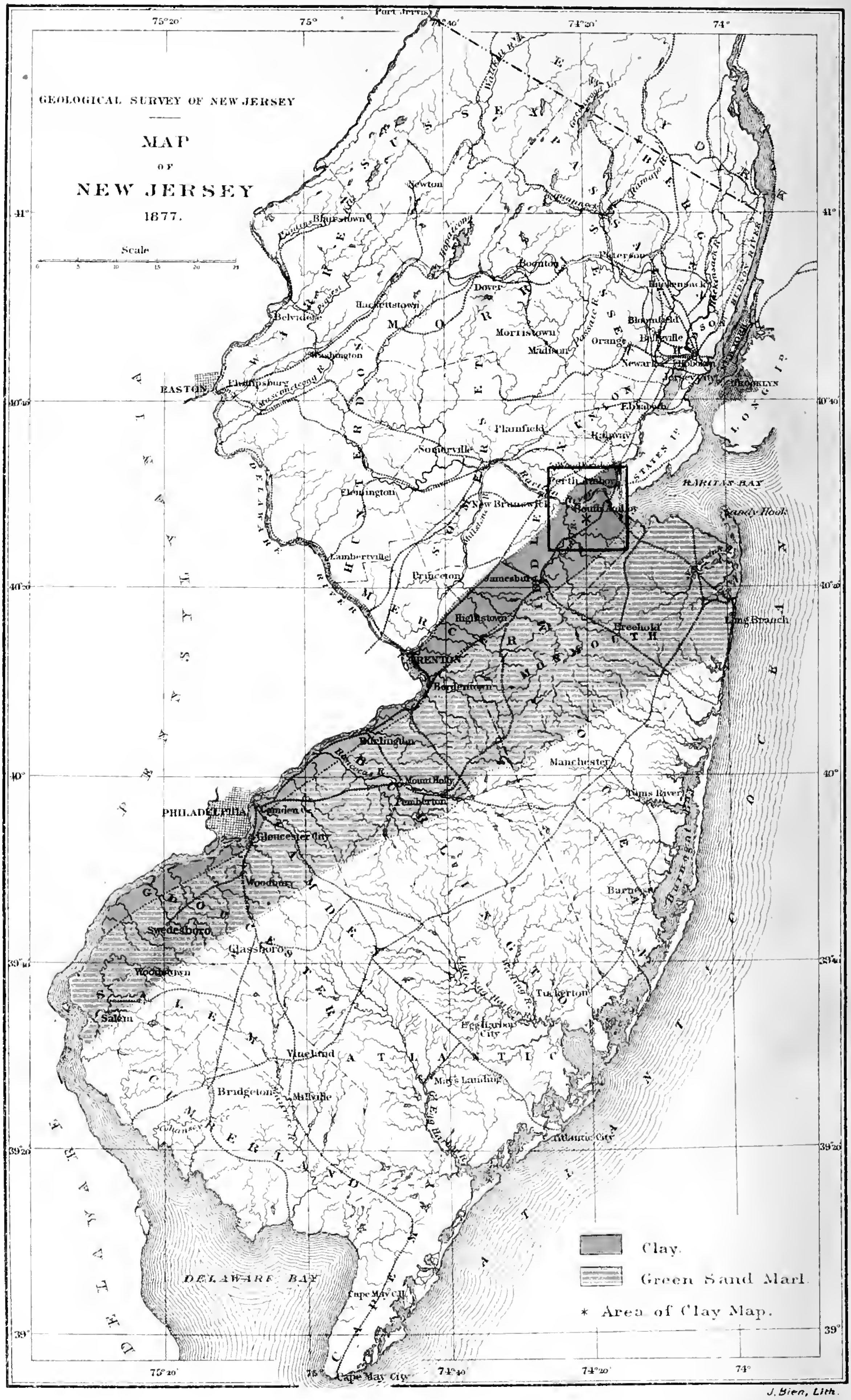

GEOLOGICAL SURVEY OF NEW JERSEY
MAP
OF
NEW JERSEY
1877.
Scale
Clay.
Green Sand Marl.
* Area of Clay Map.
DELAWARE BAY
RARITAN BAY
PHILADELPHIA
TRENTON
EASTON
BROOKLYN
J. Bien, Lith.

GEOLOGICAL SURVEY OF NEW JERSEY.

REPORT

ON THE

CLAY DEPOSITS

OF

WOODBRIDGE, SOUTH AMBOY AND OTHER PLACES

IN

NEW JERSEY,

TOGETHER WITH THEIR USES FOR FIRE BRICK, POTTERY, &C.

TRENTON, N. J.:
NAAR, DAY & NAAR, PRINTERS.
1878.

Board of Managers of the Survey.

His Excellency, Joseph D. Bedle, Governor, and *ex-officio* President of the Board........Trenton.

I. CONGRESSIONAL DISTRICT.

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Hon. Andrew K. Hay........Winslow.

II. CONGRESSIONAL DISTRICT.

Hon. William Parry........Cinnaminson.
Hon. H. S. Little........Trenton.

III. CONGRESSIONAL DISTRICT.

Henry Aitkin, Esq........Elizabeth.
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IV. CONGRESSIONAL DISTRICT.

Selden T. Scranton, Esq........Oxford.
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V. CONGRESSIONAL DISTRICT.

Hon. Augustus W. Cutler........Morristown.
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VI. CONGRESSIONAL DISTRICT.

William M. Force, Esq........Newark.
Thomas T. Kinney, Esq........Newark.

VII. CONGRESSIONAL DISTRICT.

Benjamin G. Clark, Esq........Jersey City.
William W. Shippen, Esq........Hoboken.

Geologists.

George H. Cook, State Geologist........New Brunswick.
John C. Smock, Assistant Geologist........New Brunswick.

To his Excellency, Joseph D. Bedle, Governor of the State of New Jersey, and ex-officio President of the Board of Managers:

SIR:—

I have the honor herewith to submit a report on the Clay Deposits of New Jersey, and trust that it may meet your approval, and aid in making more widely known one of our most abundant and useful natural products.

With high respect,

Your obedient servant,

GEO. H. COOK,

State Geologist.

New Brunswick,

Jan. 1, 1878.

Table of Contents.

Note.

The facts contained in this report have been greatly increased in number by the liberal contributions of our citizens. Information of the most valuable kind has everywhere been freely given. Wherever it has been possible credit has been given for this in the body of the work. And it would be invidious to begin to mention here the names of our citizens who have aided the survey. It should be stated, however, that for the large collection of clays from outside of the State, which are mention in the appendix, and which are so useful for comparison, we are indebted to the friendly aid of Alex. L. Holley, Esq., of New York city, who secured them for us from his numerous professional correspondents among the iron manufacturers everywhere.

INTRODUCTION.

