brick,	22.6	5.5	149	231	185	8	1.8	15.34	......	......	2.5	11.97	......	......	5.8	2.86	......	......	......	......	
109	177	Bordentown—Bordentown Brick Co.,	Clay loam,	......	3.6	......	......	......	......	......	......	......	......	3	14.49	3	14.55	3.4	12.29	......	......	......	......	
137	639	Fish House—Hatch & Sons,	Green brick mixture; gritty, sticky; does not feel highly plastic,	27.5	7	240	315	258	12	3	9.96	5	6.83	6	3.08	6.3	.02	......	......	......	......	......	......	
137	668	do do	Black clay,	37.1	6	231	266	243	6	......	......	7.3	5.96	7.6	4.90	......	......	......	......	......	......	......	......	
178	671	South of Millville,	Soft, plastic; sample from boring,	31.7	7.3	......	......	......	......	......	......	......	......	3.7	8.25	......	......	......	......	......	......	......	......	
179	702	do do	Not used,	23.7	4.6	......	......	......	......	......	......	......	......	2.7	10.78	......	......	......	......	......	......	......	......	Cone 9—Fire shrinkage, 4.2; impervious, viscosity beginning.
180	646	Buckshutem—A. E. Burcham,	Green brick mixture,	27.2	7	266	351	291	12	3.3	12.46	5	9.41	6	5.50	6.3	4.48	7	3.51	......	......	......	......	
181	645	South of Millville—Golder & Hess,	Used for common brick,	25.2	10	252	338	289	12	2	13.13	2	9.05	4	6.29	4	4.24	4.3	2.86	......	......	......	......	
184	669	Vineland—Hobart,	Tough, micaceous, sandy clay for common brick,	36	6.3	......	......	133	3	......	......	3.7	16.29	4.4	13.00	......	......	5.3	10.35	......	......	......	......	
184	663	Vineland,	Very gritty; plasticity fair; used for common brick,	28.5	5.3	......	......	......	......	.7	16.94	2	17.32	2.7	13.49	......	......	......	......	......	......	......	......	Cone 01—Fire shrinkage, 2.3; absorption, 14.79.
188	660	Belle Plain—Greenlee & Hand,	Green brick mixture, representing run of bank,	22.9	5.3	136	162	148	3	......	......	......	......	1.7	11.98	......	......	2.7	10.82	......	......	......	......	
189	678	Woodbine—Bushnell & Westcott,	Tough, gritty, moderately plastic, bluish white clay,	27.8	6	......	......	......	......	......	......	......	......	......	......	......	......	5.3	6.33	4.6	5.45	......	......	Cone 15—Fire shrinkage, 3.3; absorption, 1.61.
189	705	do do	Run of bank, gritty,	21.4	4.3	86	92	90	6	......	......	......	......	1	12.77	......	......	......	......	......	......	3.7	......	
190	664	West side Cohansey creek, ½ mile south of Bridgeton,	Very plastic, gritty; not used,	26	6	208	232	219	4	......	......	......	......	4.3	7.51	......	......	7.3	2.76	......	......	......	loses shape	
300	983	North of Asylum station, Trenton,	Gritty loam,	25.6	5.6	90	121	104	12	2	13.14	......	......	......	......	2.6	11.59	3.3	8.74	......	......	......	......	

Pleistocene and Post-Pleistocene Clays (Glacial and Colluvial).

Loc. No.	Lab. No.	LOCALITY.	CHARACTER OF MATERIAL.	Tempering—H_2O req., per cent.	Air shrinkage.	TENSILE STRENGTH. Lbs. per sq. in.				Cone 05.		Cone 03.		Cone 1.		Cone 3.		Cone 5.		Cone 8.		Cone 10.		REMARKS.
						Minimum.	Maximum.	Average.	Number tested.	Fire shr.	Absorption.	Fire shr.	Absorption.	Fire shr.	Absorption.	Fire shr.	Absorption.	Fire shr.	Absorption.	Fire shr.	Absorption.	Fire shr.	Absorption.	
234	659	Somerville—J. C. Ross,	Red, stony clay,	20.5	5	272	317	297	10	......	......	5	......	6.6	.64	......	......	......	......	viscous		......	......	
276	726	Flemington—G. E. Pedrick,	Lean, gritty loam for common brick,	23.9	3.5	137	171	159	10	1.1	12.34	......	......	7.1	4.94	7.1	3.90	......	......	......	......	......	......	
280	725	Washington—C. Blazer,	Not worked,	26.2	6.3	......	......	......	......	1	14.07	......	......	......	......	......	......	......	......	......	......	......	......	
284	724	Schooley's Mountain—J. A. Parker,	Not worked,	35.4	8	......	......	......	......	4	10.90	......	......	......	......	......	......	......	......	......	......	......	......	
290	727	Murray Hill—H. Wilcox,	Not worked,	30.8	8	......	......	134	......	11	3.12	......	......	......	......	......	......	......	......	......	......	......	......	
291	618	Little Ferry—Mehrhof Brick Co.,	Used for common brick,	22	6	100	127	108	12	4.3	7.88	......	......	8.6	.10	7	nearly viscous	viscous		......	......	......	......	Cone 01—Fire shrinkage, 7.3; absorption, .28.
292	734	Ogdensburg—A. D. Tallman,	Not worked,	......	7.5	57	77	65	......	......	......	......	......	4.10	14.14	......	......	4.8	11.11	......	......	......	......	

were being removed. Where common brick are to be made, this overlying sand can sometimes be used to mix with the clay, but in most cases it has little value except for filling. Most of the Cohansey clays when freshly dug are fairly dry, and show but little change in the upper layers due to weathering, because the heavy overburden acts as a protective coating.

Water for tempering.—In 28 samples tested, the water required for mixing ranged with one exception from 15.6 per cent. to 38.2 per cent. One sample (not included in the 28), a fine silty ochre from near Toms River, absorbed 65 per cent. The average, leaving out this one high one, was 28.99 per cent.

Air shrinkage.—In such a variety of clays as the Cohansey formation presents, there is considerable variation in the air shrinkage, although the majority of samples show from 6 per cent. to 8 per cent. The lowest was 2.5 per cent. in the sandy loam from Herbertsville (Loc. 219), and the highest was 9 per cent. on a clay from the Northridge property, two and one-half miles southwest of Tuckerton (Loc. 211).

Tensile strength.—With 6 exceptions, the average tensile strength of all the clays tested exceeded 120 pounds per square inch, 11 exceeded 150 pounds per square inch, and 3 had a tensile strength of over 250 pounds per square inch.

Burning tests.—The Cohansey clays can be divided into two groups, 1) red-burning clays, and 2) buff-burning clays. The former were found at localities 191, 197, 206, 208, 211, 218 and 219 (see table).

None of these burned steel-hard at cone 05, and all had to be heated to at least cone 1, to reach this condition. As will be seen from the tabulated tests, many samples were not tested below cone 5, since on account of their being more refractory than most common-brick clays, and their sandiness, they do not burn steel-hard below that point.

The buff-burning clays are found at a number of localities, notably 183, 185, 195, 201, 202, 209 and 213, and many of them burn to a nearly impervious body at cone 10 or 12. A few, however, such as those from localities 199 and 213, are porous even when burned to cone 10. The clay from locality 206 contains much organic matter, and that from locality 213 shows tiny specks of iron oxide after it is burned.

One curious feature of some of the Cohansey clays is that their color, when freshly dug, is sometimes so brilliant as to deceive one regarding their buff-burning character.

In several pits where red-burning clays are dug for brickmaking, patches of lighter clay are also found in the same bank, and are often referred to as buff-burning clays. While these may burn buff in a common-brick kiln, where the temperature does not usually exceed the fusing point of cone 05, they will not retain this color if burned to cone 7 or 8, these being the cones at which the manufacturers of buff ware, such as terra cotta or pressed brick, commonly burn their product.

Uses.—So far as the writer is aware, no attempts have been made to wash out the grit from the Cohansey clays and use them for floor tile, but this might be found profitable. Their most important use at the present time is for the manufacture of pressed brick. These are made at Rosenhayn and also at Mays Landing by the stiff-mud process, and by the hydraulic dry-press method at Winslow Junction. Conduits have been made at Clayville, and common brick from more impure beds at Bridgeton and Toms River. Considerable sandy clay has been shipped from near Woodmansie for making terra cotta, and clay for the same purpose has been dug at Blue Anchor and east of Millville. The ochre dug at Toms River is said to have been used by linoleum manufacturers. Next to the Raritan clays, those of the Cohansey formation seem to have the most extensive use of any found in the State. Some of the Cohansey clays have been incorrectly termed fire clays, and have even been used to make bricks for lining brick kilns, or even boiler settings, but in neither of these cases would they be subjected to a high heat. So far as the writer's experiments have gone, only one of the series examined is to be classed as a fire clay, and it seems doubtful whether any, with the exception of this one, should be used in anything which requires burning at a higher heat than cone 10.

Further details regarding their occurrence are given under the description of clay in Ocean, Burlington, Camden, Atlantic and Cumberland counties.

Physical Characters of Alloway Clay.

Loc. No.	Lab. No.	LOCALITY.	CHARACTER OF MATERIAL.	Tempering—H_2O req., per cent.	Air shrinkage.	TENSILE STRENGTH. Lbs. per sq. in.				Cone 05.		Cone 03.		Cone 1.		Cone 3.		Cone 5.		Cone 8.		REMARKS.
						Minimum.	Maximum.	Average.	Number tested.	Fire shr.	Absorption.	Fire shr.	Absorption.	Fire shr.	Absorption.	Fire shr.	Absorption.	Fire shr.	Absorption.	Fire shr.	Absorption.	
160	675	Richmondville,	Black clay, lean, no grit, 7-ft. boring,	30	8	83	136	90	8	4	20.17	5	15.45	5.5	13.48	......	......	......	......	......	......	
162	617	Yorktown,	Mixture for brick and draintile; plastic, fine grit,	27	7.6	204	245	229	10	1	13.42	......	......	2.7	8.90	4.4	6.96	......	......	5.7	1.21	Cone 01—Fire shrinkage, 2.7; absorption, 8.58.
164	680	Railroad cut north of Alloway,	Very plastic; some coarse grit; not used,	32.1	8.6	401	506	453	6	......	......	4.4	8.07	5.2	3.94	......	......	......	......	......	......	Vitrified at cone 12.
165	690	1 mile south of Alloway,	Yellow, dense, mottled, micaceous,	35.6	9	......	......	......	......	......	......	......	......	7	.47	......	......	......	.07	......	......	
161	691	West of Yorktown,	Quite plastic; no grit; sample from 4-ft. boring; not used,	36.1	8	......	......	......	......	......	......	......	......	7	1.41	......	......	......	......	......	......	
162	677	Yorktown,	Top clay,	30.2	9.3	270	381	308	10	2.7	12.62	......	......	6	4.62	......	......	7.7	.22	7	.34	
162	694	do	Blue bottom clay,	29.9	8	193	248	223	10	5.3	6.89	......	......	6.3	2.82	7.3	1.07	4.6	......	......	......	
163	685	½ mile northeast of Alloway,	Sample from 7-ft. boring; some fine grit,	26.5	8	226	272	246	12	0.	16.59	......	......	......	......	2	10.57	5.3	4.51	5.3	6.39	Viscous at cone 27.
167	688	3 miles north of Alloway,	Sample from 7½-ft. boring,	48.7	11	74	86	80	2	......	......	......	......	5.6	5.18	......	......	8.3	.46	......	......	Viscous at cone 12.
168	672	Cut near Riddletown,	Very plastic; somewhat soft; little grit; not used,	46.5	10.6	308	414	337	6	......	......	3.4	9.89	3.4	7.96	......	......	......	......	......	......	
169	674	Fenwick yard,	Sample from boring; fat, with some grit,	29.7	7.6	251	374	327	3	......	......	1	11.86	......	......	......	......	......	......	......	......	
175	687	Farwell farm,	Sample from 7½-ft. boring; tough; no grit,	32.1	9.3	181	239	208	6	......	......	......	......	2.7	5.40	......	......	4.7	2.21	......	......	Vitrified at cone 12.
176	693	1 mile east of Harrisonville,	Sample from 4-ft. boring; plastic; no grit; not used,	47.7	8.3	371	454	405	3	......	......	......	......	5.7	......	8.3	.20	......	......	......	......	
177	673	2 miles northeast of Woodstown,	Sample from 4-ft. boring; tough, plastic; very little grit; not used,	35.8	8.3	......	......	......	......	4.7	11.76	5.7	9.45	7.7	3.59	......	......	9.3	.36	......	......	Viscous at cone 12.
						Micaceous Talc-Like Clay.																
172	689	Along road, northeast of Woodstown,	Sample from boring; very lean; micaceous; soapy feel; not used,	45.2	3.3	......	......	......	......	......	......	......	......	......	......	......	......	......	......	5.3	24.73	Cone 10—Fire shrinkage, 7.3; absorption, 19.23.
173	679	......	Sample from 7½-ft. boring; lean, soapy, micaceous; not used,	38.5	5	......	......	......	......	1	28.73	......	......	3	24.65	......	......	3	20.61	......	......	

Physical Characters of Asbury Clay.

Loc. No.	Lab. No.	LOCALITY.	CHARACTER OF MATERIAL.	Tempering—H_2O req., per cent.	Air shrinkage.	TENSILE STRENGTH. Lbs. per sq. in.				Cone 05.		Cone 1.		Cone 3.		Cone 5.		Cone 10.		REMARKS.
						Minimum.	Maximum.	Average.	Number tested.	Fire shr.	Absorption.	Fire shr.	Absorption.	Fire shr.	Absorption.	Fire shr.	Absorption.	Fire shr.	Absorption.	
217	658	West of Asbury Park—Drummond Bros.' brick clay,	Yellow, sandy, part of brick mixture; laminated clay,	20.9	3.3	94	114	107	8	......	......	......	......	0.	16.87	......	......	2	......	
217	696	do	Lean, gritty, black,	37.3	5.6	156	202	182	3	3.3	28.31	7	16.79	......	......	......	......	......	......	Cone 01—Fire shrinkage, 6.4; absorption, 24.76.
217	697	do	Very gritty, slightly plastic loam,	27	6.3	124	149	137	3	.4	20.12	1	16.22	......	......	......	......	......	......	Cone 9—Fire shrinkage, 3; steel-hard.
217	696–7	do	Mixture,	31.2	6.3	243	283	258	6	.3	23.53	2.2	17.59	......	......	......	......	......	......	Cone 9—Fire shrinkage, 2.4; absorbent.
269	738	South of Eatontown,	Black, sandy clay,	......	......	......	......	......	......	total 6.6	22.39	total 7.3	19.51	......	......	......	......	......	......	
270	736	South of Eatontown—D. H. Applegate,	Plastic, somewhat gritty,	25	6.3	122	150	124	6	1	18.69	3	12.27	......	......	3.7	9.10	......	......	

Physical Characters of Cohansey Clays.

Loc. No.	Lab. No.	LOCALITY.	CHARACTER OF MATERIAL.	Tempering—H_2O req., per cent.	Air shrinkage.	TENSILE STRENGTH. Lbs. per sq. in.				Cone 05.		Cone 03.		Cone 1.		Cone 3.		Cone 5.		Cone 8.		Cone 10.		REMARKS.
						Minimum.	Maximum.	Average.	Number tested.	Fire shr.	Absorption.	Fire shr.	Absorption.	Fire shr.	Absorption.	Fire shr.	Absorption.	Fire shr.	Absorption.	Fire shr.	Absorption.	Fire shr.	Absorption.	
182	661	West of Millville,	Sample from boring; not used,	36.4	6.6	283	289	286	2	......	......	......	......	......	......	......	......	3.4	9.46	4	8.78	......	......	
183	653	Northeast of Millville,	Very sticky; not much grit; represents run of bank; used for conduits,	32.3	4	144	181	163	10	......	......	4.6	13.07	7.3	6.14	8	8.34	......	......	10	.42	8	.46	Cone 15—Fire shrinkage, 7.3; absorption, 2.64.
185	682	Rosenhayn,	Quite plastic; some coarse grit; tears some; red top clay; used some in brick,	32.4	8	150	165	158	7	......	......	......	......	5.3	10.82	......	......	8	4.68	7.3	.01	......	......	
185	683	do	Sticky, gritty and plastic; used for buff brick,	28.9	8.6	118	152	127	12	1.4	......	......	......	5.4	......	6	......	6	......	6.7	......	......	......	
186	704	Carmel,	Sample from boring; tough; not very plastic; sandy; cracks in molding; not used,	28.1	6	......	......	......	......	......	......	......	......	......	......	......	......	4	7.68	......	......	......	......	
187	676	Old P. A. T. C. Co. pit, east of Millville,	Very plastic; little grit; not used,	34	8.6	154	157	155	3	......	......	......	......	......	......	......	......	7.4	3.26	7.7	......	8.4	1.80	Cone 12—Fire shrinkage, 9; absorption, .09.
191	619	Bridgeton,	Used for common brick,	30	7	121	146	133	12	3.6	14.81	......	......	5.3	7.96	7.6	5.57	7.6	4.19	......	......	......	......	
195	634	Mays Landing,	Gritty; some limonite; little mica; no pyrite; quartz grains,	23.17	7.5	249	313	282	10	......	......	......	......	2.8	8.09	4.1	4.50	4.5	3.08	6.5	.84	7.1	.18	Thoroughly viscous at cone 23.
195	642	do	Pompeian clay,	23.4	8	262	320	293	10	.3	11.65	......	......	3.3	6.20	4	3.60	4	4.36	5	......	......	......	Cone 12—Absorption, .74.
197	667	De Costa,	Light clay, very smooth and plastic,	29.1	7.5	185	199	192	5	.5	17.20	......	......	2.5	12.04	2.5	12.01	2.5	......	5.1	......	......	......	
197	701	do	Plastic; some grit; used for common brick,	30.8	6.6	177	232	206	7	.7	16.56	......	......	2	15.72	4	10.87	4	8.34	......	......	......	......	
199	681	Pleasant Mills,	Gritty; lean; not worked,	32.1	6.6	......	......	......	......	......	......	......	......	......	......	......	......	2.7	13.25	......	......	......	......	
201	657	Winslow Junction,	Dense; moderately plastic; not much grit; used for dry-pressed brick,	37.5	5.5	180	211	196	4	......	......	......	......	6.5	12.96	......	......	......	......	9.1	4.01	......	......	Cone 15—Fire shrinkage, 10; absorption, 2.37.
202	692.	Blue Anchor,	Not worked at present,	38.2	7.3	133	154	146	4	......	......	......	......	......	......	......	......	6.3	5.09	7.6	4.3	9.2	1.90	
206	665	Toms River,	Yellow clay, fine-grained, lean; used for paint clay,	65	8	63	81	74	3	2.6	35.12	9.3	26.15	......	......	......	......	......	......	......	......	......	......	Cone 01—Fire shrinkage, 14.6; absorption, 14.33.
206	684	do	Brick mixture, lean, very sandy,	26	4.3	65	71	68	6	......	......	......	......	2.3	15.37	......	......	3.7	12.53	......	......	......	......	
207	706	do	Moderately plastic; not used,	29.1	5	......	......	......	......	......	......	......	......	......	......	4	11.92	5.1	11.03	5.6	7.88	......	......	Cone 15—Fire shrinkage, 4.3; absorption, 3.01; vitrified at cone 27.
208	686	Davenport,	Pasty, gritty; not used; pulls in molding,	33.1	7.6	127	143	130	10	1.7	19.09	......	......	6	10.21	6.4	7.98	7	6.68	7.2	7.21	......	......	
209	666	Mayetta,	Represents upper 5 feet; gray clay, but no mica; to be used in future for dry-pressed brick,	......	4	......	......	......	......	......	......	......	......	......	......	4	12.83	5	8.80	6	......	......	......	
209	700	do	Represents bottom 5 feet of section; to be used in future for dry-pressed brick,	......	5.3	......	......	......	......	......	......	......	......	4.7	10.52	......	......	8	3.06	......	......	......	......	
210	662	½ mile west of Tuckerton,	Not very plastic to feel; gritty; outcrop along road not used,	26.3	5.5	158	181	173	......	......	......	......	......	.5	13.16	......	......	......	......	4.1	6.73	......	......	Cone 9—Fire shrinkage, 5.1; slightly absorbent.
211	670	2½ miles southwest of Tuckerton,	Formerly used for common brick,	27.6	9	......	......	......	......	1	15.29	......	......	1	9.45	3	6.06	3.3	4.52	3.6	......	......	......	
213	656	Woodmansie,	Gritty; yellowish white; much silica; porous; lean; used for terra cotta,	23.3	4.8	65	77	73	6	......	......	......	......	......	......	......	......	2.7	9.08	2.7	9.67	3	8.13	
	609a	Mayetta,	......	37	7	......	......	183	......	......	......	......	......	......	......	4	8.82	1.7	6.82	......	......	......	......	Cone 15—Fire shrinkage, 3.6; viscous; absorption, 2.07.
218	695	1 mile south of Herbertsville—Herbertsville Brick Co.,	......	32.6	5.3	102	116	108	8	.3	20.19	......	......	......	......	......	......	2.7	12.98	......	......	6	......	
218	695s	do	......	15.6	3.3	62	70	65	6	.7	14.76	......	......	0.	14.06	......	......	......	......	......	......	......	......	
219	698	2 miles southeast of Herbertsville—I. H. Tilton,	Not very plastic; much coarse grit; used in common brick,	29.3	4.4	66	81	73	6	.2	20.84	......	......	2.6	16.93	......	......	......	......	......	......	......	......	
219	699	do	Very sandy loam; used in common brick,	21.3	2.5	45	54	49	4	.5	17.64	......	......	1.5	16.52	......	......	......	......	......	......	......	......	
219	698–9	do	Green brick mixture, clay and loam,	25	4	65	77	70	8	.3	19.26	......	......	1.4	16.16	......	......	......	......	......	......	......	......	
294	750	Lakewood,	Sandy clay; lean,	20	7.3	......	......	......	......	......	......	......	......	0.7	13.10	......	......	0.7	......	......	......	......	......	Cone 15—Fire shrinkage, 1.7; gray, brown speckled.
212	412	Whitings,	......	......	5.5	120	130	125	......	......	......	......	......	5.5	......	......	......	10.8	......	10.8	......	......	......	

Prospecting for Cohansey clays is attended with considerable difficulty, partly because of the heavy pine and brush growth covering most of the regions in which they are found, and partly because the clays are often overlain by a considerable bed of sand, so that it is completely hidden. The flatness of the region and absence of many rivers which would provide clay outcrops along their banks, further interfere with the search. The absence of outcrops along a river bluff would not necessarily mean that there was no clay deposit in that vicinity for the reason that the Cohansey clay beds are rather basin-shaped, and do not underlie large areas in unbroken extent. The river might, therefore, have cut its channel but a few feet beyond the limit of the deposit, and thus give no indication of its presence. In searching for Cohansey clays, therefore, the necessity of careful and detailed prospecting with an auger cannot be too strongly emphasized. Dug wells and records of artesian wells where available may also be of value.

ALLOWAY CLAY.

This is one of the largest individual deposits found in New Jersey (Pl. XIII), and yet one of the least worked, although it is commonly found outcropping on the hill slopes, under conditions that would facilitate its extraction or favor the erection of a plant. The overburden in many cases is thin, and the beds where examined were usually found to be quite free from water. The clay is commonly a tough, dense, plastic material, with little coarse sand, and some fine grit, mica grains are comparatively rare, and the pebbles when present are commonly quartz. Most of the Alloway clays are so fine-grained that but few mineral particles are recognizable with a hand lens, and quartz or rarely small flakes of muscovite are the only ones distinguished. Even sand grains one-eighth of an inch in diameter do not always show except on mechanical analysis, because they form such a small proportion of the clay. Many of the clays are stained or mottled.

Owing to the fact that the Alloway clay is but little worked, a number of localities, 13 in all, were sampled. Nearly all the samples are very plastic, sticky clays, with little coarse grit and practically no mica. Owing to their high plasticity, they soaked up considerable water in tempering, and showed an air shrinkage somewhat higher than most of the other clays, as well as greater tensile strength.

Slaking.—The majority of the Alloway clays are quite dense and slake slowly when thrown into water.

Water required.—The amount of water necessary to temper the mass ranged from 26.5 per cent. up to 48.7 per cent., with an average of 35 per cent., which is greater than the average water required in any of the other clays. The high water absorption is to be expected, however, in such plastic clays.

Air shrinkage.—This varied from 7.6 per cent. to 11 per cent., and in a general way stands in direct relation to the amount of water required for mixing. The air shrinkage is somewhat high, however, so that in the manufacture of this clay, some more sandy clay would have to be added to it. This can usually be found in the loamy beds overlying the clay at many localities. Near Yorktown, where the Alloway clay is used for bricks, enough loam is added to the mixture to decrease its shrinkage the proper amount. The laboratory tests on samples from this locality showed an air shrinkage of 8 per cent. and 9 per cent. for the clay alone, and of 7.6 per cent. for the mixture. As the latter was not quite so stiff as the material which is worked on the stiff-mud machine, the shrinkage in actual practice would be a little less.

Tensile strength.—With very few exceptions, all of the Alloway clays show a very high tensile strength, one having the high average of 453 pounds per square inch, and a phenomenal maximum of 506 pounds per square inch.[1] Two samples only had a low tensile strength.

Burning qualities.—It is difficult to generalize regarding the burning qualities of this clay, but the majority of samples burn steel-hard at cone 05, and were all red-burning. The fire shrinkage is variable, as can be seen from a comparison of those burned at cone 1 (see table opp.), but some samples, it will be noticed,

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[1] This sample was in part made up of a secondary clay resting directly on the Alloway clay, and derived from it by stream action.

viz, those from localities 161 and 165, are nearly impervious at the above-mentioned cone. Few of them become viscous below cone 12 while some do not fuse until cone 27 is reached.

Uses.—The Alloway clay at the present time is worked at one locality for making brick and draintile, and yields excellent results, the bricks showing up well on both cross-breaking and crushing test. Indeed, it would seem that these clays were worth being tried, also, for the manufacture of stoneware, not alone, perhaps, but mixed with other materials.

Talc-like, micaceous sand.—This material, which is found under the Alloway clay, in the vicinity of Woodstown (p. 144), is a highly micaceous clayey sand, of a whitish color when unweathered. It has very little plasticity, and absorbs considerable water, viz., 38.5 per cent. in one case and 45.2 per cent. in another. The air shrinkages were 3.3 per cent. and 5 per cent., but the material does not get steel-hard until cone 5 to 8, and the burned bricklet is exceedingly porous, for one at cone 10 had an absorption of 19.23 per cent.

It is doubtful if this material has any value, if used alone, but as a packing material or filler it could no doubt find application.

ASBURY CLAYS.

The character of these clays is in marked contrast to those found about Alloway, which are higher in the Miocene, and their distribution is rather restricted. They form a series of beds or lenses of thinly-laminated character, the layers of clay being separated by thin layers of sand. The clays are thus nearly always gritty, some containing so much sand that even at cone 9 they do not burn dense. The excess of sand has also the additional effect of decreasing the plasticity, tensile strength, air and fire shrinkage. The clays show many coarse grains of quartz and numerous scales of mica. In some beds the sand layers are cemented by iron and these lumps of limonite sand are very likely to cause splitting of the bricks, or fused spots in burning, unless they are separated by screening or broken up in tempering. Furthermore, in any one locality, the section shows beds of different character, overlying each other. Thus west of Asbury Park the clay bank at Drummond's brick works shows the following section beginning at the top:

Section at Drummond's clay pit, Asbury Park.

Top loamy clay,	6 feet.
Yellow loam, sand and clay,	6 "
Black laminated sandy clay,	8 "

The black clay contains considerable organic matter and sand.

The Asbury clays are exposed in many of the gullies and along the roadway west of Asbury Park, but are worked at only a few localities.

Slaking.—The Asbury clays are mostly rather porous and hence slake fast.

Air shrinkage.—The air shrinkage is usually low, and ranges from 3.3 per cent. to 6.3 per cent. in the samples tested, as might be expected from the gritty character of the material.

Water required.—The amount of water necessary to work up the clay into a plastic mass is high, as compared with its low plasticity, and ranges from 20.9 per cent. to 37.3 per cent. Where several distinct beds are found in the same bank these may differ in their behavior towards water, a point which is discussed in more detail below.

Tensile strength.—Although very sandy, there is still considerable clay substance in the raw material to bind the sand grains together, and produce a briquette of very fair tensile strength, so that, when the clay alone was tested, averages of 107, 124, 137 and 182 pounds per square inch were obtained. A mixture sometimes produced better results, but at other times it decreased the strength, as shown below.

Behavior in firing.—Not one of the Asbury clays, so far as tested, burns steel-hard at cone 05, nor do any of them burn a good brick red at this temperature, unless heated longer than is required in the case of the Clay Marls. One from locality 217 (Lab. No. 658), does not burn better than a very light pink at this cone. Their fire shrinkage is also low, being under 1 per cent. in most cases, and they are therefore very porous.

Some improvement was shown when the bricklets were burned to cone 1, but it was not marked except in the case of one sample from Asbury Park (Loc. 217, Lab. No. 697). The light-colored sandy clays remained quite porous even when fired to cone 10.

Variations in the same bank.—The bank of Asbury clay exposed in Drummond Brothers' brickyard at Asbury Park, forms an excellent example of the dissimilarity of three beds in the same section. The top layer is a loamy clay. (Lab. No. 658.) The second layer consists of a light-colored, gritty clay, made up of alternating fine layers of sand and clay. (Lab. No. 697.) The third is a black, micaceous clay, rather dense, but with thin layers or laminæ of sand every few inches. (Lab. No. 696.) A mixture of equal parts of the three is used for making stiff-mud brick. If, however, a mixture of equal parts of 696 and 697 is used, the effect is interesting, as shown by No. 4 of the following table:

For purposes of comparison the physical characters of the three clays alone, as well as the mixture of two layers, are given below:

Physical characters of clays from Drummond's clay pit, Asbury Park.

	1st layer.	*2d layer.*	*3d layer.*	*Mixture of 2d and 3d layers.*
Water required to temper, ...	20.9%	27 %	37.3%	31.2%
Air shrinkage, ...	3.3%	6.3%	5.6%	6.3%
Average tensile strength, lbs. per square inch, ...	107	137	182	258
Fire shrinkage at cone 05, ...	......	0.4%	3.3%	0.3%
Fire shrinkage at cone 1, ..	......	1. %	7. %	2.2%

The water required for a mixture of No. 2 and No. 3 is much less than for No. 3. The air shrinkage has not been decreased below that of No. 2, but the most curious effect perhaps is the increase in tensile strength to a point considerably above that of No. 3; the fire shrinkage at cone 05 has been diminished.

Uses.—Up to the present time the Asbury clays have been used only for making common brick, the clays being dug 1) near Asbury Park, 2) on the N. J. Southern R. R., southwest of Pine Brook, and 3) near Howell Station. Some of the lighter sandy layers seem to yield a fine-grained, fairly homogeneous product, which, when washed, might be used in the manufacture of dry-pressed floor tile, and preliminary experiments made on some have yielded favorable results.

In some of the banks, layers are occasionally found which in their natural condition are sufficiently plastic and homogeneous for the manufacture of earthenware, but they have not been utilized for this purpose, and in fact the available quantity seen at any one locality would be sufficient only to supply a small pottery.

CLAY MARL IV.

Clays from this member of the Clay Marl series are not as yet commercially important, and, so far as observed, are not suitable for much else than common brick. Just west of Mount Holly (Loc. 123) a loamy surface clay, which is perhaps the weathered portion of this bed, or more likely is a Pleistocene deposit is utilized intermittently for common brick.

A sample of Clay Marl IV was collected for testing from the railroad cut near Bellmawr station (Loc. 148), on the P. & R. railroad, and 1 mile south of Mt. Ephraim. The clay from this locality is of yellowish color when fresh and of sandy texture with scattered mica scales. Owing to its sandy character it slakes rapidly. The material, in its color-burning qualities, is as good as the best of the samples from Clay Marls I and II, burning to a brick red of uniform tint. It required 20.8 per cent. water in mixing, and had an air shrinkage of 9 per cent. with an average tensile strength of 195 lbs. per square inch. Its behavior in burning is shown below:

Burning tests on a Clay Marl IV.

Cones.	*03*	*1*	*3*	*5*	*10*
Fire shrinkage, ...	3 %	3 %	3.5 %	4.3%	Viscous
Absorption, ...	14.55%	12.71%	12.06%	......	....

It is by no means a refractory clay.

CLAY MARL III.

As already indicated (pp. 156, 157) the clay found in this member of the Clay Marl series consists of local deposits surrounded by sand. The material is worked at Thackara's brickyard south of Woodbury (Loc. 155), and it is there rather sandy. It is also exposed at Dobb's old yard a short distance south of Thackara's, where it forms an extremely sticky, dense, plastic clay with the following characters:

Physical characters of a clay in Clay Marl III.

Water required for mixing,	40.5%
Air shrinkage,	9 %

Tensile strength, lbs. per sq. in.	Minimum, 133. Maximum, 136. Average, 134.

In burning it behaved as follows:

Cone.	*05.*	*01.*
Fire shrinkage,	4.3 %	4.6 %
Absorption,	11.28%	8.76%

It is doubtful if this clay could be used alone for anything except common pottery, and for brickmaking considerable sand would have to be mixed with it. The test of this single sample, however, cannot be taken as necessarily indicative of the quality of other clay lenses in this formation.

CLAY MARL II.

The area of outcrop of Clay Marl II, and its stratigraphic characters have been described (p. 157). On account of the undulating character of the region in which this clay occurs, it is often possible to find exposures along the banks of streams or in road cuttings, from which a knowledge of the character of the material can be obtained. The exposures are often of considerable thickness such as fifteen or twenty feet, and when weathered present beds of a dove-colored clay, which is generally less granular than Clay Marl I, and breaks up into many blocks when dry. (Pl. XVIII, Fig. 1.) The weathered clay is also of more open character, and sometimes less plastic than the unweathered portion, which is dark gray, dense and plastic. The overburden is either a sandy loam of post-Pleistocene age, beds of Pensauken gravel, or sometimes a sand bed belonging to the overlying formation, Clay Marl III. This capping has often protected the clay from discoloration and other changes due to weathering, which, when overburden is not heavy, usually extends to a depth of 6 to 8 feet or even more. A secondary change noticed in several of the deposits was the formation of masses of limonite crusts. These do not form solid lumps, but are thin streaks extending through the clay in many directions, and sometimes in such abundance as to form a perfect network. These net-like masses may be very rare, or occur only in certain parts of the bank, so that they can be avoided in digging the clay, while at other times they permeate the entire deposit, practically necessitating its abandonment. Only one instance of the excessive development of these crusts was seen, viz., at locality 125, west of Rancocas, where the sandstone crusts were all-prevading in their extent and it is doubtful whether a deposit could be worked under such conditions.

In the field work a number of deposits located by Mr. G. N. Knapp were tested by boring, and showed in most instances, at least 6 to 7 feet of good clay, which is of course a very small fraction of the total thickness of this formation.

Samples were tested from fourteen different localities (see table p. 360). The clay at two of these is being worked; the other samples are, therefore, from deposits which are not being used, and were either taken by boring into the deposit with an auger or else by sampling the face of the bank.

As compared with the clays of Clay Marl I, the samples all show less mica and grit; they are consequently more plastic, and show higher air shrinkage. Some of them are even fat and greasy. The samples from localities 231 (Lab. No. 607) and 129 (Lab. No. 608) represent weathered samples, and are plentifully stained with limonite. They do not slake more rapidly, however, than the unweathered ones, and in fact most of the samples, with the exception of the sandy ones, slake rather slowly. All show a few small mica scales.

Water required.—In the samples tested the percentage of water necessary to produce a pasty mass ranged from 22.8 per cent. up to 38.5 per cent., with an average of 29 per cent. One brick mixture of clay and loam required but 21.8 per cent of water.

Air shrinkage.—The air shrinkage with a few exceptions is rather high, ranging from 3 per cent. to 11 per cent., with a number showing shrinkage of 7 per cent. or over. This high air shrinkage is sometimes accompanied by a warping of the clay in air drying, and the addition of sandy material is often necessary to avoid it.

Tensile strength.—The samples of Clay Marl II show considerable variation in their tensile strength, ranging from an average of 126 pounds for the lowest sample, to 286 pounds per square inch for the highest. The one with the highest strength, from 1 mile south of Collingswood (Loc. 144) is used in the manufacture of brick and tile. Its air shrinkage at the factory is lower than that given in the table, because it is molded much drier than was the sample in the laboratory. None of the clays of this formation are, however, deficient in tensile strength.

Behavior in burning.—With the exception of the sample from 1½ miles south of Haddonfield (Loc. 145) all burn to a light brick-red at cone 05, but they did not all burn steel-hard, only those from 1 mile west of Woodbury (Loc. 157) and north of Matawan (Loc. 231) doing so. Most of them become steel-hard at cone 1, and two, viz., those already mentioned from Loc. 231 and Loc. 157 vitrify at cone 3, but the others did not vitrify below cone 5. When heated above cone 1, most of them lose the bright red color, and become grayish or brownish in tone. Since glauconite grains are wanting in Clay Marl II, none of the samples show the fused specks of this mineral, so noticeable in Clay Marl I. They also lack the numerous large mica scales found in the clays of the preceding member.

The fire shrinkage at cone 05 ranged from 0.4 up to 4.7 per cent., being greatest in the most dense-burning samples. At cone 1 there was, however, less variation among the different samples than at cone 05, the majority showing between 4 per cent. and 5 per cent. fire shrinkage. One sample from north of Matawan (Loc. 231) shows a fire shrinkage of 8.7 per cent. at cone 1. Very few of the clays of this formation become viscous below cone 10, but they are not semirefractory. One from a locality along Matthew's brook, 1 mile south of west of Woodbury (Loc. 157), became viscous at cone 8. This same clay warped considerably at all the temperatures at which it was burned.

Uses.—The deposits of Clay Marl II are at present used either alone or with other clays at nine localities, so far as known. They are worked at Crosswicks for the manufacture of draintile and hollow bricks; at Hightstown in connection with a surface clay for making stiff-mud brick; at Collingswood for brick and draintile; at Lorillard, near Keyport (224), for fireproofing; at Matawan (228) for brick (with Clay Marl I); at Jamesburg (295) for brick; at Maple Shade (149 and 150), for brick (both alone and with Clay Marl I). The only place where the material is dug for pottery manufacture is near Matawan, and there the weathered part of the deposit is mined and made use of for red earthenware flowerpots. It is highly probable that some of the other occurrences could be used for the manufacture of earthenware. There seems no good reason why these clays should not be re-pressed for front brick. No buff-burning clays or fire clays are to be looked for in this formation.

CLAY MARL I.

The exposures of Clay Marl I sometimes occur along streams and are favorably located for working as banks with the easy maintenance of proper drainage, but at other times the bed has to be worked as a pit and drained by pumping. Clay Marl I is dark-colored, lean-feeling clay with much organic matter, coarse sand, mica (Figs. 32, 33) and green grains of glauconite, but the weathered outcrops are sandy and colored cinnamon brown. The

Physical Characters of Clay Marl I.

Loc. No.	Lab. No.	LOCALITY.	CHARACTER OF MATERIAL.	Tempering—H_2O req., per cent.	Air shrinkage.	TENSILE STRENGTH. Lbs. per sq. in.				Cone 05.		Cone 01.		Cone 1.		Cone 3.		Cone 5.		REMARKS.
						Minimum.	Maximum.	Average.	Number tested.	Fire shr.	Absorption.	Fire shr.	Absorption.	Fire shr.	Absorption.	Fire shr.	Absorption.	Fire shr.	Absorption.	
109	600	Bordentown—Bordentown Brick Co., ...	Black micaceous clay; used in common brick,........	23.4	8.8	235	275	251	12	8.3	10.74	11.8	5.83	11.8	4.01	11.8	......	......	......	
131	614	½ mile east by south of Bridgeboro,....	Moderately plastic; coarse grit; not used,............	27.1	7	138	154	145	3	.3	15.05	2.3	11.76	......	......	......	......	......	......	
140	605	Railroad cut 1 mile east of Merchantville,	Good plasticity; fine grit; not used,.................	23	8.3	228	291	257	10	1.7	14.95	1.7	9.95	2	5.57	2.3	5.80	......	......	Cone 8—Viscous.
142	604	On road to Stockton, 2½ miles southeast of Cooperstown, ...	Not used, ...	25	6	......	......	......	......	1	22.61	4	16.07	3.6	15.85	......	......	......	......	
143	620	Camden—Budd Bros., ...	Green brick mixture; contains some loam,...........	20	6	146	177	156	12	1.3	16.54	1.5	......	2.6	12.68	2.6	10.66	2.3	10.17	
143	624	Camden—Budd Bros., ...	Lean, gritty, micaceous clay, with much carbonaceous matter; used in brick mixture,................	24	6	146	185	164	10	.5	9.36	......	......	2	8.62	2	10.75	......	......	Viscous at cone 8.
*149	647	Maple Shade—A. Reeve, ...	Green brick mixture; gritty; no pyrite; quite plastic,..	28.6	7.5	259	313	282	8	......	......	......	......	4.5	10.58	......	......	......	......	Viscous, cone 8 (inc.).
192	602	Windsor, ...	Sample from boring, ...	31	8.6	235	275	251	12	0	17.09	3.4	10.78	1.4	12.22	......	......	......	......	
194	609	Hightstown—Reed Bros., ...	Tough; not highly plastic; used for common brick,...	34	6.6	......	......	......	......	......	......	......	......	5.4	10.59	5.4	......	6.4	......	Cone 03—Fire shrinkage, 3.4; absorption, 16.66.

* A mixture of Clay Marl I and II.

Physical Characters of Clay Marl II.

Loc. No.	Lab. No.	LOCALITY.	CHARACTER OF MATERIAL.	Tempering—H_2O req., per cent.	Air shrinkage.	TENSILE STRENGTH. Lbs. per sq. in.				Cone 05.		Cone 03.		Cone 01.		Cone 1.		Cone 3.		Cone 5.		REMARKS.
						Minimum.	Maximum.	Average.	Number tested.	Fire shr.	Absorption.	Fire shr.	Absorption.	Fire shr.	Absorption.	Fire shr.	Absorption.	Fire shr.	Absorption.	Fire shr.	Absorption.	
118	708	½ mile west of Columbus,............	Not used, ...	......	......	......	......	......	......	6.6 total	30.47	......	......	......	......	......	......	......	......	......	......	
128	610	1 mile northwest of Moorestown,........	Tough, dense, little grit, ...	35	9	114	139	127	2	1.3	17.89	......	......	......	......	8	4.85	......	......	......	......	
129	608	2 miles east of North Pennsville,.......	Not used, ...	29.2	8.8	......	......	......	......	1.2	16.34	1.2	16.41	......	......	4.2	9.95	......	......	......	......	
144	650	1 mile south of Collingwood,..........	Brick mixture; used for common brick and tile,.....	34.9	10	200	354	286	10	3.3	11.12	......	......	......	......	3.3	9.92	......	......	......	......	Cone 10—viscous.
145	715	1½ miles north of Haddonfield,........	Gritty, plastic; not used,.........................	30.7	6.6	144	188	168	6	.4	19.98	......	......	......	......	......	......	......	......	4.9	7.70	
146	638	1 mile north of Westmont,............	Not used, ...	......	......	......	......	......	......	......	......	......	......	......	......	total 11.2	10.22	......	......	......	......	
147	635	Northeast of Haddonfield, ...	Not used, ...	29	7	......	......	243	......	......	......	3.3	17.24	......	......	5	10.31	5	......	......	......	
149	648	Maple Shade, ...	Bottom clay, fat and micaceous,...................	32.8	9	......	......	......	......	......	......	......	......	3	12.62	4	10.06	......	......	......	......	
152	714	2 miles southeast of Merchantville, on road to Evesboro, ...	Plasticity low, little grit; not used,................	38.5	8.3	118	131	126	3	......	......	......	......	......	......	7	8.19	......	......	......	......	
157	613	1 mile south of west of Woodbury, along Matthews brook, ...	Not used, ...	28	11	162	255	193	10	4.3	11.23	......	......	4.3	9.34	5.3	6.88	6.3	3.03	......	......	Viscous at cone 8.
158	612	Southwest side Little Timber creek, 1¼ miles south of west of Mt. Ephraim,	Not used, ...	22.8	7	......	......	......	......	2	18.28	4	15.72	......	......	8	8.42	......	......	......	......	
227	616	Along road south of Matawan,..........	Not used, ...	22.9	5.3	149	177	166	6	......	......	.7	18.27	......	......	1.7	14.98	2.7	13.97	......	......	
231	607	North of Matawan, ...	Used for common earthenware, ...	26	9.3	105	145	128	10	4.7	11.93	......	......	6	5.81	8.7	5.24	10.7	3.46	......	......	
147	735	1½ miles northeast of Haddonfield,.....	Lean, gritty, micaceous, black; not used,...........	27.7	3	......	......	......	......	1.7	21.52	......	......	......	......	1	18.78	......	......	3.6	9.75	
228	601	Matawan, ...	Brick mixture, ...	21.8	6.3	194	200	197	2	1	17.31	......	......	1.7	......	3.7	9.65	......	......	......	......	

weathering, in unprotected deposits, frequently extends to a depth of 6 to 8 feet or even more.

The overburden is either Pensauken gravel, a pebbly loam, or a sandy loam, the two latter being utilized at some yards for mixing with the clay. In some banks, as at Maple Shade (Reeve's), certain layers occur, which are very fat, of high shrinkage, and which are unsafe to use alone. Those which are highly glauconitic are also undesirable.

Samples were tested from nine different localities, the location of which can be seen by reference to the following table of tests.

Slaking.—The clays of this formation are not dense, but, on the contrary, are often porous, and hence slake very fast to a powdery mass. Few of the samples tested show much evidence of weathering. Where weathering has occurred the clay is commonly stained with limonite and is very sandy.

Water required.—In tempering the amount of water required by weight ranged from 20 per cent. to 34 per cent., with an average of 26.2 per cent.

In two cases, viz., localities 143 (620) and 149 (647) the tests given are for the green-brick mixture, which in the case of locality 143 consists of Clay Marl I with a small amount of surface loam added and at locality 149 of a mixture of Clay Marl I and II with some loam. The effect of this addition did not materially affect the quantity of water required for mixing the material up to a stiff, pasty mass.

When the clays of Clay Marl I are compared with those of Clay Marl II it is noticeable that on account of their greater sandiness they require much less water.

Air shrinkage.—In the samples tested this ranged from 6 per cent. to 8.8 per cent., with an average of 7.1 per cent. The higher shrinkage shown by several is apparently due to their finer grain, but the one with the maximum air shrinkage of 8.8 per cent. does not absorb the greatest quantity of water. The air shrinkages given in the table are slightly greater than those obtained in practice, because most of these clays are molded in a stiff-mud machine with little or no water added.

Tensile strength.—None of the samples of Clay Marl I, so far as tested, run low in tensile strength, and some of them, indeed, run high. The lowest one of the series gave 145 pounds per square inch, while the highest of the clay alone was 282 pounds per square inch. The addition of the loam in some cases seems to decrease slightly the strength. Thus the clay from Budd Brothers, City Line station, near Camden (Loc. 143), when tested alone, gave an average of 164 pounds per square inch, but with loam added and mixed for molding on a stiff-mud machine, the tensile strength dropped to 156 pounds per square inch. A brick mixture of Clay Marl I and II, with some loam, used at Maple Shade (Loc. 149) averages 282 pounds per square inch.

Burning.—All the samples tested burned red, although of different degrees of brightness. Where this degree of coloration was obtained at as low a cone as 05, the bricks deepen rapidly in color and lose their brightness when heated above cone 01, at which point even the color was rather deep. Although few of them reached a condition of steel-hardness before cone 1, still it is not necessary to heat them this high to make a good brick. No measurements were made of the common-brick kilns, yet it is probable that they do not exceed the melting point of cone 03, if we may judge from the color and hardness of the brick.

The fire shrinkage of all is low when burned at cone 05, ranging from practically 0 per cent. to 8.3 per cent. The last figure indicates a higher fire shrinkage than that of any of the other clay marls. Of the samples tested, those from Windsor (Loc. 192) and Hightstown (Loc. 194) burn the hardest at cone 05, but in the case of the latter the hardness is due probably in part to the fact that the sample came from the boundary of Clay Marl I and Clay Marl II, and, therefore, would naturally possess some of the denser-burning qualities of the clays from the latter formation.

Uses.—On account of the high percentage of organic matter in the Clay Marl I, brick made from it must be burned slowly at first, until the carbon is all burned off. Failure to regard this point causes black cores, and sometimes even swelling or bursting of the brick. None of the samples were sufficiently fine-grained, or vitrifiable at low enough temperature, to be useful for the manufacture of vitrified brick, neither do they as a rule lend themselves to the manufacture of pottery, although it is possible at times to find certain layers in the bank that are sufficiently fine-grained and plastic to be used in the manufacture of common earthenware flowerpots.

The scattered grains of glauconite found in Clay Marl I fuse very easily, so that bricklets burned at as low a temperature as cone 01 show small fused specks dotting the surface. These were especially noticeable in the samples from localities 140, 194 and 143. The fusion point of the samples from Clay Marl I is commonly about cone 10 to 12, indicating that it is a nonrefractory clay, and in no sense a fire clay.

RARITAN CLAYS.