The following report is intended to present an intelligible description of the clay deposits of New Jersey. They have long been known, but their importance and extent have been understood only for a few years. Their uses for common earthen and stoneware pottery, first attracted attention about the beginning of the present century. Clay from Morgan's clay banks at South Amboy, was used in making stoneware at Van Wickle's pottery at Old Bridge, now Herbertsville, about 1800. Ebenezer Price, Ebenezer Price, Jr., and Xerxes Price purchased the property at the Roundabout, now Sayreville, on the Raritan, in 1802, and began making stoneware pottery, using for the purpose clay from Morgan's banks, at South Amboy. The use of the stoneware clay for pottery gradually extended, and it is now carried to potteries everywhere along our Atlantic coast.

The use of New Jersey clays for making fire brick and other refractory materials began after the war of 1812. Mr. G. W. Price, of New Brunswick, informs me that his father carried a vessel load of fire clay from Woodbridge to Boston, soon after 1816. It was dug on Mr. Cotheal's property, and was used for making fire bricks; and Mr. Price thinks it was the first load sent from Woodbridge for this use. Mr. Samuel Dally, of Woodbridge, says the white Woodbridge clay was known to the soldiers quartered at Perth Amboy, before and during the revolution. They called it *fuller's earth*, and used it for cleaning their buckskin breeches. About 1820 Jacob Felt, of Boston, bought 50 tons of the clay of Jeremiah Dally. He paid 25 cts. a ton, in the ground, for it. This was shipped to Boston; and it was sent on regularly to the same place, from that time onward for many years. It was used in satining wall papers in Philadelphia in 1835, by Howell & Brothers. J. R. Watson, of Perth Amboy, began the manufacture of fire brick in 1833 and had his works in regular operation in 1836. Gordon, in his *Gazetteer of New Jersey*, published in 1833, says "extensive beds of white pipe clay, composed principally of alumine, and infusible, have been observed between Woodbridge and Amboy."

So little, however, was known of its extent and uses, in 1840, that Prof. Rogers, in his Final Report on the Geology of New Jersey, published that year, says "about one mile southwest of Woodbridge, near the level of a small stream, on the road to New Brunswick, there occurs an insulated deposit of white clay and white sand, in which both materials are of remarkable purity. This local bed is surrounded by the red-shale rocks of the middle secondary series, and would seem to be a remnant of the lowermost layers of the upper secondary group, lying in a depression of the surface, where it has escaped removal during the general denudation of the strata.

"Beneath about ten feet of reddish diluvial matter derived from the adjoining red-shale, we find a bed of pure white sand, regularly stratified, and dipping gently westward. Its thickness is about ten feet. This sand is much esteemed as an ingredient for the manufacture of fire bricks. Underneath the sand lies the white clay, in a bed about eight feet thick; when dry it is very nearly white, some portions of it, however, have a very slight bluish tinge. It is much used in the manufacture of pottery and fire bricks. The purer varieties are admirably adapted for making the glaze for paper hangings, being employed for this purpose. About three-fourths of a mile southwest of this excavation, another similar deposit is exposed in some recent diggings. The clay at the latter place surpasses even that of the former in whiteness, and in its exquisite smoothness of texture.

"In the descending order, the beds at this place are, first, diluvial matter ten or twelve feet thick, then a layer of sand, and under this again the clays, between seven and eight feet thick."

In the Geological Report for 1855, statistics collected showed that clay for making 50 million fire bricks was taken yearly from the pits at Woodbridge, Perth Amboy, and South Amboy; 2,000 tons of clay were sold for facing paper hangings; 2,000 tons for making alum, and a considerable quantity for making fine pottery at Jersey City, Trenton, and Green Point. About 10,000 tons a year of stoneware clay were needed to supply the demand. The Geology of New Jersey, 1868, shows an increase in the aggregate of clays dug for market of about double the quantity dug in 1855.

The Geological Report for 1874, pages 42 and 43, says:

"It is estimated that two hundred and sixty-five thousand tons of fire clay are dug annually in the places mentioned above, and sent into market for making fire brick, fine pottery, sewer pipe, terra cotta ware, retorts and crucibles, facing for wall paper, alum, &c. The prices at which it is sold vary from $1.50 to $13 a ton, according to its quality, but its average price may be safely set down at $3.50, which produces an aggregate of $927,500 for the amount of annual sales of the fire clays.

"The amount of stoneware clay dug annually in the vicinity of South Amboy, is estimated at twenty thousand tons. It is shipped to all parts of the United States, and supplies the material for most of the stoneware that is used in the country. Its price varies slightly, but an average is near $4 a ton, the aggregate of which is $80,000 a year.

"Fine earthen ware was formerly imported almost wholly from Europe, but within the last ten years potteries have been established at Trenton, which have been remarkably successful in the quality of the wares made and in finding a ready market for them. There are now twelve potteries in Trenton, which employ about one thousand men, and one thousand women and boys, and turn out $1,500,000 worth of ware annually. The ware made is of the common white earthen and ironstone, and its quality is now fully equal to the best English ware of those grades. The manufacture of such ware was very limited at the beginning of the late civil war; it has now grown so as to supply a quarter of the demand in the country, and the market for it is still kept up, even under the present financial distress. A few years more of like progress, and we shall be able to fully supply the demands of our own market, and from the peculiar advantages of New Jersey, in regard to materials, fuel, and markets, it must become the centre of such manufactures."

The business depression which has been continued from 1873 to the present (1877), has greatly shortened the demand for clays; but it must revive again with the general improvement in financial matters. The manufacture of pottery has continued to prosper and grow even during the present stagnation in trade.

THE abundance of the clay, its superior qualities, and its convenience to market, have made it almost essential to the successful prosecution of some of the great industries of our country.

And the progress of manufactures gives it promise of still greater importance in the future.

This report with its maps, drawings and descriptions will aid explorers in searching for new locations for digging clay, in enabling owners to judge of the value of their lands, and in directing buyers of clay to the various qualities of the material and the sources for their supply.

THE work is based on the explorations of the survey in 1855, and on the results of the work as published in the Geology of New Jersey in 1868. But in the fullness and accuracy of its detailed descriptions and drawings, it is largely the work of Assistant Geologist, Prof. J. C. Smock.

The beautiful MAP of the clay district was drawn by the late James Kennedy Barton, C. E., and his own surveys and levels furnished nearly all the material for it. In addition to the matter on ordinary maps, it gives the elevation of all parts of its surface above the sea. The numerous analyses of clays have been made by Mr. Edwin H. Bogardus, in the laboratory of the Geological Survey. They furnish an addition to our knowledge of fire and potters' clays, and will be appreciated wherever such materials are used.

IN the arrangement of the various details of the report, Part I. treats of the geography and topography of the Middlesex county clay district, and of its place in the general geology of New Jersey. Part II. describes the geological structure of the clay district of Middlesex county, with full local details. It gives the extension of the Middlesex clays across the State and along the Delaware River. It also gives the clays of southeastern New Jersey, and those of northern New Jersey. Part III. gives the composition, properties and origin of the clays. Part IV. shows the economical uses of the clays. Part V. gives statistics of peculiar products of the clay districts, directions for exploring for clay, digging and mining clay, and some account of its relations to transportation and market.

For list of "Errata" see page 382. after Index.

PART I.

ON THE GEOGRAPHY, TOPOGRAPHY AND GEOLOGY OF THE CLAY DISTRICT OF MIDDLESEX COUNTY.

The clay district, which is the chief subject of this report, includes the portion of Middlesex county which lies along the Raritan and South rivers, and the Woodbridge and Chesquake creeks, and extends from Woodbridge on the north to the Monmouth county line on the south; and from Staten Island sound and Raritan bay on the east, to Martin's dock, and the mouth of Lawrence brook on the west. Its boundaries are as follows: beginning at the northeast on Staten Island sound near the mouth of Woodbridge creek, the line runs west southwest up that creek till opposite Edgar station on the Woodbridge and Perth Amboy railroad, which is three-quarters of a mile north of Woodbridge; thence from the creek running west and southwest near the old Woodbridge and Metuchen road, and intersecting the Metuchen and Bonhamtown road a half mile north of the latter village; thence southwest through Piscataway to Martin's dock on the Raritan river; south of the Raritan river its western limit may be said to be defined by Lawrence brook and the Old Bridge and New Brunswick turnpike; the southern boundary is not plainly marked, but it may be approximately described as running from Old Bridge to Jacksonville, and thence to the Monmouth county line, near Raritan bay shore; and the waters of Raritan bay and Staten Island sound, being the State line,* limit it on the east.

On the northwest the clay district joins that of the red-shale and sandstone, and the frequent outcrops of the latter make the location of the northern boundary of the clay easy and accurate. Towards the west the boundary is entirely arbitrary, the later geological deposits, over which the Old Bridge and New Brunswick turnpike runs, being without any breaks, and effectually concealing the underlying formations. Indeed, it is probable that

* Geologically, this clay district extends over a part of the south end of Staten island, and probably to Long island also.

the equivalent of the clay is not limited by the boundary above given; but that like all the other deposits of the cretaceous formation it extends entirely across the State in a southwesterly direction to the Delaware river, and beyond. In the flat and sandy country south of the South river, and stretching east as far as Jacksonville, yellow sand and gravel drift reach down to tide level, and so effectually discourage explorations for clay that this boundary must be considered the limit of the district in which clay can be profitably dug, rather than the end of the beds of clay. From Jacksonville to the bay shore the outcropping clay-marl accurately defines the southeastern margin of the clay district. The map accompanying this report shows the whole of this district which produces clay, including all the pits of the county and of the adjoining parts of Staten island, in which fire clay or stone-ware clay is dug; but it does not exhibit the whole area of the county in which clay may, possibly, yet be found. The belt of country underlaid by the plastic clays extends entirely across the State, and includes an area of 320 square miles. In this area it is possible much valuable clay land may yet be found which can be worked to profit. The area of the clay district of Middlesex county within which is included all the clay pits at present worked is only 68 square miles.

The map of the clay district, which accompanies this report, exhibits the above described boundaries and area on a scale of three inches to a mile. It will be further described in its relations to topography and structural geology.

Although this district borders the tide waters of Staten Island sound and Raritan bay, and is intersected by the tide waters of Raritan and South rivers, and belongs in the general Atlantic slope of the country, it has not the flat surface, or general long seaward slope which are such marked features of most of the land along our coast. On the contrary, the surface is uneven, and its average elevation is quite as great as that of the red sandstone country on its northwest border, or the marl region on its southeast. North of the Raritan river nearly all the upland has an elevation exceeding 30 feet, and fully one-third of it is over 100 feet above tide water level. This area is subdivided by a series of hills or flattened ridgeswhich extend southeast from the Short hills near Metuchen to Perth Amboy. The Perth Amboy and

Metuchen road runs almost level, high up on the side of this elevated ridge. From this elevated ground as the water shed, the drainage is northeast and east into Woodbridge creek and Staten Island sound, and southward into the Raritan river. Poplar hill is the highest point in this ridge or chain of hills, and the highest in the district being 240 feet above tide level. From Ford's Corners westward to Bonhamtown, and thence southwest to Piscataway, the old road runs on high ground, most of the way about 100 feet above tide. Bordering the sound and along Woodbridge creek there is a narrow fringe of tide marsh. The largest body of tidal meadow, however, is along the Raritan river. That on its north side extends the whole distance from Martin's dock to the Crossman Clay Company's works, and is from a half mile to a mile wide, and nearly five miles long. On the south of this stream there is but little tide marsh on the shore of the bay; Chesquake creek is widely bordered by tide marsh from its mouth to its head; there is a fringe of marsh along the south shore of the Raritan between South Amboy and Kearney's dock, and smaller patches from there up to Sayreville, and a much larger tract above Sayreville about the mouth of South river, and stretching up that stream nearly four miles. The area of the district, which is tide marsh, is as follows, in acres:

TOWNSHIPS.	ACRES.
Perth Amboy	403
Woodbridge	690
Raritan	2,067
East Brunswick	673
Sayreville	1,797
South Amboy	40
Madison	1,568
Total	7,238

The surface of the quadrilateral area bounded by these streams and Raritan bay is nearly all 40 feet and upwards above tide-level, and a large part of it is about 100 feet high, while a number of hilltops are from 140 to 180 feet in height. These hills are irregularly grouped. One ridge of 100 to 180 feet high can be traced from Sayreville southeast, east, and again southeast nearly to Chesquake creek. The Burt's creek and Jacksonville road runs a little east and northeast of the crest line of this ridge.

West, southwest and south from South Amboy, most of the surface is between 100 and 140 feet high. The Camden and Amboy railroad cuts through this high ground near the Sayreville road, ascending from the depot at South Amboy, to an elevation of 100 feet near this road, and descending a little near the clay pits of W. C. Perrine and E. R. Rose, and again running up to 100 feet across the ridge near the Burts creek and Jacksonville road. It runs for over three miles on the watershed between the streams flowing north and west into the Raritan and South rivers, and those flowing east and south into the bay and Chesquake creek. The slopes of the upland toward the Raritan and South rivers are comparatively gentle, and terminate, except in a few cases, in tide marshes. South of South Amboy, along Raritan bay and up Chesquake creek, the upland is high quite to the water or marsh, and forms bluffs that mark clearly the upland from the marsh. The New York and Long Branch railroad runs at the base of these bluffs from South Amboy to the Chesquake creek at Morgan station.