The Raritan formation is by far the most important clay-bearing formation in New Jersey, containing as it does the best clays of the State, as well as some of the poorest. They range from clays that are highly refractory to others that are easily fusible, from fat to lean ones and from those of high tensile strength to others of exceedingly low bonding power.

Even a hasty consideration of the uses to which they are put indicates in a measure what a wide range of materials must be contained within the limits of the Raritan strata, for the products made from these clays include common brick, fireproofing, draintile, conduits, terra cotta, front brick, fire brick, stoneware, earthenware, tubs and sinks, foundry materials, paper filling, etc. For these reasons, it is rather a difficult matter to discuss these clays collectively.

Extending, as the Raritan formation does, across the State from Perth Amboy to Trenton, and down the Delaware river, its clay beds are well located for working and shipment, either by water or by rail. The question of shipping facilities is, indeed, an important one, since so much of the clay mined is sent to distant points. Unfortunately the formation is heavily covered by later gravel deposits over a large portion of its area, so that, except in a few favored regions, mining this clay is either very difficult or impossible.

Structurally the Raritan clays present a great series of beds of varying character, the majority of which seldom retain their thickness for any great distance but may thicken and thin at frequent intervals. The most persistent beds are the black laminated sands and clays found above the Woodbridge fire clay and so extensively developed along the Raritan river.

In texture the Raritan clays are mostly fine-grained, this being especially true of the fire clays found in the Woodbridge, Perth Amboy, South Amboy and Piscataway districts, and while they often feel very plastic and sticky when wet, still their tensile strength is low. Closely associated with these fine-grained ones, we find the very coarse, impure, sandy and micaceous laminated clays referred to above. The Raritan clays found to the southwestward along the Delaware river from Burlington to Camden are also coarsely gritty in most cases, but are usually of No. 2 grade.

Slaking qualities.—The slaking quality of the Raritan clay depends to a large extent on its degree of porosity and coarseness, the sandy open-textured ones slaking rather fast.

Tensile strength.—The average tensile strength is not high and rarely exceeds 100 pounds. The only high ones are those from Kinkora (Loc. 112) and near Monmouth Junction (Loc. 271).

Burning qualities.—Leaving out the black, sandy, laminated clays of the district along the Raritan, and found to a smaller extent around Woodbridge, and the brick clays near Cliffwood and of the Delaware river district, it is seen that practically all the materials burn buff, or even yellowish white at cone 8. These same clays may, if dense burning, become steel-hard at cone 1 or 3, but usually do not reach this condition until they have been heated to cone 5 or in some cases to cone 8. Comparing a number of fire-clay samples from the Middlesex district, which have been burned to cone 5, it is seen that the fire shrinkage may vary from 1 per cent. up to 13 per cent., and the absorption from 0.05 per cent. to 19 per cent., while at cone 8 the fire shrinkage ranged from 3 per cent. to 12 per cent., and the absorption from 2 per cent. up to 15 per cent.

With such a variation in the characters of the raw materials, it is possible for the miner of clay to meet many different demands

Physical Character of Raritan Clays.

Loc. No.	Lab. No.	Locality.	Character of Material.	Tempering—H_2O req., per cent.	Air shrinkage.	Tensile Strength. Lbs. per sq. in.				Cone 05.		Cone 01.		Cone 1.		Cone 3.		Cone 5.		Cone 8.		Cone 10.		Remarks.
						Minimum.	Maximum.	Average.	Number tested.	Fire shr.	Absorption.	Fire shr.	Absorption.	Fire shr.	Absorption.	Fire shr.	Absorption.	Fire shr.	Absorption.	Fire shr.	Absorption.	Fire shr.	Absorption.	
		Cliffwood Lignitic Sands and Clays.																						
220	611	Cliffwood—Carmen & Avery,	Mixture for stiff-mud brick,	25.5	6.5	77	100	88	10	1.5	17.93	3	11.34	3	13.61	3.2	11.12	3.7	9.98	6	10.70			
220	615	do	Gritty, moderately plastic, light clay; most northern pit along railroad (Aug., 1902),	23.5	6	101	110	103	4	3.5	18.13					7.5	6.90							Cone 03—Fire shrinkage, 5; absorption, 13.73.
222	603	Cliffwood—A. H. Furman,	Brick mixture,	23	5.3	105	110	106	5	.2	17.59	2.5	13.37	3	10.10	3.3	9.38							Nearly viscous at cone 8.
222	606	do	Fat, black clay; used in brick,	30	6	82	108	91	12	4.3	11.16	4.6	6.78	7	7.87	9.3	3.74							Well vitrified at cone 8.
		Amboy Stoneware Clay.																						
81	395	South Amboy—H. C. Perrine & Son,	Much fine grit; used for stoneware,	37	7	108	120	109				6	11.65	6	8.77	7.6	9.95					9	.24	Not beyond incipient fusion at cone 27. Viscous at cone 30.
		South Amboy Fire Clay.																						
67	389	South Amboy—J. R. Such,	Soft, fine-grained, washed ball clay,	40	5		low											9	16.42	12	10.20			Vitrified at cone 27.
67	390	do	Red clay, with very little grit,	39	4.5	55	78	65.5		1.5	28.90					8.7 Cone	13.59 3-4	11.5	8.26			15.5	2.19	
67	391	do	Crude, blue ball clay; very plastic; fine-grained,	39	5 or 6			59								total 11.1				total 18	10.84	total 18.6	5.93	Well vitrified at cone 27.
67	392	do	Whitish clay, irregular break, considerable grit; sagger clay,		6			48										3.3	14.17	5	11.72			Cone 15—Fire shrinkage, 10.3; absorption, 2.33.
45	401	Eagleswood—McHose Bros.,	Flaky, moderately plastic, No. 1 buff clay,	32	5	60	70											5	11.68	6.6	11.34			Incipiently fused at cone 27.
45	402	do	Sandy, fine clay; very gritty, yellowish white, of porous nature; No. 1, sandy, fine clay,	26	6.5			45										1.9	15.39			1.8	13.52	Fused at cone 30.
45	403	do	Red, dense clay, with angular fracture,	32	6.6			75				6	14.28	6.3	13.00	6.6*								* Burned at cone 2.
65	386	Burt Creek—J. R. Crossman,	Red, mottled clay, rather low plasticity,	30	4			15								8.3	16.85	11	11.31	11	10.02	12.6	7.32	Viscous at cone 31.
65	409	do	Blue clay; lean, fine-grained clay; little particles of iron,		6			20										7	19.35	11	11.59			Fused at cone 29.
64	387	do	Pipe clay; gritty clay of low plasticity,	35	5			20										11	15.45	11	16.65	12	11.49	
268	722	Sayreville—Edgar Bros.,	Dense, fine-grained, No. 1 blue fire clay,	39.1	4.4	32	33	32.5	2		14.98											11.6		Vitrified at cone 27.
268	723	do	Washed ball clay,	39.1	5	very low				11								10.6	10.53			16.3	3.98	Cone 15—Fire shrinkage, 16; absorption, .63. Vitrified at cone 27.
		Woodbridge Black Laminated Sandy Clays.																						
46	399	Keasbey—National Fireproofing Co.,	Pipe clay; clay from bottom of bank; dense, tough; good plasticity; contains organic matter,	30	6	50	55							7.3	1.58	9	1	9.3						Vitrified between cones 8 and 10.
46	400	do	Flue clay; sandy; used for hollow brick,	28	4	75	100									7.3	8.81	12	6.10					
46	451	do	Laminated sand and clay, pyrite and limonite lumps; hollow-brick mixture,		5.5	100	156	112	8	2.5														
47	447	Perth Amboy—National Fireproofing Co.,	From laminated sand and clay; used for hollow-brick mixture; small lumps of pyrite,		5	126	162	145	10	1.6		2				2.9								Becomes viscous at 1444° C.
71	371	South River—Sayre & Fisher Co.,	Dark gray, with much organic matter and mica scales; used for hollow brick,	25	6.3	80	100	84						8				10.7						Vitrified at cone 5.
71	393	do	Gritty; colored by organic matter; some mica and sand grains; used for common brick,	30.5	4	70	75							6.6	10.17			7	9.30	8				Fused at cone 12.
		Woodbridge Fire Clays.																						
7	385	Woodbridge—Perth Amboy Terra Cotta Co.,	Smooth, dense, dark gray clay; very few mica scales; some shreds of lignitic matter; used for terra cotta,	34	6.6			142				5.6	3.40	5.6	3.33					7.4	3.01	slightly less		Vitrified at cone 26, but not viscous; hence, very refractory.
14	382	Woodbridge—M. D. Valentine & Bro.,	Very little grit; homogeneous texture; smooth fracture; No. 1 fire clay,	25	7											5.5	24.25	6.5	19.65			13	7.76	Incipiently fused at cone 27. Fused at cone 34+.
16	381	Woodbridge—J. H. Leisen,	Mixture of retort and fine fire clay; medium plasticity; feeling quite sticky,	34	6			91.5						4.6	19.51			8	9.79	11.3	6.69			Vitrified at cone 27.
18	384	Near Woodbridge—Staten Island Clay Co.,	Hollow-brick clay; tough, red, mottled clay; dense, having angular fracture,	33	4.5			60										12.1	8.95	13.5	3.75	16.5	3.27	
6	372	Woodbridge—Anness & Potter,	Light gray, mottled, sandy clay; No. 2 fire clay,	29.5	5.5			45								5.5	15.87	5.5	16.85	8.5	10.54	10.5	10.04	Well fused at cone 33.
6	373	do	Soft, grayish white clay; irregular fracture, and some porosity; No. 1 fire clay,	33	5	40	45	41										7.5	13.74	11	9.10			At cone 27 only shows incipient fusion; fused at cone 34+.
6	377	do	Top, sandy clay; soft, whitish, gritty, with tiny mica scales; fairly plastic, but not very sticky,		4.6	70	89	78	10									1.4*	11.98	3.4	2.90			* Burned at cone 4. Fused at cone 27.

Physical Character of Raritan Clays.—Continued.

Loc. No.	Lab. No.	Locality.	Character of Material.	Tempering—H_2O req., per cent.	Air shrinkage.	Tensile Strength. Lbs. per sq. in.				Cone 05.		Cone 01.		Cone 1.		Cone 3.		Cone 5.		Cone 8.		Cone 10.		Remarks.
						Minimum.	Maximum.	Average.	Number tested.	Fire shr.	Absorption.	Fire shr.	Absorption.	Fire shr.	Absorption.	Fire shr.	Absorption.	Fire shr.	Absorption.	Fire shr.	Absorption.	Fire shr.	Absorption.	
24	374	Woodbridge—H. Maurer & Son,	Blue top clay,	33	5.5	109	136	122	9							4.5	9.80	5.1	7.86	5.6	6.17			Cone 15—Fire shrinkage, 7.1; abs., 1.86; vitrified at cone 27; viscous at cone 30.
24	379	do	Yellow top clay; sandy feeling; many tiny mica scales,	16	3.3			48			18.20					1	14.76			3	8.90			Viscous at cone 27.
24	383	do	Sandy, speckled or finely mottled clay, with small mica scales; fire-mortar clay,	23	5	86	117	99								3	10.75	4	5.98	5	4.20			Viscous at cone 27.
29	378	Woodbridge—W. H. Cutter,	Ware and ball clay from bottom of bank; very fine grained; little or no grit, with conchoidal fracture,	33	3.4	32	34											6.2		14.6	7.14	16.6	.22	Vitrified at cone 27. Fused at cone 34+.
29	380	do	Gritty clay; used for stoneware,	28	7			60								2	12.33	3	10.02	3.3	8.37			
54	397	Sand Hills—Ostrander Fire Brick Co.,	Sandy clay; hard, yellowish, mottled; a fire clay,	28	5			20										1	17.75	2	15.82			Viscous at cone 33.
54	407	do	Dense, brownish black clay; little iron; from southern pit,	30	6			36								4.6	20.05	6	15	7	13.36	9.3	11.31	
86	404	Sand Hills—R. H. & N. Valentine,	No. 1 blue fire clay, fairly plastic,	33	4.4	45	50											13.6	7.07			13.8	6.47	Fused at cone 32.
86	410	do	Red-mottled fire clay; very gritty,	34	6.6			35								5.4	16.62	9	11.09			11.4	6.45	Cone 15—Fire shrinkage, 12; absorption, 3.01. Fuses at cone 30.
233	627	East of Milltown—Not opened,	Sandy clay,		5									.3	17.95									
256	729	East of Milltown—American Enameled Brick and Tile Co.,	Sandy clay; used in enameled brick,	25.9	4.6									4	11.55			7.5	6.83					
		Raritan Fire and Terra Cotta Clay.																						
5	376	Woodbridge—G. H. Cutter,	Gritty, red clay, streaked with white; used for terra cotta,	26	4.6			57		4	12.59			9.4	1.05			12	.05					Becomes viscous at cone 14.
93	396	Piscataway—C. Richards, Lessee,	Very gritty; not highly plastic; once used for hollow brick,		5.5	45	50			2.5	19.32	2.1	14.09	2.5	13.01	3.4	12.48					11.5	1.44	
94	405	Bonhamtown—C. S. Edgar,	Homogeneous, gritty clay, with porous texture and smooth fracture; sagger clay,	32	7			52				2		3	19.69			5	16.75					Cone 15—Fire shrinkage, 9.6; absorption, 4.87. Vitrified at cone 27.
94	406	do	Dark gray clay, with small mica scales; fire clay,	25	6.5			98				7.1	10.51	7.5	8.89			9.5	3.69	14				Cone 15—Fire shrinkage, 15.5; absorption, .69. Viscous at cone 30.
96	408	Piscataway—Brinckman Terra Cotta Co.,	Red, very plastic feeling clay; contains pebbles up to ⅛ inch in diameter; used for hollow brick,	36	7	109	141	129		4	13.12	10	.12			10.7	.09							
237	718	Piscataway—Calvin Pardee,	Run of bank; not now worked,		7.3	111	153	134						10.3	9.15	11								
		Trenton Fire Clay.																						
101	629	Dogtown—J. J. Moon,	No. 1 blue clay; whitish; some fine grit,	18	5.3	79	96	85	10							7.3	13			8.7	8.64			Cone 15—Fire shrinkage, 11.7; absorption, 1.21.
101	632	do	No. 1 sagger clay,	28.5	4.6			90		1.4	19.82					6	13.63	7.4	8.26	9.4				Cone 10—Vitrified. Cone 03—Fire shrinkage, 3; absorption, 20.
101	644	do	Tough, red clay; little grit; wad clay,	38.5	6	65	85	72	10					8	15.39	9.3	11.73	10	11.33	11.6	3.71			Fuses at cone 30.
101	710	do	Used for No. 2 sagger,		7									7	15.08									
		Delaware River Belt.																						
112	652	Kinkora—Graham & Shreve,	Black, sandy, laminated clay; fair plasticity; used for common brick,	27.8	7	145	193	168	8					5.6	7.12	5.6								Cone 03—Fire shrinkage, 5; absorption, 11.89.
115	625	Kinkora—J. Martin,	Brick mixture of Raritan clay, surface loam and Clay Marl I,	22	6	93	108	97	10	1	13.55			4		3.3	7.33	5.3						Viscous at cone 8.
120	623	On Assiscunk creek, 1½ miles east of Burlington—J. Scott,	Yellowish white, gritty clay; little mica; used in foundry work,	19.2	4.6			95		1.4	15.01							2	10.25	4	5.25	5.4	5.07	
120	654	do	Fairly plastic; some grit; no mica; red and white mottled; used in foundry work,	23.8	5	68	94	80	10					2	13.61	3	12.42					5.6	2.19	Cone 03—Fire shrinkage, 1; absorption, 15.94.
121	640	Assiscunk creek, near Burlington—Hayes property,	Fairly plastic, with some grit; white mottlings; tears in molding; not used,	28	5.3	73	77	75	2	.7	18.04					6	10.12							Cone 03—Fire shrinkage, 3.7; absorption, 14.33.
132	622	Bridgeboro—J. W. Paxson Co.,	Plastic, some coarse grit, mottled clay from main bank; used for terra cotta and foundry work,	22	5.3	100	110	104	10	1.3	13.81					4.7	9.88	4.7	9.13	6.7	2.96			
132	630	do	Sandy clay; not very coherent; scattered white mica scales; used for terra cotta,	30.8	4.3	111	136	119	3													2.7	7.99	Cone 15—Fire shrinkage, 3; absorption, 2.96.
134	621	Palmyra—H. Hylton,	Plasticity fair; gritty clay,	20	5.3	63	70	65	10	1.3								1.3	14.52	2	12.82			Cone 15—Fire shrinkage, 2.3; absorption, 8.40.
139	631	Morris Station—P. Erato,	Mottled, sandy, little mica,	17.7	2											1.3	15.41							Cone 27—Nearly viscous.
136	703	Pit on south side road ¼ mile southeast of Fish House station; not worked,	White clay,	19.2	0.							.6	15.43	.6	14.13			2	12.93					
135	643	⅓ mile south of Fish House station,		21.9	3.3			80														4.7	8.52	Cone 27—Viscous.
		Miscellaneous.																						
271	731	2 miles south of Monmouth Junction, on New Brunswick-Trenton trolley line,	Sampled by boring,		7	140	170	160	10					7	4.28			9	3.05					

and for the manufacturer to make up mixtures of many different properties.

The fusibility of this same grade of clay is commonly high. The best No. 1 fire clays do not fuse below cone 35, but some so-called ones may fuse at 30. The fusion point of the so-called No. 2 fire clays commonly ranges from cone 27 to cone 33. The stoneware clays show a refractoriness equal to the good No. 2 fire clays, while many of the terra-cotta clays fuse at cone 27.

To discuss the kinds of clay mined in the Raritan belt, and their uses, would involve repeating much that is said on other pages, and therefore reference is here made to the description of the clays of Middlesex, Mercer and Burlington counties (Chapter XIX), and to the chapter on the Clay Mining Industry (p. 335).

TRIASSIC SHALES.

The Triassic shale is used for the manufacture of common brick, and front brick at Kingsland, Bergen county, where very fine-grained beds are quarried in the face of the bluff overlooking the Hackensack meadows. The rock is moderately hard, occurring in thick beds, and is quarried in large blocks which are broken first by a jaw crusher and then pulverized in dry pans. It has sufficient plasticity to be used in a stiff-mud machine, burns to a good red color and makes a hard dense brick, but it becomes viscous at cone 1.

Samples of the shale from several other localities were tested in the course of these investigations, but in all cases they were too sandy and lacked plasticity, but beds equally as well adapted to the manufacture of brick as those at Kingsland can undoubtedly be found, although they may not be so favorably situated as regards ease of working and transportation.

HUDSON SHALES.

This shale formation is for the most part too sandy for use along these lines, but it is worked for clay products at one locality, viz., Port Murray, where it is fine-grained and has been deeply weathered. There is an inexhaustible quantity of the material, but the great objection to it is its lack of plasticity, for the shale is very lean. Weathering improves it, and as much of the weathered material as can be obtained is mixed with the less weathered portion. It burns to a good red color and becomes steel-hard at a moderately low temperature, but is not at all refractory.

The shale is used for making fireproofing, and its physical characters are given under Warren county.

CHAPTER XIX.

CLAYS AND CLAY INDUSTRIES BY COUNTIES.

BY HEINRICH RIES AND HENRY B. KÜMMEL.

CONTENTS.

In this chapter the clay deposits of the State are taken up by counties, and details are given regarding the most important individual localities, which could not be touched upon in the general descriptions of the preceding chapter, nor be included in the tabulated physical tests. No attempt is made to describe all the occurrences of clay in the State, particularly in those counties where they are numerous. Samples were taken from certain of the clay beds, which are now utilized and which seemed fairly representative, and also from many unworked localities which seemed promising. It was of course impossible, within the limits of time and money available, to make physical tests of samples from all outcrops of clay, or even from all the clay pits in the State, but this work was so distributed geographically as to give definite and accurate information as to the economic value and character of all the important clay beds. In the following pages details are given relating to all the localities from which samples were taken, as well as of some other important deposits. It was not thought best to attempt to describe individual plants except where they illustrate some particular feature of technological interest.

ATLANTIC COUNTY.

Most of the deposits worked in this county belong to the Cohansey formation, and openings have been made near Bakersville, Da Costa, Elwood, Egg Harbor City and Mays Landing. At Bakersville there are extensive deposits which seem best referred to the Cape May, although perhaps they belong to the Cohansey. In nearly every instance the occurrences represent a more or less basin-shaped deposit, covered by sand, and lying in a flat region covered with a thick growth of underbrush.

Da Costa.—Beginning at the northwestern side of the county the first deposit seen was south of Da Costa at the brickyard of David Doerr (Loc. 197), where the pit shows the following section:

Gravelly loam, ...	2-4 ft.
Yellowish-gray clay, underlain by some black clay,.......	9 "
Sand, ...	.....

The clay, which is mostly red-burning, shows occasional streaks of sand, which are sometimes cemented by limonite, and, if these get into the bricks, they are liable to cause fused spots. The lighter-colored, as well as lighter-burning clay, forms irregular patches here and there in the deposit and is not much used in the bricks. Two openings have been made, indicating that the length of the deposit is probably not less than 300 feet. The run of the bank, excluding the light-burning material, was obtained by taking a sample by boring to a depth of 5 feet, with an additional 4 feet from the sides of the pit.

This clay showed the following physical characters. Water required for tempering, 30.8 per cent.; air shrinkage, 6.6 per cent. Average tensile strength 206 pounds per square inch. Its behavior in burning was as follows:

Burning tests of clay of David Doerr from Da Costa.

	Cone 05	*Cone 1*	*Cone 3*	*Cone 5*
Fire shrinkage, ...	0.7 %	2 %	4 %	4 %
Absorption, ...	16.56%	15.72%	10.87%	8.34%
Color, ...	pink red	light red	......	red
Condition, ...	not steel-hard	not steel-hard	......	steel-hard

This material shows a good color and low fire shrinkage, which accounts for its high absorption. The grit holds back the shrinkage, but still there is not enough sandy matter to lower its tensile strength.

The whitish clay is similarly a somewhat plastic material, but has less grit. It took a little less water to mix, viz., 29.1 per cent., but its air shrinkage, 7.5 per cent., is slightly greater. Its tensile strength is also good, averaging 192 pounds per square inch. Its burning qualities are as follows:

Burning tests of a clay from David Doerr's pit, Da Costa.

Cone	*05*	*1*	*3*	*5*	*8*
Fire shrinkage,	0.5 %	2.5 %	2.5 %	2.5 %	5.1%
Absorption, ...	17.20%	12.04%	12.01%	......	nearly impervious
Color, ...	pale yellow	yellow	buff	buff	deep buff
Condition, ...	not steel-hard	steel-hard		......	......

Comparing the two, it will be seen that the latter has a lower fire shrinkage at cone 5 than the former or red-burning clay, but shrinks about the same at the temperature of common-brick kilns. The lighter burning one is not a fire clay, and it is doubtful whether it could be used for buff brick. If any of the buff-burning clay gets into the brick mixture it shows as whitish spots in the brick. The clay is now employed for common, soft-mud, building brick.

Elwood.—In the summer of 1902 a new pit was started by Messrs. Rupp & Sawyer (Loc. 198) at a point 2 miles northeast of Elwood, exposing a bed of yellowish, sandy clay from 4 to 5 feet thick and with 2 to 11 feet overburden. The bottom is sand, which at times is gravelly, and is mixed in with the bricks. This clay is red-burning like the run of the bank at Da Costa, and burns equally porous. At the time the pit was visited it had not been opened up enough to give a very definite idea of the extent or thickness of the clay. If many pebbles get into the clay it tends to split in burning.

Mays Landing.—Clay for making pressed brick has been dug to a considerable extent (Loc. 195) at Mays Landing, several strata of clay being found in one pit. In part they resemble those dug at Rosenhayn, Cumberland county. The section recognized there was as follows:

Section of clay bank at Mays Landing.

1. Yellow, gravelly sand.
2. Light clay.
3. "Pompeian" clay.
4. Sandy clay.

The characters of Nos. 2 and 3 are as follows:

Physical tests on clay from Mays Landing.

	No. 2	*No. 3*
Water required to temper,	23.17%	23.40%
Air shrinkage,	7.50%	8.00%
Average tensile strength, lbs. per sq. in.,	282	293
Cone 05—		
Fire shrinkage,	......	0.3 %
Absorption,	......	11.65%
Cone 1—		
Fire shrinkage,	2.80%	3.30%
Absorption,	8.09%	6.20%
Cone 3—		
Fire shrinkage,	4.1 %	4.00%
Absorption,	3.50%	3.60%
Cone 5—		
Fire shrinkage,	4.50%	4.00%
Absorption,	3.08%	4.36%
Cone 8—		
Fire shrinkage,	6.50%	5.00%
Absorption,	0.84%	......
Cone 10—		
Fire shrinkage,	7.1 %	......
Absorption,	0.18%	......

The lighter clay burns to a deep yellow, which on vitrification passes into a gray green. The other one burns buff and then reddish yellow as it becomes impervious. Neither are fire clays, but they make a strong buff-colored front brick.

Pleasant Mills.—Cohansey clays also outcrop at Pleasant Mills (Loc. 199) on the Atlantic county side of the stream, but the bed is thin. The material is variable in color, ranging from a bluish-black to a light-yellow or mottled clay, with occasional streaks of bluish-white sand. The mottled clay close to the bridge across the creek is of promising appearance, and may expand in thickness. It is a gritty and not highly plastic clay with an air shrinkage of 6.6 per cent. It burns buff, and its fire shrinkage at cone 5 is only 2.7 per cent., the bricklet having an absorption of 13.25 per cent. Its visible extent is not great, but still it should encourage further prospecting in this region.

Deposits of buff-burning clays are also known around Doughty's, but are not being worked at present.

Bakersville. — At Bakersville a large deposit of clay occurs which is probably referable to the Cape May formation and which differs considerably from the Cohansey deposits in its physical characters. The section shows 1) a bottom clay, 2) a middle sandy layer, 3) a top sandy clay. The bottom clay alone, although very plastic, has too great a fire shrinkage to be used by itself, for the latter at cone 1 amounts to 15.5 per cent., and even then the clay does not burn dense. The top clay softens rapidly when water is added, and cannot be used alone, even though its strength is 105 pounds per square inch. The best results are, therefore, obtained by using a mixture of the top and bottom clays and molding them with as little water and as much pressure as possible.

Clay-working industry.—Common brick are made in large quantity by the Somers Brick Company, at Bakersville, much of the product going to supply the local market at Atlantic City. Other yards are those of David Doerr, near Da Costa, and of Rupp & Sawyer, northeast of Elwood. Pressed brick are made by the Atlantic Brick Manufacturing Company, of Mays Landing, while earthenware is produced by Julius Einsiedel, at Egg Harbor City, a portion of his clay being obtained from small pits near that place.

BERGEN COUNTY.

Hackensack and Little Ferry.—The extensive deposits of brick clay which occur between Hackensack and Little Ferry, and also south of the latter point, have already been described somewhat in detail, pp. 124-128. They are quite uniform in character, so that the following test of a sample will serve to indicate their physical properties. Water required for mixing, 22 per cent.; air shrinkage, 6 per cent.; average tensile strength, 108 pounds per square inch.

At cone 05, fire shrinkage 4.3 per cent., absorption 7.88 per cent., color good red, bricklet nearly steel-hard.

At cone 01, fire shrinkage 7.3 per cent., absorption .28 per cent., bricklet red. At cone 1 bricklet practically vitrified, fire shrinkage 8.6 per cent., absorption .1 per cent., color good red.

At cone 3 the clay was beyond vitrification, and it had begun to swell so that its fire shrinkage was only 7 per cent.; in fact, it was unable to hold its shape at this point. In actual practice the clay is always mixed with a certain proportion of the overlying sand, in order to reduce the fire shrinkage and make it stand up better in burning. The bricks are always molded by the soft-mud process and burned in scove kilns.

Analyses of common-brick clays.

	Little Ferry.	*Hackensack.*
Silica (SiO_2),	66.67	59.69
Alumina (Al_2O_3),	18.27	24.05
Iron oxide (Fe_2O_3),	3.11	
Titanic oxide (TiO_2),	0.85	0.44
Lime (CaO),	1.18	1.63
Magnesia (MgO),	1.09	2.03
Potash (K_2O),	2.92	0.54
Soda (Na_2O),	1.30	2.39
Water (H_2O),	4.03	4.85
Moisture,	....	0.80
Total,	99.42	96.42
Total fluxes,	9.60	......

Analysis of a glacial brick clay[1] from Garfield.

Silica (SiO_2),	73.71
Alumina (Al_2O_3),	11.09
Ferric oxide (Fe_2O_3),	4.30
Lime (CaO),	2.31
Magnesia (MgO),	1.71
Potash (K_2O),	1.87
Soda (Na_2O),	1.42
Combined water (H_2O),	3.93
Total,	100.34
Total fluxes,	11.61

This would indicate a red-burning clay, fusing at a low temperature.

Kingsland.—At Kingsland the red Triassic shale is used for brick. The rock is here a moderately thick-bedded, brownish-red shale, more earthy and less sandy than at many localities in the State, but not exceptionally so. The quarry has been opened in the face of the high bluff bordering the Hackensack meadows, and closely adjoining the D. L. & W. railroad, so that facilities for handling the raw material and shipping the product are unexcelled. Inasmuch as the raw material has to be crushed and ground, an expense not present in the manufacture of brick from soft clay, it is essential that there be economy in other directions in order to compete successfully with clay-made brick. This fact may prevent the utilization of the red shale at many localities where it is otherwise available.

Samples of the shale which had already been crushed, ground and made into a green brick were tested with the following results. When mixed with 21 per cent. of water it gave a mass of fair plasticity, containing considerable grit, but of low air shrinkage, only 2 per cent. The average tensile strength was 150 pounds per square inch, with a maximum of 164 pounds, the number of samples tested being 12. At cone 05 the fire shrinkage was 2 per cent., color brownish red and the absorption 6.56 per cent. The bricklet was barely scratched with steel. Some cracks were developed in burning. At cone 03 the fire shrinkage was

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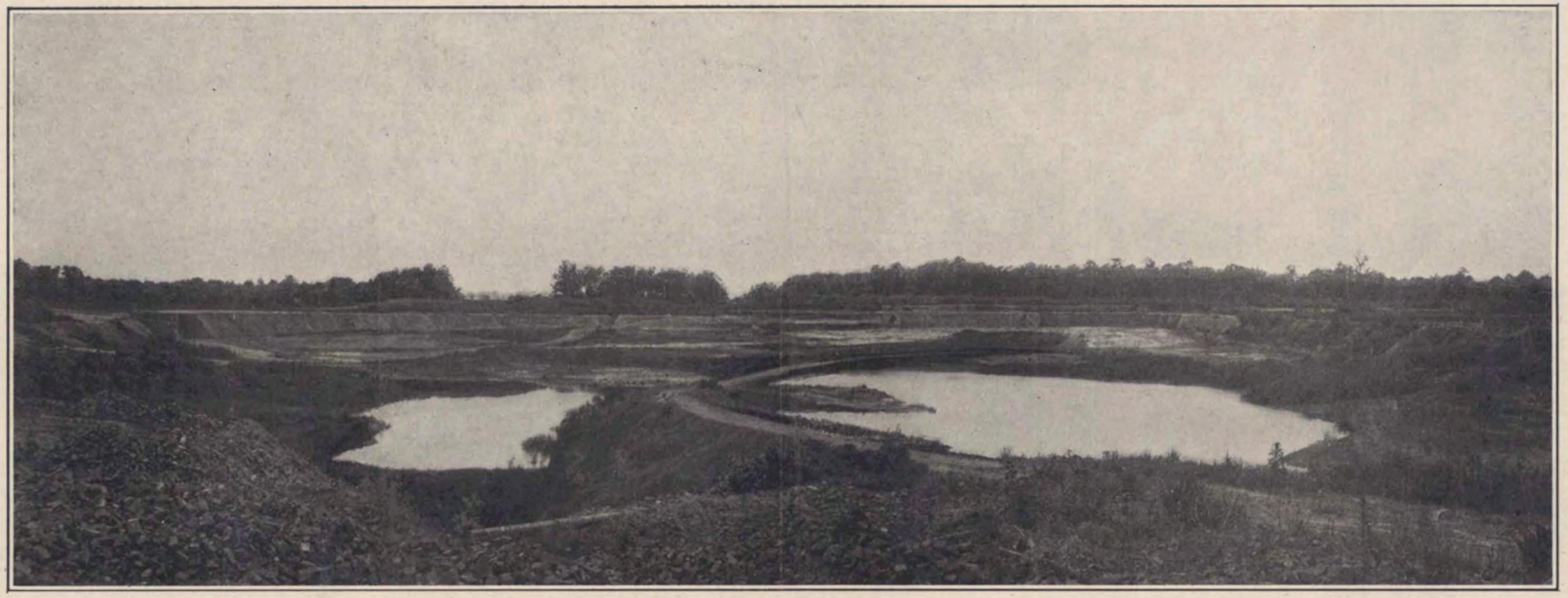
[1] Analysis furnished by Campbell, Morrell & Co., Passaic, N. J.

Fig. 1.

General view of brickyards along the river at Little Ferry, Bergen county, showing sheds along the water front.

Fig. 2.

Clay pit behind the yards, which has been dug below sea level. In the background are the sails of a large schooner whose hull is level with the top of clay bank. Mehrhof Brick Company.



Mehrhoff Brick Company's clay pits at Little Ferry.

4 per cent., color red and the bricklet steel-hard, with absorption of 2.03 per cent. The clay became viscous at cone 1, which shows that it is of very low fusibility. It burns to a good hard brick, however, at a low temperature. When molded in a dry press and burned at cone 03 the fire shrinkage was 3.3 per cent., the absorption 5.33 per cent. and the color brownish red. The bricklet was barely scratched. On account of the shaly character of the material a number of hard grains remain after the grinding, and these, at least when the clay is wet molded, interfere with the soft, smooth surface of the brick. However, this is not sufficient to be looked upon as a defect, but would be rather liked by many architects. So far as shown by these tests, it is doubtful whether the material could be used successfully for the manufacture of paving brick, since it softens rapidly in burning, and in making a vitrified product, such as a paving brick, there might be some danger of overburning and fusing the product.

Clay-working industry.—The development of the common-brick industry between Hackensack and Little Ferry is the second most extensive in the State, ten firms manufacturing brick from these clays (p. 267). Many million common brick are made here annually by the soft-mud process, and with the yards all situated along tide water the product can be easily shipped. The clays are mixed with at least 25 per cent. sand, which is found immediately underlying the surface and above the clay. A large area has been dug over (Pls. XXXVIII and XXXIX), and some of the clay pits have been dug to a depth of 60 feet. As indicated in Chapter VI, these or similar clays occur over somewhat extensive areas and have been observed at widely separated points. Common brick and front brick are made by the Kingsland Brick Company, at Kingsland, from the Triassic red shales.

Art tile are made at Maywood, near Hackensack, but not from any clays found in the county.

BURLINGTON COUNTY.

This county extends from the Delaware river, between Bordentown and Palmyra, to the Atlantic coast, between Tuckerton and New Gretna. It is thus roughly triangular in form, and since it stretches across the State, it includes portions of a number of different formations, and consequently produces probably a greater variety of clays than any other county of southern New Jersey. The clay-bearing formations in Burlington county include the Raritan, Clay Marl I, Clay Marl II, Clay Marl III, Cohansey, Cape May, and Pleistocene, other than Cape May.

Raritan Clays.

The Raritan clays outcrop and are dug chiefly along the Delaware river, although smaller banks are found on Assiscunk creek. The banks show three different classes of clay, viz., buff-burning semirefractory clays, red-burning clays, and common-brick clays.

Bridgeboro.—Of the first type, the most northern occurs just southeast of Bridgeboro (Loc. 132) along Rancocas creek, where a series of pits have been opened by the J. W. Paxson Company, of Philadelphia. The general character of the clay in the main bank is shown by the following section from top downward.

Section at J. W. Paxson Company's Pits.

Pebbly sand,	8 to 10 ft.
Reddish-mottled clay,	6 to 8 ft.
Red sandy clay,	1 to 2 ft.
Light-blue and white-mottled clay,	2 ft. or more

The reddish-mottled clay is used for foundry purposes, and is also sent to Moorestown for terra-cotta manufacture. In some of the openings larger quantities of the light-colored or so-called white clay are found, but in others a black lignitic sand occurs at the same level, this change representing the horizontal variations that are not uncommon in the Raritan deposits, particularly along the Delaware river. The stripping is used for filling, and the close proximity of the clay to the river permits it to be shipped by water.

The mottled clay (Lab. No. 622), representing the run of the bank, is fairly plastic, although containing some coarse grit, and has the following physical properties: Water required to temper, 22 per cent.; air shrinkage, 5.3 per cent.; average tensile strength, 104 pounds per square inch. Its behavior in burning was as follows:

Burning tests on mottled clay from J. W. Paxson Company's pit, Bridgeboro.

Cone	*05*	*3*	*5*	*8*
Fire shrinkage, ...	1.3 %	4.7 %	4.7 %	6.7 %
Absorption, ...	13.81%	9.88%	9.13%	2.96%
Color, ...	pale red	light red	dark red	gray
Condition, ...	barely steel-hard	steel-hard	......	......

This clay, which is probably to be classed as a semifire clay, is used for making terra cotta and for foundry purposes.

The whitish sandy clay (Lab. No. 630) shows a marked difference in its character. It is less coherent, with scattered white mica scales, and slakes very fast. It takes somewhat more water in mixing, viz, 30.8 per cent., but its air shrinkage is less, being but 4.3 per cent. The average tensile strength is higher, viz, 119 pounds per square inch. Its low fire shrinkage is seen from the fact that at cone 10 it is only 2.7 per cent., the bricklet having an absorption of 7.99 per cent. and a light-buff color. It was steel-hard. A sample was burned up to cone 15, and the fire shrinkage of this was but 3 per cent., and its absorption 2.96 per cent. It burned gray with brown specks. Its fusing point was not determined, but it contains too much sand to be highly refractory.

A dry-press tile, screened to 80-mesh and burned at cone 8, was steel-hard, buff-colored, but still slightly absorbent.

This last mentioned clay should make a good material to add to terra cotta in order to lower its shrinkage. It is more refractory than the mottled clay from the same bank, but there is much less of it available.

Florence.—Clays apparently similar to those just described occur in the vicinity of Florence. They were formerly dug by

J. Eayre, half a mile northwest of Florence station and the following analysis of the best white clay from his bank was given by Dr. Cook.[1]

Analysis of clay from J. Eayre's pit, Florence.

Sand,	40.50
Silica (SiO_2),	26.57
Alumina (Al_2O_3) and Titanic acid (TiO_2),	21.06
Ferric oxide (Fe_2O_3),	1.98
Lime (CaO),	....
Magnesia (MgO),	0.60
Potash (K_2O),	2.47
Soda (Na_2O),	0.21
Water (H_2O),	5.80
Moisture,	0.80
	99.99

Specific gravity 1.989-2.023. This analysis corresponds closely to that of some of the Middlesex county stoneware clays. Associated with the white clay is a reddish one that was used for saggers.

At locality 114, due north of Florence station the following section was shown in an old clay pit near the river:

Wind-blown sand,	6–8 ft.
Cretaceous sand,	4–5 ft.
Tough red and yellow clay,	5 ft.
Tough, white clay, base not shown,	5 ft.

A large area had been dug over, but nothing is known regarding the clay.

At Haedrick's pit, nearer Florence, beds of Raritan clay occur beneath the sand, but they have not been tested.

At Martin's brickyard (Loc. 115) a white, sandy clay is dug by Jos. C. West, some of which is sold at Trenton and some at the Florence foundry. The clay in these pits sometimes reaches a thickness of 18 feet. A black clay of much later age occurs elsewhere in the yard, above the white Raritan clay and is used for brick (see below).

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[1] Loc. cit. p. 243.

Assiscunk creek.—Some buff-burning clay is found on Assiscunk creek, 1½ miles east of Burlington (Loc. 120), on property belonging to Jos. Scott. Since the outcrop consists chiefly of red-burning clays it is mentioned in more detail below. The properties of the buff-burning clay are given here. It (Lab. No. 623) is a yellowish-white, gritty fast-slaking clay with little mica. It took 19.2 per cent. of water to temper it, and its air shrinkage was 4.6 per cent. The average tensile strength was 95 pounds per square inch. It was burned with the following results:

Burning tests of clay from Jos. Scott's property, near Burlington.

Cone.	*05*	*5*	*8*	*10*
Fire shrinkage, ...	1.4 %	2 %	4 %	5.4 %
Absorption, ...	15.01%	10.25%	5.25%	5.07%
Color, ...	buff	deep buff	deep buff with tiny specks	buff
Condition, ...	not steel-hard	steel-hard	.	

The red-burning type of Raritan clay, mentioned as occurring in Burlington county, is found on Assiscunk creek, 1½ miles east of Burlington. One exposure (Loc. 120) forms a considerable bank on the south side of the creek on Jos. Scott's property, and has been dug from time to time for foundry purposes. The material consists of alternating layers of light, yellowish-white, mottled clay and red clay spotted with white, while near the top of the bank is a white sandy clay. It is doubtful if the different grades could be separated in mining without considerable trouble. and the bank as a whole would probably not average better than a low grade of No. 2 fire clay at the very best.

Two samples were tested, one representing the run of the bank and the other the whitish clay (see above), which appears about twelve feet above the creek. The former (Lab. No. 654) is fairly plastic, slightly gritty clay, with no mica and red and white mottlings, and slakes slowly. It works up with 23.8 per cent. of water to a mass having an air shrinkage of 5 per cent. Its average tensile strength was 80 pounds per square inch. When burned the following results were obtained:

Burning test of Jos. Scott's clay, near Burlington.

Cone	*03*	*1*	*3*	*10*
Fire shrinkage,	1 %	2 %	3 %	5.6 %
Absorption,	15.94%	13.61%	12.42%	2.19%
Color,	pale red	light red	red	gray
Condition,	not quite steel-hard	steel-hard		

On the north side of the creek, on the Hay property (Loc. 121), Raritan clay is found underlying the flat bordering the streams. A boring made at stream level showed:

Loam (flood deposit),	2 feet.
Whitish-mottled clay,	10 inches.
Red clay, white mottlings,	4 feet plus.

The latter runs still deeper. In the strip parallel with the creek there is 6 to 8 feet of overburden, but back of this it increases because the land rises. Trouble might also be caused by the creek water if the clay were dug below stream level. The physical characters of the samples were as follows:

The material (Lab. No. 640) worked up with 28 per cent. of water to a fairly plastic mass whose air shrinkage was 5.3 per cent. Its average tensile strength was 75 pounds per square inch. It was burned with the following results:

Burning tests of clay from Hay property, Assiscunk creek.

Cone	*05*	*03*	*3*
Fire shrinkage,	0.7 %	3.7 %	6 %
Absorption,	18.04%	14.33%	10.12%
Color,	light pink	reddish	reddish pink
Condition,	not steel-hard	steel-hard	

This is a clay of higher shrinkage than those found on the opposite side of the bank. It might be used for foundry work or terra cotta, but by itself is not sufficiently dense burning for stoneware.

Fieldsborough.—The third type of Raritan clay, viz., that which is used for common brick is worked near Fieldsborough. It is used at S. Graham & Co.'s (Pl. XL, Fig. 1) brick works, 1 mile south of Fieldsborough (Loc. 112). The clay forms a large

PLATE XL.

Fig. 1.

General view of S. Graham & Co's. brickyard, near Bordentown.

Fig. 2.

Bank of black Raritan clay overlain by gravel at S. Graham & Co's. brickyard. The man stands just below the contact, which is sharply marked.

deposit showing 16 feet of clay (Pl. XL, Fig. 2), underlain by white sand and covered by 4 to 6 feet of Pensauken gravel.[1] It is black, micaceous, and the clay layers are separated by thin laminæ of white sand. Pyrite concretions are very abundant, and owing to the large amount of carbonaceous matter, care has to be exercised in the early stages of burning, not to push the firing too fast, otherwise the bricks are liable to swell and crack. Drying takes about 48 hours. As a matter of fact the clay is not used alone but is mixed with a certain proportion of surface loam of Pleistocene age.

The black clay (Lab. No. 652) has the following physical characteristics:

Water needed for tempering, 27.8 per cent.; air shrinkage, 7 per cent.; average tensile strength, 168 pounds per square inch.

Cone	*03*	*1*	*3*
Fire shrinkage,	5 %	5.6 %	5.6%
Absorption,	11.89%	7.12%	....
Color,	pale red	pale red	pale red
Condition,	steel-hard	......	....

The addition of the loam improves its color-burning properties and renders it more porous. The material burns to a good red brick, of moderate absorption, but is too coarse-grained to make a good smooth pressed brick.

Kinkora.—At Murrell Dobbins' brickyard the upper portion of the sandy laminated Raritan clays are shown, but most of the clay used comes from the overlying Clay Marl I. An analysis of the laminated Raritan clay was given by Dr. Cook[2] as follows:

Analysis of clay from Murrell Dobbins' yard, Kinkora.

Sand,	31.80
Combined silica (SiO_2),	25.50
Alumina (Al_2O_3),	17.70
Ferric oxide (Fe_2O_3),	6.40
Lime (CaO),	0.16

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[1] Since this was written, continued excavation into the hillside has shown a few feet of Clay Marl I on the Raritan clay and beneath the gravel. The contact is distinctly marked by an abrupt change in the character of the deposits and a line of nodules, but owing to the sameness of color of the two formations here it is not obtrusive. H. B. K.

[2] Clay Report, 1878, p. 241.

Magnesia (MgO),	0.65
Potash (K_2O),	1.54
Soda (Na_2O),	....
Titanic oxide (TiO_2),	0.90
Water (H_2O),	11.80
Moisture,	3.50
Total,	99.95

The Clay Marl Beds.

A number of clay works are supported by the Clay Marl deposits in the northwestern part of the county. Some of these use Clay Marl I and others Clay Marl II, while still others have opened pits along the boundary between Clay Marls I and II, and use a mixture.

At many localities the Clay Marl is overlain by a ferruginous sand or gravelly loam, of which a certain proportion is added to the clay. In addition to the worked localities, samples were taken from a number of outcrops of Clay Marl for the purpose of determining the general character of these clays. The worked deposits will be first discussed.

Bordentown.—Clay Marl I is worked in Burlington county at The Bordentown Brick Company's brickyard, near Bordentown (Loc. 109). In the main pit there are 8 feet of a black sandy clay of marly (glauconitic) aspect, with numerous quartz grains and mica scales visible to the naked eye. The upper foot or so is weathered and lean. Above the clay are 2 to 3 feet of Pensauken gravel, with a similar amount of sand and more gravel.

The black clay alone (Lab. No. 600) has a high shrinkage, and cannot be used by itself, hence a clay loam is mixed with it. It takes 23.4 per cent. water to temper it, and it shrinks 8.8 per cent. in drying, which is somewhat high. Its average tensile strength is 251 pounds per square inch. When burned, it gives the following results:

Burning tests of a black clay, Bordentown Brick Company.

Cone	*05*	*01*	*1*	*3*
Fire shrinkage,	8.3 %	11.8%	11.8 %	11.8%
Absorption,	10.74%	5.83%	4.01%	......
Color,	deep red	......	......	......
Condition,	not steel-hard	softened somewhat		beyond vitrification

On account of the low cone number at which the clay softens care has to be used in burning, so that the bricks do not crush out of shape. This clay shows the highest fire shrinkage of any of the Clay Marls tested and cannot be used alone, but is mixed with considerable top loam (See tables of Pleistocene tests, p. 348). The latter burns to a porous body of low shrinkage, and, therefore, counteracts the undesirable properties of the clay. The bricks show up well when tested.

Kinkora.—As noted above (p. 381), Clay Marl I is used for common brick, at Murrell Dobbins' brickyard, Kinkora (Loc. 113), along with some sandy clay from the Raritan and some clay loam of late Pleistocene age. It is a black, very micaceous clay with more or less greensand marl and is from 12 to 14 feet thick in the bank. Samples were not tested.

Crosswicks.—Clay Marl II is worked at Crosswicks (Loc. 110), by J. Braislin & Son, for making hollow bricks (Pl. XXXIV, Fig. 2). The clay bank is about 20 feet high and is one of the best exposures of this formation in Burlington county. The clay burns red, and is probably of low fusibility judging from the behavior of the ware in the kiln.

Maple Shade.—The same Clay Marl formation is worked by T. Saucelein, at Maple Shade (Loc. 150), on the north side of the railroad tracks. Here the beds are mostly weathered, but burn to a hard, red brick, and make a good product on stiff-mud machines.

On the south side of the railroad, and just south of the trolley road from Merchantville to Moorestown is A. Reeve's brick-clay pit (Loc. 149, Pl. XLI, Fig. 1), but here the clay dug is at the line of contact between Clay Marl I, and Clay Marl II, both being used. The section exposed in 1902 was about thirty feet high and showed the following layers beginning at the top:

Section in A. Reeve's clay pit, Maple Shade.

No. 1.	Loamy gravel,	2 ft.	
No. 2.	Weathered clay,	8 ft.	Clay Marl II.
No. 3.	Black clay,	6 ft.	
No. 4.	Greensand and clay,	6 ft.	Clay Marl I.
No. 5.	Black clay,	5 ft.	