TABLE OF ELEVATIONS IN THE CLAY DISTRICT OF MIDDLESEX COUNTY, TAKEN WITH AN ENGINEER'S LEVEL.

The following table of elevations, ascertained by leveling, gives the heights at many easily identified points. They were got from railroad surveys, and surveys made for the Geological Survey. The maps give many additional heights of hills and crests of ridges. These, with the contour lines, show both the elevation and the shape or configuration of the country, much better than any verbal description.

The figures give the elevation in feet above mean high water level.

VICINITY OF WOODBRIDGE.

	Feet.
David Flood's clay bank, *floor* of platform scales	75.0
David Ayers' clay bank, *floor* of office	88.0
Floor of bridge, near D. Shotwell's house, old Woodbridge and Metuchen road	90.7
Surface of water in brook under the bridge	85.0
Floor of bridge, above-mentioned road, and one mile northeast of above bridge	73.0
Summit of hill, New Brunswick and Woodbridge road, near E. Stackpole's house	165.0
Same road, near I. Liddle's house	162.0

	Feet.
Same road, *bridge* over brook from Mutton Hollow, *top* of stone abutment, northwest corner	55.0
Surface of road, David Flood's tenant house, north of Mutton Hollow	103.0
H. Cutter's *platform* scales, on road to his pits	37.0
Woodbridge and Perth Amboy road, Spa Spring brook bridge, *top* of northwest parapet	8.4
Perth Amboy road, corner of road to Cutter's dock, *surface*	20.0

PERTH AMBOY AND WESTWARD, NORTH OF THE RARITAN RIVER.

Track, E. & A. R. R. and N. Y. & L. B. R. R. crossing	50.0
Summit on E. & A. R. R., near Ford's corners	94.0
E. & A. R. R. *track*, crossing New Brunswick and Woodbridge straight road	89.0
Metuchen and Perth Amboy and New Brunswick and Woodbridge roads intersection, *surface*	105.0
Bridge *floor* on Florida grove road over the E. & A. R. R	101.0
Surface at Benjamin Valentine's gate, near Florida grove	67.0
Summit, New Brunswick and Perth Amboy road near the Eagleswood road	104.0
Surface corner of road north northwest of Manning House (hospital)	122.0
Surface, at Manning clay shaft	103.0
Centre of New Brunswick road, opposite entrance to Eagleswood	98.8
Flooring of culvert, New Brunswick road at corner of road on the west line of Perth Amboy	108.7
Railroad *track* over small culvert at entrance to Phillip Neukumet's clay bank	38.4
Rail at end of track, E. F. Roberts' pits	84.4
Surface, west end of grinding pit house at old brick yard, Raritan Clay Company	40.6
Frog of switch at junction of railroads from pits of Chas. A. Campbell & Co	14.5
Surface, New Brunswick and Perth Amboy road, at "Half-way House"	86.0
Surface, New Brunswick and Perth Amboy road, at west end of pits of Samuel Dally	77.4
Surface, pits of Samuel Dally, near red house at pits of N. J. Clay and Brick Company	73.0
Top of post near corner of road leading to pits of R. N. & H. Valentine	108.2
Top of platform of David Flood, side of N. J. Clay and Brick Co.'s railroad	45.4
Platform of scales near office of R. N. & H. Valentine	78.5
Railroad *track*, at the scales of N. J. Clay and Brick Co	41 0
New Brunswick road, *surface* in front of David Mundy's house, east of Bonhamtown	112.0
New Brunswick road, *surface* in front of Martin Schofield's house, half-mile east of Bonhamtown	103.0
Railroad *track*, entrance to gravel pit of P. R. R. Co., north of Bonhamtown	67.0

WASHINGTON TO SOUTH AMBOY.

Brick pavement (west end) in front of M. E. Church, Washington	67.5
Lower *rail* on curve of track entering Willett & Yates' brick yard, Washington	15.6

	Feet
Sayreville, *surface* in centre of road in front of M. E. Church	41.4
Sayreville, *surface* at frame barn of Sayre & Fisher, near the fire brick works	20.0
Surface, Washington and South Amboy road, corner of road to Whitehead's dock	45.0
Surface, Washington and South Amboy road, Such's railroad crossing	11.5
Summit, Washington and South Amboy road, between Such's gate and Roberts' west pits	44.4
Summit, on road from Roberts' pits to Kearney's dock	61.8
Such's railroad *track*, at clay works	13.8
Street, in front of R. C. Church, South Amboy	47.0
Surface, southeast corner of R. C. cemetery, main street, South Amboy	122.5
Summit of hill south of the village	144.0
Floor of bridge over C. and A. R. R., Washington road	115.0

MADISON TOWNSHIP.

Surface, South Amboy and Jacksonville road, at corner of road to Theodore Smith's clay pits	80.0
Surface, in front of E. Disbrow's house, on road to Theo. Smith's clay pits	45.0
Surface, north corner of —— Fitznack's house, at Theo. Smith's clay pits	38.5
Otto Ernst's clay mines, *floor* at top of shaft of 1868	31.3
Otto Ernst's clay mines, *floor* at top of shaft of 1874	27.6

ELEVATIONS OF EACH OF THE CLAY BEDS AT VARIOUS POINTS IN THE DISTRICT.

RARITAN CLAY BED.

Geo. W. Ruddy's pits, south end, *surface of clay*	35
Geo. W. Ruddy's pits, near house, *surface of clay*	36
Wm. B. Dixon's clay, *top*	31
New Jersey Clay and Brick Company, *top*	44
David Flood's fire clay, southeast of Bonhamtown, *top of clay*	47
David Flood's southwest pits, *top of clay*	43
Geo. Phœnix's clay pits, north of Bonhamtown, *top of clay*	76
W. C. & E. Mundy's pits, north of Bonhamtown, *top of clay*	77
Carman's brick yard, north of Bonhamtown, *top of clay*	78
Charles M. Dally's pits, south of Bonhamtown and north of the Raritan river, *top of clay*, [below tide]	—11

WOODBRIDGE FIRE CLAY BED.

WOODBRIDGE AND VICINITY.

Wm. P. Edgar's bank, *top of clay*	83
Wm. P. Edgar's bank, 120 feet east of above (*top*)	89
Wm. H. Berry's pits, (east) *top of clay*	73
Wm. H. Berry's pits, northwest of farm house, *top of clay*	81

	Feet.
David Flood's bank, near his residence, *top of blue clay*, at northeast end of the bank	76
David Flood's bank, *top of sandy clay*, 100 yards northwest of above	89
J. H. Campbell, estate, *top of best clay*	78
David Ayers' bank. *top of clay*	80
Charles M. Dally's bank, *top of fire clay*	65-77
Salamander Works bank, *top of white clay*	79
Loughridge & Powers' pits, *top of white clay*	73
Loughridge & Powers' pits *bottom of fire clay—deepest*	48
Mellick Brothers' pits, *top of fire clay*	57
B. Kreischer's pits, *top of sandy (stoneware) clay*	59
B. Kreischer's pits, *top of fire clay*	53
Wm. H. Berry's bank, adjoining New Brunswick road, on the south, *top of black clay*	88
S. A. Meeker & Son's pits, " Mutton Hollow," *top of fire clay*	56
J. R. Watson & Son's bank, *top of (stoneware) clay*	59
J. R. Watson & Son's bank, *bottom of fire clay*	41
A. Hall & Son's bank, *top of fire clay*	67
A. Hall & Son's bank, southwest end of bank, *top of fire clay*	73

BANKS SOUTHWEST AND SOUTH OF WOODBRIDGE.

Isaac Inslee's pits, *top of clay*	52
Isaac Inslee's pits, *bottom of fire clay*	38
James Valentine's pits, *top of clay*	48
James Valentine's pits, *bottom of fire clay*	36
Hampton Cutter & Sons, northeast pits, *top of white fire clay*	32
Hampton Cutter & Sons, south pits, *top of clay bed*	34
Hampton Cutter & Sons, south pits, *bottom of fire clay*	20
Hampton Cutter & Sons, west bank, *top of black clay*	63
Hampton Cutter & Sons, west bank, *top of blue clay*	41
Hampton Cutter & Sons, west bank, *bottom of blue clay*	20
Isaac Flood, clay pits, *top of (stoneware) clay*	38
E. Cutter's estate, old pipe clay bank, *top of clay*	25
W. H. P. Benton's pits, *top of clay*, [below tide]	—7
Charles Anness & Son's pits, *top of clay*, [below tide]	—5-10

CLAY ALONG THE NORTH SHORE OF THE RARITAN RIVER.

Woodbridge Clay Company's pits, east of Crows' Mill creek, *top of the fire clay*, [below tide]	—18
Woodbridge Clay Company's pits, near Crossman Clay & Manufacturing Company's works, *top of fire clay*, [below tide]	—3.5
Woodbridge Clay Company's pits, *bottom of fire clay*, [below tide]	—11.5
Augustine Campbell's pits, near Crows' Mill creek, *bottom of fire clay* (average).	—20
A. Weber's bank, *top of fire clay*	20.5
A. Weber's bank, *bottom of fire clay*	11
Crossman Clay & Manufacturing Company's east bank, *top of fire clay*	21.5

	Feet.
Crossman Clay & Manufacturing Company's east bank, *bottom of fire clay*	10.5
Crossman Clay & Manufacturing Company's middle bank, *top of fire clay*	26
Crossman Clay & Manufacturing Company's middle bank, *bottom of fire clay*	17
Crossman Clay & Manufacturing Company's west bank, *top of fire clay*	37
Crossman Clay & Manufacturing Company's west bank, *bottom of fire clay*	25
Ph. Neukumet's bank, *top of fire clay*	38
Ph. Neukumet's bank, *bottom of fire clay*	29–32
Chas. A. Campbell & Co.'s north or blue clay bank, *top of fire clay*	40
Chas. A. Campbell & Co.'s south or white clay bank, *top of fire clay*	38
Isaac Flood & Son's bank, east end, *top of fire clay*	56
Isaac Flood & Son's bank, west end, *top of fire clay*	61
R. N. & H. Valentine's bank, *top of fire clay*	51–54
R. N. & H. Valentine's southwest pits, *top of fire clay*	50
Samuel Dally's pits, north of New Brunswick road, *top of clay*	74
Samuel Dally's pits, south of New Brunswick road, *top of clay.*	66
N. J. Clay and Brick Company, northeast pit, *bottom of fire clay*	64

KAOLIN AND FELDSPAR BED.

Forbes' farm, *feldspar* bank, *top of sandy clay*	104
Forbes' farm, *top of feldspar*	96
Forbes' farm, *bottom of feldspar*	90
Chas. Anness & Sons' *feldspar* bank, *top of feldspar*	91
Chas. Anness & Sons' *feldspar* bank, east end of the bank, *top of feldspar*	99
Chas. Anness & Sons' *feldspar* bank, *top of sandy red clay*	104
Edgar Bros'. *feldspar* bank, *top of feldspar*	83
Knickerbocker Life Insurance Company's farm, fire sand bank, *top of black clay*	50
Knickerbocker Life Insurance Company's farm, fire sand bank, *top of fire sand*	71
Isaac Inslee, Sr. ~~Knickerbocker Life Insurance Company's~~ farm, fire sand bank, *top of fire sand*	58
" " ~~Knickerbocker Life Insurance Company's~~ south pit, *top of kaolin*	65
Jas. Valentine's *kaolin*, N. Y. & L. B. R. R. cut, *bottom of kaolin*	38
Mrs. Merritt's *kaolin* pits, *top of kaolin*	53
Whitehead Bros'. bank, Sayreville, *top of kaolin*	50
J. K. Brick estate, Burts' creek, *top of kaolin*	30
Whitehead estate, bank, Washington, *top of kaolin*	82

SOUTH AMBOY FIRE CLAY BED.

NORTH OF THE RARITAN RIVER.

Manning shaft, *top of the clay*	100
E. F. Roberts' pits, Manning farm, *top of fire clay*	80
E. F. Roberts' pits, Manning farm, *bottom of fire clay*	69
E. F. Roberts' pits, Manning farm, east end, *bottom of fire clay*	60
John De Bow's pits, *top of red clay*	80–83

SOUTH OF THE RARITAN RIVER.

Kearney tract, E. F. & J. M. Roberts, north of Washington road, *top of fire clay*	32–36

	Feet.
Kearney tract, E. F. & J. M. Roberts, north of Washington road, *bottom of fire clay*	26
Kearney tract, E. F. & J. M. Roberts, south of Washington road, *top of fire clay*	29–35
Kearney tract, E. F. & J. M Roberts, south of Washington road, *bottom of fire clay* (deepest)	15
Geo. Such's pits, southern end, *top of fire clay*	25
Geo. Such's pits, southern end, *bottom of fire clay*	13
J. K. Brick estate, bank, *top of fire clay*	28–36
Whitehead Bros' pits, (old southeastern) *top of fire clay*	54
Whitehead Bros' old Bolton pit, *top of clay*	70–72
Whitehead Bros' bank, near Sayreville, *top of clay*	70–76
Whitehead Bros' bank, near Sayreville, (south end) *top of clay*	59–62
Whitehead Bros' bank, near Sayreville, (south end) *bottom of fire clay*	51–54
Sayre & Fisher's bank, top of fire clay	65

STONEWARE CLAY BEDS.