The run of the bank mixed with screened gravel gives the best results. The bottom black clay (Lab. No. 648) is fat and greasy and has much mica and organic matter, and does not work well alone. The greensand is also a dangerous element and causes a swelling and bursting of the brick unless they are set in the kiln dry and burned slowly. The bottom black clay has a high air shrinkage, but its fire shrinkage is not excessive, as can be seen by the following characters: Water required for mixing 32.8 per cent.; air shrinkage, 9 per cent.

Burning test on bottom black clay, A. Reeve, Maple Shade.

Cone	*01*	*1*
Fire shrinkage,	3 %	4 %
Absorption,	12.62%	10.06%
Color,	red	red
Condition,	......	barely steel-hard

The run of the bank showed lower air shrinkage, but the fire shrinkage is not much different, and the mixture can probably be burned somewhat faster than the black clay can. The physical characters of the brick mixture (Lab. No. 647) are also given herewith: Water required for mixing, 28.6 per cent.; air shrinkage, 7.5 per cent.; average tensile strength, 282 pounds per square inch. The clay behaved as follows in burning:

Burning test of bottom black clay, A. Reeve, Maple Shade.

Cone	*1*
Fire shrinkage,	4.5 %
Absorption,	10.58%
Color,	red
Condition,	steel-hard

The clay becomes viscous at cone 8. This mixture works well on a stiff-mud machine.

Of the unworked areas the following may be enumerated and their physical characters given.

Bridgeboro.—A bed of Clay Marl I outcrops along a tributary to Rancocas creek, about one-fourth mile southeast of Bridgeboro (Loc. 131). The clay in appearance is not unlike that in the

Fig. 1.

Reeve's clay pit, Maple Shade. Clay Marl I and II.

Fig. 2.

View of Jos. Martin's clay pit, showing Pleistocene black clay overlain by wind-blown sand, the bench marking the line of contact.

brick-clay pits at Bordentown, but only 2 feet is exposed above the talus, and there is 10 to 12 feet of sandy loam overburden. It is fairly accessible for shipping by water.

The clay (Lab. No. 614) differs from the Bordentown material in having a lower air and fire shrinkage, and does not burn to steel-hardness at so low a temperature, nor to so deep a red. It mixes up with 27.1 per cent. water, and has an air shrinkage of 7 per cent. Its average strength is 145 pounds per square inch. At cone 05 the fire shrinkage is 0.3 per cent., absorption 15.05 per cent., color light mottled-red, and not steel-hard. At cone 01, fire shrinkage 2.3 per cent., absorption 11.76 per cent., color red and bricklet steel-hard, so that the material could be burned to a good brick at a low cone.

Rancocas.—Clay Marl II is exposed at an abandoned brickyard (Loc. 125) on the northeast side of Rancocas creek, three-fourths of a mile due north of Borton's Landing and west of Rancocas. It shows well how an otherwise good deposit of clay may be ruined by the formation in it of a perfect network of iron oxide crusts. These are sometimes found in Clay Marl II, and their presence should have been determined beforehand by careful boring or a few test pits. An expensive plant was erected and abandoned.

Moorestown.—An exposure of Clay Marl II is found at the crossroads 1 mile northwest of Moorestown and on the road to North Pennsville (Loc. 128). The clay outcrops in the ditches along the road for some distance, and a boring made to a depth of 6 feet 4 inches did not pass through it. The upper layers of the section were chiefly a chocolate color, and passed downward into a mixture of yellow and chocolate clay and finally into bluish-black material. Although the clay contains much mica, there is no evidence of pyrite. The deposit was also quite dry, until the lower foot of the section was reached. There is very little overburden, and the slope of the land would insure good drainage. Careful search should be made to prove the absence of limonite crusts, as there seemed to be a slight tendency towards their formation where the boring was made.

In the laboratory examination the clay (Lab. No. 610) was found to be rather free from grit. It worked up with 35 per cent.

of water to a plastic mass whose air shrinkage was 9 per cent. The average tensile strength was 127 pounds per square inch. In burning it gave the following results:

Burning test of sample from northwest of Moorestown (Loc. 128).

Cone	*05*	*1*
Fire shrinkage,	1.3 %	8 %
Absorption,	17.89%	4.85%
Color,	light red	light red
Condition,	not steel-hard	steel-hard

This shows too high a fire shrinkage for use alone.

On the road to Parry, 1 mile due north of the preceding locality, and 2 miles northwest of Moorestown, there is another exposure of Clay Marl II (Loc. 129). Here a boring was made to a depth of 6 feet that showed 5 feet of chocolate clay with a little yellow mottling and 1 foot of sandy marl. The clay is denser than at locality 128, somewhat more sandy, and is probably a lower-lying bed. The boring showed no water, and there is little overburden. Black sand is said to occur at a depth of 20 feet. Physically the clay (Lab. No. 608) is not very unlike that from Loc. 128, although it took less water to mix it up, viz., 29.02 per cent. Its air shrinkage was 8.8 per cent. In burning it showed the following:

Burning test of a clay from two miles northwest of Moorestown (Loc. 129).

Cone	*05*	*03*	*1*
Fire shrinkage,	1.2 %	1.2 %	4.2 %
Absorption,	16.34%	16.41%	9.95%
Color,	light red	light red	red
Condition,	not steel-hard	not steel-hard	steel-hard

It would probably have to be burned to cone 01 or 1 to make a good, hard brick.

A similar bed of clay outcrops about one-fourth mile northeast of the previous locality at Loc. 130, and has but little overburden.

Wilson's station.—Along the North Branch of Pensauken creek both Clay Marl I and II are exposed on the south side of the creek, one-half mile south of Wilson's station (Loc. 151). A boring of 8 feet was made in the deposit, mostly in Clay Marl II, but the lower foot was distinctly marly (Clay Marl I), and near the bottom there was also evidence of iron oxide crusts. A bank near by showed 20 feet of chocolate-colored clay, Clay Marl II. The deposit is well located for working and the haulage distance to the wagon road is not more than 500 feet. The stripping of Pensauken sand and gravel will probably not exceed 6 feet.

Clay Marl IV, or a surface clay derived from it, is worked at two localities in Burlington county. It is dug in two clay pits just north of Timbuctoo (Loc. 123) (Pl. XV, Fig. 2) and 1½ miles northwest of Northampton, and supplies two small brickyards. When molded by hand and burned in scove kilns, it makes a porous brick. Harder burning would improve it.

Another exposure is found 2 miles due east of Rancocas, on a stream 200 feet south of a small bridge, and just before reaching the farm house on M. Hayne's property (Loc. 124). The bed is 4 feet thick, underlain by coarse sand and overlain by 12 to 15 feet of loam and gravel. It is of low plasticity, coarse-grained and sandy. Unless the bed thickens, when dug into, it would have no value.

In addition to the above localities, from which samples were taken, the Clay Marls are known to outcrop at many other points in the county, the following localities being shown on map Plate Xa.

Black's creek.—Both I and II are frequently exposed along the banks of Black's creek and its tributaries, particularly in the steep-sided ravines. At locality 111, just south of Bordentown, the sandy clays of the Raritan are exposed near the creek, overlain by 60 feet of green-black, sandy clay, becoming more chocolate colored in some higher beds, and all belonging to Clay Marl I. At the top of the bluff, in an old clay pit, the bottom layers of Clay Marl II, a chocolate-colored, nonglauconitic clay are found. The overburden is not heavy and the bank could be easily worked, although the material is somewhat sandy.

Other good exposures occur near Mansfield Square both along Black's creek and also along the brook west of Mansfield Square.

Kinkora to Columbus.—So, too, the Clay Marl beds are exposed along the creek northwest of Columbus. At locality 117, 2½ miles from Columbus, a sandy black, micaceous clay with some greensand is exposed along the banks of a mill pond. It is not far distant from the Kinkora branch of the Pennsylvania R. R. At locality 118, one-half mile west of Columbus, a black, micaceous clay is exposed to a depth of 6 feet. Its weathered portion, however, is yellowish in color. A sample, burned at cone 05, had an air and fire shrinkage of 6.6 per cent. and absorption, 30.47 per cent., showing that the bricklet was very porous. A mile farther west (Loc. 119) another outcrop of a chocolate-colored clay was noted along the road. The clay was smooth and plastic and was exposed for 4 feet. Both of these outcrops belong to Clay Marl II, and at both a great thickness of clay could undoubtedly be found.

Bustleton.—Four feet of mottled, weathered clay outcrops along a brook a mile northeast of Bustleton, on the road to Three Tuns. It belongs to Clay Marl I, and is apparently a good brick clay.

Jacksonville. — Numerous exposures of Clay Marl II occur along Assiscunk creek, north of Jacksonville, and at some localities, as at 122, a mottled, yellowish clay, probably a local deposit along the stream, was noted.

Pensauken creek.—The exposures of the Clay Marls on Pensauken creek, near Maple Shade, have already been described. At locality 154, 1¼ miles north of Maple Shade, the contact of Clay Marl I, a marly, sandy clay, upon the underlying Raritan sand, is shown. The locality is not promising from an economic standpoint, but it is interesting, since it shows the sharp contact of the two formations.

Cohansey Clays.

Mount Misery.—Clays belonging to the Cohansey formation are known to occur in Burlington county, near Mount Misery, one mile south of Hanover station, where they have been worked at intervals. The pits were near the old Browns Mills road and one-half a mile northwest of Mount Misery. At the village, also, a brick clay was formerly dug in the south bank of the stream, but it is very sandy.

South Park.—A large tract at South Park (Loc. 298), 2½ miles northwest of Harris station, on the Jersey Southern R. R., is reported to be underlain by clay, probably belonging to the Cohansey formation. The clay is on property owned by Constant Le Duc, and is reported to be from 13 to 15 feet deep, and covered by a few feet of sand or gravel. The general character of these beds can be inferred from what has already been said regarding the Cohansey clays (p. 348).

Pleistocene Clays.

Clays belonging to the Pleistocene formation are worked at three localities, one lying one-fourth mile southeast of Edgewater Park station (Loc. 127), another at Martin's brickyard southwest of Kinkora (Loc. 115), and the third at Scattergood's brickyard north of Rancocas (Loc. 126).

Edgewater Park.—The clay here forms a bed about 8 feet thick, covered by 1 to 3 feet of loam and this in turn by 2 to 6 feet of wind-blown sand. The clay is colored bluish-black by much organic matter, and is quite sandy due to numerous small mica scales and quartz grains. The upper portion has been yellowed by weathering. In working, about one-third loam has to be mixed with the clay.

The latter (Lab. No. 651), when examined in the laboratory, was found to slake fast and mixed up with 22.6 per cent. of water to a mass that was fairly plastic to the feel. The air shrinkage was 5.5 per cent., and the average tensile strength 185 pounds per square inch. In burning it behaved as follows:

Burning tests of brick clay, Edgewater Park.

Cone	*05*	*1*	*5*
Fire shrinkage,	1.8 %	2.5 %	5.8 %
Absorption,	15.34%	11.97%	2.86%
Color,	red	......	deep red
Condition,	nearly steel-hard	steel-hard	

Joseph Martin's brickyard (Pl. XLI, Fig. 2), is located half-way between Florence and Kinkora (Loc. 115). The materials used are a mixture of Raritan sandy clay, black sandy clay of late Pleistocene age and a surface loam. This produces a mixture whose air shrinkage is 4.3 per cent., and fire shrinkage is 4.4 per cent. The clays burn to a red brick with the exception of the light sandy Raritan material, which burns whitish and shows as spots in the brick.

At W. Scattergood's brickyard, north of Rancocas (Loc. 126), a surface clay loam has been used for brick and draintile. The deposit is dug only to a depth of 3 or 4 feet, but is reported to be much deeper. While its age and manner of origin are not definitely known, yet it is probably of late Pleistocene age.

Clay-working Industry.

A large portion of the brick industry so extensively developed along the Delaware river is included within the limits of Burlington county.

Common red brick of good quality are made in considerable quantities at Bordentown, by the Bordentown Brick Company; at Kinkora, by J. Martin and M. Dobbins; at Fieldsborough, by S. Graham & Co.; at Edgewater Park, by H. C. Adams, and at Maple Shade, by A. Reeves and Theo. Saucelein. The product is made by the stiff-mud process and burned in updraft kilns. Brick and draintile are also made intermittently by W. Scattergood, at Rancocas. The raw materials are Clay Marls, Raritan, or Pleistocene clays, to which there is added a certain proportion of surface loam of Pleistocene age.

Hollow brick are made from Clay Marl II, at Crosswicks, by J. Braislin & Son, and by A. Reeves, at Maple Shade, who makes some draintile also. Terra cotta is manufactured at Burlington and Moorestown, by the Burlington Terra Cotta Co., the clays for this latter product being dug partly in the county, and in part brought from the Woodbridge district. Whiteware is made at Bordentown, but no other potteries are in operation in the county. Much of the Raritan clay dug along the Delaware river is sold for foundry use, and to a smaller extent for fire brick. It is not highly refractory, but would be classed as a No. 2 fire clay.

CAMDEN COUNTY.

The workable clay deposits of this county are found in the Raritan, Clay Marls I and II, Cohansey and Pleistocene formations. With the exception of the Cohansey clays these are all in the northern portion of the county, within a few miles of the Delaware river, and the large population centering about Camden and Philadelphia. The Cohansey clays are in the southern half of the county entirely.

Raritan Clays.

North Pennsville.—Raritan clay is found along Pensauken creek (Loc. 133), southwest of North Pennsville. This is a bed of sandy clay and sand, covered by a great thickness of Pensauken gravel. The overburden is altogether too thick to permit the clay to be worked alone, but, if the gravel were dug and sold as is done at other places in the vicinity, it might then become profitable to work the clay, for the latter is at least 15 feet thick in places. It is interstratified at times with much white sand, and is not unlike many of the Raritan and Patuxent No. 2 fire clays found in Maryland.

Palmyra.—The largest and best exposures of this Raritan clay are those in H. Hylton's pits, 1¼ miles due south of Palmyra (Loc. 134). Here a vast excavation has been made in digging the gravel, sand and clay and in doing so several large masses of the bluish-white, and occasionally yellow-mottled, sandy Raritan clay (Pl. XXII, Figs. 1 and 2) have been uncovered.

When visited in 1902, one clay bed was exposed at the eastern end of the line of excavation and showed 6 feet of bluish-white, yellow-mottled clay underlain by 4 feet of sand and white sandy clay, with 50 feet of sandy overburden, partly Raritan sand and partly Pensauken gravel. To the west of this a larger clay mass was exposed and from this the overburden had been removed. The upper surface of the clay showed great irregularity, and the total thickness was not shown, but it is said to range from 8 to 20 feet. The sand contents of the clay are somewhat variable and in places may form streaks running from 6 to 15 inches in thickness, but occasionally thickening out to 4 feet. The material is no doubt equal to a No. 2 sandy fire clay. There is no evidence of pyrite in it, although it might occur in some of the dark lignitic streaks seen in the pits towards the western end of Hylton's excavation. A sample of this clay (Lab. No. 621) gave the following physical tests: Plasticity, fair; clay, very gritty; water required for tempering, 20 per cent.; air shrinkage, 5.3 per cent.; average tensile strength low, being 65 pounds per square inch.

Burning tests of fire clay, H. Hylton, Palmyra.

Cone	*05*	*5*	*8*	*15*
Fire shrinkage,	1.3%	1.3 %	2 %	2.3%
Absorption, ..	....	14.52%	12.82%	8.4%
Color, ...	buff	buff	buff	buff with small black specks
Hardness, ...	not steel-hard	nearly steel-hard	steel-hard	

At cone 27 the brick was well vitrified, and was viscous below cone 30. These clays show that the material should be classed as a fire clay of medium refractoriness, such as would be used in No. 2 fire bricks, or only in small quantities in a No. 1 brick. Its fire shrinkage is very low, but at the same time it is not dense burning, as can be seen from its absorption at cone 15. Its composition was as follows:

Chemical composition of a fire clay, H. Hylton, Palmyra.

Silica (SiO_2),	77.72
Alumina (Al_2O_3),	15.74
Ferric oxide (Fe_2O_3),	0.49
Lime (CaO),	trace
Magnesia (MgO),	0.81
Alkalies (Na_2O, K_2O),	trace
Ignition,	5.62
	100.38

Hylton's pits were being worked at the time the earlier New Jersey Clay Report was written (1878), and an analysis is there given of the fine white sand and also of the clay.

Analysis of a white sand, H. Hylton, Palmyra.

Silica, total (SiO_2),	91.80
Alumina (Al_2O_3),	5.60
Potash (K_2O),	0.20
Water (H_2O),	2.20
	99.80

It was said to stand fire well and was used in the manufacture of fire brick.

Analysis of a fire clay, H. Hylton, Palmyra.

Sand,	56.80
Silica (SiO_2),	17.50
Alumina (Al_2O_3), and Titanium oxide (TiO_2),	18.11
Ferric Oxide (Fe_2O_3),	1.09
Lime (CaO),	0.11
Magnesia (MgO),	....
Potash (K_2O),	0.76
Soda (Na_2O),	0.20
Water (H_2O),	5.50
Moisture,	0.40
	100.47

This represents a very sandy clay and agrees rather closely with the later analysis given above.

The material was formerly sent to Trenton for fire brick, and was also used for retorts and condensers in zinc furnaces. Its chief use now is for foundry work.

Not far to the west of Hylton's pits, another bank has been opened by P. Erato (Pl. XXIII). It lies along the tracks of the Amboy division of the Pennsylvania R. R., just northeast of Morris station (Loc. 139), and the excavation is primarily for sand and gravel, but clay is found beneath. The amount of sand and gravel covering the clay in this bank ranges from 10 to 35 feet. Two grades of clay are recognized, a No. 2, which forms the upper portion of the bed, and a No. 1, or lower clay. The white sand associated with the clay is used for fire sand, and the yellow sand of the bank for molding purposes. A laboratory examination of the No. 2 clay (Lab. No. 631) showed it to be a mottled sandy clay with little mica. It slaked slowly but completely, and mixed up with 17.7 per cent. of water; it had an air shrinkage of 2 per cent., which is low and due to its sandy character.

At cone 3 its fire shrinkage was 1.3 per cent., and its absorption 15.41 per cent. It would probably have to be burned to cone 8 or 10 to produce a dense bricklet. Even at cone 3 it is not steel-hard.

Its chief application is for foundry work, but it could also be used in the manufacture of terra cotta, as a low-shrinkage ingredient.

Fish House.—Two other lense-like deposits of Raritan clay were seen, one about one-third mile south of Fish House station (Loc. 135), and the other (Loc. 136) the same distance southeast of that locality. At the former point the clay outcrops in a cutting along the roadside. It is a bluish-white, sandy clay, forming a lense probably 8 feet thick, and while not of great length or thickness, still there are additional lenses of clay in the vicinity. The overburden is not very heavy. A similar mass of clay is found in a pit about 1,000 feet north of the road. This clay, like the preceding, was quite free from mica. The character of this clay (Lab. 643), which was quite plastic, was as follows: Water required for mixing, 21.9 per cent.; air shrinkage, 3.3 per cent.; average tensile strength, 80 pounds per square inch.

A sample burned at cone 10 gave 4.7 per cent. fire shrinkage, and had an absorption of 8.52 per cent. It was steel-hard at this temperature and a light-buff color. It became viscous at cone 27, so that it is only a low-grade fire clay. It could be used for terra cotta or foundry work, and also for buff brick.

At the second locality mentioned above there is another lens of Raritan clay, whose thickness is at least 8 feet. The clay is very similar in appearance to that of the preceding locality, but it has several sandy layers near its base, and the overburden varies from 5 to 10 feet in thickness. The clay takes only 19.2 per cent. of water to temper it, and its fire shrinkage up to cone 5 is only 2 per cent., with an absorption of 12.93 per cent.

Clay Marl I.

Camden.—Clay Marl I is extensively used at Budd Brothers' brick works, near City Line station (Loc. 143). The clay bank is a large shallow excavation, with a working face 15 to 20 feet high, involving the following section:

Section at Budd Brothers', Camden.

Gravelly loam,	5 ft.
Mottled green, yellow and pink, coarse-grained, sandy clay,	6 ft.
Dark, sandy, micaceous clay,	8 to 10 ft.

The clay, the thickness of which is well shown in Plate XVIII, Fig. 2, is mined by falling, and the run of the bank used. If too much of the black clay is used the bricks are apt to burn grayish. The top loam at times contains stones nearly an inch in diameter.

A physical test was made in the laboratory of both the black clay and the brick mixture. The chief difference between these two would appear to be a slight decrease in the amount of water required for tempering and in the fire shrinkage at cone 01. The bricklet is also more porous, due to the presence of the loam, as can be seen from the absorption.

Physical tests of samples from Budd Brothers, Camden.

	Black clay and loam. Lab. No. 620.	*Black clay alone.* Lab. No. 624.
Water required,	20%	24%
Air shrinkage,	6%	6%
Average tensile strength, lbs. per sq. in.,	156	164
Cone 05		
Fire shrinkage,	1.3 %	0.5 %
Absorption,	16.54%	9.36%
Color,	red	red
Hardness,	not steel-hard	not steel-hard
Cone 01		
Fire shrinkage,	1.5%	......
Cone 1		
Fire shrinkage,	2.6 %	2. %
Absorption,	12.68%	8.62%
Color,	red	red
Hardness,	barely steel-hard	barely steel-hard
Cone 3		
Fire shrinkage,	2.6 %	2. %
Absorption,	10.66%	10.75%
Color,	red	red
Hardness,	steel-hard	steel-hard
Cone 5		
Fire shrinkage,	2.3%	......
Absorption,	10.17%	......
Color,	red	viscous at cone 8

Chemical composition of the brick mixture, Budd Brothers, Camden.

Silica (SiO_2),	66.66
Alumina (Al_2O_3),	14.15
Ferric Oxide (Fe_2O_3),	3.43
Lime (CaO),	2.15
Magnesia (MgO),	0.38
Potash (K_2O),	2.32
Soda (Na_2O),	1.38
Ignition (water and organic matter),	8.40
	98.87
Total fluxes,	9.6

The composition indicates a rather easily fusible clay, and the burning tests—viscous at cone 8—confirm this conclusion.

Merchantville.—Another outcrop of Clay Marl I is seen in the railroad cut on the bridge branch of the Pennsylvania R. R. (Loc. 140), three-fourths of a mile east of Merchantville. The section there shows:

Section along railroad near Merchantville.

Pensauken,	8 ft.
Greenish-yellow sand and clay sand,	6 "
Light chocolate clay,	2 "
Black clay,	4 "
Green sand, little clay,	6 "

The upper two feet of the last layer of the section are more or less cemented by iron oxide. The clay (Lab. No. 605) shows good plasticity when wet, and considerable fine grit. It takes 23 per cent. of water to temper it and has an air shrinkage of 8.3 per cent. Its tensile strength is quite high, being 257 pounds per square inch. The fire shrinkage is low.

Burning tests of clay from railroad cut near Merchantville.

Cone	*05*	*01*	*1*	*3*
Fire shrinkage,	1.7 %	1.7 %	2%	2.3%
Absorption,	14.95%	9.95%	5.57%	5.8%
Color,	light red	red	red	red
Condition,	not steel-hard	not steel-hard	steel-hard	

At cone 1 the bricklet shows small fused specks, probably of glauconite, and at cone 8 it becomes viscous. This easy fusibility is probably due to a considerable amount of greensand. Its fire shrinkage is low, and so is the absorption.

Analysis of clay from railroad cut near Merchantville.

Silica (SiO_2),	67.02
Alumina (Al_2O_3),	17.10
Ferric oxide (Fe_2O_3),	4.41
Lime (CaO),	0.93
Magnesia (MgO),	0.38
Alkalies (Na_2O, K_2O),	1.60
Water (H_2O),	8.56
	100.00

Cooperstown.—On the road to Stockton, 2½ miles southeast of Cooperstown, there is also an exposure of Clay Marl I (Loc. 142). The deposit was bored to a depth of 4 feet, and found to be weathered in its upper part. A sample (Lab. No. 604) taken for partial physical test gave the following results: Water required, 25 per cent.; air shrinkage, 6 per cent.; tensile strength not tested.

Burning tests of clay from southeast of Cooperstown (Loc. 142).

Cone	*05*	*01*	*1*
Fire shrinkage,	1%	4%	3.6 %
Absorption,	22.61%	16.07%	15.85%
Color,	red	red	.....
Condition,	not steel-hard	nearly steel-hard	steel-hard

It is seen from this that the clay burns to a very porous body, is not hard until probably cone 1, and has a low fire shrinkage. The color in burning is good, however. A more plastic clay should be mixed with it.

Clay Marl II.

Collingswood.—Clay Marl II is well exposed in Dobb's brickyard pits (Pl. XVIII, Fig. 1), 1 mile south of Collingswood (Loc. 144). Here the outcrop is worked in a face 12 to 15 feet high, the upper 5 to 6 feet being weathered and containing some sandstone crusts. The clay in the lower two-thirds of the bank is very similar to that at Crosswicks. It burns to a good, red, hard body. Practically no loam is added to the clay, so that the brick mixture represents the run of the Clay Marl. The properties of a sample (Lab. No. 650) were as follows: Water required for tempering, 34.9 per cent.; air shrinkage, 10 per cent.; average tensile strength, 286 pounds per square inch. Its behavior in burning was as follows:

Burning test of Dobb's brick mixture, Collingswood.

Cone	*05*	*1*
Fire shrinkage,	3.3 %	3.3 %
Absorption,	11.12%	9.92%
Color,	red	red

The clay burned steel-hard at cone 05, and became viscous at cone 10.

The body of the bricks made from this clay are dense and show high transverse strength.

Haddonfield.—A bed of Clay Marl II outcrops in the Pennsylvania R. R. cut, 1½ miles north of Haddonfield (Loc. 145). The clay (Lab. No. 715) is rather sandy, although quite plastic, and is covered by 8 feet of Columbus sand (Clay Marl III). When tested for its physical properties it was found to work up with 30.7 per cent. water, but its air shrinkage was only 6.6 per cent. Its average tensile strength was 168 pounds per square inch. At cone 05 the fire shrinkage was 0.4 per cent.; absorption, 19.98 per cent.; color, buff, and at cone 5, fire shrinkage was 4.9 per cent.; absorption, 7.70 per cent.; color, reddish buff, and bricklet steel-hard.

This clay burns to a somewhat lighter color than most of the Clay Marls, but not to a very dense body.

Westmount station.—A weathered plastic outcrop of Clay Marl II is seen 1 mile due north of Westmount station (Loc. 146). The sample (Lab. No. 638) was taken from a bank in the woods about 300 feet east of the Pennsylvania R. R., and the bed of weathered clay is probably not less than 8 feet thick. The total shrinkage at cone 1 is 11.2 per cent., and the absorption of the bricklet 10.22 per cent. It burns to a light-red color and is steel-hard at this cone.

Haddonfield.—Along the road near a mill pond and northeast of Haddonfield (Loc. 147), Clay Marl II is exposed in the following section:

Section near Haddonfield.

1.	Loam,	3 ft.
2.	Weathered clay,	4 "
3.	Black clay,	5 "
4.	Ironstone,	2 in.
5.	Clayey sand with marl grains,	5 ft.

A mixture of 2 and 3 (Lab. No. 635) was tested physically. It worked up with 29 per cent. of water to a mass having an air shrinkage of 7 per cent. Its tensile strength was 243 pounds per square inch. At cone 03 its fire shrinkage was 3.3 per cent.; absorption, 17.24 per cent.; color, pinkish red, and bricklet not steel-hard. At cone 1, fire shrinkage, 5 per cent.; absorption, 10.31; color, light red, and bricklet steel-hard.

Pensauken creek.—Along the road from Merchantville to Evesboro, and at a point 2 miles due north of Ellisbury, there is an outcrop of at least 7 feet of plastic, buff-colored clay along the roadside (Loc. 152). The material (Lab. No. 714) is not highly plastic, and contains little grit. When mixed with 38.5 per cent. of water it had an air shrinkage of 8.3 per cent. Its average tensile strength was 126 pounds per square inch. At cone 1 its fire shrinkage was 7 per cent., and absorption 8.19 per cent. At this cone it was steel-hard and burned red. Its fire shrinkage was higher than many of the other occurrences of Clay Marl II.

Good exposures of Clay Marl II are also found along the bank of the creek just south of Oakdale station (Loc. 159).

Little Timber creek.—Another outcrop lies along Little Timber creek (Loc. 158), 1¼ miles southwest of Mount Ephraim. The material is probably in part Clay Marl I, and outcrops along the road. The thickness of the bed as determined by boring exceeds 7 feet, while the sandy overburden is 7 to 8 feet thick. The material (Lab. No. 612) takes little water for tempering (22.8

per cent.), as compared with some of the other Clay Marls. Its air shrinkage was 7 per cent. At cone 05 the fire shrinkage was 2 per cent.; absorption, 18.28 per cent.; color, light red, and bricklet not steel-hard. At cone 03: fire shrinkage, 4 per cent.; absorption, 15.72 per cent.; color, light red. At cone 1: fire shrinkage, 8 per cent.; absorption, 8.42 per cent.; color, red, and clay steel-hard.

It is probable that the material would not make a good brick much under cone 1. The deposit is easy of access for working and shipping the product.

Oakdale station.—The chocolate-colored clay, the weathered portion of Clay Marl II, outcrops along the bank of Peters creek at numerous points one-half mile south of Oakdale station. The covering of pebbly loam is only 2 or 3 feet thick and the clay is found 15 or 20 feet above the creek. This deposit is favorably located for shipment both as respects the creek and railroad.

Clay Marl IV.

Clay Marl IV outcrops in the P. & R. railroad cut just north of Bellmawr station (Loc. 148), and 1 mile south of Mount Ephraim. The clay, which is sandy, and micaceous, is about 8 feet thick and is exposed for a distance of probably 200 feet. It has as much plasticity as many brick loams. The stripping of Pensauken gravel and sand is from 7 to 8 feet.

The physical properties of this clay (Lab. No. 633) indicate it to be as good as many other brick clays, although its air shrinkage is rather high. It worked up with 20.8 per cent. water and had an air shrinkage of 9 per cent. Its average tensile strength was 195 pounds per square inch. In burning it behaved as follows:

Burning test of a clay from Bellmawr, Camden county.

Cone	*03*	*1*	*3*	*5*
Fire shrinkage ...	3%	3%	3.5 %	4.3 %
Absorption, ...	14.55%	12.71%	12.06%	7.47%
Color, ...	red	red	red	reddish brown
Condition, ...	not steel-hard	not steel-hard	steel-hard	

The clay became thoroughly viscous at cone 10.

Cohansey Clays.

Clays belonging to the Cohansey formation have been dug at several points in southeastern end of the county.

Winslow Junction.—The most extensive excavations have been made in the immediate vicinity of Winslow Junction (Loc. 201) for supplying the works of the Eastern Hydraulic Press Brick Company, at that point. A large area has been dug over close to the railroad station, and at present another bed has been opened 1¼ miles north of the works, and connected with the factory by a narrow-gauge railroad. The latter deposit underlies an area of about 20 acres, and ranges from 4 to 7 feet in thickness, with 2 to 3 feet of yellow, sandy overburden. The material is vari-colored, being gray, black and bright yellow with much lignite in places, and is said to be more plastic than the clay at Whitings or right at Winslow Junction. The pit is operated with a long working face. (Pl. VII, Fig. 2.)

The physical properties of this material (Lab. No. 657) are as follows: Water required for tempering, 37.5 per cent.; air shrinkage, 5.5 per cent.; average tensile strength, 196 pounds per square inch. The firing tests are given below:

Burning tests of clay from near Winslow.

Cone	*1*	*8*	*15*
Fire shrinkage,	6.5 %	9.1 %	10. %
Absorption,	12.96%	4.01%	2.37%
Color,	buff	buff	gray brown

The clay burned at cone 8 was steel-hard, and that burned at cone 15 showed a blistered surface.

Some dry-press tile made from the clay, when burned at cone 5, gave a shrinkage of 8 per cent., a buff color and were steel-hard, with an absorption of 9.23 per cent. At cone 8 the same tiles burned grayish buff with a shrinkage of 15.6 per cent. The clay before pressing was screened through an 80-mesh sieve.

Another sample of clay from a pit nearer Winslow Junction was also tested (Lab. No. 411). This sample had been previously ground in a disintegrator and screened, and when worked up to a plastic mass in the laboratory had an air shrinkage of 6.6 per cent. Its tensile strength was 110 to 130 pounds per square inch.

It behaved as follows in burning:

Burning test of a clay from Winslow.

Cone	*1*	*5*	*8*
Fire shrinkage, ...	5.4%	6.0%	6.4%
Color, ...	deep buff	yellow brown	deep buff
Condition, ...	steel-hard	slightly absorbent	slightly absorbent

The clay was thoroughly viscous at cone 27, hence it is not a fire clay.

Blue Anchor.—Considerable clay, partly for terra cotta, has been dug around Blue Anchor, and shipped from there. One of these pits (Loc. 202), not being worked in 1902, showed at least 9 feet of light, bluish-gray clay, with yellow sandy clay in places. Above this is 2 to 3 feet of pebbly sand. A small sample (Lab. No. 692) that was taken for a partial test, worked up with 38.2 per cent. water and had 7.3 per cent. air shrinkage. Its average tensile strength was fair, being 146 pounds per square inch. It burned as follows:

Burning test of a terra-cotta clay, Blue Anchor.

Cone	*5*	*8*	*10*
Fire shrinkage, ...	6.3 %	7.6%	9.2 %
Absorption, ...	5.09%	4.3%	1.90%
Color, ...	buff	buff	deep gray buff

This could be classed either as a terra-cotta clay or buff-brick clay. It is not a fire clay.

Another pit (Loc. 204) is intermittently operated by Wm. Brimfield, along the railroad.

Prof. Cook noted[1] the occurrence of clay near Conrad, one mile south of Tansborough. The clay was dug at one time to make pipe, terra cotta and fire brick, and the section given was:

Stripping, ...	6 in. to 3 ft.
Clay, ...	5 to 16 ft.
White and yellow quartz sand.	

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[1] 1878 Report on Clays, p. 258.

Fig. 1.

General view of Hatch & Son's clay pit, at Fish House.

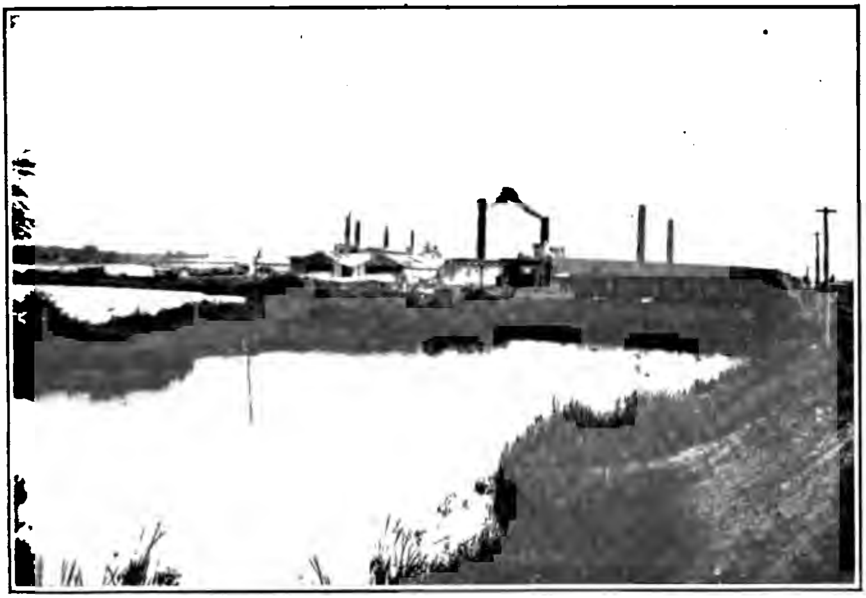

Fig. 2.

General view of the Eastern Hydraulic Press Brick Company's works at Winslow Junction. The long sheds on the left are for storing clay, and to the left of those the clay is seen spread out for weathering.

A cemented sand layer was found under the clay in places. It is said that the clay could be traced for a mile southeast of the pits. It was sandy, and its color bluish white, buff, and chocolate.

Analysis of clay near Conrad and Tansborough.

Sand,	34.50
Silica combined (SiO_2),	29.50
Alumina[1] (Al_2O_3),	23.30
Ferric oxide (Fe_2O_3),	1.50
Lime (CaO),	....
Magnesia (MgO),	....
Potash (K_2O),	1.77
Soda (Na_2O),	0.16
Water (combined) (H_2O),	7.00
Moisture,	1.60
	99.33

The composition would indicate a clay of buff-burning qualities, but not a refractory one, for the per cent. of fluxes and sand is too high. (See Silica, p. 312, and Fire clays, p. 311). Its composition resembles that of some stoneware clays.

The crude clay could all be used for pipe according to Prof. Cook, but for finer and ornamental terra cotta it was washed.

Pleistocene.

Fish House.—The deposits at Fish House (Loc. 137) have already been described in considerable detail in Chapter VI.

Two large excavations have been made, from one of which with a working face varying from 15 to 27 feet in height, clay is now dug at several points (Pl. XLII, Fig. 1).

The section here gave

Section at Fish House.

Sand,	6 ft.
Yellow clay,	2–3 "
Black clay,	24 "
Yellow clay,	1 "
Sand and gravel, somewhat cemented,	? "

---

[1] Including the titanic acid.

Most of the clay is dark, almost black in color, with occasional layers of coarse black sand and much organic matter. Lumps of lignite are not uncommon, but pyrite was not noticeable. The upper limit of the black clay varies, and at the end of the excavation nearest the factory there is a 2-foot layer, low in organic matter and sand, which is sufficiently plastic for pottery purposes and has been used for stoneware.

It is found in actual practice that it is undesirable to use the black clay alone, and that a certain amount of loam must be added to it. This decreases the fire shrinkage and makes the clay easier to burn, for the black clay alone has considerable organic matter.

The physical properties of the black and of the brick mixture can best be compared by placing them in parallel columns.

Physical characters of clays from Fish House.

	Black clay. Lab. No. 668.	*Brick mixture.* Lab. No. 639.
Water required,	37.1 %	27.5 %
Air shrinkage,	6 %	7.0 %
Tensile strength, lbs. per square in.,	243	258
Cone 05		
Fire shrinkage,	......	3.00%
Absorption,	......	9.96%
Cone 03:		
Fire shrinkage,	7.3 %	5.0 %
Color,	red	red
Condition,	steel-hard	steel-hard
Absorption,	5.96%	6.83%
Cone 1:		
Fire shrinkage,	7.60%	6.0 %
Color,	......	deep red brown
Absorption,	4.90%	3.08%
Cone 3:		
Fire shrinkage,	......	6.3%
Color,	......	deep red brown
Absorption,	......	0.02%

The black clay, in spite of its high tensile strength, does not feel very plastic when wet, and the brick mixture is much more sticky.

The following analysis was made of a green brick, as representative of the run of the bank:

Chemical Analysis of brick mixture, Fish House.

Silica (SiO_2),	65.53
Alumina (Al_2O_3),	17.21
Ferric oxide (Fe_2O_3),	5.23
Lime (CaO),	0.95
Magnesia (MgO),	0.31
Potash (K_2O),	2.84
Soda (Na_2O),	0.96
Loss on ignition,	4.54
Total,	97.57

This shows a high percentage of total fluxes, and it is doubtful if the clay could be heated to cone 10 or 12 without fusing.

Pleistocene clay loams are found overlying the Clay Marls at several localities in the county, and are usually mixed with the latter in the manufacture of brick, although the loam by itself is of little value for brickmaking in most cases, because of its low plasticity and tensile strength, and its porous-burning character. Besides this it often contains pebbles which should either be crushed or carefully removed by screening, for otherwise they tend to split the brick in burning.

Clay-working Industry.

Common building brick are made in large quantities at Fish House, by Hatch & Sons, at City Line station, Camden, by Budd Brothers, and at Collingswood, by J. C. Dobbs. The bricks in all cases are made by the stiff-mud process. Some of these yards have been in operation for a considerable period. Dry-pressed front brick of a number of shades and colors have been made by the Eastern Hydraulic Press Brick Company, at Winslow Junction, since 1890 (Pl. XLII, Fig. 2), the clays being dug at various localities.

Draintile are made at Collingswood by J. C. Dobbs. Red earthenware and stoneware are produced at Haddonfield by C. Wingender & Bro., the raw clays being derived in part from Camden county and in part from the South Amboy district. A factory for the manufacture of sanitary ware is also in operation at Camden. It is now controlled by the Camden Pottery Company.

Tests of bricks from this county compare very favorably with those from other localities.

CAPE MAY COUNTY.

Clays are dug at only one locality in this county, viz., at Woodbine (Loc. 189), where they are worked into common building brick by Bushnell & Westcott. The deposit lies 1-1½ miles southeast of the depot and not over one-eighth mile south of the agricultural school. The clay is known to be 6 feet thick, underlain by sand, and covered by about 1 foot of sandy stripping. It is, therefore, a comparatively shallow deposit. The material is mostly quite sandy, but fairly plastic. It is usually red-burning, but patches of whitish-burning clays are occasionally found, one of these occurring at the north end of the bank. The latter is bluish-white in color and is usually avoided in mining.

Plate XLIII, Fig. 1, shows one portion of the pit, and indicates well the thickness of the clay, thin overburden, and dense brush growth on the surface. The two latter interfere somewhat with the search for clays in this region, and, therefore, careful prospecting with an auger is very necessary.

The physical characters of the run of the bank (Lab. No. 705), as shown by the green brick mixture, are as follows: Water required for tempering, 21.4 per cent.; air shrinkage, 4.3 per cent.; average tensile strength, 90 pounds per square inch.

Burning test of brick mixture, Woodbine.

	Cone 1	*Cone 10*
Fire shrinkage, ...	1%	3.7%
Color, ...	red	gray brown
Condition, ...	steel-hard	......
Absorption, ...	12.77%	......

The bluish-white clay (Lab. No. 678) is tough, gritty and moderately plastic. It takes more water than the other, viz., 27.8 per cent., and its air shrinkage is also higher, being 6 per cent. On firing the brick seems to expand, possibly due to high silica contents and also to fusion. This is shown below:

Fig. 1.

Clay pit of Bushnell & Westcott, near Woodbine.

Fig. 2.

Pit of Clayville Mining and Manufacturing Company, near Clayville. The clay is in the Cohansey formation, and the area on left has been worked over.

Burning test of a blue-white clay, Woodbine.

	Cone 5	*Cone 8*	*Cone 15*
Fire shrinkage, ...	5.3%	4.6%	3.3%
Color, ...	light buff	gray buff	gray, brown specks
Condition, ...	steel-hard	speckled	slightly swelled
Absorption, ...	6.33%	5.45%	1.61%

A larger deposit of this grade of clay would be a desirable possession.

Other clay deposits are said to occur in the vicinity of Woodbine, but they have not been opened. Clay is also reported to occur near Tuckahoe, but nothing is known of its character or extent.

Clay-working Industry.—Brick are made at the one locality referred to above. There is opportunity for much prospecting to be done, and the possibility of finding larger pockets of the light-burning clay, like that found in Bushnell & Westcott's pit, should stimulate search.

CUMBERLAND COUNTY.

The clays examined in this county belong chiefly to the Cohansey and Cape May formations. One small deposit (Loc. 184) north of Vineland is probably of secondary origin in late Pleistocene times.

Cohansey Clays.

Of these the Cohansey clays are the more important in point of development and have been opened at 6 or 7 localities, although now dug at only 3 or 4 points.

Clayville.—The most extensive openings are near Clayville, north of Millville (Loc. 183), where clay was dug as early as 1860, and shipped to New York and Trenton. Later attempts to produce common brick from it were unsuccessful, the reason probably being that the clay was not burned hard enough. At the time of writing the pit is owned by the Clayville Mining & Brick Company, and worked by the Globe Fireproofing Company.

The clay bank (Pl. XLIII, Fig. 2) lies about 1 mile east of the factory, and the railroad is connected with them by a switch. The clay is variable in thickness, ranging, it is claimed, from 7 to 24 feet, although 14 feet was the greatest thickness observed. With such a variation we should look for irregularities in either the upper or lower surface of the clay deposit, and it is found that both occur, a characteristic not rare in the Cohansey clays.

The area that has been dug over is considerable, and the amount of stripping to be removed has varied from 5 to 12 feet. The line of separation between overburden and clay is sharp wherever seen. The clay itself is very tough and gritty, and has to be worked by undermining and falling. In some parts of the bank it grades horizontally into sand, and, where the base of the clay was seen, sand was found to underlie it. In mining the clay, the run of the bank is used, but there is said to be one layer at the bottom which has a high shrinkage.

On account of the size of this deposit a complete physical test was made of it (Lab. No. 653) with the following results:

Amount of water necessary to temper, 32.3 per cent.; air shrinkage, 4 per cent.; average tensile strength, 163 pounds per square inch. Its behavior in burning was as follows:

Burning tests of clay from Clayville, near Vineland.

	Fire shrinkage.	*Color.*	*Absorption.*	*Condition.*
Cone 03, ...	4.6%	yellowish white	13.07%	
1, ...	7.3%	buff	6.14%	steel-hard
3, ...	8.0%	buff	8.34%	
8, ...	10.0%	green gray	0.42%	
10, ...	8.0%	gray	0.46%	
15, ...	7.3%	gray	2.64%	slightly blistered and swelled

Chemical analysis of clay, Clayville.

Silica (SiO_2),	66.12
Alumina (Al_2O_3),	22.07
Ferric oxide (Fe_2O_3),	1.31
Lime (CaO),	0.50
Magnesia (MgO),	0.25
Alkalies, (Na_2O, K_2O),	1.81
Water (H_2O),	7.94
	100.00
Total fluxes,	3.87

The clay has been used for electrical conduits, fireproofing and buff brick. It could also be employed in terra-cotta manufacture, but it is not a fire clay.

Millville.—Another series of pits were found nearer to Millville. The most westerly of these is a 4-foot opening in a bed of sandy clay along the road west of Millville on the way to Bridgeton (Loc. 182). The locality is known as the old Wood's pit, and is not being worked. As far as could be determined the deposit is more than 4 feet thick and probably not less than 10, with 2 feet of gravelly overburden. The deposit lies immediately adjoining the main highway and has fairly good haulage facilities.

A partial test was made of it (Lab. No. 661) to determine approximately its character with the following results: Water required 36.4 per cent.; air shrinkage, 6.6 per cent.; average tensile strength, 286 pounds per square inch.

Burning tests of a clay west of Millville.

	Cone 5	*Cone 8*
Fire shrinkage,	3.4%	4%
Color,	light buff	buff
Condition,	steel-hard	steel-hard
Absorption,	9.46%	8.78%

It is not unlike other Cohansey clays used for terra cotta, and might fairly be classed as a terra-cotta clay.

South of Millville (Locality 178), on the road to Buckshutem, the clay is exposed in a pit on the west side of the creek. It is bluish above and black below, and has a thickness of not less than 7 or 8 feet. The amount of stripping, however, is as much as 12 feet, and it probably would not pay to mine the clay unless some use were found for the overlying sand. The clay is also wet in places. If the deposit on further prospecting were found desirable to work, there would be but a short haul to the Maurice river where it could be loaded upon scows for shipment. The clay (Lab. No. 671) is gritty, with an air shrinkage of 7.3 per cent. and it takes 31.7 per cent of water for mixing. It burned steel-hard, however, at cone 1, with a fire shrinkage of 3.7 per cent., although the clay was still absorbent (8.25 per cent.). At cone 10, it was vitrified, gray in color, and had a fire shrinkage of 7.7 per cent.

Another deposit of Cohansey clay has been worked 3 miles east of Millville (Loc. 187). The material from there has been shipped to the Perth Amboy Terra Cotta Company at Perth Amboy, but the pit was idle in 1902. The clay is not unlike many of the Cohansey clays already referred to, being dense, tough and gritty, with occasional sandy streaks. At the bottom of the pit there is a black lignitic clay. The light clay is about 6 feet thick with several feet of sandy overburden.

The clay when worked up with 34 per cent. of water had a rather high air shrinkage, viz., 8.6 per cent., and an average tensile strength of 155 pounds per square inch. Its behavior in burning was as follows:

Burning test of clay at Millville, Perth Amboy Terra Cotta Co.

Cone	*5*	*8*	*10*	*12*
Fire shrinkage,	7.4 %	7.7%	8.4 %	9.0%
Absorption,	3.26%	.....	1.80%	0.09%
Color,	buff	buff	deep buff	gray buff

A dry-pressed bricklet at cone 8 showed 8 per cent. shrinkage, and another one at cone 12, the same, with gray color and impervious body.

Rosenhayn.—Another important bed of Cohansey clay has been opened at Rosenhayn (Loc. 185), along the N. J. Southern R. R. (Pl. XVII, Fig. 2).

Section of clay pit at Rosenhayn.

Gravel and sand, with some iron crusts,	4–6 ft.
Clay, upper two feet more or less weathered and laminated, yellowish color, red-burning; lower part said to burn buff,	5–6 ft.
Alternating layers of clay and sand,	6 in.–1 ft.
Yellow sand,	8 ft.

Two clays are distinguished in working, viz., a lower or buff-burning clay, and a red-burning top clay. The former is underlain by a bed of sand, termed fire sand. A mixture of the two is used for making a buff brick, and the under clay with fire sand is employed for fire brick. The main use of the deposit is for making buff brick, the raw material working up well on a stiff-mud machine with few laminations and smooth surface and edges. The stripping is of little value.

The general physical characters of these two clays are as follows: The red top clay (Lab. No. 682) is a fairly plastic material with some coarse grit, and in mixing required 32.4 per cent. water. Its air shrinkage was 8 per cent., and average tensile strength 158 pounds per square inch. It behaved as follows in burning:

Burning test of the top clay, Rosenhayn.

Cone	*1*	*5*	*8*
Fire shrinkage,	5.3 %	8 %	7.3 %
Absorption,	10.82%	4.68%	0.01%
Color,	red	red	gray
Condition,	steel-hard	steel-hard	

As shown by the above figures this clay burns to a dense body at cone 5, and a very dense one at cone 8. It is said to have been tried for the manufacture of stoneware.

The mixture for buff brick (Lab. No. 683) is sticky, gritty and plastic, and required 28.9 per cent. of water. Its air shrinkage was 8.6 per cent., and its average tensile strength 127 pounds per square inch. In burning it gave the following results:

Burning tests of buff-brick mixture. Rosenhayn.

Cone	*05*	*1*	*3*	*5*	*8*
Fire shrinkage,	1.4%	5.4%	6%	6%	6.7%
Color, ...	pale red	buff red	deep buff		
Absorption, ...		slightly absorbent			
Condition, ...	not quite steel-hard	steel-hard			

A dry-pressed tile burned at cone 10 was gray brown, with an absorption of 2.36 per cent., and a fire shrinkage of 9 per cent.

Carmel.—The Cohansey clays are also found at Carmel on Mr. Miller's property (Loc. 186), but the thickness exposed in the pit is not great. When wet the clay is tough, sandy and rather lean, so that its tensile strength is probably not very high. It also pulls somewhat in molding, so that it could probably be improved by the addition of a more plastic material. The material (Lab. 704), when mixed with 28.1 per cent. of water, had an air shrinkage of 6 per cent., and at cone 5 its fire shrinkage was 4 per cent., the bricklet being buff-colored and its absorption 7.68 per cent., so that in its burning qualities it is similar to the buff clay found at Rosenhayn. Some draintile have been made from it experimentally. The bed has not been worked nor is its exact extent known. Rosenhayn, about 3 miles distant, is the nearest shipping point.

Bridgeton.—Another exposure of the Cohansey clays is worked at Bridgeton (Loc. 191), where the clay is seen in Erickson's pits on the southern edge of the town. The clay is bluish-white, mottled and often very siliceous and, so far as seen, without pebbles. The thickness of the deposit, as exposed, ranges from 6 to 9 feet, and it is underlain by a layer of sand cemented by limonite. The upper limit of the clay is fairly uniform, so that the variation in thickness is caused by a rise in the level of the bottom sandstone layer towards the south end of the pit.

The physical properties of the sample tested (Lab. No. 619) were as follows: water required to mix, 30 per cent.; air shrinkage, 7 per cent.; average tensile strength, 133 pounds per square inch. In burning it behaved as follows:

Burning test of clay from Erickson's pit, Bridgeton.

Cone	*05*	*1*	*3*	*5*
Fire shrinkage, ...	3.6%	5.3%	7.6%	7.6%
Color, ...	pale red	red	red	red
Condition, ...	nearly steel-hard	steel-hard		
Absorption, ...	14.81%	7.96%	5.57%	4.19%

The clay alone, it is seen, burns quite dense at a moderately low temperature, and, if molded stiffer, the total shrinkage could no doubt be reduced. In actual practice the clay is mixed with sand and molded quite wet, so that the total shrinkage in drying and burning is about 14 per cent. and the brick has an absorption of probably 14 or 15 per cent. It is claimed that the clay will not stand molding in a stiff-mud machine without tearing.

Certain layers of the clay are tougher and burn to a lighter color than others in the bank, and unless they are thoroughly disintegrated in the machine they show on the broken surface of the brick. This clay differs from most of those classed as Cohansey in burning red. Inasmuch as the clay occurs at an elevation of 40 feet, the height of the Cape May terrace, there is a possibility that it belongs rather to the Cape May formation, although on the whole, the stratigraphical evidence favors its reference to the Cohansey.

Cape May Clays.

Bridgeton.—A brick-clay pit (now idle) has been opened in the Cape May formation on the west side of Cohansey creek one-half mile south of Bridgeton (Loc. 190). The bed of clay, which is at least 8 feet thick and possibly more, is fairly plastic but gritty and contains numerous pebbles, some of them running up to 1 or 2 inches in diameter. Immediately overlying the clay is 2 to 4 feet of gravel, capped by 3 to 4 feet of sandy loam.

This material was formerly used for soft-mud brick and burned to a good red color. The pebbles in the clay would have to be crushed, if the clay were to be used for stiff-mud purposes. The clay seems also to have yielded good results on re-pressing.

In the laboratory the air-dried clay (Lab. No. 664) took 26 per cent. of water for tempering and had an air shrinkage of 6 per cent. The average tensile strength was 219 pounds per square inch. It behaved as follows in burning:

Burning test of a brick clay from Bridgeton.

Cone	*1*	*5*	*10*
Fire shrinkage, ...	4.3%	7.3%	....
Color, ...	light red	red	gray
Condition, ...	steel-hard	....	beyond vitrification, and somewhat swelled.
Absorption, ...	7.51%	2.76%	

To produce a good red brick this clay would have to be fired fairly hard.

Buckshutem.—The best exposures of Cape May clay in Cumberland county are found on both sides of the Maurice river at Buckshutem.

One bed is opened up at A. E. Burchem's yard (Loc. 180), on the east side of the river. The clay, which is sandy in character, is not less than 9 feet thick, but only the upper 6 feet are dug. It has 12 to 15 inches of sandy overburden, and makes a stiff-mud, red-burning brick.

On the opposite side of the river (Loc. 181) is another pit, in which clay is dug by Hess & Golder for their brickyard at Millville.

Section at Hess & Golder's clay pit, Buckshutem.

Sandy overburden, ...	4 feet.
Sandy clay, ...	8 feet.
Tough plastic clay, ...	4 feet.

It is claimed that the bottom clay will not stand much heat, and in digging it is left to prevent the water of the creek from entering the pit. The clay from this bank is mixed with clay from Cedarville, which is on the road west of Millville.

The physical properties of the run of bank from both localities 180 and 181 are given below:

Physical properties of clays from Buckshutem.

	Loc. 180 *Lab. No. 646*	*Loc. 181* *Lab. No. 645*
Water required,	27.2%	25.2%
Air shrinkage,	7%	10%
Average tensile strength, lbs. per sq. in.,	291	289
Cone 05—		
Fire shrinkage,	3.3%	2%
Absorption,	12.46%	13.13%
Color,	light red	light red
Condition,	nearly steel-hard	nearly steel-hard
Cone 03—		
Fire shrinkage,	5%	2%
Absorption,	9.41%	9.05%
Color,	red	light red
Condition,	steel-hard	steel-hard
Cone 1—		
Fire shrinkage,	6%	4%
Absorption,	5.50%	6.29%
Color,	brick red	red
Cone 3—		
Fire shrinkage,	6.3%	4%
Absorption,	4.48%	4.24%
Color,	dark red	red
Cone 5—		
Fire shrinkage,	7%	4.3%
Absorption,	3.51%	2.86%
Color,	deep red	deep red

Chemical analysis of clay, A. E. Burchem, Buckshutem.

Silica (SiO_2),	72.37
Alumina (Al_2O_3),	14.40
Ferric oxide (Fe_2O_3),	3.43
Lime (CaO),	0.75
Magnesia (MgO),	0.49
Alkalies (Na_2O, K_2O),	1.60
Loss on ignition (chiefly water),	6.70
	99.74
Total fluxes,	6.27

Comparing these two clays it is seen that the one from locality 181 has a lower fire shrinkage, but does not burn much denser. Neither of the clays is refractory and they are also too gritty for pottery manufacture.

Belleplain.—The Cape May clays[1] are still further utilized at Belleplain (Loc. 188), on the West Jersey R. R. The clay is made into bricks at a yard by the railroad station, but the deposit lies in the pines about 1 mile to the southeast. The clay which is very sandy runs 7 feet in thickness with 1 foot of stripping. The sample tested (Lab. No. 660) slaked rapidly and on account of its sandy character but little water (22.9 per cent.) was required to temper it. In the laboratory test it showed an air shrinkage of 5.3 per cent., and its average tensile strength was 148 pounds per square inch. Its burning qualities were as follows:

Burning test of clay from Belleplain.

Cone	*1*	*5*
Fire shrinkage, ...	1.7%	2.7%
Color, ...	light pinkish red	red
Condition, ...	not steel-hard	steel-hard
Absorption, ...	11.98%	10.82%

Vineland.—Two small shallow deposits of Pleistocene clay are worked at Hobart's brickyard (Loc. 184). They are known as the east and west bank respectively. The former is a gray-burning sandy clay and makes the more ringing brick, while the latter is less sandy, and burns a brighter red. A sample of the latter (Lab. No. 669) required 36.0 per cent. of water for tempering, had an air shrinkage of 6.3 per cent., and an average tensile strength of 133 pounds per square inch. Its burning properties were as follows:

Burning tests of clay from Hobart's west bank, Vineland.

Cone	*03*	*1*	*5*
Fire shrinkage, ...	3.7%	4.4%	5.3%
Color, ...	red	red	deep red
Hardness, ...	steel-hard	steel-hard	steel-hard
Absorption, ...	16.29%	13.00%	10.35%

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[1] The reference of these clays to the Cape May formation is not beyond a doubt. They may be Cohansey.

A sample of the so-called gray-burning one (Lab. No. 663), when tested in the laboratory gave the following results:

Water required for mixing 28.5 per cent.; air shrinkage, 5.3 per cent. Its behavior in burning was as follows:

Burning tests of clay from Hobart's east bank, Vineland.

Cone	*05*	*01*	*1*
Fire shrinkage, ...	0.7%	2.3%	2.7%
Absorption, ...	16.94%	14.79%	13.49%
Color, ...	pale red	light pink	reddish
Condition, ...	nearly steel-hard	nearly steel-hard	steel-hard

It will be noticed from this that the clay in the laboratory test burned a brighter color than in practice. The gray color obtained in practice is due largely to the sand used for tempering and molding, as well as in part to insufficient air in burning.

Clay-working Industry.

The clay products made in Cumberland county include common brick, pressed brick and conduits. Soft-mud brick are manufactured at Vineland by J. A. Hobart; at Millville, by Golder & Hess; at Bridgeton, by B. Erickson; and by R. T. Greenlee at Belleplain. Stiff-mud brick are made at Buckshutem by A. E. Burcham. Conduits are manufactured at Clayville by the Globe Fireproofing Co.[1] Both buff and red front brick are produced at Rosenhayn by Kilborn & Gibson. The stiff-mud process is used.

Some of the yards have been in operation for a considerable period of time.

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[1] Since writing this (1903), we learn that this factory has been closed and the Clayville clay is now chiefly shipped to Philadelphia for terra cotta.

ESSEX COUNTY.

So far as known, not much clay of commercial value occurs in Essex county, and there are at present no localities where it is dug. The northwest portion of the county lies within the area formerly covered by Lake Passaic, and lacustrine clays of Glacial age are to be looked for in the low areas along the Passaic river, particularly in Caldwell township. If present, they are more or less deeply covered by sand and gravel or by swamp muck. Local beds of glacial or alluvial clay probably also occur along many of the streams.

Clay-working Industry.

The clay-working industry of this county is of little importance. Common earthenware and some stoneware are manufactured at Newark by the Union Pottery & Drainpipe Works, Excelsior Pottery Works and the Belmont Ave. Pottery.

GLOUCESTER COUNTY.

Gloucester county includes the following clay-bearing formations: Raritan, Clay Marl I, Clay Marl II, Clay Marl III, the Alloway and probably the Cohansey. The first four are found in the northwestern part of the county, the Alloway clay in Harrison and South Harrison townships, and lenses of Cohansey clay, if present, are to be looked for in the pines in the southeastern part of the county.

Raritan Clays.

Billingsport.—Dr. Cook[1] reported the occurrence of clay on property of B. A. Lodge, 1¼ miles south of Billingsport. The opening in the river bluff showed:

Section near Billingsport.

Sand and gravel,	10-17 feet.
Yellow clay,	2 feet.
Potters clay,	10-12 feet.
Yellow clay,	1 foot.
White gravel,	....

The clay was dark-colored, and carried lignite near the top of the bed. Towards the bottom there was a little pyrite. The best clay was quite sandy and had the following composition:

Chemical analysis of clay. B. A. Lodge, Billingsport.

Sand,	56.00
Silica (SiO_2),	16.20
Alumina (Al_2O_3) and Titanium oxide (TiO_2),	15.00
Ferric oxide (Fe_2O_3),	1.20
Lime (CaO),	.....
Magnesia (MgO),	0.32
Potash (K_2O),	1.68
Soda (Na_2O),	0.39
Water (H_2O),	7.70
Moisture,	1.10
Total,	99.59

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[1] Report on Clays, 1878, p. 251.

The clay was shipped away, but for what use was not stated.

Bridgeport.—The occurrence of a tough, yellowish-white clay on the land of James Kirby, 1 mile south of Bridgeport, was also reported by Dr. Cook.[1] The locality is near Raccoon creek.

The Clay Marls.

The position of Clay Marl I in Gloucester county is shown on the map, Plate X. The formation is for the most part covered with the sand deposits of the Cape May terrace and exposures are few, except along some of the creek banks. No samples were taken for testing.

Outcrops of Clay Marl II are more frequent, and are more promising as sources of workable deposits.

Woodbury.—Good exposures are found at various points along Mathews brook (Loc. 157), three-fourths mile due west of Woodbury. Here the clay is probably of considerable thickness, and was tested by boring for more than 6 feet. It is black and plastic, but not so dense as that at locality 156, south of Woodbury. There is a variable covering of loam, but this in no case exceeds 6, or sometimes 10, feet, and much of it might be mixed with the clay. This locality is favorably situated as regards shipment, the railroad being but a few hundred feet distant. A physical test of the clay (Lab. No. 613) from this locality gave the following results: Water required for mixing, 28 per cent.; air shrinkage, 11 per cent.; average tensile strength, 193 pounds per square inch. It burned as follows:

Burning test of clay near Woodbury, locality 157.

Cone	*05*	*01*	*1*	*3*	*8*
Fire shrinkage,	4.3%	4.3%	5.3%	6.3%	
Absorption,	11.23%	9.34%	6.88%	3.03%	
Color,	pale red	red	red	deep red	
Condition,	steel-hard	.....	.....	....	viscous

From these tests it is seen that the clay burns a good color and hard at a low cone. The overlying material could easily be mixed in with it to reduce the air shrinkage.

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[1] Loc. cit. p. 252.

Clarksboro.—Wells in the vicinity of Clarksboro indicate the presence of 15 feet of clay, probably Clay Marl II, beneath a few feet of loamy sand.[1]

Swedesboro.—At several points northwest of Swedesboro a chocolate-colored clay occurs along the highway and banks of Raccoon creek at points not unfavorably situated for opening pits, but no attempt has been made to utilize it.

Clay Marl III is usually a sand bed but at certain horizons contains workable lenses of clay which have been used in Gloucester county.

Woodbury.—Such a deposit occurs at Thackara's brickyard, one-half mile south of Woodbury on the road to Wenonah (Loc. 155, Pl. XXVI, Fig. 1). The clay is loamy in character with numerous mica scales, but makes a good red hand-molded brick. Farther south on this same road, and about 1 mile from Woodbury is an abandoned brickyard (Loc. 156). In the bottom of the pit there is an extremely tough, bluish-black clay 4 feet in thickness, overlain by 6 feet of weathered chocolate clay, and this in turn capped by 4 feet of pebbly loam. It is claimed that the toughness of the clay (Lab. No. 717) caused the abandonment of the yard, for the deposit does not appear to be exhausted. The following are its physical characters: Water required for mixing, 40.5 per cent., which is rather high; air shrinkage, 9 per cent., which is also high; average tensile strength, 134 pounds per square inch. At cone 05, fire shrinkage was 4.3 per cent., and absorption 11.28 per cent.; color light red, and bricklet steel-hard. At cone 01, fire shrinkage was 4.6 per cent.; absorption, 8.7 per cent., and color red. In working this material it would probably be necessary to add a considerable quantity of the sandy overburden.

Alloway Clay.

The Alloway clay is found in southern Harrison township at several localities, and underlies considerable areas. (Pl. XIII.)

Harrisonville.—Clay crops out along the roadside 1 mile east of Harrisonville (Loc. 176). It is mottled yellow and red, and

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[1] Annual Report of the State Geologist, 1901, p. 77.

a sample was taken to a depth of 4 feet, but the clay extends below this. The material (Lab. No. 693) is rather free from grit, and quite plastic. It took a very high percentage of water, viz., 47.7 per cent. to temper it, but the air shrinkage of 8.3 per cent. is lower than that of some other Alloway clays requiring less water. Its tensile strength was also very high, averaging 405 pounds per square inch. At cone 1 its fire shrinkage was 5.7 per cent.; the bricklet steel-hard and light red. A dry-pressed tile burned at cone 8 showed a total shrinkage of 13.3 per cent.

Ewan Mills.—At locality 174, north of Ewan Mills the most northerly outcrop of Alloway clay was found, but it is probably too thin for economic working, there being not more than 4 or 5 feet of light chocolate-colored clay underlain by loose sand and overlain by a heavy burden of sand with pebbles and iron crusts, passing upwards into gravel.

A bed of clay at least 7 feet in thickness is found along the road on the North Farwell farm (Loc. 175), and in fact underlies the entire property. Brick made from it many years ago can still be seen in a good state of preservation in the walls of neighboring farmhouses. It is a smooth, light-brown clay with yellow mottlings, few iron crusts and of good plasticity. There is little or no stripping. The following are the physical characters of the material (Lab. No. 687): Amount of water required, 32.1 per cent.; air shrinkage, 9.3 per cent., this is rather high. Average tensile strength 208 pounds per square inch.

At cone 1: fire shrinkage, 2.7 per cent., and absorption, 5.4 per cent., bricklet steel-hard and yellowish red.

At cone 5: fire shrinkage, 4.7 per cent.; color, gray brown, and bricklet quite dense, absorbing only 2.21 per cent.

The clay vitrified at cone 12. On looking at the tabulated tests of Alloway clays (p. 352), it will be seen that only one other had an equally low fire shrinkage, *i. e.*, the brick mixture used at Yorktown. The latter, however, had a lower air shrinkage and required less water for tempering.

Talc-like Clay.

Harrisonville.—At locality 173 a mile due east of Harrisonville, there is an old pit which shows several feet of the micaceous talc-like clay which underlies the Alloway clay. A sample was tested with the following results: Water required for tempering, 38.5 per cent.; air shrinkage, 5 per cent.; tensile strength not tested, probably very low. It gave the following results when burned:

Burning tests of a talc-like clay, near Harrisonville.

	05	1	5
Fire shrinkage	1%	3%	3%
Color, ...	whitish	pinkish buff	light buff
Condition, ...	not steel-hard	not steel-hard	nearly steel-hard
Absorption, ...	28.73%	24.65%	20.61%

Both the Alloway clay and this talc-like clay are discussed more at length in connection with the clays of Salem county.

Clay-working Industry.

There is only one brickyard in Gloucester county, viz., the one mentioned south of Woodbury. Aside from this there are no clay-working plants in the county.

HUDSON COUNTY.

No clay deposits are being worked in this county, but there are several factories which are supplied chiefly by clays from Middlesex county.

J. H. Gautier & Co. have a factory in Jersey City and produce some fire brick and graphite crucibles. Porous white-ware cups for electrical purpose are made by W. Ross, of Jersey City. The same class of goods are also produced by Thos. Loughran of Marion, N. J.

Fig. 1.

G. C. Pedric's brickyard, Flemington, showing soft-mud machine and molding gang at the right, and drying sheds with movable roofs. The white smoke between the two kiln sheds is the water-smoke or steam from the bricks.

Fig. 2.

Clay bank at the same brick works showing the shallow character of the clay which was derived by wash from the steep hill on the right.

HUNTERDON COUNTY.

The clay deposits of Hunterdon are not extensive, but so far as known, are limited to local accumulations due directly to the disintegration of the underlying rock or to wash from steeper slopes. In the latter case, the clay is usually residuary material which has been transported at most only a few hundred yards from its source.

Lambertville.—A small deposit of ferruginous brick clay derived directly from the decomposition of trap rock is worked on the hill about one mile southeast of Lambertville (Loc. 277). It is rather shallow and contains numerous large bowlders, the disintegrated portions of the rock (Pl. XXIV, Fig. 1). Although the brickyard is a small one and worked intermittently, bricks have been made in this vicinity from this clay since 1816. There is no likelihood of finding an extensive deposit on this ridge, but clay similar in amount and character probably occurs at many points along the top of Sourland mountain between Lambertville and Neshanic. The material burns red and has a low fire shrinkage.

Flemington.—A bed of loamy clay ranging from 3 to 7 feet in thickness is worked at Flemington (Loc. 276), for the manufacture of common brick (Pl. XLIV, Figs. 1 and 2). The lower portion of the clay was derived directly from the Triassic red shale, while the upper few feet, which contain occasional pebbles of trap rock, were derived by wash from the steep slopes of a hill of trap rock a few rods west of the clay pits. Both clays are used and burn to a product of good red color and hard body, but they are too gritty for use in draintile. The physical properties of this material are as follows: Water required, 23.9 per cent.; air shrinkage, 3.5 per cent. Average tensile strength 159 pounds per square inch. The sample burned as follows:

Burning tests of a clay from Flemington, Pedrick's yard.

Cone	*05*	*1*	*3*
Fire shrinkage,	1.1 %	7.1 %	7.1%
Absorption,	12.34%	4.94%	3.9%
Color,	red	deep red	very deep red
Condition,	not quite steel-hard	steel-hard	

Holland.—The following is an analysis of clay[1] near Holland, found on the property of A. C. Rapp. It is apparently derived from the crystalline gneisses which surround it. The clay may be of buff-burning character, but is not now worked.

Analysis of a clay of A. C. Rapp, Holland.

Silica (SiO_2),	54.97
Iron oxide (Fe_2O_3) and Alumina (Al_2O_3),	33.06
Titanic oxide (TiO_2),	0.24
Lime (CaO),	0.20
Magnesia (MgO),	0.38
Soda (Na_2O),	0.61
Potash (K_2O),	0.82
Moisture,	0.26
Water (Ignition),	9.70
	100.24

Junction.—Near Junction (Loc. 281, Lab. No. 733), a clay derived by wash from the neighboring slopes of decomposed gneiss rock occurs on the property of C. N. Moore. It is not being used and its extent and thickness are unknown, but it is favorably located as respects railroad facilities. It is rather a gritty-feeling clay of medium plasticity and works up with 19 per cent. water. It burned with the following results:

Burning test of clay from C. N. Moore, Junction.

Cone	*05*	*1*	*5*
Fire shrinkage,	4%	5%	12%
Absorption,	18.29%	10.23%	0.95%
Color,	yellowish pink	light red	dark brown
Condition,	not steel-hard	nearly steel-hard	steel-hard

Bethlehem.—A bed of white clay with a large percentage of very fine quartz sand and partially-decomposed feldspar is said to occur 1½ miles southwest of Bethlehem, Hunterdon county (p. 208).

New Germantown.—A deposit of sandy brick clay is reported to occur near New Germantown on the property of P. W. Melick,

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[1] Analysis made by W. S. Myers, 1894, unpublished.

Jr. Information regarding it was received by the Survey too late to permit any physical tests.

Clay-working Industry.

Common brick are made at Flemington by G. C. Pedrick, the yard having been in operation since 1840. A small yard is also operated by T. O. Daniel southeast of Lambertville.

The Fulper Pottery Company, of Flemington, produces stoneware and some earthenware. The clays used are obtained entirely from the Middlesex district.

MERCER COUNTY.

The clay deposits in Mercer county can be referred to the Raritan formation, the Clay Marls I and II and to the Pleistocene clay loams. Owing, however, to the heavy accumulation of Pensauken gravel over much of the area occupied by the Raritan and the two lower Clay Marl beds, the localities at which these beds are worked are not numerous. The Triassic red shale formation, although also occurring in the county, has up to the present time, not been found to be of any value there for the manufacture of clay products.

The Raritan Clays.

Trenton.—To the east of Trenton in the region known as Dogtown, the Raritan clays are dug in a number of pits for sagger, wad, and fire clay. One of the largest openings is that on the property of J. J. Moon (Loc. 101), where a pit of considerable depth was opened at the time of the writer's visit and illustrated well the character of the materials obtained from the formation in this vicinity (Pl. VI). The section exposed in June, 1902, was:

Section at J. J. Moon's pit, Dogtown.

Stripping,	15 ft.
White sandy clay,	2–3 ft.
Black buff-burning clay (occasionally wanting).	
Red wad clay,	6 ft.
No. 2 sagger clay,	4 ft.
No. 1 sagger clay,	2 ft.
Sand,	4 ft.

Most of the product of these pits is hauled by wagon to Trenton and used to a large extent by the potteries of that city.

Another series of pits (Loc. 102), opened by Mr. Smith in the woods to the southwest of Moon's pit, showed the following section:

Section of Smith's pit, Dogtown.

Stripping,	3 ft.
Red wad clay,	14 ft.
No. 1 black clay,	6 ft.
Black sand,	4½ ft.
Black earth,	......

A number of other pits have been dug in this region as shown on the map at localities 100, 103, and 104, and the materials all show the usual variation characteristic of the Raritan beds. The following series of tests fairly represent the properties of these Raritan clays in the vicinity of Dogtown:

Physical tests on Dogtown clays, J. J. Moon.

I. No. 1 blue clay, whitish color, with some fine grit, from Dogtown. It slaked moderately fast and had tiny limonite specks. J. J. Moon.

II. No. 1 sagger clay. J. J. Moon.

III. Tough red wad clay with very little grit. J. J. Moon.

IV. No. 2 sagger clay.

	I *Lab. No.* *629*	II *Lab. No.* *632*	III *Lab. No.* *644*	IV *Lab. No.* *710*
Water required,	18. %	28.5 %	38.5 %	......
Air shrinkage,	5.3 %	4.6 %	6 %	7 %
Average tensile strength, lbs. per sq. in.,	85	90	72	......
Cone 05:				
Fire shrinkage,	......	1.4 %	......	......
Absorption,	......	19.82%	......	......
Color,	......	pinkish red	......	......
Condition,	......	not steel-hard	......	......
Cone 03:				
Fire shrinkage,	......	3.0 %	......	......
Absorption,	......	20.00%	......	......
Color,	......	pinkish red	......	......
Cone 1:				
Fire shrinkage,	......	......	8.0 %	7.0 %
Absorption,	......	......	15.39%	15.08%
Color,	......	......	gray	......
Condition,	......	......	steel-hard	......
Cone 3:				
Fire shrinkage,	7.3 %	6.0 %	9.3 %	......
Absorption,	13.0 %	13.63%	11.73%	......
Color,	creamy white	pinkish red	gray	......
Condition,	steel-hard	not steel-hard		

Cone 5:				
Fire shrinkage,	......	7.4 %	10.00%	......
Absorption,	......	8.26%	11.33%	......
Color,	......	light red	gray	......
Condition,	......	steel-hard	......	......
Cone 8:				
Fire shrinkage,	8.7 %	9.4 %	11.6 %	......
Absorption,	8.64%	......	3.71%	......
Color,	cream white	......	gray	......

At cone 15, No. I had a fire shrinkage of 11.7 per cent.; absorption, 1.21 per cent., and it vitrified at cone 27. No. II vitrified at cone 10; No. III was viscous at cone 30.

A white clay of the composition given below was formerly obtained by washing the clay found in A. C. Anderson & Company's pits two miles northeast of Trenton. Prof. Cook[1] gave the following analysis:

Analysis of clay. A. C. Anderson & Co., Trenton.

Silica (SiO_2),	45.30
Alumina (Al_2O_3),	37.10
Ferric oxide (Fe_2O_3),	1.30
Lime (CaO),	0.17
Magnesia (MgO),	0.22
Titanic oxide (TiO_2),	1.40
Water (H_2O),	13.40
	100.19

Clays are also known to occur below Trenton along the bluff bordering the river, and northeast of the city near Clarksville (p. 198).

Clay Marls.

Hightstown.—The most important openings made in the Clay Marls are at B. H. Reed & Bro.'s brickyard near Hightstown (Loc. 194), where pits have been dug along the boundary line of Clay Marls I and II. The material obtained from these pits is

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[1] 1878 Rep. on Clays, p. 235.

mixed with a certain percentage of sandy surface clay and used in the manufacture of bricks. The clay molds well and easily on a stiff-mud machine, and is also used to some extent for making draintile. The physical properties of a sample taken from the boundary of Clay Marls I and II at this locality are as follows: Clay (Lab. No. 609), tough and fairly plastic, working up with 34 per cent of water; air shrinkage, 6.6 per cent. The fire tests were as follows:

Burning tests of Reed & Bro's. black clay. Hightstown.

Cone	*03*	*1*	*3*	*5*
Fire shrinkage, ...	3.4%	5.4%	5.4%	6.4%
Absorption, ...	16.66%	10.59%	.....	.....
Color, ...	pale red	red	red	.....
Condition, ...	not steel-hard	steel-hard	.....	few small fused specks.

A dry-press tile made from this clay and burned at cone 5 had a fire shrinkage of 5.2 per cent. and was slightly mottled in its color.

Windsor.—A boring made along the road just by the bridge at Windsor (Loc. 192) showed at least 7 feet of Clay Marl I. The overburden is slight, but the clay appears somewhat sandy in its character, although not burning to a specially porous body. A partial physical test of this material (Lab. No. 602) showed that it required 31 per cent. of water to temper it, and that its air shrinkage was 8.6 per cent. Its average tensile strength was 251 pounds per square inch, but the latter did not seem to be an index of its plasticity, for the material did not feel especially plastic. In burning it gave the following results:

Burning test of a Clay Marl I, Windsor. (Loc. 192.)

Cone	*05*	*01*	*1*
Fire shrinkage, ...	0%	3.4%	1.4%
Absorption, ...	17.09%	10.78%	12.22%
Color, ...	light red with small black specks	bright red	
Hardness, ...	not steel-hard	not steel-hard	

From these tests it would appear that this material was suitable at least for the manufacture of common brick.

Robbinsville. — Clay of the following composition is said to occur near Robbinsville.[1]

Analysis of a clay near Robbinsville.

Silica (SiO_2),	60.10
Alumina (Al_2O_3),	21.13
Iron oxide (Fe_2O_3),	6.07
Water (H_2O),	8.90
Total,	96.20

The analysis shows that it is probably red-burning, and not a fire clay.

Clay Loams.

Trenton.—In the region around Trenton and as far north as Pennington the clay loam which mantles the Trenton gravels and extends back upon the hills to elevations of 200 feet (p. 121) has been worked for a long series of years for making common brick. The deposit is very shallow (Pl. XV, Fig. 1), and consequently large areas have been worked over. In fact the available supply near the yards has been nearly exhausted, and clay is now brought in from points near Trenton Junction and Ewing. These loamy clays around Trenton rarely run more than 5 or 6 feet thick and, moreover, may be pockety or basin-shaped in their character. On account of the large number of stones which they contain, they frequently have to be screened before use or put through rolls to crush the pebbles. When burned they produce a brick of excellent red color. Tests are given in the table facing page 348.

In the earlier years of the brick industry around Trenton, most of the brick were made by the hand process, and those which were sold for front brick were re-pressed in hand-power machines. At the present time, however, the hand molding is still used for the brick that are to be re-pressed, but the common brick are often molded in steam-power, stiff-mud machines.

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[1] Analysis by W. S. Myers, 1895. Unpublished. Exact locality unknown.

Glen Moore.—A white micaceous and very porous clayey sand, apparently disintegrated Triassic sandstone, is found at Glen Moore on property of G. C. Macauley (Lab. No. 732). A sample sent to the Survey was loose and hard to mold. It burned a loose white brick at cone 1, and had an absorption of 20.96 per cent. An attempt has been made to use it in fire brick in place of "feldspar" sand, but with unsatisfactory results, as it was found to lower the fusion point somewhat.

Clay-working Industry.

The value of the clay products produced annually in Mercer county is very great for the reason that it includes the pottery industry at Trenton. At the same time very little of the raw material used by the factories is obtained from within the limits of the county itself. Common brick have been produced in large quantities for a number of years in the region around Trenton, as mentioned under the history of the brick industry, on page 243, and in addition to those produced at this point, others are also manufactured near Hightstown. Pressed brick are made from the clay loams at several of the yards at Trenton, but at no other locality in the county, and draintile are made to a small extent at Trenton, as well as at Hightstown. The most important branch of the clay-working industry in Mercer county is the manufacture of pottery. The products produced at Trenton include white earthenware, semiporcelain, C. C. ware, sanitary ware, belleek, electrical porcelain, etc. Floor and wall tiles are also made at several factories in Trenton, and there are two factories engaged in the manufacture of fire brick. A list of the potteries is given at the end of Chapter XV (p. 305).

MIDDLESEX COUNTY.

- Importance.
- Clay-bearing formations.
- Method of classification.
- Highly refractory clays.
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  - Ball clay.
- Refractory clays.
  - Fire clays.
    - Woodbridge.
    - Florida Grove.
    - Sand Hills and Bonhamtown.
    - Burt Creek.
  - Ball clay.
  - Stoneware clay.
- Semirefractory clay.
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  - Stoneware clay.
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  - Miscellaneous.
- Nonrefractory clays.
  - Woodbridge.
  - North side of the Raritan river.
  - Sayreville.
- Feldspar.
- Fire sands.
- Clay-working industry.

IMPORTANCE OF THE COUNTY.

This is the most important clay-producing county in the State of New Jersey, and its importance was so marked even at an early date that in 1878, it was made the most prominent part of the Report on Clays issued by the New Jersey Geological Survey. Indeed, so extensively is the clay-working industry of Middlesex county developed, that it is highly probable that the value of the clay products manufactured there, together with the value of the clay mined by persons other than manufacturers, forms about 35 per cent. of the total value of the New Jersey clay-working industry.

Although the county is of large size, still the industry shows a peculiar degree of concentration, being centered in its northeastern corner.

Fig. 1.

Mutton Hollow opening. Woodbridge.

Fig. 2.

Two views of the Mutton Hollow opening, Woodbridge, showing the extensive excavations and piles of refuse clay and overburden.

This is due to several causes. In the first place the workable clays are confined chiefly to the eastern and northeastern portions of Middlesex county, in a rectangle with Cheesequake creek and New Brunswick on its east and west respectively, and Menlo Park and Old Bridge on its northern and southern boundaries. Within this area there are found a great variety of clays ranging from common brick clays up to those of a very high grade of refractoriness.

A second reason for the prominence of this area lies in the topography. There are many hillsides and valleys along which the later gravel deposits are not so thick as on the hilltops and the flatter country to the south. Hence the mining and search for clay deposits is facilitated. In this respect the Middlesex county area stands out in strong contrast to regions farther southwest.

Commercial advantage, by virtue of its position, is a third reason for the prominence of the Middlesex district. Many parts of the field are traversed by waterways, along which at many points large factories have been erected, and, in addition to this, most of the clay pits are in close proximity to them as well, thus permitting easy shipment by water to many coastal points. The region is also crossed by several important lines of railroad.

All these factors combined have helped to make the Middlesex district one of the most important clay-working areas not only of New Jersey but even of the United States.

CLAY-BEARING FORMATIONS.

Outside of the important clay-producing area in northeastern Middlesex county, there are two small ones. One of these is at Ten Mile Run, where an outlier of the Raritan formation is worked for terra-cotta manufacture. The other is a bed of Clay Marl II at Jamesburg, and is worked to a small extent by the Reform School, for brickmaking.

We thus see that the Raritan is practically the only clay-bearing formation as yet utilized in Middlesex county, although small quantities of loamy clay may be found in the Pleistocene deposits, and Clay Marl II is used in a small way as already mentioned.

As the stratigraphy of the Raritan clays has been described in some detail in Chapter VIII, it will be sufficient here simply to emphasize the fact that in this county there are five well-marked groups of clay strata, separated by much thicker beds of sand. These clay-bearing groups from the top downward are as follows:

The Cliffwood lignitic clays;
The Amboy stoneware clay;
The South Amboy fire clay;
The Woodbridge clay;
The Raritan fire and potter's clay.

The position of these subdivisions, so far as it has been possible to trace them in the field, is shown on Plate XI. Each of them, as exposed in the clay banks, is capable of further division, but these minor subdivisions are often extremely irregular, so that neighboring sections are frequently unlike. Since, however, any two successive layers often differ greatly in their physical properties, the same pit may contain five or six grades of clay. The following sections, which were taken from pits not more than 500 feet apart, show something of this difference, although the latter is more apparent than real, owing to the different names applied to the same bed.

Sections in adjoining clay banks at Woodbridge, showing variation in beds.

Locality 23.
Woodbridge District.
Known as Old Mellick Bank.
Section made Sep., 1901.

a. Drift,	18 ft.
b. Buff clay,	2 ft.
c. Sand,	2 ft.
d. Retort clay, No. 1,	2 ft.
e. Fire mortar,	4 ft.
f. Black to steel-gray fire clay,	2 ft.
g. No. 2 sandy clay,	2 ft.
h. Sand,	1 ft.
i. Fine clay,	1 ft.
j. Stoneware clay,	4 ft.
k. Black clay,	1 ft.

Locality 24.
Woodbridge District.
H. Maurer & Son.
Section made Sep., 1901.

1. Drift,	4–10 ft.
2. Pipkin clay,	2–5 ft.
3. Sand with clay layers,.	3 ft.
4. Blue "shorts" (alternating clay and sand)	4–5 ft.
5. Yellow brick clay (a No. 2 fire clay),	2 ft.
6. Yellow sand,	3 ft.
7. Yellow top clay,	2 ft.
8. Blue top clay (a light gray color),	2 ft.
9. Fire mortar,	3 ft.
10. No. 2 sandy clay,	1 ft.
11. Black sandy clay,	½ ft.
12. No. 2 fire clay,	4–5 ft.
13. Dark clay (rejected).	

Layers j and 12 are practically the same bed under different names and with perhaps somewhat different physical properties; so, too, layers f and 8 are not so different as the names given them by the miners would imply, and layers d and 5 are readily recognized in the field to be the same bed, although put to different uses, as indicated by the names. Differences in texture are more striking in the case of layers b and c, as compared to layer 4; of e compared to 6 and 7; of g and h compared to 9 and i to 10. Nothing corresponding to layers 2 and 3 is found at all in the other bank, owing to pre-Glacial erosion, which removed all clay beds higher than b.

The two sections given above will also serve to indicate something of the number of grades of clay that are recognized in the Middlesex district. The more important of these are No. 1 and No. 2 fire clays, retort clay, ball clay, wad clay, pipe clay, brick clay, hollow-brick clay, etc., but neither the use nor the physical properties of the material are always exactly indicated by the name. Sometimes the same clay may be employed for several different purposes, or again the same clay may be designated by different names in adjoining pits.

In the present description of Middlesex county it is chiefly the economic aspect of the clays that is discussed, and no attempt is made to describe all the localities where clay is dug, or to give sections of all the clay banks, for the latter vary from season to season, and nothing would be gained in publishing these details. It is suggested that the stratigraphic discussion of the Raritan clays (Chap. VIII) be read first, to insure a clearer understanding of their mode of occurrence in the field.

A systematic economic description of the Raritan clays in Middlesex county is attended with more or less difficulty, because, owing to the many different sections shown in the pits, it is difficult to discuss them collectively, and, while a great many notes were made in the field, it does not seem advisable to publish all of these details. More or less difficulty is also met with in discussing the uses of the clays from this area. One type of clay is sometimes used for three or four different purposes, or several clays of widely different physical character may all be employed for making the same kind of ware, being used not alone, but as ingredients of a mixture. In addition to this, the clay miner himself often does not know the exact use of the different clays dug in his pit, especially when they are shipped to distant points. He is, however, usually familiar with the burning qualities of the several clays found on his property, and when there is a call for a certain type of clay, supplies samples which he considers will most nearly answer the requirements.

METHOD OF CLASSIFICATION.

In treating Middlesex county, the scheme that has been adopted is to group the clays primarily according to their refractoriness, and under this according to kinds. It will do no harm, therefore, to repeat the classification given in Chapter IV, under Fusibility. The groups there made were:

Highly refractory clays, fusing above cone 33. These include the best of the so-called No. 1 fire clays.

Refractory clays, fusing at cone 31 to cone 33 inclusive. They include some of those marketed as No. 2, and some of those sold as No. 1.

Semirefractory clays, fusing at cone 27 to 30 inclusive. The lower grades of fire clay, including some sold as No. 2, the fire mortars, wad and some sagger and stoneware clays, fall under this head.

Clays of low refractoriness fusing at cone 20 to 26 inclusive.

Nonrefractory clays fusing below cone 20.

The classification above outlined may meet with the disapproval of some clay miners in the Middlesex district, for some clays called No. 1 will fall here in the second group, the refractory clays. When we consider, however, that the terms No. 1 and No. 2 clays as applied throughout the whole Middlesex clay district mean very little, it seems perfectly reasonable to adopt a classification, the meaning of which is definite, even though the lines drawn may be somewhat arbitrary, and perhaps not satisfactory to all.

HIGHLY REFRACTORY CLAYS.

Clays which are sufficiently refractory to merit this classification are found chiefly in the Woodbridge clay bed, and mostly in the vicinity of Woodbridge. Two grades are dug, No. 1 fire clay and ball or ware clay, but not all the clays known by these trade terms can rightfully be called *highly refractory.*

Fire clays.—At the middle or base of the section in many pits, there are often two grades of fire clay, known to the miners as the No. 1 and No. 2. The No. 1 is generally a fat, bluish clay, while the No. 2 is commonly mottled red and white, yellow and white, or sometimes bluish, but differing usually from No. 1 in being more sandy.

The character of the No. 1 fire clay found in the different pits varies somewhat, especially in point of refractoriness, as is shown by the detailed tests given below.

No. 1 fire clay is used in the manufacture of the best grades of fire brick, and there is consequently considerable demand for the material. Some of the No. 1 fire clays are also sold for saggers, the producers claiming to receive from $3.00 to $3.50 per ton for it. The supply of it is rather limited in the region around Woodbridge, and this is unfortunate, since it represents the most refractory type of clay found in Middlesex county, or even in New Jersey. As the Woodbridge fire-clay bed is followed to the southwestward it is found that the No. 1 clays drop off considerably in their fire-resisting qualities.

Detailed tests.—No. 1 fire clay, from pit of M. D. Valentine & Bros. Company (Loc. 14). This is a bluish clay (Lab. No. 382) with very little grit, even texture and smooth fracture, passing entirely through a 100-mesh sieve and slaking fairly fast. The air shrinkage was 7 per cent. when tempered with 25 per cent. of water, but the briquettes invariably cracked in drying, so that it was impossible to measure their tensile strength. The burning tests were as follows:

Burning tests of No. 1 fire clay. M. D. Valentine & Bros. Co., Woodbridge.

Cone	*3*	*5*	*10*
Fire shrinkage,	5.5%	6.5%	13%
Absorption,	24.25%	19.65%	7.76%
Color,	nearly white	whitish	light buff

It showed many small cracks at cone 3, and burned steel-hard at cone 5.

When tested in the Deville furnace at cone 27 it was not beyond incipient fusion, and fused above cone 34. It is, therefore, a very refractory clay, but owing to its cracking, cannot be used alone. It has the following chemical composition:

Chemical analysis of No. 1 fire clay. M. D. Valentine & Bros. Co., Woodbridge.

	Raw.	*Burned.*[1]
Silica (SiO_2),	50.60	57.93
Alumina (Al_2O_3),	34.35	39.33
Ferric oxide (Fe_2O_3),	0.78	0.89
Titanium oxide (TiO_2),	1.62	1.85
Lime (CaO),	tr	....
Magnesia (MgO),	tr	....
Loss on ignition (chiefly water),	12.90	....
	100.25	100.00

This clay is low in fluxing impurities and moderately low in silica, so that from the analysis alone its refractoriness is apparent. In order to show the percentages that would appear in the burned clay, the re-calculated analysis with the water omitted is given in the second column.

No. 1 fire clay, Anness & Potter.[2] A second sample of No. 1 fire clay, from the pit of Anness & Potter (Loc. 6), resembled the preceding in its properties. It is a soft, grayish-white clay (Lab. No. 373), of irregular fracture and medium porosity, slaking slowly in water. The water necessary to work it up was 33 per cent., and gave a plastic mass averaging 41 pounds per square inch in tensile strength. The air shrinkage was 5 per cent. In burning the material behaved as follows:

Burning tests of No. 1 fire clay. Anness & Potter, Woodbridge.

Cone	*5*	*8*
Fire shrinkage,	7.5%	11%
Absorption,	13.74%	9.10%
Color,	cream-white	cream

---

[1] This column gives the analysis re-calculated to 100 per cent., with the water left out, and shows the percentages as they would be after the clay is burned.

[2] No. 5 of section on page 455.

Fig. 1.

Clay pit of M. D. Valentine & Bro., east of Woodbridge, showing glacial drift overlying the Raritan clays.

Fig. 2.

C. A. Bloomfield's clay bank, Bonhamtown. A fire clay overlain by a great thickness of sand.

It burned steel-hard at cone 5 and warped but little. The material was barely incipiently fused at cone 27 and fused above cone 34. Its analysis was very similar to that of the preceding sample from locality 14, and was as follows:

Analysis of No. 1 fire clay. Anness & Potter, Woodbridge.

	Raw.	*Burned.*
Silica (SiO_2),	51.56	59.00
Alumina (Al_2O_3),	33.13	37.91
Ferric oxide (Fe_2O_3),	0.78	0.89
Titanic oxide (TiO_2),	1.91	2.19
Lime (CaO),	tr	....
Magnesia (MgO),	tr	....
Alkalies (Na_2O, K_2O),	tr	....
Loss on ignition,	12.50	....
	99.88	99.99

The percentage of titanium is slightly higher.

Refractory tests alone were made of some other samples with the following results:

Fusion tests on highly refractory clays.

Locality.	*Owner.*	*Material.*	*Cone.*
No. 9 Woodbridge,	Dixon Bank,	Buff clay,	33 vitrified.
No. 21 do.	P. J. Ryan,	Fine fire clay,	34+viscous.
No. 90 Bonhamtown,	J. Pfeiffer,	Black fire clay,	33+viscous.
No. 61 Burt Creek,	Sayre & Fisher Co.,	Clay from old Cream Ridge bank,	32 vitrified.
No. 69 Sayreville,	Whitehead Bros.,	Sandy clay, Whitehead's sandpit,	33+viscous.

In respect to their refractoriness, all the above compare well with the best clays tested in this country,[1] as can be seen from the following table:

Refractoriness of fire clays from other States.

Locality.	*Cone.*
Mt. Savage, Md. (flint clay),	34-35
Mineral Point, Ohio,	33
Golden, Col.,	32-31
Sayreville, N. J.,	35

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[1] Bull. N. Y. State Museum, No. 35, p. 783.

It is not known just what pit the last one of the list came from, for in the work done for this report no clays were found around Sayreville as refractory as the one quoted above.

Beds of No. 1 fire clay also occur in the pits of J. E. Berry (Loc. 11), J. H. Leisen (Loc. 16), W. H. Cutter (Loc. 29 and 30), J. P. Prall (Loc. 27), etc. They are mentioned here because they are probably as highly refractory as those described above, although their fusibility was not tested.

Ball or ware clay.—W. H. Cutter.[1] Ball clay of the same refractoriness as a high-grade No. 1 fire clay is dug in the immediate vicinity of Woodbridge by W. H. Cutter (Loc. 29, Pl. XXXVII). It is found at the extreme base of the pit and runs about 6 to 7 feet thick.

The clay is shipped as mined, and, therefore, the crude material was tested. Its physical properties are those of a very fine-grained clay containing little or no grit, and when dry breaking easily with a conchoidal fracture. It slaked rapidly in water, and when mixed with 33 per cent. gave a tough, plastic-feeling mass, the air shrinkage of which averaged 3.4 per cent., but the bricklets showed a tendency to warp somewhat in drying, and showed the same yellowish coating seen on the clay in the sheds. The tensile strength averaged 33 pounds per square inch, which is low, and not as high as one would expect from the plastic feel of the wet clay. The behavior of the bricklets in burning was as follows:

Burning test of a ball clay. W. H. Cutter, Woodbridge.

Cone.	*4*	*8*	*10*
Fire shrinkage, ...	6.2%	14.6%	16.6%
Absorption, ...	very absorbent	7.14%	.22%
Color, ...	white, tinge of yellow	yellowish white	yellowish white

The bricklet was nearly steel-hard at cone 4, and showed many small reticulating cracks. It is *highly refractory,* being nearly viscous at cone 34. The chemical composition is as follows:

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[1] No. 14 of section on page 453.

Chemical analysis of a ball clay. W. H. Cutter, Woodbridge.

	Raw.	*Burned.*
Silica (SiO_2),	45.76	53.33
Alumina (Al_2O_3),	39.05	45.51
Ferric oxide (Fe_2O_3),	trace	....
Lime (CaO),	0.95	1.10
Magnesia (MgO),	0.04	0.05
Alkalies (Na_2O, K_2O),	trace	....
Loss ignition (chiefly H_2O),	14.46	....
	100.26	99.99

This is lower in fluxing impurities than the No. 1 fire clay from the same district, and it is difficult to see just what should cause the color in burning.