E. R. Rose & Son's pits, near C. and A. R. R., *top of clay*	70
Theo. Smith's pits, *top of clay*	40
Theo. Smith's pits, *bottom of clay*	32
N. Furman's clay mine, Chesquake creek, *top of stoneware clay*	20
N. Furman's clay mine, *bottom of stoneware clay*	13
N. Furman's clay mine, western shaft, *top of stoneware clay*	19
N. Furman's clay mine, western shaft, *bottom of stoneware clay*	13
Otto Ernst's clay mines, 1868 shaft, *top of good clay*	12
Otto Ernst's clay mines, shaft of 1876, *top of good clay*	4
Morgan estate, Raritan Bay, *top of stoneware clay*	25
Morgan estate, Raritan Bay, *bottom of stoneware clay*	—

MISCELLANEOUS.

Salamander Works fire sand pits, northwest of Woodbridge, *top of sand*	72
R. N. & H. Valentine's fire sand pit, at Raritan Sand Hills, *top of sand*	49
David Flood's *kaolin* pits, southeast of Bonhamtown, *top of* (so-called) *kaolin*	49
Wm. H. Berry's bank, Woodbridge and New Brunswick road, *top of the black clay*	88
Clay pit, across road from residence of Chas. Anness, *top of black clay*	22
W. S. Petit's brick clay bank, Washington, South River, *bottom of working face of bank*	18
Willett & Yates' brick clay bank, Washington, S. R., *top of bank*	41
Everett & Fish, potters' clay bank, South Amboy, *top of clay*	82–88

The drainage of this clay district has been already described in connection with its surface elevation. It is so limited in extent that there are no large streams wholly within its bounds, and yet it is remarkably intersected by tide water and navigable channels. Thus in this area of about 68 square miles, there are about 30 miles of shore fronting on navigable water; or, counting both sides of the Raritan as high up as Sayreville, and excluding the more tortuous bends of the Raritan and South rivers and Chesquake creek, there are 25 miles of water-front. So that there is not a point in the district three miles from navigable water; and of the 100 clay, *kaolin*, and sand pits, none is more than 2½ miles away from such water-front. The advantages of this remarkable location for the development of such a country, are plainly shown by the rapid growth of its industries.

The tributaries of these rivers and creeks are small and unimportant, although most of them, for short distances, are small tide water inlets, bordered in some cases by tide meadows; and some of them are capable of being improved as canals or basins.

The character of the surface and soil throughout this clay district is so varied that detailed description would fail to convey a distinct idea of its manifold phases. And yet nearly, if not quite all the upland area can be described in two clearly characterized groups. These two groups of soils and superficial deposits, mark two kinds and two periods of the drift. These are (1) the northern or glacial drift which is composed of fragments of the red-shale and other northern rocks spread unevenly over the surface, (2) the older (southern ?) yellow sand and gravel drift, derived, apparently from some more southern source, and containing no red-shale drift whatever. The former is the more recent of the two, and is found resting at many points upon the latter; and both unconformably upon the beds of clay, &c. The district north of the Raritan is mostly covered by the former, and that south of the Raritan has only the latter kind. The yellow sand and gravel drift is found to some extent north of the Raritan.

1. Glacial Drift.—No attempt has been made to trace out all the sinuosities of the limits of this surface formation. The general outlines are as follows: Staten Island sound on the east, Raritan river on the south, and, on the west, a line drawn from the works of the Crossman Clay and Manufacturing Company north-northwest to the Sand hills, and thence west, near Bonhamtown, to the limits of the map. Northward this connects with the Short hills and the red shale country. It will be thus seen that this drift covers, or occupies, the tongue of land run-

ning southeast from the Short hills to a point between the sound and the Raritan river, forming Poplar hill and the high ground thence to Perth Amboy. It must here be stated that the sound is not its eastern limits, as the same drift covers nearly the whole of Staten Island, and there is no difference in the materials as seen at Perth Amboy or at Tottenville, on the opposite shore. No shale, or sandstone, is to be found south of the Raritan river and east of the South river, and the former, at Amboy, sharply divides the two surface formations. This drift is cut on the line of the Easton and Amboy railroad at Ford's Corner, and at several points between that place and Perth Amboy. It is best exposed in its relations to the yellow sand and gravel, in the *feldspar* banks of Chas. Anness & Son, and in the Woodbridge and New Brunswick road, near Wm. H. Berry's bank. It can also be seen in the cut on the Easton and Amboy railroad, half a mile south of Ford's Corner.

This *red-shale drift* belongs to the true, northern drift of the glacial epoch, which is seen covering nearly all of our more northern territory. This portion, thus locally described, must be considered as part of the southern end of the great sheet covering the continent; and the city of Perth Amboy stands on the southernmost point of this particular drift bank. The red-shale material, the predominating and characteristic constituent in this mass of drift, gives character to the surface of the country, which resembles somewhat the country to the north and west where the red-shale crops out in place. The soil has that peculiar purplish-red color, and is in marked contrast with the sandy surface towards the west and south. The forest on this drift area is also quite different from that growing on the sandy and gravelly loam surfaces. There is less chestnut and no pine, both of which trees are common and make up most of the wood found growing south of the Raritan river. From these statements it is evident that the boundary of this drift is easily and accurately traced.

The matrix of this drift consists of red-shale in the form of small fragments and as fine red earth. In this the pebbles, cobblestones, boulders and other rock masses are enclosed, without order and in all possible combinations. Boulders and pebbles and fragments of red and bluish (indurated) sandstone and of trap rocks are very abundant. Gneiss, granite and syenite are less abundant; the conglomerates and slaty grits of the Green-pond mountain (Potsdam) series, and the Magnesian and Trenton limestones are of much rarer occurrence. Large boulders are quite common, so much so that their removal in *clearing* new ground for tillage is laborious and quite costly. Many of them are large enough for quarrying into building stones. One on Miss Gale's land, three-fourths of a mile west of Woodbridge and a short distance south of the New Brunswick turnpike was 25 to 30 feet in diameter and was used for bridge abutments on the Easton and Amboy railroad. In Melick Bros.' clay bank near Woodbridge, a granite block, 10 feet in diameter, was found, lying with its polished and striated side down and imbedded 3 feet in the fire clay bed. Near Patrick Miles' house, west of Woodbridge, there is a trap rock boulder, whose dimensions, out of ground, are 15x10x5 feet. Others nearly as large might be cited, but they are not uncommon, although growing scarce as the country is more cleared up and farmed, or worked for its clays. Boulders from one to three feet in diameter are abundant, both in the drift bed and on the surface. Occasionally thin and irregular layers of white, sandy clay and clayey-like pebbles occur in this drift. These are, however of very limited extent and not common.