Other analyses.—The following analyses of highly refractory clays from the Woodbridge district are given by Prof. Cook, in the Report on Clays for 1878 (p. 51):

Analyses of highly refractory clays.

	1	*2*	*3*	*4*	*5*
Alumina (Al_2O_3),	40.14	37.94	38.87	36.49	37.92
Silicic acid (combined),	42.88	44.26	44.77	42.82	42.40
Water (H_2O),	13.59	14.10	12.97	12.42	14.60
Quartz sand,	0.50	1.10	0.80	5.80	1.41
Ferric oxide (Fe_2O_3),	0.51	0.96	1.14	0.78	1.05
Magnesia (MgO),	....	0.11	0.11	0.11	....
Lime (CaO),	0.10	....	....	....	....
Potash (K_2O),	0.41	0.15	0.16	0.45	0 35
Soda (Na_2O),	0.08	....	....	....	0.37
Titanium oxide (TiO_2),	1.42	1.30	1.30	1.12	1.41
Totals,	99.63	99.92	100.12	99.99	99.51

1. Loughridge & Powers' fire clay, Woodbridge.
2. Hampton Cutter & Son's fire-brick clay, Woodbridge.
3. Hampton Cutter & Son's ware clay, Woodbridge.
4. A. Hall & Son's fire clay, Woodbridge.
5. Wm. H. P. Benton's fire clay, Woodbridge.

Some of these, especially No. 3, agree very closely with analyses recently made and given on a previous page.

REFRACTORY CLAYS.

According to our classification, this group includes those clays, the fusion point of which ranges from cone 31 to 33 inclusive. It includes a large number from all the clay members of the Raritan formation except the Cliffwood clays, which are nonrefractory. They are used for a variety of purposes, and are known by various names, some denoting refractoriness, as No. 1 fire clay, No. 2 fire clay; some their possible uses, as stoneware clay, retort clay, pipkin clay, ball clay; some their texture, as top-sandy, extra top-sandy, etc. There is no fixed rule in regard to the use of these names, clay which by one man is called a No. 2 fire clay, being termed a stoneware clay by another, and some of the so-called No. 1 fire clays, when judged according to their refractoriness, being more correctly No. 2. In the following detailed description of tests the clays are grouped under three heads, fire clays, ball clays, stoneware clays.

Fire Clays.

Woodbridge.—Many occurrences of fire clays (fusing at cone 31 to 33 inclusive are found in the pits around Woodbridge. Most of them fuse between cones 31 and 32, although they show a wider range in their refractoriness than the highly refractory clays of the same district. Tests were made on several samples as follows:

Anness & Potter (Loc. 6, Lab. No. 372). The material is a light-gray, mottled, sandy clay which slakes rather fast. It took 29.5 per cent. of water to temper it, and gave a mass of only moderate plasticity, the tensile strength of which was low. The air shrinkage was 5.5 per cent. Its behavior under fire was as follows:

Burning test of a sandy clay, Anness & Potter, Woodbridge.

	Cone 3	*Cone 5*	*Cone 8*	*Cone 10*
Fire shrinkage,....	5.5 %	5.5 %	8.5 %	10.5 %
Absorption, ...	15.87%	16.85%	10.54%	10.04%
Color, ...	cream white	yellowish white	yellowish white	yellowish white, small iron specks

It was well fused at cone 33 in the Deville furnace, so that it represents a good fire clay of the *refractory* class.

Some other clays in the vicinity of Woodbridge belonging to this group, together with one from Sayreville, and their cone of fusion are given in the following table:

Fusion tests of refractory clays.

Locality No.	*Name.*	*Cone.*
29	Top-sandy, W. H. Cutter,	27 vitrified 32 viscous
24	Pipkin clay, H. Maurer & Son,	32 viscous
42	No. 2 fire clay, H. Maurer & Son,	33 viscous
11	Mottled clay, J. R. Berry,	33 viscous
14	Sandy clay, M. D. Valentine & Bros. Co.,	29-30 vitrified
14	Top-sandy clay, M. D. Valentine & Bros. Co.,	32-33 viscous
14	Bottom-sandy, M. D. Valentine & Bros. Co.,	33 viscous
17	Extra blue-sandy, Staten Island Clay Co.,	27 incipient fusion 33 viscous
18	No. 1 tough clay, Staten Island Clay Co.,	31 viscous
70	Sandy clay,	33 viscous

Florida Grove.—A number of fire-clay pits have been opened up by McHose Brothers (Loc. 45) in the South Amboy fire-clay beds, north of Florida Grove (Plate XLVII, Fig. 1). Several samples were tested from here.

The first of these was from a pit on the eastern side of the excavation, and known as a No. 1 sandy fire clay (Lab. No. 402). It is a very gritty, yellowish-white clay of porous character and slaked fast in water. The air-dried clay worked up with 26 per cent of water, and the bricklets made from it had an air shrinkage of 6.5 per cent. The tensile strength was low, averaging 45 pounds per square inch. Its behavior in burning was as follows:

Burning tests of a No. 1 sandy fire clay, McHose Bros., Florida Grove.

Cone	*5*	*10*
Fire shrinkage,	1.9 %	1.8 %
Absorption,	15.39%	13.52%
Color,	yellowish white	buff

The clay was steel-hard at cone 8, and fused at cone 30. Its composition was as follows:

Chemical analysis of a No. 1 sandy fire clay. McHose Bros.

	Raw.	*Burned.*
Silica (SiO_2),	69.78	74.66
Alumina (Al_2O_3),	19.86	21.24
Ferric oxide (Fe_2O_3),	0.62	0.66
Titanium oxide (TiO_2),	1.96	2.09
Lime (CaO), Magnesia (MgO), Alkalies (Na_2O, K_2O) by diff.,	1.24	1.32
Water (H_2O),	6.54	....
	100.00	99.97

This clay is not highly refractory, and in fact is not as refractory as some of the No. 2 fire clay dug near Woodbridge, although known commercially as a No. 1 sandy fire clay. It has been used in the manufacture of bath tubs and stove linings.

A sample of No. 1 buff clay from the same locality (Lab. No. 401) gave the following results on testing:

The material was a flaky, moderately-plastic clay, which worked up with 32 per cent. of water to a mass whose air shrinkage was 5 per cent., and the briquettes from which had an average tensile strength of 65 pounds per square inch. The behavior in burning was as follows:

Burning test of a No. 1 buff clay, McHose Bros.

Cone.	*5*	*8*	*15*
Fire shrinkage,	5%	6.6%	10.3 %
Absorption,	11.68%	11.34%	2.33%
Color,	light yellow	buff	

The clay was steel-hard at cone 5, but at cone 27 was not more than incipiently fused. From this it is evidently of good refractoriness.

Sand Hills.—South of Sand Hills there is another group of pits, with smaller ones between Sand Hills and Valentine. At Sand Hills the excavations are far deeper and more extensive than those north of Florida Grove, just mentioned. Here it is the Woodbridge fire-clay bed that is opened up. The beds corresponding to the top- and bottom-sandy of the Woodbridge district are not clearly identifiable. The deepest sections exposed are in

Fig. 1.

View in McHose Brothers' pit. Florida Grove.

Fig. 2.

View in fire-clay pit of National Fireproofing Company, north of Keasbey. The fire clay is dug in pits as at the left. Fireproofing clay overlies the fire clay.

the pits around Sand Hills, where the following succession of layers was exposed in 1902 in the pit of R. N. & H. Valentine Company (Loc. 86, Pl. XLVIII, Fig. 1).

Section in R. N. & H. Valentine's clay bank, Sand Hills.

1.	Pensauken sand and gravel,	
2.	Brick clay,	0–7 ft.
3.	Dark-blue clay, buff-burning,	6–10 "
4.	Gray-burning, terra-cotta clay,	3–4 "
5.	Black clay,	1 "
6.	Sand for masonry,	3–4 "
7.	Black clay,	6 "
8.	Gray-black sand,	2–4 "
9.	Fine fire clay,	8 "
10.	Mottled red clay,	8 "
11.	Bottom-sandy clay,	4 "

Several samples were collected from the Woodbridge fire-clay bed in this vicinity. The first of these was a so-called No. 1 blue fire clay (Lab. No. 404) from the pit just described. This was an easily-slaking clay, which required 33 per cent. of water for tempering. Its air shrinkage was 4.4 per cent., and its tensile strength from 45-50 pounds per square inch. It burned fairly dense, as can be seen from the firing tests given below.

Burning test of a No. 1 blue fire clay. R. N. & H. Valentine, Sand Hills.

Cone	*5*	*10*
Fire shrinkage,	13.6%	13.8%
Absorption,	7.07%	6.47%
Color,	streaky yellow	yellow

It burned steel-hard at cone 5, and fused at cone 32. This is used in making fire brick, but it cracks in burning and has to be mixed with other clays of better bonding qualities. Comparing this with a No. 1 clay from the Woodbridge fire-clay bed, near Woodbridge, we see that it fuses nearly three cones lower.

Another layer found in the same bank is interesting to compare with the first one, as it produces an equally dense brick at cone 10, with lower fire shrinkage. This material represents the layer 10 (Lab. No. 410), of the above section. It is a very gritty clay, mottled red, and feels plastic, but has a low tensile strength of 35 pounds per square inch. It worked up with 34 per cent. of water and the air shrinkage was 6.6 per cent. In burning it behaved as follows:

Burning test of a mottled red clay. R. N. & H. Valentine, Sand Hills.

Cone	*3*	*5*	*10*	*15*
Fire shrinkage,	5.4%	9%	11.4%	12%
Absorption,	16.62%	11.09%	6.45%	3.01%
Color,	whitish	cream	light buff	gray buff

The crude clay, when burned to cone 10, did not become quite so dense as the molded material. The clay is a fire clay, but not as refractory as the No. 1 blue, since it fuses at cone 30.

In the Ostrander pit (Loc. 54, Pl. XLVIII, Fig. 2), to the south of the Sand Hills, there is a sandy clay (Lab. No. 397), also in the Woodbridge bed, which in some respects resembles some of those of the Woodbridge district in its very low tensile strength. The material is a hard, yellowish-mottled clay, which slakes rapidly but has a low plasticity. It worked up with 28 per cent. of water and its air shrinkage was 5 per cent. The average tensile strength was 20 pounds per square inch.

At cone 5, the fire shrinkage was 1 per cent.; absorption, 17.75 per cent.; color, yellowish white. At cone 8: fire shrinkage, 2 per cent.; absorption, 15.82 per cent.; color, yellowish white. It did not become steel-hard until cone 10.

Another sample from this property was a black clay, called "steel clay," from the southern pit (Loc. 54, Lab. No. 407). In texture it resembles the top-sandy clay found in the Woodbridge district. The clay worked up with 30 per cent. water, and had an air shrinkage of 6 per cent. Its tensile strength was only 36 pounds per square inch. In burning it behaved as follows:

Burning tests of a black clay, Ostrander Co., Sand Hills.

Cone	*3*	*5*	*8*	*10*
Fire shrinkage,	4.6 %	6%	7%	9.3 %
Absorption,	20.05%	15.00%	13.36%	11.31%
Color,	yellowish white	yellow	yellow	deep cream

Fig. 1.

View of a portion of R. N. & H. Valentine's pits near Sand Hills, showing the area which has been worked over.

Fig. 2.

View in Ostrander Brick Company's southern pit, showing the amount of stripping and the uneven surface of the clay.

It is rather porous burning, in spite of its high fire shrinkage at cone 10.

Several samples were also tested from C. S. Edgar's bank (Freeman bank) (Loc. 94). The section (exposed in Sept., 1901) is given below, in order to better identify the samples:

Section at C. S. Edgar's bank, near Sand Hills.

1. Sandy clay, full of iron crusts,	7–10 ft.
2. Mottled blue and black clay, called top clay,	3 "
3. Yellow sandy clay,	1½ "
4. Blue clay,	1½ "
5. Black clay with much lignite,	5 "
6. Light blue, sandy clay,	1–3 "
7. No. 1 blue fire clay,	7 "

A sample from layer 7 (Lab. No. 405) was a homogeneous gritty clay of porous texture and smooth fracture. It slaked fairly fast and all passed through a 100-mesh sieve. When mixed with 32 per cent. water it gave a mass of moderate plasticity, whose tensile strength was 52 pounds per square inch and air shrinkage 7 per cent. It behaved as follows when fired:

Burning tests of a No. 1 blue fire clay, C. S. Edgar, Sand Hills.

Cone	*01*	*1*	*5*	*15*
Fire shrinkage,	2%	3%	5%	9.6%
Absorption,	......	19.69%	16.75%	4.87%
Color,	whitish	yellowish white	yellowish white	buff

As is shown by the absorption tests this is a rather open-burning clay, and does not become at all dense until cone 15. It burns steel-hard at cone 5, and at cone 27 is vitrified. This is a sagger clay.

A second sample tested from this pit was a mixture of layers 2 and 4 of the section given above. This mixture (Lab. No. 406) worked up with 25 per cent. of water, and had an average tensile strength of 98 pounds per square inch with an air shrinkage of 6.5 per cent. Its burning qualities were as follows:

Burning tests of a mixture from C. S. Edgar's bank, Sand Hills.

Cone	*01*	*1*	*5*	*8*	*15*
Fire shrinkage, ...	7.1%	7.5%	9.5%	14%	15.5%
Absorption, ...	10.51%	8.89%	3.69%	......	.69%
Color, ...	buff	buff	buff	gray buff	grayish

This shows a mixture of much denser-burning quality than the preceding one from the same bank, there being a difference of 13 per cent. in the absorption at cone 5, and 4 per cent. at cone 15. It is not quite as light burning, due to the presence of a greater percentage of iron oxide in the clay. It is not *highly refractory,* for at cone 30 it was viscous.

A number of fusibility tests were made on other samples from the region around Sand Hills and Bonhamtown with the following results:

Fusibility determinations of refractory clays.

Material.	*Loc. No.*	*Owner*	*Uses.*	*Formation.*	*Cone of fusion.*
Black clay, ...	88	M. Edgar, ...	Fire brick, ...	Woodbridge clay bed, ...	33
Buff clay, ...	92 layer a.,	Chas. Bloomfield, .	Fire brick and stove linings,	Raritan clay bed,	30-31[1]
Mottled clay, ...	92 layer b,	Chas. Bloomfield, .		Raritan clay bed,	30-31[1]
Black fat clay (known as No. 28), ...	98	C. S. Edgar, ...	Saggers, ...	Woodbridge fire clay bed, ...	30-31[1]
Fire clay, ...	53	Ostrander Co, ...	Fire brick, ...	Woodbridge fire clay bed, ...	29[2]
Buff clay, ...	75 b	Whitehead Bros. Co.,	Foundry, ...	South Amboy fire clay, ...	32-33
No, 1 fire clay, ...	45	McHose Bros., ...	.....	South Amboy fire clay, ...	31-32
Mottled red clay, ...	86	R N. & H. Valentine,	Fire brick, ...	Woodbridge fire clay bed, ...	32
	60	Sayre & Fisher, ...	......	South Amboy fire clay, ...	32-33

Burt Creek.—On the south side of the Raritan river, the South Amboy fire clay is opened up at several points as mentioned in Chapter VIII. The most extensive of the fire-clay pits are those of J. R. Such (Pl. L, Fig. 1) and J. R. Crossman. At the former locality (Loc. 67) a sample of No. 1 blue fire clay was collected. This is the material which in its washed form is sold as ball clay.

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[1] The fusibility of these three specimens lay on the border line between *refractory* and *semirefractory* clays, and it was thought best to include them in the *refractory* class.

[2] This specimen, from a pit 300 feet east of the stable, *vitrified* at cone 29. The cone of fusion was not determined, but the clay probably belongs in the refractory group.

PLATE L.

Fig. 1.
Digging ball clay. J. C. Such's pit.

Fig. 2.
Digging pipe clay. Crossman's pit, on Burt creek.

A sample of the crude clay (Lab. No. 391) showed it to be a very plastic feeling clay of fine grain and fast-slaking qualities. It required 39 per cent. of water to temper it to a mass of the proper consistency for molding. The air shrinkage of the bricklets was 5 to 6 per cent., but when air dried they did not feel very hard or dense, and on the contrary were rather soft and pulverulent. The tensile strength of the air-dried bricks was 59 pounds per square inch.

Burning tests of a No. 1 blue fire clay. J. R. Such, Burt Creek.

Cone	*3*	*8*	*10*
Fire shrinkage, ..	5.1%	12%	12.6 %
Absorption, ...	.....	10.84%	5.93%
Condition, ...	not steel-hard, containing fine cracks	porous	
Color, ...	white	white with yellowish tinge	yellowish white

Inasmuch as the washed ball clay, which is purer than the crude, was well vitrified at cone 27 (see below), it seems proper to classify this clay as *refractory*, although its fusibility was not tested in the Deville furnace.

Several grades of clay are mined in the pits of J. R. Crossman (Loc. 65 and 66), near Burt Creek. A good grade of fire clay from locality 66, was viscous at cone 33. This is known as No. 1 blue. At times it is found sufficiently free from impurities to wash for a ball clay, although this is not commonly done. Some of the buff fire clays from this pit are used by wall-plaster manufacturers, while other grades are sold for saggers, and enameled-brick manufacture.

A red-mottled clay[1] from another of Crossman's pits (Loc. 65, Lab. No. 386) was also tested. It was a clay of rather low plasticity but rapid-slaking qualities, working up to a plastic mass with 30 per cent. of water. Its air shrinkage was low, being 4 per cent., and its tensile strength of 15 pounds per square inch was equally low. A lump of the crude clay burned to cone 10 was

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[1] No. 7 of the section given on page 457.

quite porous and showed the presence of many small fused specks. The behavior of the molded material under fire was as follows:

Burning tests of a red-mottled clay. J. R. Crossman, Burt Creek.

Cone	*3*	*5*	*8*	*10*
Fire shrinkage, ...	8.3%	11%	11%	12.6%
Absorption, ...	16.85%	11.31%	10.02%	7.32%
Color, ...	yellowish white	yellowish white	yellowish white speckled	speckled

These speckles showed on the fracture even at cone 3, and the clay became steel-hard slightly above this cone. In spite of its red color, which suggests a high per cent. of ferric oxide, it is more refractory than a No. 1 blue fire clay dug in the same pit (p. 457), for it does not become viscous until cone 31.

Ball Clays.

Refractory ball clays occur in the South Amboy fire-clay bed, and those dug by C. S. Edgar and J. R. Such were tested with the following results.

Sayreville.—Washed ball clay from pits of C. S. Edgar, east of Sayreville (Pl. XLIX, Loc. 268, Lab. No. 723). This is a whitish, very fine-grained, soft clay. Its fineness can be judged from the fact that it contains 87 per cent. of clay particles which are under $\frac{1}{12500}$ inch in diameter. It slaked fast and worked up with 39.1 per cent. of water to a plastic-feeling mass whose air shrinkage was 5 per cent., but the clay had a very low tensile strength. Its burning qualities were as follows:

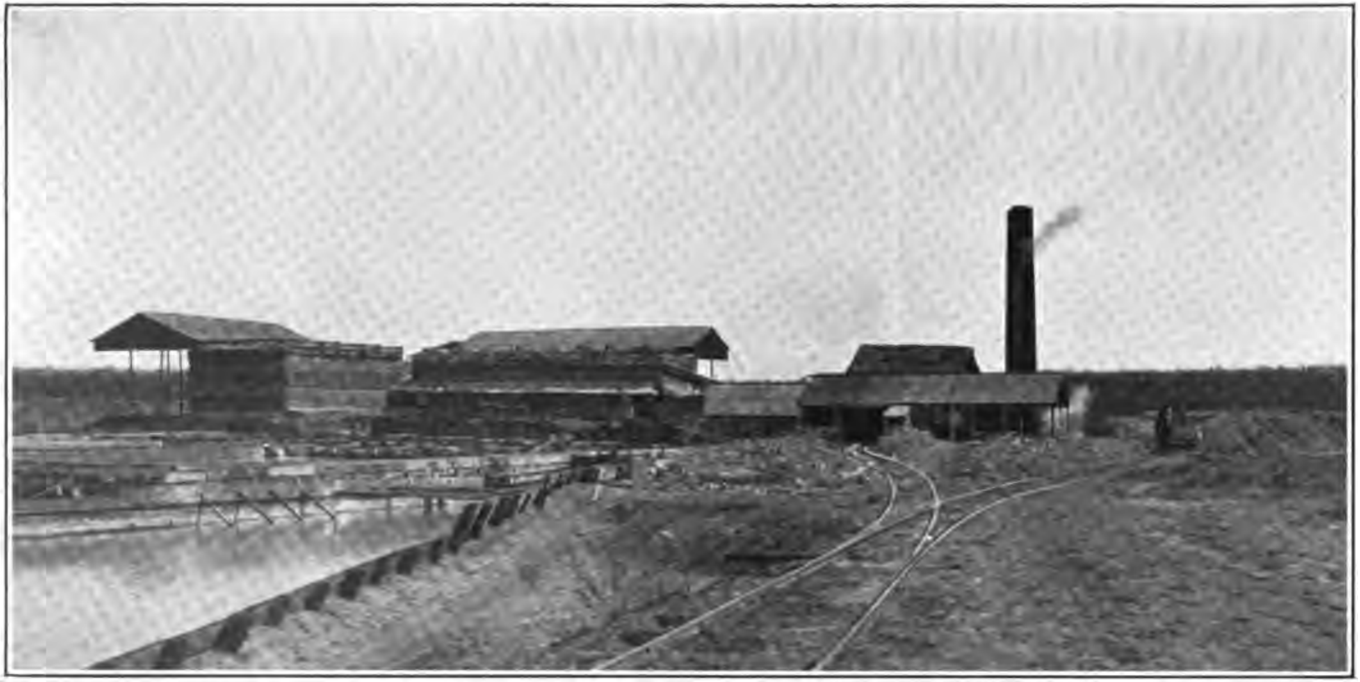
Burning tests of washed ball clay. C. S. Edgar, Sayreville.

Cone	*5*	*10*	*15*
Fire shrinkage, ...	10.6%	16.3%	16%
Absorption, ...	10.53%	3.98%	.63%
Color, ...	white	whitish	light gray

It burned steel-hard at cone 5, but showed many fine cracks. The material is not used alone, but mixed with other white-burning clays. It is refractory, being only vitrified at cone 27.

Burt Creek.—Another sample of washed ball clay was examined from J. R. Such's pit (Loc. 67, Lab. No. 389). This is like-

PLATE XLIX.



Clay-washing plant of Edgar Bros., near Sayreville, N. J. The settling tanks and troughing are seen in the center and left of the picture, while behind them are the drying sheds.

wise a soft, fine-grained clay, which slaked slowly. It worked up with 40 per cent. of water, and had an air shrinkage of 5 per cent., but its tensile strength was low and all the briquettes developed cracks in drying. It behaved as follows when burned:

Burning tests of washed ball clay. J. R. Such, Burt Creek.

Cone	*5*	*8*	*27*
Fire shrinkage, ...	9%	12%	......
Absorption, ...	16.42%	10.20%	vitrified
Color, ...	white with yellow tinge	yellowish white	gray

Stoneware Clay.

This term is used chiefly in the area around Woodbridge and South Amboy, and refers to beds of fire clay, of No. 2 grade, good plasticity, and dense-burning qualities. On account of the two last mentioned qualities they are specially adapted for the manufacture of stoneware. They can therefore be called a variety of No. 2 fire clay. In some pits two grades of stoneware clay are recognized. Those dug in the Woodbridge area are found in the Woodbridge fire-clay bed, and those on the south side of the Raritan river occur in the Amboy stoneware-clay bed.

Woodbridge.—In the Woodbridge district a sample of stoneware clay from the eastern pit of W. H. Cutter (Loc. 29) was tested.

For purposes of identification the section carrying the stoneware clay is given below:

Section of W. H. Cutter's clay bank, Woodbridge.

1.	Drift.	
2.	Hollow-brick clay.	
3.	Buff clay, for terra cotta and saggers, ...	4 ft.
4.	Gray sand, ...	1½ "
5.	Rockingham clay, used for fancy brick, ...	1½ "
6.	Gray-black sand and clay, ...	4 "
7.	Stoneware clay, ...	1 "
8.	Top-sandy clay, ...	2½ "
9.	Black clay, ...	1–2 "
10.	Sand, ...	4 in.–2 "
11.	Retort clay, for stoneware and saggers, ...	4–5 "
12.	Bottom-sandy clay, ...	2–3 "
13.	Fine fire clay, ...	7–8 "
14.	Ball or ware clay, ...	
15.	Red-mottled clay.	

The stoneware bed, which is layer 7 of the above section, increases to 3 feet in Mr. Cutter's eastern bank. It is a sandy, yellowish clay with many small mica scales, and differs from the top-sandy only in the amount of sand which it contains. When thrown into water it slaked moderately fast, and an air-dried sample required 28 per cent. of water for mixing. The air shrinkage was 7 per cent. and the average tensile strength 60 pounds per square inch. Its behavior in burning was as follows:

Burning test of stoneware clay, W. H. Cutter, Woodbridge.

Cone	*3*	*5*	*8*
Fire shrinkage,	2%	3%	3.3%
Absorption,	12.33%	10.02%	8.37%
Color,	light yellow	yellowish	deep yellow

The bricklets burned steel-hard at cone 5, and became viscous at cone 33. It, therefore, equals a good No. 2 fire clay in its refractoriness, but burns denser at all the cones at which both were tested.

South Amboy.—The stoneware clays dug in the vicinity of South Amboy differ from the other clays of equal refractoriness of the same district in being more plastic, of higher tensile strength and burning denser at cone 8 or 10. As shown in Chapter VIII they belong to an entirely different bed geologically.

The No. 1 stoneware clay from H. C. Perrine & Son's bank did not vitrify until cone 30, and probably would not have fused lower than cone 32.

The two grades of stoneware clay sometimes occur alone or may be found together in the same bank and have to be sorted by hand picking, as at locality 81, or they may be interbedded with other clays, as at locality 77, where the following section was observed in September, 1901:

Section at H. C. Perrine & Son's bank, South Amboy.

1. Yellow sand, thin laminæ of clay,	6–15 feet
2. Black sandy clay, similar to fireproofing clay, but more sandy,. .	12 feet
3. Gray-white clay with decomposed pyrite specks (No. 1 stoneware clay),	3–6 feet
4. Red-spotted clay. For foundry work,	5 feet

5. No. 2 stoneware clay. May develop a yellow-green stain on weathering, but this disappears on firing,	3-4 feet
6. Terra-cotta clay. Burns buff. More plastic than layer 5. Viscous at cone 26-27,	4-6 feet
7. Sand cemented by iron oxide,	6 feet

The second grade of stoneware clay from this district is included in the next class.

SEMIREFRACTORY CLAYS.

This class includes the lowest grades of fire clay found in the Middlesex district as well as many other clays of similar refractoriness, but known to the trade by other names, such as fire-mortar clay, No. 2 stoneware clay, pipe clay, pressed-brick clay, wad clay, terra-cotta clay, etc., as well as some purely local terms, such as "blue top clay," "yellow top clay," etc., which have no significance except to the clay miner. They fuse between cones 27 and 30 inclusive.

Fire Clays.

Most of these low-grade fire clays become viscous at cone 27. They are probably more widely distributed both geographically and geologically than either of the two other grades which have been described from Middlesex county. On analysis they often show a higher percentage of fluxes as well as greater sandiness. Their air shrinkage is somewhat lower than the No. 1 fire clays, and their tensile strength higher.

Woodbridge.—One of these sandy clays is to be seen at locality 6 (Lab. No. 377), Anness & Potter's pit, and represents layer 4 of the following section, made September, 1901:

Section at Anness & Potter's bank, Woodbridge.

1. Glacial till,	8-9	ft.
2. Hollow-brick clay,	12	"
3. Laminated sand and clay,	7	"
4. Top-sandy clay,	5	"
5. No. 1 fire clay,	3	"
6. No. 2 fire clay,	3	"
7. Bottom-sandy clay,	3-4	"
8. Red-mottled clay,	14	"
9. Poor clay and yellow sand,	.....	

It is a whitish, gritty clay, with tiny mica scales, and slakes rather slowly. It is not highly plastic, and feels flaky and gritty when mixed with water. The air shrinkage was 4.6 per cent., and its tensile strength averaged 78 pounds per square inch. It behaved as follows in burning:

Burning tests of the top-sandy clay, Anness & Potter, Woodbridge.

	Cone 4.	*Cone 8.*
Fire shrinkage,	1.4%	3.4%
Absorption,	11.98%	2.9%
Color,	light buff	gray buff

The bricklets became steel-hard at cone 4, but the clay is only semirefractory, for it fused easily at cone 27. Its composition was as follows:

Chemical analysis of the top-sandy clay, Anness & Potter, Woodbridge.

Silica (SiO_2),	68.67
Alumina (Al_2O_3),	21.46
Ferric oxide (Fe_2O_3),	0.78
Titanium oxide (TiO_2),	1.34
Loss on ignition (water),	6.40
Lime, magnesia, alkalies (By diff.),	1.35
	100.00
Total fluxes,	3.13

This analysis is an interesting one when compared with that from Valentine's pit, locality 14, on p. 440. The difference in refractoriness is so large that it seems doubtful whether it can be due entirely to increased fluxes. It is probably caused in part by the higher silica contents of the clay.

Burt Creek.—A so-called No. 1 blue fire clay belonging to the South Amboy fire-clay bed is dug in J. R. Crossman's bank, near Burt Creek (Loc. 65). Its position in the bank can be seen from the following section, made in September, 1901, near the western end of the excavation:

Section at J. R. Crossman's bank, Burt Creek.

1. Yellow Cretaceous sand,	25	ft.
2. Fat, yellow, sticky clay,	2½	"
3. Blue clay, with some fine sand,	6	"
4. Black, sandy clay, with lignite and pyrite,	8	"
5. White clay,	2	"
6. Blue fire clay No. 1.		
7. Red-mottled clay.		

A test was made of layer 6 (Lab. No. 409), which is regarded as a good fire clay. It is lean, very fine-grained, and had a low tensile strength, viz., 20 pounds per square inch. Its air shrinkage was 6 per cent. Its behavior under fire was as follows:

Burning tests of a No. 1 blue fire clay, J. R. Crossman, Burt Creek.

Cone	*5*	*8*
Fire shrinkage,	7%	11%
Absorption,	19.35%	11.59%
Color,	yellowish white	yellowish

This material is used as an ingredient of fire brick and stoneware mixtures. It becomes steel-hard at cone 5, but shows tiny iron specks. The sample fused at cone 29, so that its refractoriness is not great enough to call it a No. 1 fire clay according to the classification adopted in this report. As indicated on page 451, however, another sample of No. 1 blue fire clay from an adjoining bank (Loc. 66) did not become viscous until cone 33, so that there is evidently considerable variation in the fusibility of the No. 1 fire clays in this vicinity.

Chemical composition of a No. 1 blue fire clay, J. R. Crossman, Burt Creek.

	Raw.	*Burned.*
Silica (SiO_2),	40.64	47.27
Alumina (Al_2O_3),	41.19	48.03
Ferric oxide (Fe_2O_3),	3.27	3.69
Lime (CaO),	0.65	0.75
Magnesia (MgO),	trace	trace
Alkalies (Na_2O, K_2O),	trace	trace
Water (H_2O),	14.74	....
	100.49	99.74
Total fluxes,	3.92	4.44

This analysis is interesting as the ratio of silica to alumina is so low. It also shows that there are present nearly 4 per cent. of fluxes in the form of iron oxide and lime, and there is probably some titanium oxide present also, which, however, was not separated from the silica and alumina. Were it not for these impurities the clay would probably be highly refractory. It is interesting to compare this clay with the blue fire clay from the adjoining bank (p. 451), since the two resemble each other closely in appearance, yet differ so in fusibility.

Fire-mortar Clay.

Fire-mortar clay is a sandy type of clay found in not a few pits, and, as its name indicates, it is used for making mortar for setting fire bricks. A sample (Lab. No. 383) corresponding to layer 9 of the section on p. 436 was taken from Henry Maurer & Son's pit (Loc. 24, Pl. VIII, Fig. 2). It was a sandy, speckled, or finely-mottled clay with small mica scales, and was part of a bed about 3 feet thick. When tested it slaked fast and worked up with 28 per cent. of water to a mass, having an air shrinkage of 5 per cent. Its tensile strength averaged 99 pounds per square inch, and in burning it behaved as follows:

Burning test of a fire-mortar clay, Maurer & Son, Woodbridge.

Cone	*3*	*5*	*8*
Fire shrinkage,	3%	4%	5%
Absorption,	10.75%	5.98%	4.20%
Color,	buff	buff	gray buff

It burned steel-hard at cone 5, and became viscous at cone 27. The chemical composition was:

Chemical analysis of Maurer & Son's fire-mortar clay.

Silica (SiO_2),	67.26
Alumina (Al_2O_3),	23.36
Ferric oxide (Fe_2O_3),	1.63
Lime (CaO),	0.25
Magnesia (MgO),	trace
Alkalies (Na_2O, K_2O),	0.65
Loss on ignition (chiefly H_2O),	6.94
	100.09

Stoneware Clay.

The No. 2 stoneware clays are probably all semirefractory, but fusion tests were made on only three of them.

In the Woodbridge district one sample from locality 21, P. J. Ryan, was found to become thoroughly viscous at cone 30.

Although some of the clays mined in the areas between Woodbridge and Metuchen may be used in stoneware mixtures, none are marketed under that name. South of the Raritan river the South Amboy stoneware-clay bed is of importance and supplies several grades. A sample of No. 1 clay has been described under the refractory clays. The following represents a test on a No. 2 grade from H. C. Perrine & Son's "poorhouse bank" (Loc. 81, Lab. No. 395). This clay in its raw condition showed much fine grit and worked up to a plastic-feeling mass with 37 per cent. water. Its tensile strength ranged from 108 to 120 pounds, with an average of 109 pounds per square inch, and the air shrinkage was 7 per cent. It was fired with the following results:

Burning tests of a No. 2 stoneware clay, H. C. Perrine & Son.

Cone	*01*	*1*	*3*	*10*
Fire shrinkage, ...	6%	6%	7.6%	9%
Absorption, ...	11.65%	8.77%	9.95%	.24%
Color, ...	yellowish white	light buff	light buff	gray buff

At cone 1 the bricklet was steel-hard, at cone 27 clay incipiently fused and became viscous at cone 30.

The No. 2 stoneware clay from South Amboy (Loc. 77) fuses at cone 27.

Pipe Clay.

At Crossman's pits at Burt Creek a variety termed pipe clay is dug. A sample was collected (September, 1901) from a pit close to the highway, in which the clay was covered by little stripping (Loc. 64). The pit is shown in Plate L, Fig. 2. The section showed 6 feet of pipe clay underlain by 6 feet of fine quartz sand. The clay was a tough, yellowish-white clay, stained with limonite. The underlying sand was called kaolin by the workmen, and had been sold for mixing with asphalt in making pavements.

The pipe clay is used for mixing with some Pleistocene clays in another State to make sewer pipe, and has also been mixed with fire clay for making stove linings. It (Lab. No. 387) is a very fine-grained, gritty clay of low plasticity and low tensile strength, the latter not exceeding 20 pounds per square inch. It worked up with 35 per cent. of water, and its air shrinkage was 5 per cent. When fired it behaved as follows:

Burning tests of pipe clay, J. R. Crossman's, Burt Creek.

Cone	*5*	*8*	*10*
Fire shrinkage,	11%	11%	12%
Absorption,	15.45%	16.65%	11.49%
Color,	yellowish white	cream	buff

The reason for the slight increase in absorption at cone 8 was probably due to some slight irregularity in the bricklet.

Miscellaneous.

The "blue top" clay from Maurer's pit (Loc. 24, Lab. No. 374, layer 8 of section on p. 436) contains less sand than the fire-mortar clay described on p. 458. It is a moderately fast-slaking clay, which works up to a sticky mass. It went through a 100-mesh sieve without leaving any residue, and worked up with 33 per cent. of water. Its air shrinkage was 5.5 per cent., and its average tensile strength 122 pounds per square inch. Its burning qualities were as follows:

Burning tests of blue top clay, Henry Maurer & Son, Woodbridge.

Cone	*3*	*5*	*8*	*15*
Fire shrinkage,	4.5%	5.1%	5.6%	7.1%
Absorption,	9.80%	7.86%	6.17%	1.86%
Color,	very light yellow	light buff	buff	gray buff

The clay burned steel-hard between cones 3 and 5, and warped slightly at cone 8. When tested in the Deville furnace it was found to be thoroughly vitrified at cone 27 and became viscous at cone 30. It therefore stands intermediate in refractoriness between the No. 2 fire clay given on p. 445 and the fire mortar on p. 458.

The yellow top clay at Maurer's (Loc. 24, Lab. No. 379, and layer 7 of section on p. 436) is also a sandy clay, with many small mica scales, but it leaves no residue on a 100-mesh sieve. It slaked slowly to a powdery mass in water, and in tempering only 16 per cent. of water was needed, giving a gritty mass of low plasticity, the tensile strength of which was 48 pounds per square inch. The air shrinkage was low, being but 3.3 per cent. In burning it behaved as follows:

Burning tests of yellow top clay, Henry Maurer & Son, Woodbridge.

Cone	*05*	*3*	*8*
Fire shrinkage,	soft and underburned	1%	3%
Absorption,	18.20%	14.76%	8.90%
Color,	light red	reddish	reddish

At cone 27 it became viscous, so that its refractoriness is not any better than that of fire mortar, and in fact not as good. It is also quite porous when burned.

A red clay from Such's pits (Loc. 67, Lab. No. 390) showed very little grit and slaked rapidly in water. It all passed through a 100-mesh sieve and worked up with 39 per cent. of water to a mixture whose air shrinkage was 4.5 per cent. Its average tensile strength was 65.5 pounds per square inch, and it behaved as follows in the firing:

Burning tests of a red clay. J. R. Such, Burt Creek.

Cone	*05*	*3*	*5*	*10*
Fire shrinkage,	1.5%	8.7%	11.5%	15.5%
Absorption,	28.90%	13.59%	8.26%	2.19%
Color,	red	red	red	red

The clay burned steel-hard at cone 3, and showed small cracks that had developed in firing. Since it contains 5.36 per cent. ferric oxide, it is not highly refractory, but probably belongs in the group of semirefractory clays.

Where both retort and fine fire clay are found in the same bank, a mixture of the two is sometimes made for the use of manufacturers of chemical stoneware and other grades of pottery. Such a mixture from J. H. Leisen's bank (Loc. 16, Lab. No. 381) was tested with the following results: Water required for mixing, 34 per cent.; air shrinkage, 6 per cent.; average tensile strength, 91.5 pounds per square inch. It behaved as follows in burning:

Burning test of a mixture of retort and fire clay, J. R. Leisen, Woodbridge.

Cones	*1*	*5*	*8*
Fire shrinkage,	4.6%	8%	11.3%
Absorption,	19.51%	9.79%	6.69%
Color,	cream	light buff	light buff

The bricklets burned steel-hard at cone 1, and showed a slight tendency to warp at cones 5 and 8. At cone 27 the material was vitrified, so that it is more refractory than a retort clay, and less so than a No. 1 fire clay of this district. This mixture burns denser than did the No. 1 fire clay alone from the same bank, and has higher tensile strength.

Among the various grades of clay seen in McHose Brothers' pits, near Florida Grove, one sample selected for testing was a bright-red clay (Lab. No. 403), which, from its color, appears to be quite ferruginous, and in fact contains 12.45 per cent. of ferric oxide (Fe_2O_8). It slaked slowly and worked up with 32 per cent. of water to a mass whose air shrinkage was 6.6 per cent. The tensile strength averaged 75 pounds per square inch. Its behavior on burning was as follows:

Burning tests of a bright-red clay, McHose Bros., Florida Grove.

Cone	*01*	*1*	*2*
Fire shrinkage,	6%	6.3%	6.6%
Absorption,	14.28%	13.00%	....
Color,	red	red	red

The clay was nearly steel-hard at cone 2. It has been used in pipe manufacture, but is not refractory enough to be classed as a fire clay.

In the following table are a number of clays, the fusibility of which was alone tested:

Fusion tests on additional semirefractory clays.

Locality.	*No.*	*Name.*	*Formation.*	*Cone.*
Woodbridge,	9,	Buff clay, Dixon bank,	Raritan clay bed,	27 vitrified
do	9,	Retort clay, do	do	27 viscous
do	9,	Fine clay, do	do	30 do
do	34,	Yellow-mottled clay, Staten Island Clay Co.,	Woodbridge clay bed,	27 do
do	24,	Yellow brick clay, H. Maurer & Son,	do	27 do
do	28,	Retort clay, J. Prall,	do	27 do
Sand Hills,	53,	Fire clay,[1] Ostrander Co.,	do	26 vitrified
do	54,	Sandy fire clay,[2] do	do	29 viscous
do	86,	Buff-burning clay, No. 2 fire clay, R. N. & H. Valentine,	do	27 do
Mill brook,	95,	Red clay,	Raritan clay bed,	27 do
Bonhamtown,	98,	Pipe clay (known as 24), C. S. Edgar,	Woodbridge clay bed,	27 do
South River,	84,	Blue clay, Whitehead Bros.,	do	27 do

NONREFRACTORY CLAYS.

These include the great series of laminated sands and clays overlying the Woodbridge fire clay, as well as some of the clays found in the Raritan potter's-clay bed. In the early history of the clay-mining industry in New Jersey, these beds were either discarded or left undisturbed, but at the present day enormous pits have been opened in them and the clay is frequently dug with steam shovels, so as to produce a sufficient supply for the large fireproofing, hollow-brick, conduit and building-brick factories located in this district. They fuse below cone 20.

These clays are now dug: 1. In the Woodbridge district; 2. On the north side of the Raritan river around Keasbey; 3. Around South River; 4. Around Sayreville.

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[1] Sample from the upper five feet of bed in the most northeasterly opening.

[2] From a pit near the road, southwest of the preceding.

As pointed out in Chapter XIII, however, some of the clays used in hollow ware and conduit mixtures are a low grade of fire clay and these are discussed under "Semirefractory clays." A number of samples were collected for testing at different localities and are taken up in their geographic order.

Woodbridge.—Hollow-brick clays are dug in both W. H. Cutter's pits (Loc. 29) and J. H. Leisen's pit (Loc. 16) near Woodbridge, but no tests were made of them. A considerable quantity has also been dug at Spa Spring from a pit (Loc. 33) immediately west of the works of the Staten Island Clay Co.

North side of the Raritan river.—This same class of clay is dug at several points not far distant from the river, especially east and west of Florida Grove, and northwest of Keasbey. They belong to the laminated clay and sand series in the upper part of the Woodbridge clay bed, and are dark, thin-bedded clays, usually with much finely divided carbonaceous matter, mica scales and scattered lumps of pyrite, limonite and lignite. While the clays usually show this impure character throughout the bank, there are at times layers which are less gritty and contain fewer impurities than are found in other parts of the bank.

A test made on a sample from the bank of the National Fireproofing Company at Perth Amboy gave the following results. Clay laminated, bluish black, with considerable mica and scattered lumps of pyrite and limonite. Air shrinkage 5 per cent.; average tensile strength, 145 pounds per square inch. It behaved as follows in burning:

Burning tests of a fireproofing clay, National Fireproofing Co.

Cone	*05*	*01*	*3*	*15*
Fire shrinkage, ...	1.6%	2%	2.9%	viscous
Color, ...	grayish red	red	red	......
Condition, ...	not steel-hard	steel-hard	steel-hard	......

Another sample from Keasbey (Lab. No. 451) behaved similarly. Air shrinkage, 5.5 per cent.; average tensile strength, 112 pounds per square inch. Behavior in burning:

Burning tests of a fireproofing clay, Keasbey.

Cone	*05*	*01*
Fire shrinkage,	2.5%	......
Color,	reddish	red
Condition,	not hard	steel-hard

As an illustration of the variation in some deposits, two examples may be taken from a bank of the National Fireproofing Company near Keasbey (Loc. 46). The first represents a black "flue clay," which is used for making fireproofing and hollow brick. The second, termed "bottom pipe clay," is found in the lower portion of the bank, and is used in the mixture for conduits.

The flue clay forms the greater portion of the bank and is less dense burning than the pipe clay, which fact is shown by the difference in shrinkage and absorption of the bricklets. It is more sandy than the pipe clay, but has a higher tensile strength. The flue clay slakes quite fast and works up with 28 per cent. of water to a mass of good plasticity, whose air shrinkage was 4 per cent., and whose tensile strength ranged from 75 to 100 pounds per square inch. Its burning qualities were as follows:

Burning tests of a flue clay, National Fireproofing Company, Keasbey.

Cone.	*3*	*5*
Fire shrinkage,	7.3%	12%
Absorption,	8.81%	6.10%
Color,	brownish red	dark gray

The bottom or pipe clay is much denser and finer grained than the upper clay. It feels plastic but its tensile strength was low, running from 50 to 55 pounds per square inch. It slaked moderately fast in water and required 30 per cent. to temper. The air shrinkage of the bricklets was 6 per cent. Its chief value lies in the dense-burning quality which it possesses, but it has to be heated slowly on account of the large amount of organic matter contained in it. Its behavior in burning was as follows:

Burning tests of a pipe clay, National Fireproofing Co., Keasbey.

Cone	*1*	*3*	*5*
Fire shrinkage,	7.3%	9%	9.3%
Absorption,	1.58%	1.00%	0.78%
Color,	light brown	red	gray

It became steel-hard below cone 1, and vitrified between cone 8 and 10, but was not even semirefractory.

The deposits of these black laminated clays are the most massive found in the Raritan formation, and the only ones that are large enough to permit working with a steam shovel. The outlines of the pits on the map (Pl. XI, Loc. 47 and 46), will give a good idea of the size of the excavations that have been made, and Plate XXXII, Fig. 2, shows one of the banks with the cars being loaded along the working face. Plate XX, Fig, 2, shows an outcrop of these clays overlain by cross-bedded sands. The latter are shown in more detail in Plate I, Fig. 2. The clay is loaded on to narrow-gauge tram cars and run to the large fireproofing and conduit factories located along the shore of the Raritan river.

A curious phase of the Raritan potter's-clay bed is found near New Brunswick in the pits of the Brinckman Terra Cotta Company (Loc. 96). The clay rests directly on the decomposed red Triassic shale, and it is difficult to tell where one ends and the other begins. The material is a fat, greasy clay, the physical properties of which are as follows:

Physical tests of fireproofing clay, Brinckman Terra Cotta Co.

Water required for tempering, 36 per cent.; average tensile strength, 129 pounds per square inch; air shrinkage, 7 per cent. Its behavior in burning was as follows:

Cone	*05*	*01*	*3*
Fire shrinkage, ...	4%	10%	10.7%
Absorption, ...	13.12%	0.12%	0.9%
Color, ...	deep red	red	deep red
Condition, ...	steel-hard	vitrified	well vitrified

This clay burns harder and denser at a lower cone than any others used in Middlesex county for fireproofing.

The dark laminated clays and sands are extensively worked for common-brick manufacture around South River, but no samples were taken for testing. They probably do not differ much in their physical properties from those dug around Sayreville, and of which tests are given below.

Sayreville.—In the vicinity of Sayreville, the brick and fireproofing clays are dark-colored, gray to black, laminated, sandy clays, with more or less lignite and often much mica. They also contain scattered nodules of pyrite and limonite, and are fully as extensive as the similar clays belonging to the same beds on the north side of the Raritan river. Owing to the size of the deposits, and little need of separating the different layers, the material is often mined with a steam shovel. It is then loaded directly on to cars and hauled to the works either with a small engine or horses.

These clays in their physical character resemble those found near Keasbey. They are red-burning, nonrefractory clays, which become steel-hard at a low cone, but have to be fired somewhat slowly in the early stages of burning. The two following series of tests will indicate their character:

1. Common-brick clay from pits of the Sayre & Fisher Company, at Sayreville (Loc. 71, Lab. No. 393). This clay, which is quite micaceous and sandy, splits up rapidly along the planes ot stratification when thrown into water and then slakes to powder. It took 30.5 per cent. of water to work it to a plastic mass, whose tensile strength ranged from 70 to 75 pounds per square inch. The air shrinkage was 4 per cent. Its behavior in burning was as follows:

Burning tests of a common-brick clay, Sayre & Fisher Co., Sayreville.

Cone	*01*	*1*	*5*	*8*
Fire shrinkage, ...	6%	6.6%	7%	8%
Absorption, ...	....	10.17%	9.30%	....
Color, ...	red	red brown	deep red brown	red gray

It burned steel-hard at cone 01 and fused at cone 12. Its composition is:

Chemical analysis of a common-brick clay, Sayre & Fisher Co., Sayreville.

Silica (SiO_2), ...	60.18
Alumina (Al_2O_3), ...	23.23
Ferric oxide (Fe_2O_3), ...	3.27
Lime (CaO), ...	1.00
Magnesia (MgO), ...	0.67

Potash (K_2O),	2.58
Soda (Na_2O),	0.80
Water and organic matter,	8.54
	100.27
Total fluxes,	5.12

This analysis shows enough ferric oxide to make the clay burn red, and sufficient total fluxes to cause the clay to fuse at a low temperature. The high alkali content is due to the abundance of mica in the clay.

II. Hollow-brick clay from the Sayre & Fisher Company's pit (Loc. 71). This is also a dark-gray clay, but is much finer-grained than the preceding. It took less water to work it up, viz., 25 per cent., and it had an air shrinkage of 6.3 per cent., with an average tensile strength of 84 pounds per square inch. Its behavior in burning was as follows:

At cone 1, it gave a red-buff body, which on longer heating became red. Its fire shrinkage was 8 per cent.

At cone 5 it was vitrified with a fire shrinkage of 10.7 per cent., which is rather high.

For use it has to be mixed with other clays. A number of firms are using the above types of clay for making bricks and hollow ware at Sayreville and closely surrounding localities.

FELDSPAR.

Southwest of Woodbridge there are several pits opened for feldspar (Pl. XX, Fig. 1). The general stratigraphic relations of this deposit are discussed in Chapter VIII, so that its economic characters only need to be considered here.

Mineralogically the "feldspar," as it is incorrectly termed, is a mixture of white clay and rounded quartz grains and pebbles, with a few fragments of other minerals. The material in its natural condition should burn nearly white, but it is very porous, and, therefore, becomes easily stained by iron oxide, which filters in from the overlying glacial drift or sand beds.

The following analyses of feldspar are taken from Prof. G. H. Cook's Report on the Clays of New Jersey, 1878, p. 62:

Analyses of so-called Feldspar.

	1	2	3
Free silica,	58.89	57.41	77.40
Combined silica (SiO_2),	16.99	16.59	
Alumina (Al_2O_3),	18.95	17.55	16.07
Ferric oxide (Fe_2O_3),	0.49	0.54	0.53
Lime (CaO),	....	....	....
Magnesia (MgO),	....	....	0.25
Potash (K_2O),	0.15	0.12	0.15
Soda (Na_2O),	0.21	0.21	....
Titanic oxide (TiO_2),	with SiO_2	0.90	with SiO_2
Water (H_2O),	4.90	6.30	4.30

1. Feldspar from the Forbes farm.
2. Edgar Brothers' feldspar.
3. Feldspar bank on farm of Knickerbocker Life Insurance Company.

The analyses show great uniformity in the composition of the material, and while the fluxes are low, still there is considerable sand present, so that high refractoriness would not be looked for. In fact, were it not for the large size of the quartz grains, the material would fuse at a lower cone than it does. When tested at cone 33 it can no longer hold its shape, although the quartz pebbles remain intact. A second grade became viscous at cone 31. Since there are also layers or streaks of quartz sand which are interbedded with the "feldspar," it is necessary in mining to keep the sand separate from the "feldspar," and divide the latter into two or even three different grades. The sand is used either for fire mortar or building purposes, depending on its quality, and the feldspar is used in the fire-brick mixture.

FIRE SANDS.

The general relation of the fire sands to the clay beds of this area has been described in Chapter VIII.

The fire sand which underlies the Woodbridge fire clay is dug at a number of points in this district, and is used to some extent in fire-brick manufacture, but the use is decreasing. The material is generally a white quartzose sand, with occasional layers of fine gravel, and also scattered particles of lignite. Some of the pits show thin streaks of clay. These fire sands are highly siliceous in their composition, carrying from 92.5-98.00 per cent. of silica, as shown by Dr. Cook's analyses, and 1.45 to 6.65 per cent. of alumina and iron oxide.

CLAY-WORKING INDUSTRY.

It is but natural that with such an abundance of raw materials in Middlesex county, there should be a thriving local industry supported by them, even though much of the material mined is shipped to other counties and even other States. The clay products of the county include common, pressed, enameled, and paving brick, terra cotta, wall tiles, fire brick, hollow brick, fireproofing and conduits. The common-brick industry is developed chiefly in the region around Sayreville and South River,[1] where the vast deposits of black, laminated sands and clays are extensively worked for making common soft-mud brick. Large openings have been made, and the clays are often dug with steam shovels. These clays yield a product of very good quality, which is extensively shipped to the neighboring cities for building purposes. The pressed brick made in this region are obtained to a small extent by re-pressing the common red brick, but the large majority of them are made from a mixture of the several grades of fire clay. Their various shades and mottlings are produced in part by the manipulation of the kiln fires, and in part by the addition of artificial coloring matter. These bricks are made chiefly at Sayreville, although some have also been produced at South River, but the factory there is no longer in operation. Enameled bricks are produced by the American Enameled Brick & Tile Company, of South River, and the Sayre & Fisher Company, of Sayreville. Next to the common-brick industry along the Raritan river, the hollow-brick industry occupies a very prominent position, and the clays used for this purpose belong to the same bed

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[1] Several large yards are also located near the county line, not far from Cliffwood, Monmouth county. These are described with the Monmouth county clays.

as those used for common brick, *i. e.,* the upper part of the Woodbridge clay bed. Several very large factories are in operation (see Chap. XIV) at Perth Amboy, Keasbey, Sewaren, Spa Spring and Maurer. The product of these consists almost entirely of hollow ware for structural and fireproofing work. In addition two works at least are being run almost exclusively for the manufacture of conduits for underground electrical work. The fire-brick industry (Chap. XVI) is an old-established one in this county, as is but natural considering the vast quantities of refractory clays that have been dug and are still being dug here. Fire brick and other refractory shapes are manufactured chiefly at Woodbridge and at several points along the Raritan river. Wall tiles are made at Menlo Park, Old Bridge and Perth Amboy, but the materials used are obtained mostly from other States. Terra cotta is another important product, and a growing demand for this line of materials is supplied by three factories in the county, all of them being at Perth Amboy. Paving brick are produced by one factory at South River.

The clay-mining industry has been treated in some detail in Chapter XVII, and that should be referred to. The refractoriness of New Jersey fire brick has also been discussed in some detail in Chapter XVI.

Since the number of manufacturers in this county is so great they are not included here, but the reader is referred to the chapters on common brick, terra cotta, fireproofing, conduits, wall tile, floor tile and pottery (Chaps. XI-XVI), where the names have been already given.

gravel, and also scattered particles of lignite. Some of the pits show thin streaks of clay. These fire sands are highly siliceous in their composition, carrying from 92.5-98.00 per cent. of silica, as shown by Dr. Cook's analyses, and 1.45 to 6.65 per cent. of alumina and iron oxide.

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[1] Several large yards are also located near the county line, not far from Cliffwood, Monmouth county. These are described with the Monmouth county clays.

In making bricks from these clays the black clay is never used alone, but the run of the bank is commonly taken, and to this some of the sandy loam overburden is added. The sandy laminæ found in the clay sometimes form lenses, and it may be necessary to dig these with the clay for reasons of economy in working.

A number of clays from this district were tested and the results are given concisely in tabulated form on page 474. In the third and fourth columns there are given the physical tests of a fat black clay burned alone and with the addition of sand. The addition of sand decreased the amount of water required, the air shrinkage, and also the fire shrinkage. The tensile strength was slightly increased and the absorption very much so, indicating a much greater porosity in the brick due to the sand. The fourth and seventh columns represent soft-mud brick mixtures from yards some distance apart. The sixth column (Loc. 231) shows the qualities of the weathered outcrop of a bed of Clay Marl II, which is used in earthenware manufacture. It is not unlike the sample of Raritan clay in the third column in most of its burning qualities.

It will also be noticed that the porosity, as measured by the absorption, is quite variable in the different samples, even when burned at the same temperature. Only two of the clays burn steel-hard under cone 1, but all are hard enough for common brick at cone 01 or even perhaps cone 03.

Most of them have to be burned slowly and carefully to avoid cracking, swelling, or the formation of black cores.

In actual practice it has been found that there may sometimes be considerable difference in the behavior of the weathered and the unweathered portions of these clays. In some cases the unweathered material may crack in drying, but this can be sometimes prevented by mixing in the weathered clay of the same deposit. The clay deposits of the Matawan, Cliffwood, Keyport region are often sufficiently large to be dug by means of the steam shovel, and where the run of the bank is to be used, it would seem to be a very profitable method of extracting the raw material. Where the different layers are to be kept separate, the use of the

Tests from clays of the Cliffwood-Matawan Area.

	RARITAN. Cliffwood. Stiff-mud mixture. Loc. 220.	RARITAN. Cliffwood. Light mottled clay. Loc. 220.	RARITAN. Fat black clay. Loc. 222.	Brick mixture. Loc. 222.	CLAY MARL II. South of Matawan. Loc. 227.	CLAY MARL II. North of Matawan. Weathered. Loc. 231.	CLAY MARL I AND II. Matawan. Brick mixture. Loc. 228.
Water required, per cent.,	25.5	23.5	30.	23.	22.9	26	21.8
Air shrinkage, per cent.,	6.5	6.	6.	5.3	5.3	9.3	6.3
Average tensile strength, lbs. per sq. in.,	88	103	91	106	166	128	197
Cone 05—							
Fire shrinkage, per cent.,	1.5	3.5	4.3	0.2	0.7[*]	4.7	1
Absorption, per cent.,	7.93	18.13	11.16	17.59	18.27[*]	11.93	17.31
Condition,	Light red, not steel-hard.	Light red.	Pale red, not steel-hard.	Pale red, not steel-hard.	Red, not steel-hard.	Red, steel-hard	....
Cone 01—							
Fire shrinkage,	3.	....	4.6	2.5	....	6	1.7
Absorption,	11.34	....	6.78	13.37	....	5.81	....
Condition,	Light red, not steel-hard.	Red.	Red, steel-bard	Red, not bard.	....	Red.	Red, barely steel-hard.
Cone 1—							
Fire shrinkage,	3.	....	7.	3.	1.7	8.7	3.7
Absorption,	13.61	....	7.87	10.10	14.98	5.24	9.65
Condition,	Red, not hard.	Red, steel-hard	Red.	Red, steel-hard	Red, not steel-hard.	Red.	Red, steel-hard
Cone 3—							
Fire shrinkage,	3.2	7.5	9.3	3.3	2.7	10.7	....
Absorption,	11.12	6.90	3.74	9.38	13.97	3.46	....
Condition,	Red, steel-hard	Red, steel-hard	Brown-red.	Red.	Red, nearly steel-hard.	Red.	....
Cone 8,	....	....	Well vitrified.	Nearly viscous	....	....	....

[*] Burned at cone 03.

steam shovel is undesirable, since with it the different layers cannot readily be kept apart.

Lorillard.—In addition to the localities already mentioned Clay Marl II is also worked at Lorillard, east of Keyport, but here the material is used for the manufacture of fireproofing and not for bricks. It is the most extensive clay opening in the county, and is rapidly increasing in size. The clay is dug with a steam shovel and hauled to the works on tram cars by a small engine.

Asbury Clays.

Farther south in the county and in the eastern portion of it, the Asbury clays of the Miocene are abundantly exposed in the region west of Asbury Park, as has been somewhat fully described in Chapter VII (pp. 145, 146).

Asbury Park.—The best section exposed is that at Drummond's brickyard west of Asbury Park (Loc. 217), where three distinct beds are seen.

Section at Drummond's clay bank.

1. Top loamy clay,	6 feet.
2. Yellow laminated sand and clay,	6 feet.
3. Black laminated sandy clay,	8 feet.

In making stiff-mud brick on the auger machine, the middle laminated sandy clay is usually left out and a mixture of the top loam and the black clay is used. The materials as they come from the bank are considered to have sufficient moisture for working them through a die and therefore no water is used. It may be fairly questioned however, whether the stiff-mud process has shown itself to be better than the soft-mud for molding these Asbury clays.

The physical properties of the above clays and of a mixture of the top and bottom layers of the bank are given in the following table and by comparison show the interesting results produced by the mixture:

Physical characters of Drummond's clay. Asbury Park.

	I	*II*	*III*	*IV*
	Lab. No. 658.	*Lab. No. 696.*	*Lab. No. 697.*	*Lab. No. 696-7.*
Water required,	20.9%	37.3%	27.0%	31.2%
Air shrinkage,	3.3%	5.6%	6.3%	6.3%
Average tensile strength, lbs. per sq. in.,	107	182	137	258
Cone 05—				
Fire shrinkage,	......	3.3%	0.4%	0.3%
Absorption,	......	28.31%	20.12%	23.53%
Condition,	......	not steel-hard	not steel-hard	not steel-hard
Color,	......	light red	pink red	light red
Cone 1—				
Fire shrinkage,	......	7.0%	1.0%	2.2%
Absorption,	......	16.79%	16.22%	17.59%
Color,	......	deep red	red	red
Condition,	......	nearly steel-hard	nearly steel-hard	nearly steel-hard
Cone 3—				
Fire shrinkage,	0%	.....	.....	.....
Absorption,	16.87%	.....	.....	.....
Color,	light buff	.....	.....	.....
Cone 10—				
Fire shrinkage,	2%	.....	3.0%[1]	2.4%[1]
Color,	light gray	.....	.....	.....
Condition,	steel-hard	.....	steel-hard[1]	.....

I. Yellow, sandy laminated clay, sometimes used in bricks.
II. Black, gritty clay.
III. Very gritty top loam.
IV. Mixture of II and III.

From an inspection of the above tests, it will be seen that the yellow, sandy, laminated clay (No. I) burns to a very light color, has an exceedingly low fire shrinkage, even at a comparatively high cone is quite porous and does not burn hard at a low cone.

The mixture (No. IV) of the top and bottom layers (No. II and III) produces a material whose water absorption is intermediate between the two, and whose fire shrinkage is practically no greater than that of the surface loam. Another effect of the mixing has been to increase greatly the tensile strength which is rather an interesting point (see page 89). The fire shrinkage

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[1] Burned at cone 9.

at cone 05 is slightly lower than for either clay alone, but the porosity, as indicated by the absorption, is intermediate between that of the two clays. When burned at cone 1, the mixture had a very much lower fire shrinkage than that of the black clay, but slightly higher than that of the top loam. The porosity at this cone, however, seems to be greater in the mixture than in either of the two clays alone.

Pine Brook.—The Asbury clay is well exposed in the "black cut" along the N. J. Southern R. R. midway between Pine Brook and Shark River station, where a new brickyard has recently been started by Geo. B. Decker (Loc. 216). Considerable variation is found in the material from point to point, some of the clay being black and not unlike that found at the Asbury yard, while other beds are light yellowish or reddish and quite sandy.

Farmingdale.—In the region north of Farmingdale (Loc. 214 and Loc. 215) several brickyards are using the surface loams, mixed in some cases with underlying Miocene clay. The more sandy portions are used for common brick while the more plastic beds are separated and employed for making draintile. As an example of the character of the material worked, we may take the section seen at one of these yards (Loc. 214). Here the bank shows 3 feet of Pleistocene loam, which is underlain by a sandy, thinly laminated Miocene clay, which is exposed to a thickness of 3 feet. The material is very open-burning, but makes a good common red brick and may even be used for common draintile.

An important deposit of Asbury clay is found on the property of D. H. Applegate, 2½ miles south of Eatontown (Loc. 270).

The property has been well tested by borings, and the clay has been proved to extend over a considerable section. A boring about 150 feet from the house showed:

A. Yellow clayey loam,	4 ft.
B. Light-colored clay with thin seams of fluffy sand,	4–5 ft.
C. Black clay and thin sand seams,	5 ft.

A sample of each of these was tested by burning with the following results:

Sample A, when dry pressed and burned at cone 9, was gray-buff, with a fire shrinkage of 5.2 per cent.

Sample B took 25 per cent. of water in tempering, and had an air shrinkage of 6.3 per cent. Its tensile strength varied from 122 to 150 pounds per square inch. When burned at cone 05 the fire shrinkage was 1 per cent., and the absorption 18.69 per cent.; at cone 1 they were 3 per cent. and 12.27 per cent. respectively, and at cone 5 they were 3.7 per cent. and 9.1 per cent. The bricklet became steel-hard at cone 1, and at cone 9 the fire shrinkage was 6.6 per cent. and the color a deep red.

Sample C burned deep red.

Southard.—At Southard, 2½ miles north of Lakewood, clay has been dug for common brick. The bed is from 2 to 6 feet in thickness, and is reported to be somewhat refractory, but no tests have been made, and it is extremely questionable whether it is a fire clay.

Clay-working Industry.

The total value of the clay products of Monmouth county would, if tabulated, compare favorably, no doubt, with those produced by many other counties in the State, but the industry, as in Burlington county, is rather concentrated. Great quantities of common, soft-mud, as well as some stiff-mud, brick are produced annually around Matawan, Cliffwood and Keyport. Others are also manufactured west of Asbury Park, north of Farmingdale, and along the N. J. Southern R. R., north of Shark River station. Fireproofing is manufactured to a considerable extent at the works of the National Fireproofing Company, at Lorillard. White floor tile is made at Matawan and Keyport, but the materials used come in a large part from other States, and to a small extent from the Amboy district. The county contains one pottery works at Matawan, where stoneware and common red earthenware are manufactured. The former is made chiefly from clays of the Amboy district, and the latter from weathered beds of Clay Marl II. Draintile is made at this factory, and also at some of the brickyards north of Farmingdale.

Fig. 1.

General view of Armstrong's soft-mud brickyard at Morristown, N. Y., with a deposit of glacial clay in the adjoining lowland.

Fig. 2.

Near view of the clay deposit at the same yard.

MORRIS COUNTY.

Extensive areas in the southeastern part of Morris county are underlain by clay, some of which attains a great thickness, but for the most part they are low and swampy, often several miles from railroads, and somewhat buried by sand or swamp muck. Hence they are mostly undeveloped. In the northern and western parts of the county no extensive deposits are known, although some local beds of surface or flood-plain clays probably occur.

Morristown.—A brick works is in operation 1¼ miles from Morristown, on the Bernardsville road (Loc. 293, Pl. LI, Figs. 1 and 2), and is using a deposit of glacial clay lying in the valley at that point. The clay underlies an area of 8 to 10 acres. It is a finely laminated sandy material with a layer of many concretions, about 6 feet below the top of the bank. These cause the brick to split, if allowed to remain in the clay. The clay in the bottom of the bank is much more plastic than in the upper part. The material is used for making a soft-mud brick of good quality, tests of which are given in the table, p. 256.

Whippany.—North of Morristown, at Whippany (Loc. 294), is another brick works, which has been running intermittently and utilizes a deposit of very plastic glacial-lake clay. The material underlies an area of about 35 acres, and has been dug to a depth of 12 feet. It is finely laminated, and gets very tough towards the bottom, so that a disintegrator is required to break it up. The material burns to an excellent red color of great density, but has a high shrinkage, and would probably melt at a rather low cone. The works are shown on Plate LII, p. 480.

Schooleys Mountain.—At Schooleys Mountain (Loc. 284), in the same county, a deposit of surface clay, derived by wash from disintegrated gneiss, occurs on the property of J. A. Parker. This material is fairly plastic, and works up with 35.4 per cent. water to a mass having an air shrinkage of 8 per cent. It burns steel-hard at cone 05 with a fire shrinkage of 4 per cent., absorption 10.9 per cent. and a light-red color. The deposit is not at present worked.

Parsippany.—Brick clay also occurs at Parsippany (Loc, 297, Lab. No. 730), on the property of J. B. Ricketts. It is probably a glacial-lake clay, and at cone 1 burns to a light-pink brick, which is not steel-hard. It has a fire shrinkage of 0.3 per cent. and an absorption of 18.29 per cent. For common brick it would have to be burned somewhat harder than is usually necessary, but the low fire shrinkage is a desirable point.

In addition to the above localities, from which samples of the clay were tested, large deposits are known to occur elsewhere along the upper Passaic river. These underlie the region formerly covered by the glacial Lake Passaic. Since their distribution has been given somewhat in detail in Chapter VI, p. 128, they will be passed with this brief reference. Many of these lacustrine clays are calcareous, and contain an abundance of concretions in certain layers.

Mount Paul.—A sample of light-colored clay, not very sandy, was received by the Survey from N. B. Thompson, Mendham, from his farm near Mount Paul. It was received too late to be examined physically, and so nothing is known of its qualities.

Clay-working industry.—As already indicated, common brick are made at Logansville, Morristown and Whippany, and were formerly manufactured at Summit, Chatham, Morris Plains and Chester. Flowerpots and draintile are manufactured at Logansville, but not extensively.

Fig. 1.

Inclined plane leading from the clay pit up to the brick works, with cars of clay. Whippany, Morris county.

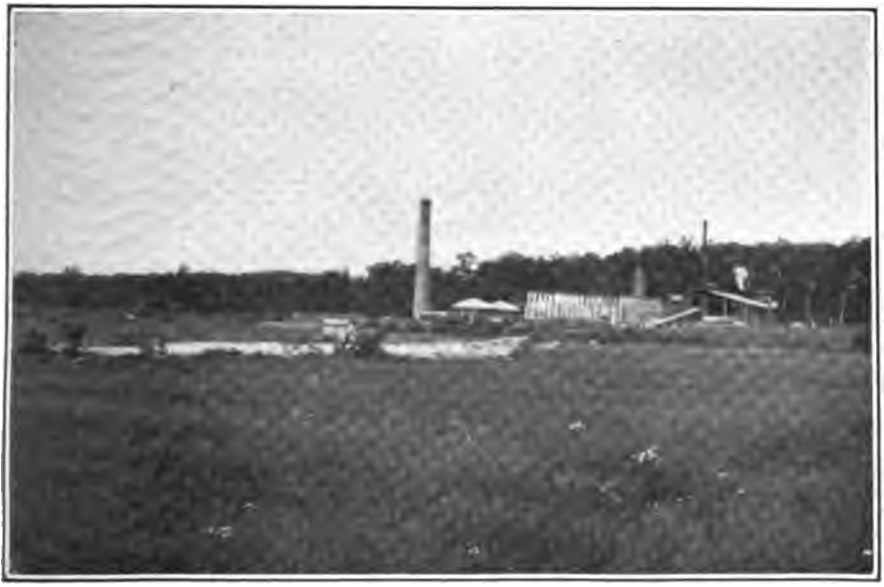

Fig. 2.

General view of the brick works at Whippany, with the clay deposit underlying the field in the foreground.

OCEAN COUNTY.

Prospecting for clay in this county is attended with more or less difficulty, on account of the thick pine growth covering the land in many places, the frequent sandy overburden, and the flatness of the region. If the clay is suspected, many borings have to be made to determine its extent (Pl. LIV, Fig. 1). The deposits visited and in some cases sampled belong entirely to the Cohansey formation.

Whitings.—The Eastern Hydraulic Press Brick Company has operated a clay pit for several years at a point about 2½ miles southeast of Whitings, and from the standpoint of development it is at the present time one of the most important deposits in the county. The stripping varies from 6 to 18 feet, and the clay is probably 15 feet deep. Since the opening of the deposit a tract of nearly 1,000 feet by 300 feet has been dug over. In working it a trench 40 to 50 feet wide is run the length of the bank, the overburden being taken off slightly in advance of the clay. The latter is then dug and loaded into large buckets, which are hoisted to the level of the track on the edge of the pit and dumped into the cars to be taken to the factory. A portion of the area worked over is shown in Plate LIII, Fig. 1, and a near view of the method employed for digging the clay is illustrated in Plate LIII, Fig. 2. The large buckets seen in the view hold about 1,500 pounds of clay. It can be seen from this last view that there is a gully just beyond the excavation in which the clay may outcrop, otherwise the whole deposit is covered by sand. A clay bed of this type serves well to illustrate the need of thorough and sufficiently deep prospecting.

As this material is a fairly good type of Cohansey clay, a sample was tested. Its physical characters were as follows:

Physical characters of clay from Whitings (Loc. 212).

Air shrinkage 5.5 per cent.
Tensile strength from 120-130 pounds per square inch.
At cone 1, fire shrinkage 5.5 per cent., color light buff.
At cone 5, fire shrinkage 10.8 per cent., color buff, steel-hard.
At cone 8, fire shrinkage 10.8 per cent., color buff,
At cone 15 fire shrinkage 9.3 per cent.

The material burns quite dense at cone 5.

Clay is also said to underlie the land south of the Hydraulic Press Brick Company's property.

Northeast of Whitings.—Cook noted the occurrence of clay along the N. J. Southern R. R., 1½ miles northeast of Whitings station. It was said to be yellowish red in color, and covered by a thin bed of gravelly earth. Red brick were made from it and the remains of the yard can still be seen (1902).

Old Half Way.—About 7 miles southwest of Whitings and 2 miles east of Woodmansie station, on the N. J. Southern R. R., is the large excavation (Loc. 213) of the Adams Clay-Mining Company (Pl. LIV, Fig. 2). The deposit lies on an elevation somewhat higher than that of the country to the east and southeast, and has less overburden than the clay at Whitings. The clay is worked out in pit-like excavations, so that the actual work of digging at any one time is confined to a small area. The stripping is first taken off by means of a scraper hitched to a cable passing around two pulleys and winding on a drum of a stationary engine, after which the clay is loaded into buckets and brought out of the pit with a conveyor, travelling on a cable. The pits have a depth of 10 or 12 feet. The clay is loaded onto narrow-gauge cars, which are drawn down to Woodmansie by a small engine.

Most of the clay is quite micaceous and siliceous, although less sandy patches are found. On the west side of the area excavated there seems to have been considerable clay of varied colors, more especially brownish black, but this variation in color is apparently not uncommon in some of the Cohansey clays. The main grade of clay sought for seems to be a buff-burning, terracotta clay, considerable quantities of which go to Pennsylvania, and in order to get this out everything else is thrown aside.

A sample of the yellowish-white, siliceous clay (Lab. No. 656) gave the following results when tested physically: It slaked very fast and felt lean when mixed with water. It required 23.3 per cent. of water for tempering, and had an air shrinkage of 4.8 per cent. The tensile strength ranged from 65 to 77 pounds per square inch, with an average of 73 pounds.

Fig. 1.

General view of the clay pit of the Eastern Hydraulic Press Brick Company, southeast of Whitings. The clay in the foreground has all been worked over.

Fig. 2.

View in same pit showing method of working the clay.

Fig. 1.
Prospecting for clay with an auger in the pines south of Whitings.

Fig. 2.
View of pits of Adams Clay Mining Company, at Old Half Way, east of Woodmansie.

As the material is not easily fusible, nor fine-grained, it was not burned below cone 5. At that cone, however, the fire shrinkage was 2.7 per cent., absorption 9.08 per cent., color whitish, and bricklet steel-hard. At cone 8 it was about the same, while at cone 10 the fire shrinkage was 3 per cent., the absorption 8.13 per cent., and the color of the bricklet gray, showing tiny fused black specks.

Some samples of the clay were screened through a 60-mesh sieve and formed into dry-press tile, which were burned buff at both cone 5 and 8. The fire shrinkage of the former was 1.3 per cent., and that of the latter 2 per cent. Both were porous, the former having 25.59 per cent., and the latter 15.49 per cent. absorption.

Wheatland.[1]—A pipe clay was formerly dug by E. N. &. J. L. Townsend 1¼ miles southeast of Wheatland station, and used in the manufacture of pipe and chimney tops at the drainpipe works of the proprietors at Wheatland station. The pits have long been abandoned, and it was not possible to learn whether the clay had been worked out.

Union Clay Works.[2]—Clay was dug years ago at the Union Clay Works, 2 miles southeast of Adams' pits, at Old Half Way.

The best clay was reported to be 10 feet thick and the deposit was said to underlie 70 acres. The manufacture of sewer pipe was started in 1866, and previously fire brick, and common pottery had been attempted. The distance from a railroad and the sandy wagon roads may have been one reason for the abandonment of the works.

Mayetta.—Between Manahawken and Tuckerton is another extensive area of Cohansey clay, which is said to underlie about 700 acres. Most of it is owned by the Eastern Hydraulic Press Brick Company. The deposit (Loc. 209) lies about one-half mile northwest of Mayetta station, and 1½ miles southwest of Manahawken, and was at one time worked for making common brick. The bricks burned red and were made chiefly from the upper layers of the clay. In the pit two beds are recognizable,

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[1] Report on the Clay Deposits in New Jersey, 1878, p. 256.

[2] Loc. cit., p. 256.

viz., an upper bluish-white, mottled clay, which is rather sandy in its upper layers, and passes upwards into the gravelly overburden. This upper clay, as exposed, ranges from 3 to 4 feet in thickness. The lower bed, which was bored into for a distance of 5 feet, consists of red and chocolate layers which may contain pebbly streaks. The total thickness of the clay is said to be as much as 24 feet, and the overburden is about 4 feet thick. The upper clay (Lab. No. 666), when examined in the laboratory, was seen to be a gray, sandy, slow-slaking clay, with practically no mica scales. It burned buff at cones 3, 5 and 8, with fire shrinkage of 4, 5 and 6 per cent., respectively, and became steel-hard at cone 5. When made up into dry-press tiles its fire shrinkage at cone 5 was 2.6 per cent., and at cone 10, 13.3 per cent., the percentages of absorption being respectively 16.36 per cent. and 6.40 per cent. The color of the former was buff and of the latter light gray. It was analyzed with the following result:

Chemical analysis of a clay from Mayetta.

Silica (SiO_2),	76.40
Alumina (Al_2O_3),	13.29
Ferric oxide (Fe_2O_3),	0.82
Lime (CaO),	0.95
Magnesia (MgO),	0.61
Alkalies (Na_2O, K_2O),	1.80
Water on ignition,	5.10
Total,	98.97
Total fluxes,	4.18

The low percentage of ferric oxide explains its buff-burning character, while the high percentage of total fluxes and silica show that it is not a fire clay.

The lower bed burned buff, also, and became steel-hard at cone 1, with fire shrinkage of 4.7 per cent. and an absorption of 10.52 per cent. At cone 5 its fire shrinkage was 8 per cent. and absorption 3.06 per cent. Its air shrinkage was 5.3 per cent. It is difficult to see how the local brickyard made red brick out of this clay, as was claimed.

An additional deposit of clay is said to exist on the adjoining property, belonging to the Hazleton estate.

Tuckerton.—A gritty, mottled clay (Loc. 210) outcrops along the road for a distance of 200 yards, one-half mile west of Tuckerton, and the section shows 5 feet of clay, but it is not worked at present. The clay is quite dry and porous, and grades downward into a mottled sand. In the laboratory when wet it (Lab. No. 662) was not very plastic to the feel, although it had a tensile strength of 173 pounds per square inch. It took 26.3 per cent. of water to temper it, and the air shrinkage was 5.5 per cent. It behaved as follows in burning:

Burning tests of a clay from Tuckerton.

Cone	*1*	*8*	*9*
Fire shrinkage,	0.5%	4.1%	5.1%
Absorption,	13.16%	6.73%	Low.
Color,	red.	red.	deep red.

The bricklet burned steel-hard at cone 1.

It is possible that this clay might be available for more than common brick, since it stands cone 9 without fusing, and burns fairly dense and of good red color. Haulage from here to the railroad would be along a fairly level road, or shipment by water would be still easier.

The following analysis of a clay from the land of Eayre Oliphant, near Tuckerton, is on file in the Geological Survey office:[1]

Analysis of clay. Eayre Oliphant, Tuckerton.

Silica (SiO_2),	58.15
Alumina (Al_2O_3),	27.37
Ferric oxide (Fe_2O_3),	4.83
Water (H_2O),	9.31
Total,	99.66

The analysis would indicate a red-burning clay.

Two and one-half miles southwest of Tuckerton (Loc. 211) there is a deposit of clay upon the Northridge property, which was formerly used for common brick, and which is reported to be of considerable extent, and to be 24 feet in thickness over at

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[1] Analysis made by W. S. Myers, 1895, unpublished.

least 60 acres. The upper part of the clay burns red at the temperature at which common brick are burned, but the lower layers are reported to be buff burning. A dock has been built on Ballenger's creek, adjoining the property, where, it is reported, vessels drawing 14 feet of water can load.

Northwest of Tuckerton, near Nugentown, a deposit of clay is reported to occur upon lands owned by C. G. Baxter, Mark L. C. Wilde and Mrs. Elkanak Palmer, of Philadelphia. The tract of 50 acres has not been fully explored, but the clay is said to underlie it all. Information regarding it was obtained by correspondence, and the tract was not visited by members of the Survey staff.

Davenport.—At Davenport,[1] 4 miles west of Toms River, on the Pennsylvania R. R., clay occurs at scattered points on the Yoder property (Loc. 208). Owing to the sandy overburden, the dense brush, as well as absence of gullies to supply outcrops, prospecting is difficult. Clay was penetrated by the auger at a number of points, but the exact quantity present is not known. At one point (Loc. 208) a red clay of good appearance and smoothness was struck in a 3-foot, and again in a 5½-foot boring, and sufficient taken for a laboratory test (Lab. No. 686). This gave the following results: Water required for tempering, 33.1 per cent.; air shrinkage, 7.6 per cent.; average tensile strength, 130 pounds per square inch. Its behavior in burning was as follows:

Burning tests of clay on Yoder property, near Davenport.

Cone	*05*	*1*	*3*	*5*	*8*
Fire shrinkage, ...	1.7%	6%	6.4%	7%	7.2%
Color, ...	pale red	red	deep red	deep red	deep red
Condition, ...	not steel-hard	steel-hard			
Absorption, ...	19.09%	10.21%	7.98%	6.68%	7.21%

The clay is pasty, gritty and tends to drag some in being molded. It will be seen from the above that it does not vitrify at a very low temperature.

Samples of clay from property of J. S. Brown, near Davenport, and not far from the Yoder tract, were sent to the Survey

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[1] Clay is now (1904) being actively dug on this property and shipped to Perth Amboy and Philadelphia for terra cotta.

by Mr. Spencer Simpson, of Camden, N. J. On testing it was found to have a very fair plasticity, and required about 25 per cent. of water for tempering. Its tensile strength was 130 pounds per square inch, and air shrinkage 7 per cent. At cone 1 the fire shrinkage was 5 or 6 per cent., color a good red. It vitrified at cone 4.

Toms River.—In rather strong contrast to the Yoder clay (Loc. 208) is one occurring on the property of Samuel Applegate (Loc. 207), 4 miles a little west of north of Toms River. This is a whitish, sandy clay, struck by boring at several points on Mr. Applegate's farm. There is no special evidence to show that it is not pockety.

As the clay (Lab. No. 706) gave superficial indications of being more refractory than most of the other Cohansey clays, a sample of it was tested with the following results: Water required for tempering, 29.1 per cent.; air shrinkage, 5 per cent. It behaved as follows in burning:

Burning tests of clay, Samuel Applegate, Toms River.

	Cone 3	*Cone 5*	*Cone 8*	*Cone 15*	*Cone 27*
Fire shrinkage,..	4%	5.1 %	5.6 %	4.3 %	
Absorption, ...	11.92%	11.03%	7.88%	3.01%	
Color, ...	light buff		light yellow	light gray	
Condition, ...	steel-hard			slight softening taking place	vitrified and not yet viscous

The clay is, therefore, at least semirefractory, and its character and presence should encourage further prospecting. It approaches nearer a good No. 2 fire clay than any of the other Cohansey clays tested.

The Cohansey clays have been worked at Tilton's brickyard (Loc. 206), near Toms River, for the manufacture of soft-mud brick, for the past twenty years, and an extensive, but not very deep, excavation has been made. The clay, which is less refractory than many of the other Cohansey clays found in the county, is a dark, sandy material with much lignitic matter and irregular streaks of whitish sand.

Its thickness is variable and difficult to estimate, as the bank is washed down at all points except the one where the clay is being dug, but the section was approximately as follows:

Section at Tilton's brickyard, Toms River.

Gravelly sand,	2-4 ft.
Whitish clay,	2-3 ft.
Black clay,	3-8 ft.
Yellow clay,	1 ft.
Sand	

For brickmaking the run of the bank, which burns red, is used as far down as the yellow clay, which is not suitable for this purpose, since it possesses very different properties from the clay found in the rest of the bank, as can be seen below. The deposit is more or less basin-shaped, and seems to be in line with several others, one of these lying to the west on the land of Roberts and Brank, and the other lying in the opposite direction and extending down to the Toms river.

Physically, the brick mixture is a rather coarse-grained, lean, sandy clay. It worked up with 26 per cent. of water to a mass having an air shrinkage of 4.3 per cent. and an average tensile strength of 68 pounds per square inch. It did not burn hard at as low a temperature as many common-brick clays. At cone 1 its fire shrinkage was 2.3 per cent., clay not steel-hard, and absorption 15.37 per cent.

At cone 5, fire shrinkage 3.7 per cent., bricklet red, nearly steel-hard, and absorption 12.53 per cent.

The yellow clay underlying this can probably not be used in a burned form, as it shows rather undesirable physical properties. It is extremely silty in its character, but not sandy, and is very lean. It does not dry to a dense mass, but, on the contrary, has a porous, brittle body. It took 65 per cent. of water to mix it, owing to its porosity, and yet its air shrinkage was only 8 per cent. The tensile strength averaged 74 pounds per square inch. In burning it gave these results:

Burning test of an ochreous clay. Tilton's pit, Toms River.

	Cone 05	*Cone 03*	*Cone 01*
Fire shrinkage,	2.6%	9.3%	14.6%
Color,	red	bright red	red
Condition,	not steel-hard	nearly steel-hard	steel-hard
Absorption,	35.12%	26.15%	14.33%

The material has more value as an ochre or mineral paint, and is said to have been used to some extent in the manufacture of oilcloth. Its high percentage of iron oxide and low silica contents can be seen from the following analysis:

Analysis of an ochreous yellow clay. Tilton's pit, Toms River.

Silica (SiO_2),	31.96
Alumina (Al_2O_3),	21.93
Ferric oxide (Fe_2O_3),	31.39
Lime (CaO),	0.45
Magnesia (MgO),	0.18
Loss on ignition (chiefly H_2O),	12.92
Total,	98.83
Total fluxes,	32.02

The high percentage of water, as compared with the low amount of alumina, is due to the iron oxide being present as limonite, which has about 14 per cent. of chemically combined water. The clay contains approximately 36.00 per cent. of limonite, 56 per cent. of clay base and 8 per cent. of sand.

Herbertsville.—A thinly laminated clay often very sandy and elsewhere very plastic, occurs at a number of points south of Herbertsville (Loc. 218, 219). It differs somewhat in appearance from the Cohansey clays found elsewhere in the county, but it seems on the whole probably referable to that horizon. Whether the various outcrops are parts of a continuous bed or a series of closely lying lenses it is not possible to say. The clay has been opened up by the Herbertsville Brick Company at their yard, and at Isaac Tilton's yard, south and southeast of Herbertsville, respectively.

At the former (Loc. 218) the clay is exposed in a shallow excavation 200 feet long, 20 feet wide and about 4 feet deep. It varies from a very plastic clay to one of very sandy character with interlaminated beds of sand. By digging a large quantity at once and piling it up the two kinds become more or less mixed. The clay, sandy as it is, is not used alone, however, but a large quantity of sand obtained from a separate pit near by is added to it. The effect of this addition is very marked, as can be seen below, where the tests are given in parallel columns:

Physical characters of clay. Herbertsville Brick Company.

	Clay.	*Clay and sand (equal parts).*
Water required,	32.6%	15.6%
Air shrinkage,	5.3%	3.3%
Average tensile strength, lbs. per sq. in.,	108	65
Cone 05—		
Fire shrinkage,	0.3%	0.7%
Color,	pink red	pinkish
Condition,	not steel-hard	not steel-hard
Absorption,	20.19%	14.76%

The clay alone remains porous even when burned to cone 5, at which point its fire shrinkage was 2.7 per cent. and its absorption 12.98 per cent. At cone 10 the fire shrinkage was 6 per cent.

At the other locality (No. 219), southeast of Herbertsville, on the road to West Point Pleasant, the clay is exposed in a number of pits which have been dug in the woods. None of them are deep, and the working face is rarely more than 4 feet high. The main opening at the time the pit was visited showed a yellow, sandy clay 3 to 4 feet deep, with 4 feet of sandy overburden. In this pit the clay grades horizontally into a fluffy, sandy loam, and in an adjoining pit the clay is quite plastic, and contains much less sand, so that the best results are obtainable by using a mixture from several different pits. The common method consists in making a mixture of the clay and loam, and for purposes of comparison these tests are also given in parallel columns:

Physical characters of clay, Isaac Tilton's brickyard, Herbertsville.

	Clay Lab. No. 698	*Loam* Lab. No. 699	*Clay and loam* Lab. No. 698-9
Water required,	29.3 %	21.3 %	25 %
Air shrinkage,	4.4 %	2.5 %	4 %
Tensile strength, lbs. per sq. in.,	73	49	70
Cone 05			
Fire shrinkage,	0.2 %	0.5 %	0.3 %
Absorption,	20.84%	17.64%	19.26%
Color,	light red	light red	light red
Condition,	not steel-hard	not steel-hard	not steel-hard
Cone 1			
Fire shrinkage,	2.6 %	1.5 %	1.4 %
Absorption,	16.93%	16.52%	16.16%
Color,	red	red	red
Condition,	not steel-hard	not steel-hard	not steel-hard

It will be noticed on comparing these tests with those of the preceding locality that the effect of the sand is better than that of the loam, because it produces a denser and consequently stronger brick.

Lakewood.—Cohansey clays are also found at Lakewood and have been worked to a slight extent. One deposit, which occurs on the property of Mrs. Le Conte and Wm. Clayton, is a very sandy clay, working up with 20 per cent. of water and having an air shrinkage of 7.3 per cent. It is said to have a thickness of 6 to 8 feet. Its behavior on burning was as follows:

Burning tests of clay from near Lakewood.

	Cone 1	*Cone 5*	*Cone 15*
Fire shrinkage,	0.7 %	0.7%	1.7%
Absorption,	13.10%	......	......
Color,	buff	buff	gray brown
Condition,	not steel-hard	......	steel-hard

Bennett Mills.—Prof. Cook[1] notes the occurrence of clay on the lands of Chas. H. Appleget, near Bennett Mills. The deposit is said to "lie near a tributary of Metedeconk creek, and not far from the latter stream." The material was described as a tough, sandy, plastic clay streaked with red and yellow.

Seven Stars.—Red-burning clay was also mentioned (p. 254 Ibid) as occurring on the Bricksburg tract near the old Seven Stars Hotel. It is described as "a very stiff, tough clay, and most of it is some shade of yellow or red, although some of it is said to be white." The overburden was 4 feet, and it was suggested that selected portions might be used for pottery.

Bricksburg.—A belt of clay land is also mentioned as extending from Bricksburg to Toms River, the surface layers of the clay being mixed with gravel.[2] A clay for red brick was dug (1878) 1 mile north of the village. Its average thickness was 13 feet, and the overburden 4 feet. The clay is said to burn light colored, and the bricks were not very hard. This is probably due to their being burned at too low a temperature.

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[1] Report on Clays, 1878, p. 254.

[2] Ibid., p. 254.

Dillon's Island.—Cook also mentioned a bed of yellowish-white clay, 3 feet thick, in the bluff on the south side of Dillon's Island. The overburden is recorded as being 10 to 15 feet thick.

Clay-working industry.—Few clay products are manufactured in Ocean county. Common brick have been made at Toms River for twenty years or more, and three small yards are in operation near Herbertsville. Some brick have also been made near Lakewood. Considerable clay for pressed brick is dug southeast of Whiting station, and clay for terra cotta at Old Half Way, 2 miles east of Woodmansie.

There is opportunity for much prospecting in searching for pressed-brick and terra-cotta clays in the Cohansey formation. It is possible also that some fire clay might be found, although none has been up to the present time, with the exception of that on the Applegate property north of Toms River.

Where deposits are located at some distance from a railroad it would be necessary and economical to take the clay out to the main line by rail, as the roads in this region are very sandy.

PASSAIC COUNTY.

So far as known, the only clays in Passaic county which are commercially important are of Glacial age, and probably connected in origin with the glacial Lake Passaic. They are extensively developed north of Singac and Little Falls, where common brick are manufactured by the Singac Brick Company (Loc. 287) and Geo. Conners (Loc. 286), and at Mountain View, where there are extensive brick plants belonging to the Standard Brick Company, of Newark (Loc. 288), and Uschwold & Ulrich (Loc. 289). These deposits are not limited to the localities where worked at present, but are known to extend as far north as Preakness, although over much of this area they are buried by silt and sand.

The clay is usually dark colored, often black, sometimes distinctly laminated, the latter beds being free from stones. At some pits the clay is overlaid by sand; in others, notably that at locality 286, the laminated clay is covered by several feet of stony clay—glacial till—(Pl. XVI, Figs. 1 and 2), which is also used, the bowlders being rejected in digging, the larger stones being separated by a rotary sieve, and those under an inch in diameter often finding their way into the brick. All these clays burn red and are rarely used with the admixture of sand. The brick are made by the soft-mud process, and since all the yards are located either along the railroad or on the Morris and Essex canal or its feeder, shipping facilities are excellent.

Small local deposits of surface or glacial clay doubtless exist elsewhere in the county, but they have never been developed.

SALEM COUNTY.

This county extends from the Delaware river in a southeast direction to the Maurice river, a distance of about 27 miles. It, therefore, might include clays belonging to the Raritan, Clay Marl, Alloway, Cohansey and Cape May formations, but some of these are not exposed on account of the heavy capping of surface materials. The Alloway clay is the only important deposit exposed and worked.

Pentonville.—The Cape May has been opened to supply a small brickyard at Pentonville (Loc. 166), but the deposit is a shallow one, from 2 to 4 feet in thickness, and is underlain by sand. It burns to a red color and is quite porous at the temperature reached in common-brick kilns. The Cape May clays have also been worked for brick at Salem.

Alloway Clay.

The Alloway clay is the most important clay deposit in this county, and it was examined at a number of localities. Its extent is shown in detail on the map, Plate XIII.

Yorktown.—The most extensive opening, although not a very deep one, is seen at the brickyard of David Haines, south of Yorktown (Loc. 162, Pl. LV). The clay bank forms a long, shallow excavation to the west of the yard, and exposes an upper and lower bed of clay, covered by loam which is in part gravelly.

If the pit is followed from east to west it is found that the sandy overburden increases in thickness. The upper clay bed is a whitish clay with yellow mottling, containing occasional seams or crusts of limonite (Pl. II, Fig. 2), and varies from 8 to 15 feet in thickness. The under clay is a blue, very plastic material, of great cohesiveness. It is said to run 50 feet in depth, and was bored into for a distance of 8 feet to obtain a sample.

At the western end of the clay bank the sand is found apparently to rest directly on the blue clay, as if the mottled clay had thinned out. This apparent fading out of the one bed is due

Fig. 1.

General view of D. F. Haines' brick works, at Yorktown.

Fig. 2.

Bank of Alloway clay adjoining Haines' yard.

to the fact that the mottled clay is probably only a weathered phase of the blue, and it is absent from the western end of the pit, because the heavy capping of sand has prevented the weathering agents from changing the clay. In working the clay, all portions containing the limonite crusts are avoided, as they are difficult to break up by grinding.

Three samples were tested from this locality, viz., the top clay, the bottom clay and the brick mixture.

Top clay. (Lab. No. 677.)—This was a somewhat gritty clay and slaked slowly. It worked up with 30.2 per cent. of water to a mass having an air shrinkage of 9.3 per cent. and an average tensile strength of 308 pounds per square inch. In burning the following results were obtained:

Burning tests of top clay. D. F. Haines, Yorktown.

	Cone 05	*Cone 5*	*Cone 8*
Fire shrinkage,	2.7%	7.7%	7. %
Color,	yellowish red	red	deep red
Condition,	steel-hard	......	......
Absorption,	12.62%	0.22%	0.34%

Bottom clay. (Lab. No. 694.)—This was much denser, and was slow slaking. It took 29.9 per cent. water and had an air shrinkage of 8 per cent. Its average tensile strength was 223 pounds per square inch. In burning it behaved as follows:

Burning tests of bottom clay. D. F. Haines, Yorktown.

	Cone 05	*Cone 3*
Fire shrinkage,	5.3%	7.3%
Color,	light red	red
Condition,	steel-hard	.....
Absorption,	6.89%	1.07%

Brick mixture. (Lab. No. 617.)—The brick mixture was very plastic and contained more or less fine grit, as it had some loam added to it. It took only 27 per cent. water and its air shrinkage was 7.6 per cent. The average tensile strength was 229 pounds per square inch.

Burning tests of brick mixture. D. F. Haines, Yorktown.

	Fire shrinkage.	*Color.*	*Hardness.*	*Absorption.*
Cone 05,	.1%	red	not steel-hard	13.42%
Cone 01,	2.7%	red	nearly steel-hard	8.58%
Cone 1,	2.7%	red	steel-hard	8.9%
Cone 3,	4.4%	red		6.96%
Cone 8,	5.7%	red		1.21%

It will be seen that the two clays alone do not differ much in their air shrinkage, but that the bottom clay has a much higher fire shrinkage, and at cone 05 is nearly twice as dense as the top clay.

The mixture has had its air shrinkage as well as its fire shrinkage decreased by the addition of loam. Its composition was as follows:

Chemical analysis of brick mixture. D. F. Haines, Yorktown.

Silica (SiO_2),	68.96
Alumina (Al_2O_3),	17.87
Ferric oxide (Fe_2O_3),	3.27
Lime (CaO),	0.25
Magnesia (MgO),	0.25
Alkalies (Na_2O, K_2O),	2.10
Water (H_2O),	6.95
Total,	99.65
Total fluxes,	5.87

The Alloway clay also outcrops at a point west of Yorktown in the ditch along the north side of the road (Loc. 161). The clay, which is a yellow-mottled color, is at least 4 feet thick, as determined by boring (total thickness probably much greater), and is covered by 6 to 7 feet of Bridgeton gravel. The latter thins out, however, down the slope to the west, as well as on the south side of the road. The clay (Lab. No. 691) is quite plastic to the feel, has little grit, but mica scales are fairly abundant in it. It took 36.1 per cent. water to mix it, and its air shrinkage was 8 per cent. A bricklet burned at cone 1 had a fire shrinkage of 7 per cent., which is somewhat high. Its color was brownish red, and its absorption only 1.41 per cent., showing its dense-burning character.