The surface of much of the area occupied by this drift is remarkably uneven. The hills are irregular in outline and of uneven slopes, and *sink holes* and small ponds are numerous. These irregularities of the surface are striking features in the higher grounds west and southwest of Woodbridge, in what may be termed a continuation of the Short hills.

The thickness of the red shale drift, as cut in many places, does not exceed 20 feet, but in Poplar hill there must be a much greater thickness—possibly more than 100 feet. The average or mean thickness may be put at 20 feet. An examination of the table of elevations of the clays, *kaolins, feldspars* and fire sands, and a comparison of these heights and the heights of the surface at these places, shows that there is not anywhere more than 40 feet of drift, excepting in Poplar hill. So far as excavations indicate, it is frequently quite thin, sometimes amounting to little more than a soil and subsoil. This is more particularly the case towards the southeast and near its boundary lines, or where the sheet thins out and disappears.

That this drift is a part of the great northern drift and of the glacial epoch is evident from the nature of the materials. The large and numerous boulders in it belong to rocks whose outcrop is to the north, and these occur in numbers proportional to the nearness of such rock formations. Thus the trap rocks and sandstones are in excess over the gneiss and conglomerates. Then the great mass of shaly material has certainly not traveled far, as much of this is in the form of fragments, which are incapable of long transportation without being reduced to earth. This character of constituent materials and entire absence of all sorting, or stratification, corresponds with what is observed in the great northern drift elsewhere. No organic remains have been discovered in it, although it has been so largely excavated and at so many points.

2. Yellow Sand and Gravel.—This so called sand and gravel drift includes all the more or less sandy and gravelly layers which form the surface materials, or superficial covering of this clay district, outside of the lines above given as the boundaries of the more recent red-shale, or northern drift. As has already been stated it underlies much of the latter and extends north and northwest beyond the limits of this district. In all directions it goes beyond the comparatively small area represented by this map. The almost endless gradations of sand, sandy loams, gravel, gravelly loams, &c., generally of a yellowish color, but with many other shades, accidental to the surface, are embraced in this formation. It is not only thus marked by the general character of its material components, but more definitely by the sorted or stratified arrangement of these materials—a characteristic, which everywhere distinguishes it from the unsorted, red-shale drift. And it might very appropriately be termed the stratified drift. Towards the northwest, between Bonhamtown and Martin's dock, some red-shale earth and fragments and boulders appear in it—as if there had been a mingling of materials by alternate currents, carrying shale and sand and gravel. Excepting on the northwest border of this district there is a remarkable absence of shale in this formation. And this is another of its distinguishing features.

This sand and gravel or *stratified drift* is found as a surface covering, unconformably resting upon all the clay and other beds of the plastic clay series, excepting in the area of the red-shale drift, where it is overlaid by the latter.

The thickness of this surface formation varies exceedingly from point to point, even within the limits of a single clay bank. In those about Woodbridge and north of the Raritan river, it ranges from one to thirty feet, or possibly, in rare instances, even more widely. In William P. Edgar's clay bank it is thirty feet thick, and the red shale drift is wanting—this forming the surface. In the bank of William H. Berry a few rods southwest of Edgar's, it is cut 20–25 feet thick, under six feet of red-shale drift. A few rods west of this and on the same property the latter rests immediately upon the top black clays. The same irregularities and breaks appear in it in the Mutton Hollow clay banks, west of Woodbridge, and in those of the Salamander Works and others, north of the New Brunswick road. And the two in their relation to each other and in their varying thickness, are beautifully exposed in Anness' *feldspar* bank; in E. F. Roberts' bank, near Eagleswood; in the cuts of the Easton and Amboy Railroad; in the east bank of the Crossman Clay and Manufacturing Company, and at many other points which might be mentioned since most of the digging for clay about Woodbridge has to penetrate both of these drift formations. The average thickness may be put at 10 feet. In the clay banks at the Sand hills and along the north shore of the Raritan river, the thickness is from 4 to 25 feet. Here it forms the surface material. South of the Raritan it appears to be thicker, ranging from 15 to 40 feet in the several clay banks from Sayreville to South Amboy. At the sand bank of Maxfield & Parisen, in South Amboy, it is at least 30 feet; at Otto Ernst's clay mines, near Chesquake creek, it is about 40 feet thick. From the elevation of some of the hills and ridges in the district southwest of South Amboy (140–180 feet) the maximum thickness of this sand and gravel is thought to be not less than 100 feet.

The materials of this formation, whether sand, gravel, or less rounded rock fragments, are always stratified. The lines of stratification, or layers, are sometimes horizontal, but frequently they are seen to be wavy, or gently undulating. The dip or inclination of these laminæ, or layers, is not uniform in direction. A prevailing dip towards the northwest, as might be expected, is not shown by the observations. This sorted arrangement appears in the layers of sands, gravels, &c., although these layers are not, generally, persistent to any great distance, but taper out and are then replaced by others. In the examination of the surface of the country a marked feature is nearly everywhere observed in the gravelly hills and crests of ridges and more sandy valleys and depressions. This may be owing to some systematic arrangement of the gravels and sands, but more likely the result of surface drainage, which, operating through ages, has carried down the more easily transported sands and left these gravelly accumulations in the shape of hills and ridges such as we now see. The sand and gravel generally alternate, but irregularly, and in some places there are thick beds of sand without any lines of gravel, as, for example, at the clay banks of Sayre & Fisher, George Such, Messrs. Roberts, and the sand bank at South Amboy. Very frequently a thin gravel stratum, a few inches thick, is seen lying immediately upon the clay. The sand beds generally exhibit a double system of lines, or oblique lamination, known as cross stratification. This can be seen at nearly all of the clay banks on the south shore of the Raritan, from Sayreville to South Amboy. The sand is mostly a fine white to a yellowish-white granular quartz mass, which is in some layers mixed with earthy matter. On the north side of the Raritan there is less sand and a larger proportion of earth and gravel. Quartz constitutes nearly the whole of the yellow sands, and most of this is in the form of grains and pebbles of white to yellowish, transparent, translucent, chalcedonic varieties. Some black grains of hornblende and very small, angular grains of magnetite occur with the quartz. In some places these grains are cemented together by oxide of iron, making a friable, stony mass. Fragments of feldspar are rare; and most strange is the general absence of mica from these yellow sands and gravels. It does occur in places, as in Whitehead's moulding sand, east of Sayreville, and in the South Amboy pits. This absence of so common a mineral and rock constituent may, perhaps, be suggestive of the source of the materials found in this drift. In the vicinity of Piscataway, and at Weidener's cut near Martin's dock, both rounded and angular fragments of red shale are quite abundant in this formation. This exceptional occurrence of the shale is also seen further southwest, beyond the limits of this map, and always near the southeast border of the shale outcrop. But here the deposition was in water, and a mixture of materials was such as would be expected. Further east, the glacial action carried the red-shale further south and covered the stratified drift, and in that manner made a marked line between the two surface formations.