Alloway.—A number of outcrops of the clay were also found around Alloway. One of these was in the railroad cut just north of Alloway station (Loc. 164), where there is a deposit which is well located for shipment and which could be easily drained.

Section in railroad cut, near Alloway.

Loam or pebbly loam,	3 to 4 ft.
Weathered, very plastic clay (derived from the Alloway clay),	5 ft.
Blue clay,	1 ft.

The latter is very similar to the blue clay in the brick pits at Yorktown. The physical characters of a sample representing the run of the bank were as follows: Water required, 32.1 per cent.; air shrinkage, 8.6 per cent.; average tensile strength, 453 pounds per square inch.

At cone 03. Fire shrinkage 4.4 per cent., color red, bricklet steel-hard, absorption 8.07 per cent.

At cone 1. Fire shrinkage 5.2 per cent., color red, absorption 3.94 per cent.

Cone 12. Vitrified.

This clay showed a phenomenally high tensile strength, probably one of the highest ever recorded. It also burns quite dense at a low cone.

One mile south of Alloway the clay again outcrops along the highroad opposite an ice house (Loc. 165). It is covered by 4 feet of gravel and sand and is at least 7 feet deep, as determined by boring. It is quite plastic, even sticky, and moist in places. There were also occasionally iron crusts at the point where the boring was made. The clay slaked moderately fast and completely. It is not unlike the clay from locality 161, west of Yorktown. It required 35.6 per cent. of water to work it up, and it had an air shrinkage of 9 per cent. At cone 1 the fire shrinkage was 7 per cent. and the clay burned exceedingly dense, having an absorption of only 0.47 per cent. Cone 5, absorption .07. The color was red.

Another well-located deposit is found at a point 3 miles north of Alloway (Loc. 167). Here a boring showed at least 7 feet of light-mottled clay, similar to the upper clay in the brick-clay pits at Yorktown, and covered by not more than 2 feet of pebbly loam. The outcrop is well located on account of the thin stripping, dryness of the deposit and good drainage. The material (Lab. No. 688) required considerable water to temper it, viz., 48.7 per cent., and had a high air shrinkage of 11 per cent. Its tensile strength was low, being 80 pounds per square inch. It burned quite dense, however, for at cone 1, with a fire shrinkage of 5.6 per cent., its absorption was 5.18 per cent., and at cone 5, with a fire shrinkage of 8.3 per cent., it absorbed only 0.46 per cent. of water. It became viscous at cone 12. It burned red at cone 1, brown at cone 5, and gray at cone 8. A dry-press tile was burned at the last-named cone, and showed 13.3 per cent. total shrinkage, which of course occurred mostly in the firing.

The Alloway clay outcrops again along the road opposite a farmhouse, at a point one-half mile east of Alloway (Loc. 163). Its thickness is more than 7 feet, the upper 5 feet being a light, sandy clay, while the lower 2 feet had occasional sand streaks. The clay (Lab. No. 685) worked up with 26.5 per cent. of water, and had an air shrinkage of 8 per cent. Its tensile strength was excellent, averaging 246 pounds per square inch. Its fire shrinkage was low, being 0 per cent. at cone 05, 2 per cent. at cone 3, and 5.3 per cent. at cones 5 and 8. Its absorption at these cones was 16.59 per cent., 10.57 per cent., 4.51 per cent. and 6.39 per cent., respectively. It was viscous at cone 27.

It burned red up to cone 5, and a gray brown above that. Its fire shrinkage was somewhat lower than that of most of the other Alloway clays.

Richmanville.—Other outcrops of Alloway clay occur at Richmanville, along the bank of the stream (Loc. 160). The clay, as determined by boring, extends at least 7 feet below the stream level, and an additional thickness of 5 feet is exposed in the bank. The overburden of gravel and sand increases in thickness as one recedes from the stream. The clay even below stream level is comparatively dry, and on the outcrop it dries and breaks up into irregular fragments looking not unlike those of Clay Marl II. The sample (Lab. No. 675) was a smooth, very dense, dark-colored clay of low plasticity, and fairly free from grit. It took

30 per cent. of water to temper it, and it had an air shrinkage of 8 per cent. Its average tensile strength was 90 pounds per square inch.

In burning, at cone 05, its fire shrinkage was 4 per cent., color bright red, not steel-hard, and absorption 20.17 per cent. At cone 03 the fire shrinkage was 5 per cent., color red, not steel-hard, and absorption 15.45 per cent. At cone 1 fire shrinkage 5.5 per cent., color deep red, steel-hard, and absorption 13.48 per cent.

It will be seen, therefore, that it does not burn as dense as some of the other Alloway clays mentioned above.

Fenwick.—Near Fenwick there is also an abundance of this clay. It was worked at one time on the flat near the station (Loc. 169), and the remains of a small brickyard are still to be seen there. While the deposit at the brickyard is probably not very extensive, it is interesting to compare it with the one from the railroad cut north of Alloway, because it has such a high tensile strength, viz., an average of 327 pounds per square inch. At both localities, however, the deposit is not strictly speaking the Alloway clay, but a secondary clay, which has been derived from the Alloway by stream action at a much later date than the original deposition of the clay. This re-working has greatly increased the tensile strength. The clay at Fenwick has, however, a lower air shrinkage, 7.6 per cent., when mixed with 29.7 per cent. water, as compared to 8.6 per cent. for the clay from the railroad cut (Loc. 164). At cone 03 the fire shrinkage was only 1 per cent., and the absorption of the bricklet 11.86 per cent. It was steel-hard, and a bright red color. Just northeast of Fenwick station there is a great flat underlain by massive Alloway clay, with practically no overburden.

Big Mannington hill.—The clay is finely developed on the lower slopes of Big Mannington hill, west of Fenwick, where extensive banks could be opened up in the hillside with little or no trouble with good drainage and with only a short haul to the railroad.

Riddletown.—In the railroad cut on the West Jersey R. R., near Riddletown (Loc. 168), the Alloway clay is again well exposed. Here at least 12 feet is to be seen, with 3 feet of overburden in the cut, but increasing up the slope away from the railroad. When the clay dries out on the surface it breaks into blocks. When tempered with 46.5 per cent. of water, its air shrinkage was 10.6 per cent., and it had an average tensile strength of 337 pounds. At cone 03 the fire shrinkage was 3.4 per cent., the absorption 9.89 per cent.; at cone 1 they were 3.4 per cent., and 7.96 per cent. respectively.

Woodstown.—Two miles east of Woodstown (Loc. 177) there is an exposure of the usual tough, dry, mottled clay so characteristic of the Alloway formation. The material (Lab. No. 673) was sampled by boring to a depth of 4 feet, and when worked up was found to be quite plastic. It tempered with 35.8 per cent. water to a mass having 8.3 per cent. shrinkage. Its burning qualities were as follows:

Burning tests of a clay near Woodstown (Loc. 177).

Cone	*05*	*03*	*1*	*5*
Fire shrinkage, ...	4.7%	5.7%	7.7%	9.3%
Absorption, ...	11.76%	9.45%	3.59%	.36%
Color, ...	pale red	streaky red	red	deep dirty red
Hardness, ...	steel-hard	steel-hard	steel-hard	steel-hard
Viscous at cone 12.				

The following are two analyses of clays of the Alloway formation:

Chemical analyses of two Alloway clays.

	1	*2*
Silica (SiO_2), ...	52.30	67.40
Alumina (Al_2O_3), ...	32.01	19.62
Iron oxide (Fe_2O_3), ...	1.59	2.45
Lime (CaO), ...	.....	0.25
Magnesia (MgO), ...	.....	0.34
Water (H_2O), ...	12.02	8.08

1. Source unknown.
2. Sample collected by the Survey from railroad cut north of Alloway, and analyzed for this report.

Micaceous, talc-like Clay.

As before indicated (p. 144), a soapy, micaceous, talc-like clay underlies the Alloway clay in the vicinity of Woodstown. It is exposed in the railroad cut just north of the town (Loc. 170), where 3 or 4 feet of the material is seen under several feet of gravel and loam. Northeast of Woodstown where the road descends to Old Mans creek, there is another exposure of the same material from which a sample was taken, although at this locality (172), owing to the heavy overburden of gravel (12 to 14 feet), and the thinness of the deposit, 2½ feet, it is not likely to have any economic value. Although it has nowhere been seen to occur other than in thin beds, prospecting might develop a thicker bed of this material, which may ultimately have some value. This deposit is not similar to the micaceous sand, mined in the Woodbridge district, and erroneously termed *kaolin*. The latter has less mica and much more coarse sand.

In its raw condition the micaceous, talc-like clay is a whitish, loose clayey mica sand. It digs readily, but on account of its open character, is easily penetrated by water and therefore is readily stained by iron from the overlying sands and gravels. In its crude condition it might perhaps serve as a filler for asbestos. When mixed with water, molded and burned, the sample from locality 172 behaved as follows: Water required for tempering, 45.2 per cent.; air shrinkage, 3.3 per cent. It is not hard burning at low or moderate temperatures. Thus at cone 8, the fire shrinkage was only 5.3 per cent., the bricklet not steel-hard, color white and absorption 24.73 per cent.

At cone 10, the fire shrinkage was 7.3 per cent.; color yellowish white, bricklet barely steel-hard, and absorption 19.23 per cent. The mica scales were still visible at cone 8, and had not in most cases fluxed with the other particles of the clay.

A test of another sample is given in the description of the clays from Gloucester county.

The Cohansey clays are not worked in Salem county, nor were any exposures seen, but they may occur, as the formation probably extends across southeastern Salem county. They are worked just across the county line at Rosenhayn, in Cumberland county, and similar beds very probably occur in southeastern Salem county.

A considerable deposit of clay is recorded from Fort Mott on the Delaware river.[1] The section is as follows:

Section at Fort Mott.

Yellow sand and gravel,	25 ft.
Black sandy clay,	25 ft.
Dark hard clay,	45 ft.
Whitish clay,	17 ft.

The material was penetrated in a boring.

Clay-working Industry.—The clay products produced in Salem county at the present time are building brick and draintile. Stiff-mud brick are manufactured from a mixture of Alloway clay and surface loam, at Yorktown, by D. F. Haines. The product shows up well on testing. Draintile are also made at this locality. S. B. Sickler makes soft-mud common brick at Penton, and common brick have been made at Salem.

It would seem as if the clays of this county should form the basis of a much more extensive clay industry. The Alloway clay, as seen from the tests given above, forms a good, red, dense body, and should recommend itself not only for the manufacture of brick, but also for the lower grades of pottery such as earthenware and even stoneware.

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[1] N. J. Geol. Surv., 1900, p. 131.

SOMERSET COUNTY.

With the exception of a small outlier of Raritan clay east of Rocky Hill, all the clays worked in this county are of Pleistocene or post-Pleistocene age. They are generally sandy and at times even stony, but make an excellent common brick, judging from the hardness and ring of the product, although no crushing or transverse tests were made.

Somerville.—The largest of the clay pits is 1 mile northeast of Somerville (Loc. 234). The deposit is a red clay with numerous pebbles in certain portions of it. Its origin has been discussed on p. 130. The run of the bank is used and there is no stripping.

The physical characters of the material are those of a good brick clay. Thus it mixed up with 20.5 per cent. of water to a mass having an air shrinkage of 5 per cent. The average tensile strength was very high, being 297 pounds per square inch.

At cone 03 the fire shrinkage was 5 per cent. At cone 1 it is 6.6 per cent., with an absorption of 0.64 per cent. The clay became viscous at cone 8. It burns red and is worked up in a soft-mud machine. The bricks which are probably not burned above cone 05, show a linear air shrinkage of 7.3 per cent. and a fire shrinkage of 3.0 per cent. The greater air shrinkage than that obtained in the laboratory is due to their being molded softer.

North Plainfield.—Another deposit of Pleistocene clay is worked at the brickyard of D. Hand & Son, two miles north of Plainfield (Loc. 236). The clay itself is quite gritty but more sand is added to it, so that the air shrinkage is extremely low only 1.4 per cent., while the linear fire shrinkage is 5.8 per cent. The cubic air and fire shrinkages are 11.5 per cent. and 7.3 per cent., respectively. The clay burns red.

Dunellen.—At Rajotte's brickyard (Loc. 235) near Green brook just north of Dunellen, Union county, a black flood-plain and swamp clay is used. The clay is from 4 to 6 feet deep and is underlain by glacial gravel. It is said to cover 14 acres.

Rocky Hill.—Terra-cotta clay has been found east of Rocky Hill (Loc. 299) at a number of points, several of which are just across the line in Middlesex county. It varies from 7 to 14 feet in thickness, is variously colored, and is overlain by several feet of sand. At present it is dug by the Excelsior Terra Cotta Company for use in their factory at Rocky Hill.

Analysis of a very white clay. Isaac Webster.[1]

Alumina (Al_2O_3),	35.09	
Silica (SiO_2),	38.20	
Water (combined) (H_2O),	12.10	
		85.39
Clay base—		
Silica (sand),	8.60	
Titanic acid (TiO_2),	1.30	
		9.90
Fluxes—		
Potash (K_2O),	2.44	
Magnesia (MgO),	0.21	
Ferric oxide (Fe_2O_3),	1.89	
		4.54
Total,		99.83

Clay-working Industry.—Common brick are made at the three yards as already mentioned, and terra cotta is manufactured at Rocky Hill by the Excelsior Terra Cotta Company, but the clay is obtained chiefly from Middlesex county, although some of it is dug at pits a mile or two northeast of the works.

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[1] Cook & Smock, Report upon the Clays of New Jersey, 1878, p. 232.

SUSSEX COUNTY.

The clays of Sussex county so far as known are exclusively glacial or alluvial in origin, and are not extensively worked.

Newton.—A black clay containing much organic matter is dug for common brick at Newton (Loc. 285). The clay is about 8 feet in thickness and is found at the margin of the large tract of swamp land lying just north of the city. It is highly probable that clay underlies the whole of this area, although somewhat buried by swamp muck towards the center. The tract was probably a shallow lake at the close of the Glacial period. The presence of the organic matter indicates that swamp conditions prevailed to a greater or less extent when the clay was formed.

Branchville.—A sandy glacial clay of the following composition is found near Branchville:

Chemical analysis of clay near Branchville.

Silica (SiO_2),	80.03
Alumina (Al_2O_3) and ferric oxide (Fe_2O_3),	12.94
Lime (CaO),	0.48
Magnesia (MgO),	0.36
Water (H_2O),	2.67
Total determined,	96.48

Ogdensburg.—Highly calcareous clays are found on the property of A. D. Tallman, at Ogdensburg (Loc. 292), but so far as known they are not worked.

Clays are also known to underlie the drowned lands along the Wallkill river, but they are not available commercially.

Sussex (Deckertown).—Clay was formerly dug for brick along Clove brook not far from Fuller's mill.

These probably do not exhaust the localities in this county at which shallow clay deposits occur, but they include the more important ones which have been brought to the notice of the Survey.

UNION COUNTY.

Murray Hill.—A red-burning clay occurs at Murray Hill, on the property of H. Wilcox (Loc. 290). It is fairly plastic, working up with 30.8 per cent. water to a mass whose air shrinkage is 8 per cent. The tensile strength was 134 pounds per square inch. The clay had a high fire shrinkage at cone 05 of 11 per cent. and an absorption of 3.12 per cent. It burned red and steel-hard at this cone. At cone 1 it began to fuse, so that it is a very easily fusible material, but burns to a hard red brick at a rather low temperature.

Elizabethport.—Red clay for common brick,[1] 6 to 10 feet deep, has been worked at Elizabethport for a number of years, at Jacob Hammer's plant, located on south Front street and Bayway.

Berkeley Heights.—A bed of black clay, 30 feet deep and covered by 1 to 2 feet of soil, has been worked at Berkeley Heights, under lease by Kresner & Holland, for common-brick manufacture.[2] The clay is said to be free from grit and very plastic.

Linden.—A very plastic surface clay near Linden is drawn on for supplying several earthenware potters in neighboring towns. It is red burning.

Netherwood.—A very tough, stiff-working clay, requiring the admixture of large quantities of loam, has been worked at Netherwood for brick, but none were being made when the canvass for this report was undertaken.

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[1] N. J. Geol. Surv., 1898, p. 205.

[2] Ibid.

Fig. 1.

Shale pit of the National Fireproofing Company, at Port Murray, Warren county.

Fig. 2.

Outcrops of shale in the railroad cut at Port Murray.

WARREN COUNTY.

The most extensively worked deposit in this county is the Hudson shale, which is being utilized at Port Murray (Loc. 282), on the D., L. & W. railroad (Pl. LVI, Figs. 1 and 2). It is used for the manufacture of fireproofing. The shale is weathered, but not thoroughly softened, to a depth of 5 or 6 feet, and is capped by 4 to 5 feet of glacial drift. A mixture of the weathered and unweathered material is used.

The lean character of the material can be seen by the fact that it took only 18.5 per cent. of water to temper it and that it had an air shrinkage of 2 per cent. Its average tensile strength was 51 pounds per square inch. Its behavior under fire was as follows:

Burning tests of a clay shale near Port Murray.

Cone	*05*	*01*	*1*	*5*
Fire shrinkage,	1.6 %	2.4 %	4.6 %	7%
Color,	pale red	red	deep red	deep red
Absorption,	16.14%	14.67%	8.82%	3.26%

It burned steel-hard at cone 01. Even if the shale were more plastic, the material alone does not vitrify at a sufficiently low temperature to make it of value for the manufacture of paving brick.

Washington.—Clay is known to occur in this county at Washington on the property of C. Blazer (Loc. 280). It is a fairly plastic surface clay, derived by wash from the disintegrated gneiss. It worked up with 26.2 per cent. of water, and had an air shrinkage of 6.3 per cent. At cone 05 its fire shrinkage was 1 per cent., absorption 14.07 per cent., color pale red, and bricklet steel-hard, so that it ought to produce a good common brick.

Beattystown.—At the old Beattystown hematite mine (Loc. 283), on the property of L. T. Labar and neighbor, there occurs a series of colored clays, several samples of which were sent the Survey. Of these No. 1[1] might make a fair grade of brick. No.

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[1] These designations, No. 1, No. 2, etc., refer only to the numbers on the samples when received. All the clays except No. 5 were somewhat sandy.

2 might be available for the same purpose. No. 4 (Lab. 753) when burned to cone 1 is brownish red, steel-hard and has an absorption of 3.79 per cent. Another sample, No. 5 (Lab. No. 751), closely resembles the ochre in Tilton's yard, near Toms River. It is more plastic, however, and at cone 1 burned to a pinkish brick of steel-hard body, with a total shrinkage of 9.3 per cent. and an absorption of 8.66 per cent. Still another sample, No. 6 (Lab. No. 752), burns dark brown and steel-hard at cone 1, with a total shrinkage of 10 per cent. and an absorption of 2.05 per cent.

Brass Castle.—A shallow, ferruginous clay, derived by wash from decomposing gneiss rock, occurs at Brass Castle, and is worked in a small way by John Benward for the manufacture of common brick. The clay was not tested.

Alpha.—A yellow clay formed by the decomposition of the Portland cement rock (Trenton limestone formation), is dug at Alpha (Loc. 278) near the cement plant for the manufacture of brick. These are made by the soft-mud process, are of good color, and have been used in the new factory of the Alpha Portland Cement Company. The deposit is a shallow one, but covers a considerable area.

Danville.—Glacial clay is said to occur on the land of A. W. Davis, near Danville. The following is an analysis of it:

Chemical analysis of a clay. A. W. Davis, Danville.

Silica (SiO_2),	60.25
Alumina (Al_2O_3),	10.90
Ferric oxide (Fe_2O_3),	4.90
Ferrous oxide (FeO),	0.63
Lime (CaO),	5.10
Magnesia (MgO),	4.72
Alkalies (Na_2O, K_2O),	4.59
Water (H_2O),	8.50
Total,	99.59
Total fluxes,	19.94

This must be an exceedingly fusible clay.

Karrsville.—Common brick have been made intermittently at Karrsville by David E. Cole,[1] but the deposit is said to be of limited area and depth.

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[1] N. J. Geol. Surv., 1898, p. 198.

APPENDIX A.

STATISTICS OF PRODUCTION.

New Jersey ranks third in the total value of its clay products, Ohio being first and Pennsylvania second. So steadily and rapidly has the output increased that since 1897 it has nearly doubled.

The value from 1895 to 1902 is given below, the figures being taken from the reports on Mineral Resources issued by the United States Geological Survey:

Value of clay products of New Jersey from 1895 to 1902

Year.	Value.	Rank.	Proportion of United States product. Per cent.
1895,	$4,899,120	5	7.50
1896,	4,728,003	5	7.58
1897,	6,180,847	3	9.91
1898,	8,706,357	3	12.01
1899,	10,787,273	3	11.26
1900,	10,928,423	3	11.36
1901,	11,681,878	3	10.60
1902,	12,613,263	3	10.32

The detailed statistics of production taken from the same series of reports are as follows:

Clay products of New Jersey, 1898–1902.

PRODUCT.	1898.	1899.	1900.	1901.	1902.
Brick:					
Common—					
Quantity,	291,734,000	394,764,000	331,579,000	351,886,000	300,583,000
Value,	$1,422,612	$1,809,906	$1,449,694	$1,675,746	$1,506,224
Average per M.,	$4.88	$4.58	$4.37	$4.76	$5.01
Pressed—					
Quantity,	30,876,000	37,825,000	25,229,000	29,239,000	42,926,000
Value,	$568.106	$609,819	$426,692	$473,138	$552,000
Average per M.,	$18.40	$16.12	$16.91	$16.18	$12.86
Vitrified—					
Quantity,	(*a*)	(*a*)	(*a*)	2,251,000	1,014,000
Value,	(*a*)	(*a*)	(*a*)	$22,024	$10,437
Average per M.,	$14.00	$12.80	$12.43	$9.78	$10.29
Fancy or ornamental, value,	$15,852	$43,368	$4,112	$11,514	$11,407
Fire, do	$519,688	$633,158	$1,072,535	$780,327	$819,580
Stove lining, do	(*b*)	(*a*)	(*a*)	(*a*)	$8,477
Draintile, do	$13,762	(*a*)	$55,655	$22,612	$33,020
Sewer pipe, do	$34,808	$99,000	$154,481	(*a*)	(*a*)
Ornamental terra cotta, do	$635,007	$660,304	$647,884	$920,664	$861,730
Fireproofing, do	$762,370	$653,144	$873,706	$610,864	$965,047
Tile, not drain, do	$292,644	$37,123	$508,392	$486,122	$795,153
Pottery:					
Earthenware and stoneware, value,	$23,100	$59,500	$75,250	$82,009	$59,820
Yellow and rockingham ware, value,	(*a*)	(*a*)	(*a*)	(*a*)	(*a*)
C. C. ware, value,	$733,958	$751,444	$544,249	$443,455	$581,267
White granite ware, do	$483,917	$442,354	$1,139,620	$1,486,263	$1,431,270
Semivitreous porcelain ware, value,	$439,356	$372,350	$375,926	$225,962	
China, value,	(*a*)	$494,870	$577,593	$665,948	$680,368
Bone china, delft, and belleek ware, value,	$52.500	$42,000	$65,800	$270,696	$90,840
Sanitary ware, do	$1,477,192	$1,850,225	$1,843,358	$2,244,904	$2,807,322
Porcelain electrical supplies, value,	$182,000	$154,807	$285,466	$342,479	$358,496
Miscellaneous, *c*, value,	$1,049,485	$2,073,901	*d* $828,010	*e* $917,151	*f* $1,040,805
Total value,	$8,706,357	$10,787,273	$10,928,423	$11,681,878	$12,613,263
Number of operating firms reporting,	139	159	149	160	154
Rank of State,	3	3	3	3	3

a Included in miscellaneous.

b Stove lining not separately classified prior to 1899.

c Includes all products not otherwise classified, and those made by less than three producers, in order that the operations of individual establishments may not be disclosed.

d Includes pottery for New Hampshire.

e Also includes enameled brick valued at $177,128.

f Also includes enameled brick valued at $202,740.

The pottery industry of Trenton deserves some special mention on account of its size and importance. Thus, in 1901 and 1902 the value of the wares produced in Trenton alone was as follows:

Value of the Trenton pottery industry.

	1901.	*1902.*
C. C. ware,	$443,455	$581,267
White granite ware,	1,485,263	1,426,270
Semivitreous porcelain,	225,962	
China,	660,948	680,368
Bone china, delft, and belleek,	270,696	90,840
Sanitary ware,	1,788,030	2,408,339
Porcelain electrical supplies,	399,279	358,496
Miscellaneous,	106,060	151,831
	$5,319,693	$5,697,411

The total value of the pottery production of the United States in 1901 was $22,463,860, so that Trenton produced 23.68 per cent. of this, exceeding the production of East Liverpool, the other great pottery centre of the United States, by 0.06 per cent. In 1902 Trenton produced 23.61 per cent. of the whole pottery product, exceeding East Liverpool by 0.41 per cent. The entire New Jersey pottery production for 1902, as reported by fifty-one firms, was valued at $6,192,959, which was 25.67 per cent. of the United States production.

The following list also gives the rank of New Jersey in the manufacture of other lines of clay products in 1901 and 1902, so far as was obtainable:

Rank of New Jersey in various lines of clay products.

Product.	*Rank in 1901.*	*Rank in 1902.*
Common brick,	5	9
Front brick,	3	3
Paving brick,	13	14
Fancy brick,	7	6
Fire brick,	3	3
Draintile,	10	8
Terra cotta,	1	2
Fireproofing.	1	1
Tile, not drain,	3	2
Pottery,	2	2
Raw clay,	1	1

We therefore see that in 1901 New Jersey ranked first in the production of terra cotta, fireproofing and raw clay, and in 1902 first in fireproofing and raw clay and second in terra cotta, tile (not drain) and pottery.

APPENDIX B.

BIBLIOGRAPHY OF CLAY LITERATURE.

In the following bibliography no attempt is made at completeness, it being intended simply to give the titles of the more important and accessible works relating to the technology of clay and the occurrence of clay in different localities in the United States. Any one desiring a more detailed list of titles can easily find it by consulting the Bibliography by Branner, referred to below:

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APPENDIX C—*Chemical Analyses.*

In the following table there are given all the chemical analyses of New Jersey clay which are at hand. In the first column is a reference to the page on which the analysis is given. Numbers preceded by C, as C 243, refer to the pages in the Report on the Clay Deposits of Woodbridge, South Amboy and other places in New Jersey, 1878, Cook and Smock. Numbers alone refer to pages in the present report. Analyses without numbers are from unpublished records in the files of the Survey. The analyses in the earlier Clay Report were made by Mr. Edwin H. Bogardus; those from the files of the Survey were made chiefly by Dr. Wm. S. Myers, of New Brunswick; the others are by Dr. Heinrich Ries.

The asterisk (*) indicates that the Titanium oxide is included in the Alumina.

Page in Report.	LOCALITY AND OWNER.	MATERIAL.	Sand.	Combined Silica. SiO_2	Alumina. Al_2O_3	Ferric Oxide. Fe_2O_3	Titanium Oxide. TiO_2	Calcium Oxide. CaO	Magnesium Oxide. MgO	Potassium Oxide. K_2O	Sodium Oxide. Na_2O	Loss on Ignition.	Mechanically Combined Water.
	BERGEN COUNTY.												
374	Garfield—Campbell, Morrell & Co., ...	Brick clay, ...	73.71		11.09	4.30	....	2.31	1.71	1.87	1.42	3.93	....
373	Hackensack, ...	do	59.69		24.05		0.44	1.63	2.03	0.54	2.39	4.85	0.80
·373	Little Ferry, ...	do	66.67		18.27	3.11	0.85	1.18	1.09	2.92	1.30	4.03	....
	BURLINGTON COUNTY.												
C 243 378	Florence—Joshua Eayre, ...	White clay, ...	40.50	26.57	21.06	1.98	....	....	0.60	2.47	0.21	5.80	0.80
C 241 381	Kinkora—Mulford & Pine, ...	Black sandy clay, ...	31.80	25.50	17.70	6.40	0.90	0.16	0.65	1.54	....	11.80	3.50
	CAMDEN COUNTY.												
396	Camden—Budd Bros., ...	Brick mixture, ...	66.66		14.15	3.43	....	2.15	0.38	2.32	1.38	8.40	....
405	Fish House—Hatch & Son, ...	do	65.53		17.21	5.23	....	0.95	0.31	2.84	0.96	4.54	....
397	Merchantville, ...	Unworked clay, ...	67.02		17.10	4.41	....	0.93	0.38	1.60		8.56	....
392	Palmyra—H. Hylton, ...	Fire clay, ...	77.72		15.74	0.49	....	tr	0.81	tr	tr	5.62	....
C 248 393	do	do	56.80	17.50	18.11*	1.09	*	0.11	....	0.76	0.20	5.50	0.40
C 247 393	do	Sand, ...	91.80		5.60	....	....	....	....	0.20	....	2.20	....
C 259 403	Tansborough, ...	Unworked clay, ...	34.50	29.50	23.30*	1.50	*	....	....	1.77	0.16	7.00	1.60

Page in Report.	LOCALITY AND OWNER.	MATERIAL.	Sand.	Combined Silica. SiO₂	Alumina. Al₂O₃	Ferric Oxide. Fe₂O₃	Titanium Oxide. TiO₂	Calcium Oxide. CaO	Magnesium Oxide. MgO	Potassium Oxide. K₂O	Sodium Oxide. Na₂O	Loss on Ignition.	Mechanically Combined Water.
	CUMBERLAND COUNTY.												
415	Buckshutem—A. E. Burchem, ...	Brick clay, ...	72.37		14.40	3.43	....	0.75	0.49	1.60		6.70	....
409	Clayville—Clayville Mining and Brick Co., ...	Buff-burning clay, ..	66.12		22.07	1.31	....	0.50	0.25	1.81		7.94	....
	GLOUCESTER COUNTY.												
C 261 419	Billingsport, ...	Dark sandy clay,....	56.00	16.20	15.00*	1.20	*	....	0.32	1.68	0.39	7.70	1.10
	HUNTERDON COUNTY.												
426	Holland—A. C. Rapp, ...	Unworked clay, ...	54.97		33.06		0.24	0.20	0.38	0.82	0.61	9.70	0.26
	MERCER COUNTY.												
432	Robbinsville, ...	Unworked clay, ...	60.10		21.13	6.07	....	....	....	....	....	8.90	....
C 236 430	Trenton—A. C. Anderson & Co., ...	Unworked clay, ...	45.30		37.10	1.30	1.40	0.17	0.22	....	....	13.40	....
	MIDDLESEX COUNTY.												
C 160	Bonhamtown—M. Compton, ...	Coarse fire sand, ...	98.00		1.45		....	tr	....	0.20	tr	0.25	....
C 160	do	Fine fire sand, ...	96.40		2.10		....	....	....	....	....	....	....
C 165	Bonhamtown—B. Ellison, ...	Sandy clay, ...	77.90		15.60*	1.00	*	....	....	0.25	....	5.20	....
C 166	do	do	40.43	29.14	20.45	1.21	1.61	tr	0.51	0.17	0.48	5.87	....
C 164	Bonhamtown—Freeman & Vanderhover, ...	White clay, ...	47.10		36.33	1.07	1.60	....	....	0.20	....	13.60	....
457	Burt Creek—J. R. Crossman, ...	Fire clay, ...	40.64		41.19	3.27	....	0.65	tr	tr	tr	14.74	....
C 198	Burt Creek—Geo. Such, ...	Washed white clay,..	1.50	42.90	38.34	0.86	1.20	....	....	0.26	0.18	13.50	1.10
C 224	Cheesequake—Otto Ernst, ...	Stoneware clay, ...	39.95	28.80	20.20	1.45	0.90	tr	0.50	1.58	....	5.80	1.20
C 226	Cheesequake—Noah Furman, ...	do	37.85	29.23	21.13	1.68	....	....	0.22	1.81	0.18	6.81	0.69
446	Florida Grove—McIlose Bros., ...	Sandy fire clay, ...	69.78		19.86	0.62	1.96	(1.24)				6.54	....
C 135	Florida Grove—E. F. Roberts, ...	No. 1 fire clay,......	5.20	40.40	38.40*	1.20	*	0.22	0.25	0.59	....	12.50	1.30

Page in Report.	Locality and Owner.	Material.	Sand.	Combined Silica.	Alumina.	Ferric Oxide.	Titanium Oxide.	Calcium Oxide.	Magnesium Oxide.	Potassium Oxide.	Sodium Oxide.	Loss on Ignition.	Mechanically Combined Water.
				SiO₂	Al₂O₃	Fe₂O₃	TiO₂	CaO	MgO	K₂O	Na₂O		
	Middlesex County—*Con.*												
C 181	Old Bridge—A. J. Disbrow,	Unworked clay,	44.80	24.55	19.85	1.00	1.00	......	......	1.90	0.32	5.70	0.90
C 130	Perth Amboy—Merritt,	So-called kaolin,	77.10		17.10		......	......	......	1.30	......	4.50	......
C 172	Piscataway—W. N. Weidner,	White clay,	0.71	45.61	39.04	1.13	......	......	......	2.26	0.25	10.90	......
C 151	Sand Hills—Chas. A. Campbell & Co.,	White fire clay,	12.20	36.20	35.94	0.96	1.50	......	......	0.08	......	12.10	1.10
C 145	Sand Hills—Crossman Clay Co.,	Top-white clay,	64.00		29.08*	1.12	*	......	......	2.64	......	6.80	......
C 146	do	No. 1 fire clay,	10.50	37.85	35.75	0.95	1.60	......	tr	0.37	......	12.30	1.00
C 146	do	No. 2 fire clay,	......	......	......	0.78	......	......	......	0.21	......	7.00	
C 154	R. N. & H. Valentine,	Blue fire clay,	8.10	39.80	36.34*	1.01	*	......	0.04	0.15	......	12.90	1.20
C 156	do	Fire sand,	96.00	......	4.20		......	......	......	......	......	......	......
C 186	Sayreville—Sayre & Fisher Co.,	Front-brick clay,	27.80	28.30	27.42	2.68	1.00	......	0.18	2.71	......	6.60	2.90
C 189	do	No. 1 fire clay,	3.10	41.10	38.66	0.74	1.20	......	......	0.28	0.18	13.55	1.00
467	do	Common-brick clay,	60.18		23.23	3.27	......	1.00	0.67	2.58	0.80	8.54	......
C 206	South Amboy—Mrs Clark,	Stoneware clay,	53.20	19.50	17.58*	1.42	*	tr	0.43	2.24	......	4.50	1.20
C 201	South Amboy—E. F. & J. M. Roberts,	No. 1 fire clay,	0.70	42.71	39.24	0.46	1.60	0.20	......	0.47	0.42	13.32	1.58
C 203	do	Buff paper clay,	0.20	44.20	39.14	0.45	1.05	......	......	0.25	......	14.05	0.90
C 210	South Amboy—E. R. Rose & Son,	Stoneware clay,	37.10	28.60	20.12	1.38	1.10	......	0.29	1.50	tr	7.22	4.18
C 175	Weston Mills—Island Farm,	White clay,	0.50	45.20	34.85	1.35	1.40	0.25	tr	0.12	tr	13.60	2.80
C 116	Woodbridge—Chas. Anness & Son,	No. 1 fire clay,	20.60	34.30	31.66*	0.74	*	......	......	1.53	......	10.50	0.60
441	Woodbridge—Anness & Potter,	No. 1 fire clay (raw),	51.56		33.13	0.78	1.91	tr	tr	tr	tr	12.50	......
441	do	do (burned),	59.00		37.91	0.89	2.19	......	......	......	......	......	......
456	do	Top-sandy clay,	68.67		21.46	0.78	1.34	(		1.35	)	6.40	......
C 113	Woodbridge—W. H. P. Benton,	Top-sandy clay,	29.10	33.00	23.80	1.60	1.70	tr	0.57	2.01	0.76	6.70	1.00
C 51 } 443 }	do	No. 1 fire clay,	1.41	42.40	37.92	1.05	1.41	......	......	0.35	0.37	14.60	......
C 82	Woodbridge—W. H. Berry,	Sewer-pipe clay,	68.38		20.11	1.71	1.01	......	0.73	2.58	......	5.55	......
C 83	do	Retort clay,	6.51	41.18	36.52	1.11	1.32	......	......	0.28	0.16	11.30	1.50
C 107	Woodbridge—H. Cutter & Sons,	Dark sandy clay,	56.00		20.75	1.60	0.95	0.22	0.18	0.91	0.22	10.67	2.40
C 51 } 443 }	do	Fire clay,	1.10	44.26	37.94	0.96	1.30	tr	0.11	0.15	0.00	14.10	......
C 51 } 443 }	do	Ware clay,	0.80	44.77	38.87	1.14	1.30	tr	0.11	0.16	0.00	12.97	......
443	Woodbridge—W. H. Cutter,	Ball clay,	45.76		39.05	tr	......	0.95	0.04	tr	tr	14.46	......
	do	do	43.65		42.19		......	......	......	......	......	14.68	......
	do	Retort clay,	43.70		40.45		......	......	......	......	......	15.16	......
	do	Red-spotted clay,	48.22		38.43		......	......	......	......	......	13.68	......
	do	Bottom-sandy clay,	62.52		23.13		......	......	......	......	......	9.30	......

Page in Report.	Locality and Owner.	Material.	Sand.	Combined Silica. SiO$_2$	Alumina. Al$_2$O$_3$	Ferric Oxide. Fe$_2$O$_3$	Titanium Oxide. TiO$_2$	Calcium Oxide. CaO	Magnesium Oxide. MgO	Potassium Oxide. K$_2$O	Sodium Oxide. Na$_2$O	Loss on Ignition.	Mechanically Combined Water.
	MIDDLESEX COUNTY—*Con.*												
C 79	Woodbridge—Wm. B. Dixon, ...	Fire clay, ...	28.81	31.12	26.95	1.24	1.90	....	0.07	tr	tr	9.63	0.57
C 62 469	Woodbridge—Edgar Bros., ...	"Feldspar,"	57.41	16.59	17.55	0.54	0.96	....	....	0.12	0.21	6.30	....
C 51 443	Woodbridge—A. Hall & Son, ...	No. 1 fire clay, ...	5.80	42.82	36.49	0.78	1.12	....	0.11	0.45	....	12.42	....
C 127	Woodbridge—I. Inslee, Jr., ...	Blue clay, ...	54.80		28.80	2.20	1.00	0.20	0.64	2.97	....	7.80	1.50
C 62 469	Woodbridge—Knickerbocker Life Ins. Co., ...	"Feldspar,"	77.40		16.07	0.53	....	....	0.25	0.15	....	4.30	....
C 57 443	Woodbridge—Loughridge & Powers, ..	Ware clay, ...	0.50	42.88	40.14	0.51	1.42	0.10	....	0.41	0.08	13.59	....
C 93	do ..	Extra-sandy clay, ...	51.80	20.00	18.92	0.88	....	....	....	0.48	....	6.70	0.50
	do ..	Fire clay, ...	10.57	34.23	39.03		1.44	0.06	0.28	0.25	0.53	13.91	0.67
458	Woodbridge—Henry Maurer & Son, ..	Fire mortar clay, ...	67.26		23.36	1.63	....	0.25	tr	0.65		6.94	....
C 99	Woodbridge—S. A. Meeker, ...	Stoneware clay, ...	48.40	19.44	21.83	1.57	....	0.28	0.24	2.24	....	5.90	0.80
	Woodbridge—J. P. Prall, ...	Sandy clay, ...	50.67		37.29		....	....	....	....	....	12.65	....
	do	Fire clay, ...	44.05		41.84		....	....	....	....	....	14.63	....
	do	Retort clay, ...	43.18		39.72		....	....	....	....	....	15.10	....
	do	Speckled clay, ...	58.75		30.95		....	....	....	....	....	7.60	....
C 89	Woodbridge—Salamander Co., ...	Black pipe clay, ...	61.25		22.20	5.30	....	....	0.94	2.44	....	8.00	lignite 0.30
440	Woodbridge—M. D. Valentine & Bros. Co., ...	No. 1 fire clay (raw),	50.60		34.35	0.78	1.62	tr	tr	....	....	12.90	....
440	do	do (burned),	57.93		39.33	0.89	1.85	....	....	....	....	....	....
	OCEAN COUNTY.												
484	Mayetta—Eastern Hydraulic P. B. Co.	Unworked clay, ...	76.40		13.29	0.82	....	0.95	0.61	1.80		5.10	....
489	Toms River—E. R. Tilton, ...	Yellow ochre clay, ..	31.96		21.93	31.39	....	0.45	0.18	....	....	12.92	....
485	Tuckerton, ...	Unworked clay, ...	58.15		27.37	4.83	....	....	....	....	....	9.31	....

Page in Report.	LOCALITY AND OWNER.	MATERIAL.	Sand.	Combined. Silica. SiO$_2$	Alumina. Al$_2$O$_3$	Ferric Oxide. Fe$_2$O$_3$	Titanium Oxide. TiO$_2$	Calcium Oxide. CaO	Magnesium Oxide. MgO	Potassium Oxide. K$_2$O	Sodium Oxide. Na$_2$O	Loss on Ignition.	Mechanically Combined Water.
	SALEM COUNTY.												
500	Alloway—R. R. cut, ...	Unworked clay, ...	67.40		19.62	2.45	....	0.25	0.34	....	....	8.08	....
500	Woodstown, ...	....	52.30		32.01	1.59	....	....	....	....	....	12.02	....
496	Yorktown—D. Haines, ...	Brick mixture, ...	68.96		17.87	3.27	....	0.25	0.25	2.10		6.95	....
	SOMERSET COUNTY.												
C 232 } 504 }	Rocky Hill—Isaac Webster, ...	Terra-cotta clay, ...	8.60	38.20	35.09	1.89	1.30	....	0.21	2.44	....	12.10	....
	SUSSEX COUNTY.												
505	Branchville, ...	Unworked clay, ...	80.03		12.94		....	0.48	0.36	....	....	2.67	....
	WARREN COUNTY.												
508	Danville—A. W. Davis, ...	Unworked clay, ...	60.25		10.90	4.90	FeO 0.63	5.10	4.72	4.59		8.50	....

All the physical tests as described in detail in Chapter XIX are tabulated below. They are arranged alphabetically by localities under the respective county headings. The locality number, the laboratory number and the page in the report on which the clay is more fully discussed are given in the first three columns. By means of the locality number, the exact location of each clay sample can be determined from the geological maps, Plates Xa, XI, XII, XIII.

The asterisk, *, indicates that the bricklet when burned became steel-hard at the cone number given at the head of the column. F. S., fire shrinkage. Abs., per cent. of water absorbed.

Locality Number.	Laboratory Number.	Page in Report.	Locality.	Owner.	Material.	Water required, per cent.	Air shrinkage.	Tensile Strength.				Cone 05.			Cone 03.			Cone 1.			Cone 3.			Cone 5.			Cone 8.			Cone 10.			Additional Tests.
								Min.	Max.	Aver.	No. Tested.	F. S.	Color.	Abs.	F. S.	Color.	Abs.	F. S.	Color.	Abs.	F. S.	Color.	Abs.	F. S.	Color.	Abs.	F. S.	Color.	Abs.	F. S.	Color.	Abs.	
			Atlantic County.																														
275	......	372	Bakersville,	Somers Brick Co.,	Brick clay,	......	......	......	......	105	......	......	......	......	......	......	......	15.5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	
197	701	369	Da Costa,	David Doerr,	Brick clay,	30.80	6.6	177	232	206	7	0.7	Pink red,	16.56	......	......	......	2.0	Light red,	15.72	4.0	......	10.87	4.0*	Red,	8.34	......	......	......	......	......	......	
197	667	369	do	do	do	29.10	7.5	185	199	192	5	0.5	Pale yellow,	17.20	......	......	......	2.5*	Yellow,	12.04	2.5*	Buff,	12.01	2.5*	Buff,	......	5.1	Deep buff,	low	......	......	......	
195	634	370	Mays Landing,	Atlantic Brick Mfg. Co.,	Buff-brick clay,	23.17	7.5	249	313	282	10	......	......	......	......	......	......	2.8	Yellow,	8.09	4.1	......	3.50	4.5	......	3.08	6.5	......	0.84	7.1	......	0.18	
195	642	370	do	do	Pompeian-brick clay,	23.40	8.0	262	320	293	10	0.3	......	11.65	......	......	......	3.3	......	6.20	4.0	......	3.60	4.0	......	4.36	5.0	......	......	......	......	......	
199	681	371	Pleasant Mills,	......	Unworked clay,	high	6.6	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	2.7	......	13.25	......	......	......	......	......	......	
			Bergen County.																														
301	......	374	Kingsland,	Kingsland Brick Co.,	Red shale,	21.00	2.0	......	164	150	12	2.0	Brownish red,	6.56	4.0*	Red,	2.03	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	Viscous, cone 1.
291	618	373	Little Ferry,	Mehrhoff Brick Co.,	Brick clay,	22.00	6.0	......	......	108	......	4.3	Red,	7.88	......	......	......	8.6*	Red,	0.10	7.0	......	......	......	......	......	......	......	......	......	......	......	Cone 01—See p. 373.
			Burlington County.																														
120	623	379	Assiscunk Creek,	Jos. Scott,	Unworked clay,	19.20	4.6	......	......	95	......	1.4	Buff,	15.01	......	......	......	......	......	......	......	......	......	2.0*	Deep buff,	10.25	4.0	Buff,	5.25	5.4	Buff,	5.07	
120	654	379	do	do	do	23.80	5.0	68	94	80	10	......	......	......	1.0	Pale red,	15.94	2.0*	Light red,	13.61	3.0	Red,	12.42	......	......	......	......	......	......	5.6	Gray,	2.19	
121	640	380	do	Hay,	do	28.00	5.3	73	77	75	2	0.7	Light pink,	18.04	3.7*	Red,	14.33	......	......	......	6.0	Red pink,	10.12	......	......	......	......	......	......	......	......	......	
109	600	382	Bordentown,	Bordentown Brick Co.,	Brick clay,	23.40	8.8	235	275	251	12	8.3	Deep red,	10.74	......	......	......	11.8	......	4.01	11.8	......	......	......	......	......	......	......	......	......	......	......	Cone 01—See p. 382.
132	622	376	Bridgeboro,	J. W. Paxson Co.,	Terra-cotta clay,	22.00	5.3	100	110	104	10	1.3	Pale red,	13.81	......	......	......	......	......	......	4.7*	Light red,	9.88	4.70	Dark red,	9.13	6.7	Gray,	2.96	......	......	......	
132	630	377	do	do	White sandy clay,	30.80	4.3	111	136	119	3	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	2.7*	Buff,	7.99	Cone 15—See p. 377.
131	614	385	do	......	Unworked clay,	27.10	7.0	138	154	145	3	0.3	Mottled red,	15.05	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	Cone 01—See p. 385.
118	......	388	Columbus,	......	Unworked clay,	......	......	......	......	......	......	Total 6.6	......	30.47	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	
127	651	389	Edgewater Park,	Henry Adams,	Brick clay,	22.60	5.5	149	231	185	8	1.8	Red,	15.34	......	......	......	2.5*	......	11.97	......	......	......	5.8	Deep red,	2.86	......	......	......	......	......	......	
112	652	380	Fieldsborough,	S. Graham & Co.,	Brick clay,	27.80	7.0	145	193	168	8	......	......	......	5.0*	Pale red,	11.89	5.6	Pale red,	7.12	5.6	Pale red,	......	......	......	......	......	......	......	......	......	......	
115	......	389	Kinkora,	Jos. Martin,	Brick mixture,	......	4.3	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	See p. 389.
149	648	383	Maple Shade,	A. Reeves,	Brick clay,	32.80	9.0	......	......	......	......	......	......	......	......	......	......	4.0*	Red,	10.06	......	......	......	......	......	......	......	......	......	......	......	......	Cone 01—See p. 383.
149	647	384	do	do	Brick mixture,	28.60	7.5	259	313	282	8	......	......	......	......	......	......	4.5*	Red,	10.58	......	......	......	......	......	......	viscous	......	......	......	......	......	
128	610	385	Moorestown,	......	Unworked clay,	35.00	9.0	114	139	127	2	1.3	Light red,	17.89	......	......	......	8.0*	Light red,	4.85	......	......	......	......	......	......	......	......	......	......	......	......	
129	608	386	do	......	do	29.02	8.8	......	......	......	......	1.2	Light red,	16.34	1.2	Light red,	16.41	4.2*	Red,	9.95	......	......	......	......	......	......	......	......	......	......	......	......	
			Camden County.																														
148	633	400	Bellmawr,	......	Unworked clay,	20.80	9.0	156	211	195	10	......	......	......	3.0	Red,	14.55	3.0	Red,	12.71	3.5*	Red,	12.06	4.3	Red brown,	7.47	......	......	......		viscous		
202	692	402	Blue Anchor,	......	Terra-cotta clay,	38.20	7.3	133	154	146	4	......	......	......	......	......	......	......	......	......	......	......	......	6.3	Buff,	5.09	7.6	Buff,	4.30	9.2	Gray buff,	1.90	
143	620	395	Camden,	Budd Bros.,	Brick mixture,	20.00	6.0	146	177	156	12	1.3	Red,	16.54	......	......	......	2.6	Red,	12.68	2.6*	Red,	10.66	2.3	Red,	10.17	......	......	......	......	......	......	Cone 01—See p. 395.
143	624	395	do	do	Brick clay,	24.00	6.0	146	185	164	10	0.5	Red,	9.36	......	......	......	2.0	Red,	8.62	2.0*	Red,	10.75	......	......	......	......	......	......	......	......	......	Viscous, cone 8.
144	650	397	Collingswood,	Dobbs & Son,	Brick clay,	34.90	10.0	200	354	286	10	3.3*	Red,	11.12	......	......	......	3.3	Red,	9.92	......	......	......	......	......	......	......	......	......	......	viscous	......	
142	604	397	Cooperstown,	......	Unworked clay,	25.00	6.0	......	......	......	......	1.0	Red,	22.61	......	......	......	3.6*	......	15.85	......	......	......	......	......	......	......	......	......	......	......	......	Cone 01—See p. 397.
135	643	394	Fish House,	......	Unworked clay,	21.90	3.3	......	......	80	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	4.7*	Buff,	8.52	Viscous, cone 27.
136	703	394	do	......	do	19.20	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	2.0	......	12.93	......	......	......	......	......	......	
137	668	403	do	Hatch & Son,	Brick clay,	37.10	6.0	231	266	243	6	......	......	......	7.3*	Red,	5.96	7.6	......	4.90	......	......	......	......	......	......	......	......	......	......	......	......	
137	639	403	do	do	Brick mixture,	27.50	7.0	240	315	258	12	3.0	......	9.96	5.0*	Red,	6.83	6.0	Red brown,	3.08	6.3	Red brown,	0.02	......	......	......	......	......	......	......	......	......	
145	715	398	Haddonfield,	......	Unworked clay,	30.70	6.6	144	188	168	6	0.4	Buff,	19.98	......	......	......	......	......	......	......	......	......	4.9*	Red buff,	7.70	......	......	......	......	......	......	
147	635	399	do	......	do	29.00	7.0	......	......	243	......	......	......	......	3.3	Pink red,	17.24	5.0*	Light red,	10.31	......	......	......	......	......	......	......	......	......	......	......	......	
158	612	399	Little Timber Creek,	......	do	22.80	7.0	......	......	......	......	2.0	Light red,	18.28	4.0	Light red,	15.72	8.0*	Red,	8.42	......	......	......	......	......	......	......	......	......	......	......	......	
140	605	396	Merchantville,	......	do	23.00	8.3	228	291	257	10	1.7	Light red,	14.95	......	......	......	2.0*	Red,	5.57	2.3	Red,	5.8	......	......	......		viscous		......	......	......	See p. 396.
139	631	393	Morris Station,	P. Erato,	Foundry clay,	17.70	2.0	......	......	......	......	......	......	......	......	......	......	......	......	......	1.3	......	15.41	......	......	......	......	......	......	......	......	......	See p. 394.
134	621	391	Palmyra,	H. Hylton,	Fire clay,	20.00	5.3	63	70	65	10	1.3	Buff,	......	......	......	......	......	......	......	......	......	......	1.3	Buff,	14.52	2.0*	Buff,	12.82	......	......	......	See p. 391.
152	714	390	Pensauken Creek,	......	Buff clay,	38.50	8.3	118	131	126	......	......	......	......	......	......	......	7.0*	Red,	8.19	......	......	......	......	......	......	......	......	......	......	......	......	
146	638	398	Westmount,	......	Undeveloped clay,	......	......	......	......	......	......	......	......	......	......	......	......	11.2*	Red,	10.22	......	......	......	......	......	......	......	......	......	......	......	......	
201	657	401	Winslow,	Eastern Hydraulic Press Brick Co.,	Front-brick clay,	37.50	5.5	180	211	196	4	......	......	......	......	......	......	6.5	Buff,	12.96	......	......	......	......	......	......	9.1*	Buff,	4.01	......	......	......	See p. 401.
......	411	402	do	do	Brick mixture,	......	6.6	110	130	120	......	......	......	......	......	......	......	5.4*	Deep buff,	......	......	......	......	6.0	Yellow brown,	slight	6.4	Deep buff,	slight	......	......	......	See p. 402.
			Cape May County.																														
189	705	406	Woodbine,	Bushnell & Westcott,	Brick clay,	21.40	4.3	86	92	90	6	......	......	......	......	......	......	1.0*	Red,	12.77	......	......	......	......	......	......	......	......	......	3.7	Gray brown,	......	
189	678	406	do	do	do	27.80	6.0	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	5.3*	Light buff,	6.33	4.6	Gray buff,	5.45	......	......	......	See p. 406.

Locality Number.	Laboratory Number.	Page in Report.	Locality.	Owner.	Material.	Water required, per cent.	Air shrinkage.	Tensile Strength.				Cone 05.			Cone 03.			Cone 1.			Cone 3.			Cone 5.			Cone 8.			Cone 10.			Additional Tests.
								Min.	Max.	Aver.	No. Tested.	F. S.	Color.	Abs.	F. S.	Color.	Abs.	F. S.	Color.	Abs.	F. S.	Color.	Abs.	F. S.	Color.	Abs.	F. S.	Color.	Abs.	F. S.	Color.	Abs.	
			Cumberland County.																														
188	660	416	Belleplain,	Greenlee & Hand,	Brick clay,	22.90	5.3	136	162	148	3	......	......	......	......	......	......	1.7	Pink red,	11.98	......	......	......	2.7*	Red,	10.82	......	......	......	......	......	......	
191	619	412	Bridgeton,	B. Erickson,	do	30.00	7.0	121	146	133	12	3.6	Pale red,	14.81	......	......	......	5.3*	Red,	7.96	7.6	Red,	5.57	7.6	Red,	4.19	......	......	......	......	......	......	
190	664	413	do	......	Unworked clay,	26.00	6.0	208	232	219	4	......	......	......	......	......	......	4.3*	Light red,	7.51	......	......	......	7.3	Red,	2.76	......	......	......	......	Gray,	......	Cone 10—Loses shape.
180	646	415	Buckshutem,	A. E. Burchem,	Brick clay,	27.20	7.0	266	351	291	12	3.3	Red,	12.46	5.0*	Light red,	9.41	6.0	Brick red,	5.50	6.3	Dark red,	4.48	7.0	Deep red,	3.51	......	......	......	......	......	......	
181	645	415	do	Hess & Golden,	do	25.20	10.0	252	338	289	12	2.0	Red,	13.13	2.0*	Light red,	9.05	4.0	Red,	6.29	4.0	Red,	4.24	4.3	Deep red,	2.86	......	......	......	......	......	......	
186	704	412	Carmel,	Miller,	Undeveloped clay,	28.10	6.0	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	4.0	Buff,	7.68	......	......	......	......	......	......	
183	653	408	Clayville,	Clayville Mining and Brick Co.,	Conduit clay,	32.30	4.0	144	181	163	10	......	......	......	4.6	Yellow white,	13.07	7.3*	Buff,	6.14	8.0	Buff,	8.34	......	......	......	10.0	Green gray,	0.42	8.0	Gray,	0.46	See p. 409.
182	661	409	Millville,	Perth Amboy Terra Cotta Co.,	Terra-cotta clay,	36.40	6.6	283	289	286	2	......	......	......	......	......	......	......	......	......	......	......	......	3.4*	Light buff,	9.46	4.0	Buff,	8.78	......	......	......	
178	671	410	do	......	Unworked clay,	31.70	7.3	......	......	......	......	......	......	......	......	......	......	3.7*	......	8.25	......	......	......	......	......	......	......	......	......	7.7	Gray,	vit'fied	
187	676	410	do	......	do	34.00	8.6	154	157	155	3	......	......	......	......	......	......	......	......	......	......	......	......	7.4	Buff,	3.26	7.7	Buff,	......	8.4	Deep buff,	1.80	See p. 411.
185	682	411	Rosenhayn,	Kilborn & Gibson,	Brick clay,	32.40	8.0	150	165	158	7	......	......	......	......	......	......	5.3*	Red,	10.82	......	......	......	8.0	Red,	4.68	7.3	Gray,	0.01	......	......	......	
185	683	412	do	do	do	28.90	8.6	118	152	127	12	1.4	Pale red,	......	......	......	......	5.4*	Buff red,	slight	6.0	Deep buff,	......	6.0	......	......	6.7	......	......	......	......	......	See p. 412.
184	669	416	Vineland,	J. A. Hobart,	do	36.00	6.3	......	......	133	3	......	......	......	3.7*	Red,	16.29	4.4*	Red,	13.00	......	......	......	5.3	Deep red,	10.35	......	......	......	......	......	......	
184	663	417	do	do	do	28.50	5.3	......	......	......	......	0.7	Pale red,	16.94	2.0	......	17.32	2.7*	Reddish,	13.49	......	......	......	......	......	......	......	......	......	......	......	......	See p. 417.
			Gloucester County.																														
175	687	422	Ewan Mills,	......	Unworked clay,	32.10	9.3	181	239	208	6	......	......	......	......	......	......	2.7*	Yellow,	5.40	......	......	......	4.7	Gray brown,	2.21	......	......	......	......	......	......	Viscous, cone 12.
176	693	421	Harrisonville,	......	do	47.70	8.3	371	454	405	3	......	......	......	......	......	......	5.7*	Light red,	......	......	......	......	......	......	......	......	......	......	......	......	......	See p. 422.
173	679	422	do	......	Talc-like clay,	38.50	5.0	......	......	low	......	1.0	White,	28.73	......	......	......	3.0	Pink buff,	24.65	......	......	......	3.0	Light buff,	20.61	......	......	......	......	......	......	
157	613	420	Woodbury,	......	Unworked clay,	28.00	11.0	162	255	193	10	4.3*	Pale red,	11.23	......	......	......	5.3	Red,	6.88	6.3	Deep red,	3.03	......	......	......	viscous	......	......	......	......	......	See p. 420.
156	717	421	do	Thackara,	Brick clay,	40.50	9.0	133	136	134	3	4.3*	Red,	11.28	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	See p. 421.
			Hunterdon County.																														
276	726	425	Flemington,	G. C. Pedrick,	Brick clay,	23.90	3.5	137	171	159	10	1.1	Red,	12.34	......	......	......	7.1*	Dark red,	4.94	7.1	Dark red,	3.90										
281	733	426	Junction,	C. N. Moore,	Unworked clay,	19.00	......	......	......	......	......	4.0	Yellowish pink,	18.29	......	......	......	5.0	Light red,	10.23	......	......	......	12.0*	Dark brown,	0.95	......	......	......	......	......	......	
			Mercer County.																														
......	732	433	Glen Moore,	G. C. Macauley,	Clayey sand,	......	......	......	......	......	......	......	......	......	......	......	......		White,	20.96	......	......	......	......	......	......	......	......	......	......	......	......	
194	609	430	Hightstown,	Reed Bros.,	Brick clay,	34.00	6.6	......	......	......	......	......	......	......	3.4	Pale red,	16.66	5.4*	Red,	10.59	5.4	Red,	......	6.4	Fused specks,	......	......	......	......	......	......	......	See p. 431.
101	629	429	Trenton (Dogtown),	J. J. Moon,	Fire clay,	18.00	5.3	79	96	85	10	......	......	......	......	......	......	......	......	......	7.3*	White,	13.00	......	......	......	8.7	Cream white,	8.64	......	......	......	Vitrifies, cone 27; see p. 430.
101	632	429	do	do	No. 1 sagger clay,	28.50	4.6	......	......	90	......	1.4	Pink red,	19.82	3.0	Pink red,	20.00	......	......	......	6.0	Pink red,	13.63	7.4*	Light red,	8.26	9.4	......	......		vitrified		
101	644	429	do	do	Wad clay,	38.50	6.0	65	85	72	10	......	......	......	......	......	......	8.0*	Gray,	15.39	9.3	Gray,	11.73	10.0	Gray,	11.33	11.6	Gray,	3.71	......	......	......	Viscous, cone 30.
101	710	429	do	do	No. 2 sagger clay,	......	7.0	......	......	......	......	......	......	......	......	......	......	7.0	......	15.08	......	......	......	......	......	......	......	......	......	......	......	......	See p. 431.
300	983	432	Trenton Junction,	......	Brick loam,	25.60	5.6	90	121	104	12	2.0	......	13.14	......	......	......	......	......	......	2.6	......	11.59	3.3	Red,	8.74	......	......	......	......	......	......	
192	602	431	Windsor,	......	Unworked clay,	31.00	8.6	235	275	251	12	0.0	Red with specks,	17.09	......	......	......	1.4	......	12.22	......	......	......	......	......	......	......	......	......	......	......	......	
			Middlesex County.																														
65	386	451	Burt Creek,	J. R. Crossman,	Red-mottled clay,	30.00	4.0	......	......	15	......	......	......	......	......	......	......	......	......	......	8.3	Yellow white,	16.85	11.0	Yellow white,	11.31	11.0	Yellow white,	10.02	12.6	Speckled,	7.32	Viscous, cone 31.
64	387	460	do	do	Pipe clay,	35.00	5.0	......	......	20	......	......	......	......	......	......	......	......	......	......	......	......	......	11.0	do	15.45	11.0	Cream,	16.65	12.0	Buff,	11.49	
65	409	457	do	do	Fire clay,	......	6.0	......	......	20	......	......	......	......	......	......	......	......	......	......	......	......	......	7.0*	do	19.35	11.0	Yellowish,	11.59	......	......	......	Fuses, cone 29.
67	391	451	do	J. R. Such,	Ball clay,	39.00	5.6	......	......	59	......	......	......	......	......	......	......	......	......	......	5.1	White,	......	......	......	......	12.0	White,	10.84	12.6	Yellow white,	5.93	
67	389	452	do	do	Washed ball clay,	40.00	5.0	cracked in drying				......	......	......	......	......	......	......	......	......	......	......	......	9.0	do	16.42	12.0	Yellowish white,	10.20	......	......	......	Vitrifies, cone 27.
67	390	461	do	do	Red clay,	39.00	4.5	55	78	65.5	......	1.5	Red,	28.90	......	......	......	......	......	......	8.7*	Red,	13.59	11.5	Red,	8.26	......	......	......	15.5	Red,	2.19	
45	402	445	Florida Grove,	McHose Bros.,	No. 1 buff clay,	26.00	6.5	......	......	45	......	......	......	......	......	......	......	......	......	......	......	......	......	1.9	do	15.39	*	......	......	1.8	Buff,	13.52	Fused, cone 30.
45	401	446	do	do	......	32.00	5.0	60	70	65	......	......	......	......	......	......	......	......	......	......	......	......	......	5.0*	Yellow,	11.68	6.6	Buff,	11.34	......	......	......	See p. 446.
45	403	462	do	do	Red clay,	32.00	6.6	......	......	75	......	......	......	......	......	......	......	6.3	Red,	13.00	......	......	......	......	......	......	......	......	......	......	......	......	See p. 462.
46	451	464	Keasbey,	National Fireproofing Co.,	Fireproofing clay,	......	5.5	100	156	112	8	2.5	Red,	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	See p. 465.
46	400	465	do	do	do	28.00	4.0	75	100	87	......	......	......	......	......	......	......	......	......	......	7.3	Brown red,	8.81	12.0	Dark gray,	6.10	......	......	......	......	......	......	
46	399	465	do	do	do	30.00	6.0	50	55	52	......	......	......	......	......	......	......	7.3*	Light brown,	1.58	9.0	Red,	1.00	9.3	Gray,	0.78	......	......	......	......	......	......	Vitrified, cones 8-10.
47	447	464	Perth Amboy,	do	do	......	5.0	126	162	145	10	1.6	Gray,	......	......	......	......	......	......	......	2.9*	Red,	......	......	......	......	......	......	......	......	......	......	See p. 464.
96	405?	466	Piscataway,	Brinckman Terra Cotta Co.,	Terra-cotta clay,	36.00	7.0	......	......	129	......	4.0*	Deep red,	13.12	......	......	......	......	......	......	10.7	Deep red,	0.9	......	......	......	......	......	......	......	......	......	Vitrified, cone 01.
94	405	449	Sand Hills,	C. S. Edgar,	Sagger clay,	32.00	7.0	......	......	52	......	......	......	......	......	......	......	3.0	Yellow white,	19.69	......	......	......	5.0*	Yellowish white,	16.75	......	......	......	......	......	......	Vitrified, cone 27; p. 449.
94	406	449	do	do	Fire clay,	25.00	6.5	......	......	98	......	......	......	......	......	......	......	7.5	Buff,	8.89	......	......	......	9.5	Buff,	3.69	14.0	Gray buff,	......	......	......	......	Viscous, cone 30; p. 450.
54	397	448	do	Ostrander F.-B. Co.,	do	28.00	5.0	......	......	20	......	......	......	......	......	......	......	......	......	......	......	......	......	1.0	Yellowish white,	17.75	2.0	Yellow white.	15.82	*	......	......	
54	407	448	do	do	do	30.00	6.0	......	......	36	......	......	......	......	......	......	......	......	......	......	4.6	Yellow white,	20.05	6.0	Yellow,	15.00	7.0	Yellow,	13.36	9.3	Cream,	11.31	
86	404	447	do	R. N. & H. Valentine,	do	33.00	4.4	45	50	47	......	......	......	......	......	......	......	......	......	......	......	......	......	13.6*	Yellow,	7.07	......	......	......	13.8	Yellow,	6.47	Fuses, cone 32.
86	410	448	do	do	do	34.00	6.6	......	......	35	......	......	......	......	......	......	......	......	......	......	5.4	White,	16.62	9.0	Cream,	11.09	......	......	......	11.4	Buff,	6.45	Fuses, cone 30; see p. 448.
268	723	452	Sayreville,	C. S. Edgar,	Washed ball clay,	39.10	5.0	32	33	32.5	......	......	......	......	......	......	......	......	......	......	......	......	......	10.6*	White,	17.53	......	......	......	16.3	White,	3.98	See p. 452.
71	393	467	do	Sayre & Fisher Co.,	Brick clay,	30.50	4.0	70	75	72	......	......	......	......	......	......	......	6.6	Red brown,	10.17	......	......	......	7.0	Deep red brown,	9.30	8.0	Red gray,	......	......	......	......	See p. 467; fuses, cone 12.
71	371	468	do	do	Hollow-brick clay,	25.00	6.3	80	100	84	......	......	......	......	......	......	......	8.0	Red buff,	......	......	......	......	10.7	Vitrified,	......	......	......	......	......	......	......	
77	......	454	South Amboy,	H. C. Perrine & Son,	Stoneware clay,	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	Vitrified, cone 30.
81	395	459	do	do	do	37.00	7.0	108	120	109	......	......	......	......	......	......	......	6.0*	Buff,	8.77	7.6	Light buff,	9.95	......	......	......	......	......	......	9.0	Gray buff,	0.24	Viscous, cone 30.
6	373	440	Woodbridge,	Anness & Potter,	No. 1 fire clay,	33.00	5.0	40	45	41	......	......	......	......	......	......	......	......	......	......	......	......	......	7.5*	Creamy white,	13.74	11.0	Cream,	9.10	......	......	......	Fused, cone 34+.
6	372	444	do	do	No. 2 fire clay,	29.50	5.5	......	......	45	......	......	......	......	......	......	......	......	......	......	5.5	Cream white,	15.87	5.5	Yellow white.	16.85	8.5	Yellow white,	10.54	10.5	Yellow white,	10.04	Fused, cone 33.
6	377	455	do	do	Top-sandy clay,	......	4.6	70	89	78	10	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	3.4	Gray buff,	2.9	......	......	......	See p. 456.
29	378	442	do	W. H. Cutter,	Ball clay,	33.00	3.4	32	34	33	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	14.6*	Yellow white,	7.14	16.6	Yellow white,	0.22	See p. 442.
29	380	454	do	do	Stoneware clay,	28.00	7.0	......	......	60	......	......	......	......	......	......	......	......	......	......	2.0	Yellow,	12.33	3.0*	Yellowish,	10.02	3.3	Deep yellow,	8.37	......	......	......	Viscous, cone 33.
16	381	462	do	I. H. Leisen,	Fire and retort clay,	34.00	6.0	......	......	91.5	......	......	......	......	......	......	......	4.6*	Creamy,	19.51	......	......	......	8.0	Buff,	9.70	11.3	Buff,	6.69	......	......	......	Vitrified, cone 27.
24	383	458	do	H. Maurer & Son,	Fire-mortar clay,	28.00	5.0	86	117	99	......	......	......	......	......	......	......	......	......	......	3.0	Buff,	10.75	4.0*	Buff,	5.98	5.0	Gray buff,	4.20	......	......	......	Viscous, cone 27.
24	374	460	do	do	Fire clay,	33.00	5.5	109	136	122	9	......	......	......	......	......	......	......	......	......	4.5	Light yellow,	9.80	5.1*	Buff,	7.86	5.6	Buff,	6.17	......	......	......	See p. 460.
24	379	461	do	do	Yellow top clay,	16.00	3.3	......	......	48	......	......	Red,	18.20	......	......	......	......	......	......	1.0	Reddish,	14.76	......	......	......	3.0	Reddish,	8.90	......	......	......	Viscous, cone 27.
14	382	439	do	M. D. Valentine & Bros. Co.,	No. 1 fire clay,	25.00	7.0	......	......	......	......	......	......	......	......	......	......	......	......	......	5.5	White,	24.25	6.5*	White,	19.65	......	......	......	13.0	Buff,	7.76	Fused, cone 34+.

Locality Number.	Laboratory Number.	Page in Report.	Locality.	Owner.	Material.	Water required, per cent.	Air shrinkage.	Tensile Strength.				Cone 05.			Cone 03.			Cone 1.			Cone 3.			Cone 5.			Cone 8.			Cone 10.			Additional Tests.
								Min.	Max.	Aver.	No. Tested.	F. S.	Color.	Abs.	F. S.	Color.	Abs.	F. S.	Color.	Abs.	F. S.	Color.	Abs.	F. S.	Color.	Abs.	F. S.	Color.	Abs.	F. S.	Color.	Abs.	
			Monmouth County.																														
217	658	476	Asbury Park,	Drummond Bros.,	Brick ay,	20.9	3.3	94	114	107	8	......	......	......	......	......	......	......	......	......	0.0	Buff,	16.87	......	......	......	......	......	......	2*	Light gray,	......	
217	696	476	do	do	d	37.3	5.6	156	202	182	3	3.3	Light red,	28.31	......	......	......	7.0	Deep red,	16.79	......	......	......	......	......	......	......	......	......	......	......	......	
217	697	476	do	do	Loam,	27.0	6.3	124	149	137	3	0.4	Pink red,	20.12	......	......	......	1.0	Red,	16.22	......	......	......	......	......	......	......	......	......	......	......	......	See p. 476.
217	696–7	476	do	do	Brick ixture,	31.2	6.3	243	283	258	6	0.3	Light red,	23.53	......	......	......	2.2	Red,	17.59	......	......	......	......	......	......	......	......	......	......	......	......	See p. 476.
220	611	474	Cliffwood,	Carman & Avery,	Brick ay,	25.5	6.5	77	100	88	10	1.5	Light red,	7.93	......	......	......	3.0	Red,	13.61	3.2*	Red,	11.12	......	......	......	......	......	......	......	......	......	See p. 474.
220	615	474	do	do	d	23.5	6.0	101	110	103	4	3.5	Light red,	18.13	......	......	......	*	Red,	......	7.5*	Red,	6.90	......	......	......	......	......	......	......	......	......	See p. 474.
222	606	474	do	A. H. Furman,	d	30.0	6.0	82	108	91	12	4.3	Pale red,	11.16	......	......	......	7.0	Red,	7.87	9.3	Brown red,	3.74	......	......	......	......	......	......	......	......	......	Vitrified, cone 8; see p. 474.
222	603	474	do	do	Brick ixture,	23.0	5.3	105	110	106	5	0.2	Pale red,	17.59	......	......	......	3.0*	Red,	10.10	3.3	Red,	9.38	......	......	......	......	......	......	......	......	......	Viscous, cone 8; see p. 474.
270	736 B	477	Eatontown,	D. H. Applegate,	Brick ay,	25.0	6.3	122	150	......	6	1.0	......	18.69	......	......	......	3*	......	12.27	......	......	......	3.7	......	9.10	......	......	......	......	......	......	See p. 478.
227	616	474	Matawan,	......	Brick y,	22.9	5.3	149	177	166	6	......	......	......	0.7	Red,	18.27	1.7	Red,	14.98	2.7	Red,	13.97	......	......	......	......	......	......	......	......	......	
231	607	474	do	......	d	26.0	9.3	105	145	128	10	4.7*	Red,	11.93	......	......	......	8.7	Red,	5.24	10.7	Red,	3.46	......	......	......	......	......	......	......	......	......	See p. 474.
228	601	474	do		Brick xture,	21.8	6.3	194	200	197	2	1.0	......	17.31	......	......	......	3.7*	Red,	9.65	......	......	......	......	......	......	......	......	......	......	......	......	See p. 474.
			Morris County.																														
297	730	480	Parsippany,	J. B. Ricketts,	Undeoped clay,	......	......	......	......	......	......	......	......	......	......	......	......	0.3	Pink,	18.29	......	......	......	......	......	......	......	......	......	......	......	......	
284	724	479	Schooleys Mountain,	J. A. Parker,	do	35.4	8.0	......	......	......	......	4.0*	Light red,	10.9	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	
			Ocean County.																														
......	......	486	Davenport,	J. S. Brown,	Undeoped clay,	25.0	7.0	......	......	130	......	......	......	......	......	......	......	5.6	Red,	......	......	......	......	......	......	......	......	......	......	......	......	......	Vitrified at cone 4.
208	686	486	do	B. Yoder,	do	33.1	7.6	127	143	130	10	1.7	Pale red,	19.09	......	......	......	6*	Red,	10.21	6.4	Deep red,	7.98	7	Deep red,	6.68	7.2	Deep red,	7.21	......	......	......	
218	695	489	Herbertsville,	Herbertsville Brick Co.,	Brickay,	32.6	5.3	102	116	108	8	0.3	Pink red,	20.19	......	......	......	......	......	......	......	......	......	2.7	......	12.98	......	......	......	6	......	......	
218	695S	490	do	do	(	15.6	3.3	62	70	65	6	0.7	Pinkish,	14.76	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	
219	698	490	do	I. H. Tilton,	(	29.3	4.4	66	81	73	6	0.2	Light red,	20.84	......	......	......	2.6	Red,	16.93	......	......	......	......	......	......	......	......	......	......	......	......	
219	699	490	do	do	Brickam,	21.3	2.5	45	54	49	4	0.5	Light red,	17.64	......	......	......	1.5	Red,	16.52	......	......	......	......	......	......	......	......	......	......	......	......	
219	698–699	490	do	do	Brickxture,	25.0	4.0	65	77	70	8	0.3	Light red,	19.26	......	......	......	1.4	Red,	16.16	......	......	......	......	......	......	......	......	......	......	......	......	
294	750	491	Lakewood,	Mrs. Le Conte and Wm. Clayton,	Undeped clay,	20.0	7.3	......	......	......	......	......	......	......	......	......	......	0.7	Buff,	13.10	......	......	......	0.7	Buff,	......	......	......	......	......	......	......	See p. 491.
209	666	483	Mayetta,	Eastern Hydraulic Press Brick Co.,	Bricky,	......	4.0	......	......	......	......	......	......	......	......	......	......	......	......	......	4.0	Buff,	......	5*	Buff,	......	6.0	Buff,	......	......	......	......	See p. 484.
209	700	484	do	do		......	5.3	......	......	......	......	......	......	......	......	......	......	4.7*	Buff,	10.52	......	......	......	8	Buff,	3.06	......	......	......	......	......	......	
213	656	482	Old Half Way,	Adams Clay Mining Co.,	Terrta clay,	23.3	4.8	65	77	73	6	......	......	......	......	......	......	......	......	......	......	......	......	2.7*	Whitish,	9.08	2.7	White,	9.08	3	Gray,	8.13	See p. 483.
207	706	487	Toms River,	S. Applegate,	Semiactory clay,	29.1	5.0	......	......	......	......	......	......	......	......	......	......	......	......	......	4.0*	Light buff,	11.92	5.1	......	11.03	5.6	Yellow,	7.88	......	......	......	Vitrified, cone 27; see p. 487.
206	684	488	do	E. R. Tilton,	Bricky,	26.0	4.3	65	71	68	6	......	......	......	......	......	......	2.3	......	15.37	......	......	......	3.7	Red,	12.53	......	......	......	......	......	......	
206	665	488	do	do	Oche clay,	65.0	8.0	63	81	74	3	2.6	Red,	35.12	9.3	Bright red,	26.15	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	See p. 488.
210	662	485	Tuckerton,	......	Bricly,	26.3	5.5	158	181	173	......	......	......	......	......	......	......	0.5*	Red,	13.16	......	......	......	......	......	......	4.1	Red,	6.73	......	......	......	See p. 485.
212	412	481	Whitings,	Eastern Hydraulic Press Brick Co.,	Bric y,	......	5.5	120	130	125	......	......	......	......	......	......	......	5.5	Light buff,	......	......	......	......	10.8*	Buff,	......	10.8	Buff,	......	......	......	......	See p. 481.
			Salem County.																														
164	680	497	Alloway,	......	Undoped clay,	32.1	8.6	401	506	453	6	......	......	......	4.4*	Red,	8.07	5.2	Red,	3.94	......	......	......	......	......	......	......	......	......	......	......	......	Vitrified, cone 12.
165	690	497	do	......	lo	35.6	9.0	......	......	......	......	......	......	......	......	......	......	7.0	Red,	0.47	......	......	......	......	Red,	0.07	......	......	......	......	......	......	
167	688	498	do	......	lo	48.7	11.0	74	86	80	2	......	......	......	......	......	......	5.6	Red,	5.18	......	......	......	8.3	Brown,	0.46	......	Gray,	......	......	......	......	Viscous, cone 12; see p. 498.
163	685	498	do	......	lo	26.5	8.0	226	272	246	12	0.0	Red,	16.59	......	......	......	......	......	......	2.0	Red,	10.57	5.3	Gray brown,	4.51	5.3	Gray brown,	6.39	......	......	......	Viscous, cone 27.
169	674	499	Fenwick,	......	lo	29.7	7.6	251	374	327	3	......	......	......	1.0*	Bright red,	11.86	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	
160	675	498	Richmanville,	......	lo	30.0	8.0	83	136	90	......	4.0	Bright red,	20.17	5.0	Red,	15.45	5.5*	Deep red,	13.48	......	......	......	......	......	......	......	......	......	......	......	......	
168	672	499	Riddleton,	......	lo	46.5	10.6	308	412	337	6	......	......	......	3.4	......	9.89	3.4	......	7.96	......	......	......	......	......	......	......	......	......	......	......	......	
177	673	500	Woodstown,	......	lo	35.8	8.3	......	......	......	......	4.7*	Pale red,	11.76	5.7*	Streaky red,	9.45	7.7	Red,	3.59	......	......	......	9.3	Deep red,	0.36	......	......	......	......	......	......	Viscous, cone 12.
172	689	501	do	......	lo	45.2	3.3	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	5.3	White,	24.73	7.3	Yellow white,	19.23	
161	691	496	Yorktown,	Haines & Son,	lo	36.1	8.0	......	......	......	......	......	......	......	......	......	......	7.0	Brownish red,	1.41	......	......	......	......	......	......	......	......	......	......	......	......	
162	677	494	do	do	Top	30.2	9.3	270	381	308	10	2.7*	Yellowish red,	12.62	......	......	......	......	......	......	......	......	......	7.7	Red,	0.22	7.0	Deep red,	0.34	......	......	......	
162	694	495	do	do	Botfay,	29.9	8.0	193	248	223	10	5.3*	Light red,	6.89	......	......	......	......	......	......	7.3	Red,	1.07	......	......	......	......	......	......	......	......	......	
162	617	495	do		Bri ture,	27.0	7.6	204	245	229	10	1.0	Red,	13.42	......	......	......	2.7*	Red,	8.90	4.4	Red,	6.96	......	......	......	5.6	Red,	1.21	......	......	......	See p. 496.
			Somerset County.																														
234	659	503	Somerville,	......	Bri,	20.5	5.0	272	317	297	10	......	......	......	5.0	Red,	......	6.6	Red,	0.64	......	......	......	......	......	......	·	viscous		......	......	......	See p. 503.
			Union County.																														
290	727	506	Murray Hill,	H. Wilcox,	Unped clay,	30.8	8.0	......	......	134	......	11.0*	Red,	3.12	......	......	......		fused		......	......	......	......	......	......	......	......	......	......	......	......	
			Warren County.																														
283	753	507	Beattystown,	L. T. Labar,	Undeveloped clay,	......	......	......	......	......	......	......	......	......	......	......	......	*	Brownish red,	3.79	......	......	......	......	......	......	......	......	......	......	......	......	
283	751	507	do	do	do	......	......	......	......	......	......	......	......	......	......	......	......	Total 9.3*	Pinkish,	8.66	......	......	......	......	......	......	......	......	......	......	......	......	
283	752	507	do	do	do	......	......	......	......	......	......	......	......	......	......	......	......	Total 10.0*	Dark brown,	2.05	......	......	......	......	......	......	......	......	......	......	......	......	
282	......	507	Port Murray,	......	Fireproofing shale,	18.5	2.0	......	......	51	......	1.6	Pale red,	16.14	......	......	......	4.6	Deep red,	8.82	......	......	......	7	Deep red,	3.26	......	......	......	......	......	......	See p. 507.
280	725	507	Washington,	C. Blazer,	Undeveloped clay,	26.2	6.3	......	......	......	......	1.0*	Pale red,	14.07	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	See p. 507.

APPENDIX E.

EXPLANATION OF MAPS.

Five maps, Plates X, Xa, XI, XII, XIII, accompany this report, in the envelope attached to the cover.

Plate X.—This map shows the distribution of the principal clay-bearing formations in the State, as explained by the legend.

North of the terminal moraine, and also within the basin of the extinct Lake Passaic there are considerable areas of clay of glacial derivation which are of value for common brick. They do not, however, occur over all this area, but, on the contrary, are found in more or less widely separated localities.

The Raritan belt of sand and clay (light-green horizontal lines, K r,) extends from Woodbridge, Middlesex county, to Lower Penns Neck, in Salem county. Since thick beds of sand occur in this formation, the clay beds occur on the surface over only a part of the area thus marked. Since, moreover, beds of sand and gravel of much later age (Pleistocene) in places cover the Raritan and other formations quite deeply, the area within which these clays can be mined is still further circumscribed. Prospecting for the Raritan clays should not extend beyond the area indicated by this pattern on the map, although it is certain that they do not occur within workable depths at all points within these limits.

The two clay deposits, known as Clay Marl I and II, are here indicated by one color and pattern (dark-green, vertical lines, K c m). Clay Marl I occurs along the northwestern part of the belt, Clay Marl II along the southeastern. These brick clays occur everywhere along the belt thus mapped, but locally they are deeply buried by the later gravels, and therefore are not exposed.

The area of Miocene and Pliocene sands and clays is much larger than the others. The surface is chiefly sand, and over much of the region there is no evidence of clay. Nevertheless, lenses of valuable buff- and red-burning clays frequently occur, the presence of which can usually be detected only by boring. Under these circumstances it has not been practicable to attempt their actual delimitation.

The areas in which clays of Cape May and Pensauken age occur are not indicated since these formations are so irregularly distributed, and lie upon those already mentioned. Nor has it been practicable to map the clay-loam deposits which mantle many of the older formations. Their general distribution is referred to in the text.

Plate Xa.—This map shows 1) the location of all clay pits which were visited in the course of this investigation, 2) many localities where clay is known to occur but is not worked, and 3) the distribution of the various kinds of clay manufactures throughout the State.

The numbers are the locality numbers used in the text of the report. By reference to the index all important data respecting the clay at each of these localities can be found. Since the red circle is carefully marked on the map at the place where the clay was observed, all the deposits can be located in the field by anyone at any time.

No attempt has been made to plot *all* the occurrences of clay in the State. Doubtless some, particularly in the pine belt, where sand covers the surface, have been omitted.

The various grades of clay ware manufactured are indicated by different symbols, which are explained in the legend on the map. Their position does not indicate the exact location of the factory, but they are placed near the name of the town, which is itself underscored in red.

Plate XI.—The clay deposits of northeastern Middlesex county are shown on this map. The attempt has been made, not only to represent the belts where the various clay beds occur at the surface, or are only thinly covered, but also their probable extension beneath thicker beds of sand or gravel, and the limits within which they are probably available. The differences in pattern used to accomplish this result are shown in the legend on the map. There is no question but what the clays extend far beyond the limits thus marked, and underlie much of the area left uncolored, particularly south of the Raritan river, but in these districts they are buried so far beneath the surface that only occasional deep wells penetrate them, and they are commercially valueless. On the southeastern part of the map, the area where Clay Marl I (K m I) and Clay Marl II (K m II) occur, no attempt has been made to differentiate between the areas where the clay is bare and where it is covered by gravel deposits of Pleistocene age. Two areas in which Clay Marl III—a heavy sand bed—occurs, are left uncolored.

The numbers *in black* near the various clay openings are the locality numbers used in the text of the report. By reference to the index all available data respecting each deposit may be found.

Plate XII.—The clay deposits near Keyport and Matawan are shown on Plate XII, no attempt being made to differentiate the areas in which the clay is at the surface from those where it is covered more or less thickly by gravel beds or along the streams by the swamp and salt-marsh deposits. Thus, for example, immediately around Keyport the gravel and sand is locally ten to twenty feet thick, and for the most part nothing else is exposed along the stream bluffs. Yet occasional small exposures show that the clay underlies these later deposits, and it would appear as represented on the map if they were removed.

The figures on the water indicate the depth in feet at mean low tide. The larger figures in black near the various clay pits are locality numbers as used in the text of the report.

Plate XIII.—This map shows the distribution of the Alloway clay in the region about Woodstown. Over the areas marked A c a (diagonal yellow lines), older formations occur, the Alloway clay having been removed by erosion. These older beds are of various kinds, but as the purpose of the map is to show only the distribution of the clay, these are not differentiated. The areas, A c (dark yellow), show where the clay is bare or only thinly covered to a depth of a few feet. In the areas, A c b (vertical lines), the clay is so deeply buried as to be for the most part commercially valueless. The small circles represent outcrops noted, and from those with numbers samples were taken for examination and testing.

INDEX.

GEOLOGICAL SURVEY OF NEW JERSEY

HENRY B. KÜMMEL, State Geologist C. C. VERMEULE, Topographer

MAP SHOWING THE DISTRIBUTION OF CLAY PITS AND CLAY MANUFACTURES IN NEW JERSEY IN 1903

Scale. 5 miles to an inch

MILES

KILOMETERS

1904

LEGEND

Numbers refer to localities mentioned in the Report See Appendix E for list of localities with names of owners so far as known.

- ♂ Clay pits
- ○ Clay exposures (not exhaustive)
- ■ Brick
- ♦ Fire brick
- □ Fireproofing & conduits
- ▲ Tiles, wall and floor
- + Terra Cotta
- ● Potteries

See Plates XI and XII for location of clay pits between Woodbridge, South River and Keyport.

GEOLOGICAL SURVEY OF NEW JERSEY

HENRY B. KÜMMEL, State Geologist C. C. VERMEULE, Topographer

MAP SHOWING THE DISTRIBUTION OF THE PRINCIPAL CLAY BEARING FORMATIONS OF NEW JERSEY

1903

G. N. KNAPP, H. B. KÜMMEL, R. D. SALISBURY

Scale: 5 miles to an inch

GEOLOGICAL SURVEY OF NEW JERSEY

HENRY B. KÜMMEL, STATE GEOLOGIST C. C. VERMEULE, TOPOGRAPHER

A MAP OF THE CLAY FORMATIONS IN NORTHEASTERN MIDDLESEX COUNTY

GEOLOGY BY HENRY B. KÜMMEL, 1902-3

1904

Scale 2000 ft. to 1 inch

LEGEND

CRETACEOUS

- ▥ KwII Clay marl II (Woodbury)
- ▤ KmI Clay marl I (Merchantville)
- ■ Kas Amboy stoneware clay (outcrop or thinly covered)
- ■ Kas' Amboy stoneware clay (buried but probably available)

CRETACEOUS

- ■ Ksa South Amboy fire clay (outcrop or thinly covered)
- ■ Ksa' South Amboy fire clay (buried but probably available)
- ■ Kwc Woodbridge clays (outcrop or thinly covered)
- ■ Kwc' Woodbridge clays (buried but probably available)

CRETACEOUS

- ▥ Krf Raritan fire and potter's clay (outcrop or thinly covered)
- ▦ Krf' Raritan fire and potter's clay (buried but probably available)

TRIASSIC

- ▨ Tns Newark shale (soft red shale)

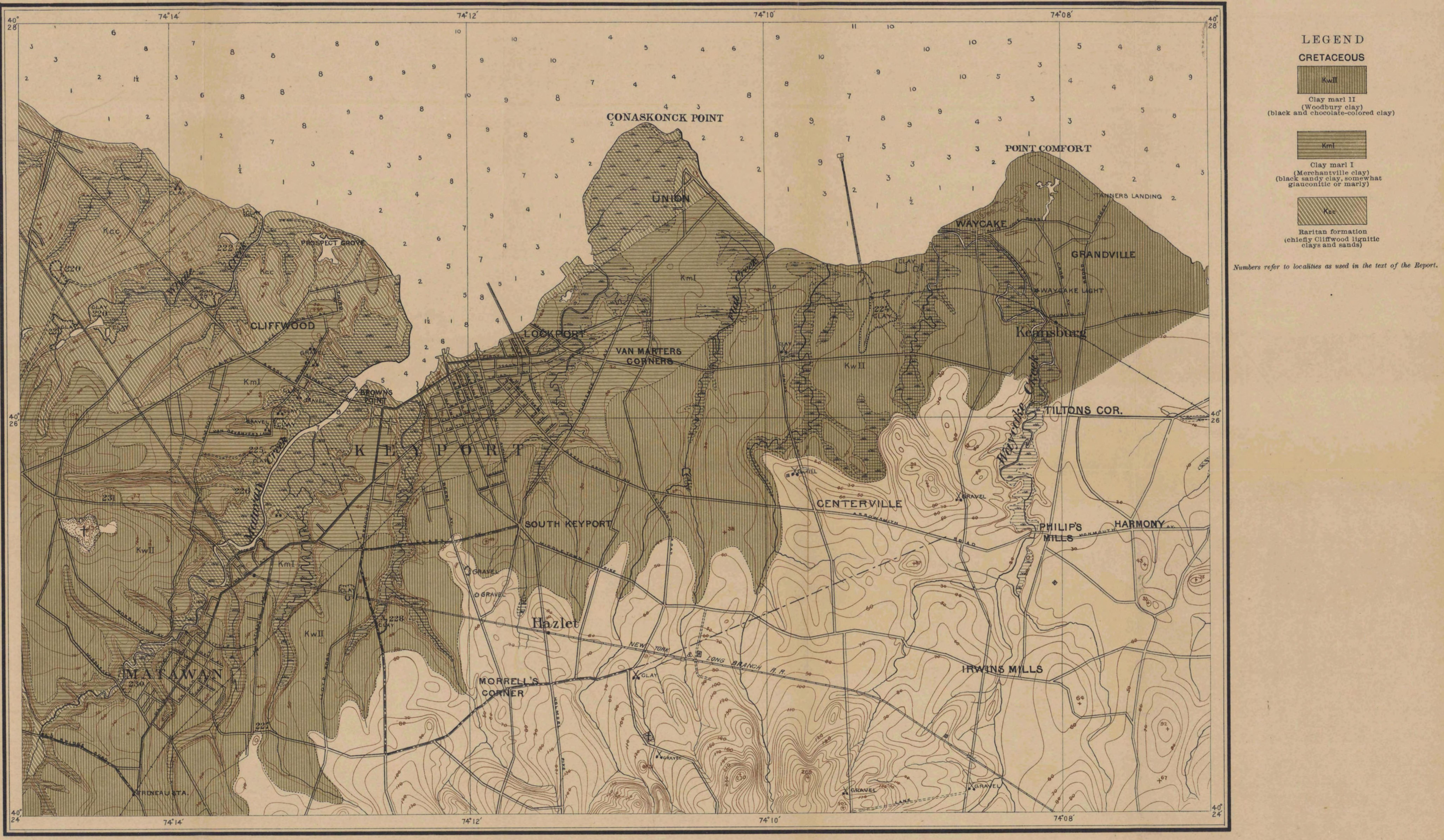
Numbers refer to localities as used in the text of the Report. For more complete description of the map see Appendix E.

GEOLOGICAL SURVEY OF NEW JERSEY

HENRY B. KÜMMEL, STATE GEOLOGIST C. C. VERMEULE, TOPOGRAPHER

VOLUME VI

PLATE XII

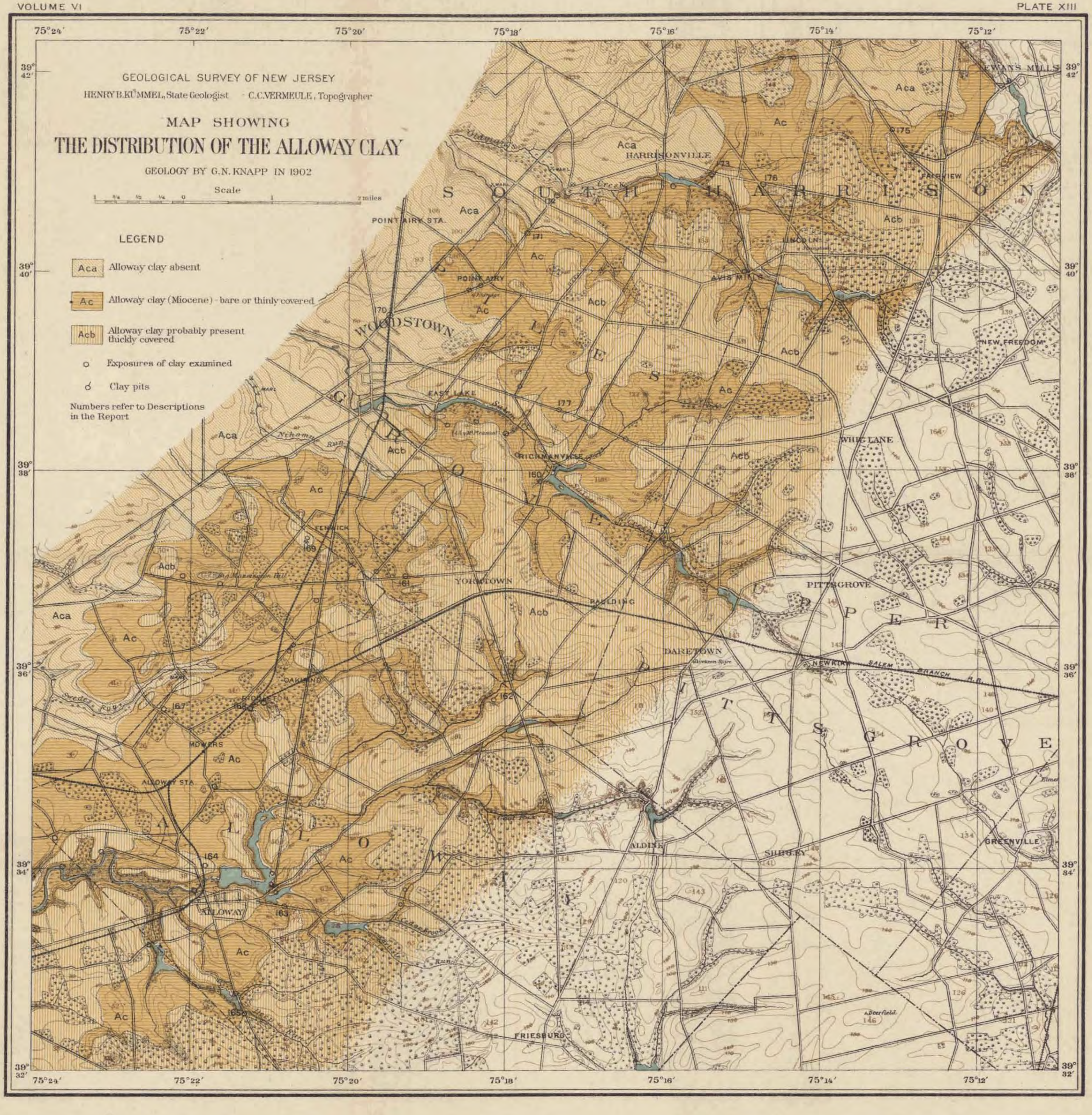


MAP SHOWING THE CLAY FORMATIONS NEAR KEYPORT AND MATAWAN

GEOLOGY BY HENRY B. KÜMMEL, 1903

Scale 2000 ft. to 1 inch

2000 1 0 2 4 6000 Ft.



GEOLOGICAL SURVEY OF NEW JERSEY

HENRY B. KÜMMEL, State Geologist C. C. VERMEULE, Topographer

MAP SHOWING

THE DISTRIBUTION OF THE ALLOWAY CLAY

GEOLOGY BY G. N. KNAPP IN 1902

Scale

LEGEND

Aca	Alloway clay absent
Ac	Alloway clay (Miocene) - bare or thinly covered
Acb	Alloway clay probably present thickly covered
○	Exposures of clay examined
ó	Clay pits

Numbers refer to Descriptions in the Report