Wherever the white sands of this formation constitute the surface, the soil is light and poor, and the timber is mainly yellow pine, chestnut and scrubby oak. The gravel has more earth in it and makes a tighter and better soil. But as a whole the area occupied by this sand and gravel formation is quite inferior as a soil to the red-shale drift north of the Raritan river. As these formations make the soil, their occurrence explains the differences so marked in this district, not only in the natural soil itself, but in its forest covering. And much of the general development of the agricultural wealth of this part of the State is also due to this occurrence of the northern drift. The mouth of the Raritan river also owes its place to the glacier whose foot terminated at Perth Amboy. So that the glacier of the past geological age has left an impress upon this country which all subsequent tillage and improvement has not effaced.

This formation has been described as drift. It must not be confounded with glacial drift, as its origin was due to water. Its stratification—its lines and layers—indicate that flowing water and not ice was the moving power. And these alternations of pebbles and sand show that there were great changes in the force of the currents that carried them. The dip of these layers is not at all uniform, although several to the northwest have been observed. These may point to a northward movement of these currents. The general absence of red-shale also points to a southern origin. Again, the prevalence of pebbles of mottled white and chalcedonic quartz and of a reddish variegated quartz, unlike any known rocks to the north or northwest and the existence of rolled fossils, more abundant than in the more northern gravels and true boulder drift, all point to a southeastern origin—a wash or drift from lands now under the waves of the Atlantic. Possibly the same continent furnished the materials for the older beds below—the clays, *kaolins* and fire sands—and this, in part gravelly formation, may have been the last of the successive floods that came from that direction. If so, there must have been a long interval between the deposition of these clays and this drift, since these, as well as the more recent greensand marl beds of the Cretaceous and Tertiary ages, are all alike covered unconformably by it. The glacial drift came later and partly covered this, but as to the length of time between the two formations we have no data for knowing. As no fossils have been found in the older, sand and gravel drift, excepting the rolled pebbles and fragments, it is impossible to determine its age. It may belong to the later Tertiary and have preceded the Glacial age. It is hoped that future explorations in many localities may result in the discovery of some remains which will enable us to determine its place in the geological series, and also point more conclusively to the source of its materials.

In this notice of the surface these two drift formations have been described as constituting the whole of the area of this clay district. They do not, however, form the whole surface, since there are here and there small, isolated outcrops of the several clays, *kaolins*, *feldspars*, and fire sands. These are, as it were, little islands in the great sea of drift. But these outcrops are of so limited extent, and they have been so nearly all dug out for their materials, that they are altogether insignificant, so far as surface features are concerned.

There is one other outcrop deserving attention, not so much from its size as its geological importance—this is the red-shale hill in Perth Amboy township, one and a half miles northwest of Perth Amboy and about a third of a mile east of the Woodbridge and Perth Amboy road. This outcrop of shale is not more than an eighth of a mile in diameter and is surrounded on all sides by drift. The shale has a northwestern dip and appears to be fast rock. It is probably an elevated point in the floor on which the clays and drift have been successively deposited. And it was probably never covered by them, or at least, not by the clay and *feldspar* bed. The drift may have been removed by subsequent denudation. This hill, or outcrop, of shale *in situ* is at least two miles from any other—or from the southeast border of the shale formation, and appears to be an outlier from the main body.

The tidal meadows have already been referred to in the above general description of the surface of this clay district. They constitute the more recent alluvial formation. The boundary lines of such meadows are easily traced and are represented on the map. This alluvium rests unconformably upon the older formations. Very generally there is either red-shale drift, or the sand and gravel under the meadow mud. At a few points valuable clays have been found a few feet beneath the surface of the tide meadows. The depth of the workable deposits below tide water level and the expenses of raising both water and clay from such pits have retarded the examination of such ground for clay, and consequently only a few pits have been dug in the meadows, and these are near the upland border. The depths below mean tide level at which clays have in several places been discovered, show that the beds are continuous underneath the meadows and the Raritan river. It is only the difficulty and expense of contending against water that hinders the opening of clay pits at any proper place in these meadows. The beds of clay were deposited before the Raritan had cut its present channel to the sea.

MAP.

The map of the clay district shows the variations of the surface by means of its contour lines; and a careful study of these will enable a person to understand the form and elevation of ridges and hills, the shape and location of valleys, and the drainage area of streams, better than any detailed description can possibly do. And a comparison of the map at any point with the columnar and cross sections will show what beds of clay or sand underlie the surface at that point, and at what depths they can be found. It is drawn to a scale of three inches to a mile; and the cross sections have the same horizontal scale, and a vertical scale of one inch to 200 feet.

The data from which the map was drawn were obtained as follows:—The water lines of the Raritan bay, Staten Island sound, Raritan river and South river (to Bissett's brick yard), were taken from the United States Coast Survey maps of "New York, Lower bay and environs," published 1844, and of "Raritan river," published 1874.

The city of Perth Amboy and the villages of Woodbridge, Washington, South Amboy and Old Bridge, were transferred from local maps. The straight road from Old Bridge to Hardenberg Corners and the roads south and west of it; the roads southeast of Chesquake creek; and the roads north of Piscataway, and east as far as Bonhamtown, were taken from the map of Middlesex county. The vicinity of Sayreville was taken from a private map belonging to Sayre & Fisher. The railroads were drawn partly from railroad maps and partly from odometer surveys

The remaining roads on the north side of the Raritan river and the principal ones on the south side of the same, were surveyed with odometer and compass. On some of the *lanes* on the north side of the Raritan and on several of the less important roads and by-roads on the south side, pacing was substituted for the odometer, the courses being determined by a compass. This method was also applied to all the salt meadow lines, to Woodbridge and Chesquake creek, South river (above Bissett's brick yard), Lawrence brook and most of the smaller streams. The field work was constantly verified by plotting.

The datum plane, or plane of reference for levels, was taken at ordinary high tide.

The heights of the surface of the clay at most of the openings, and the surface of the ground at many points, were obtained by an engineer's leveling instrument.

The heights of all other points were measured by an aneroid barometer.

To show the elevation of the surface of the ground on all parts of the map, contour lines of level were then drawn through all points having the same elevation. These lines are drawn at intervals of ten feet. The contour line which is nearest to the shore would be the shore line, if the water rose ten feet above present high tide level. The second line from the shore would be the shore line, if the water rose twenty feet higher than present high tide level. The third, if it rose thirty feet, &c. The small figures on the contour lines denote their height above high tide. The *limit* of error of the contour lines may be assumed at ten feet. In places where they have been checked by a levelling instrument it was rarely found to exceed that amount, and usually it has been much less.

GEOLOGY.

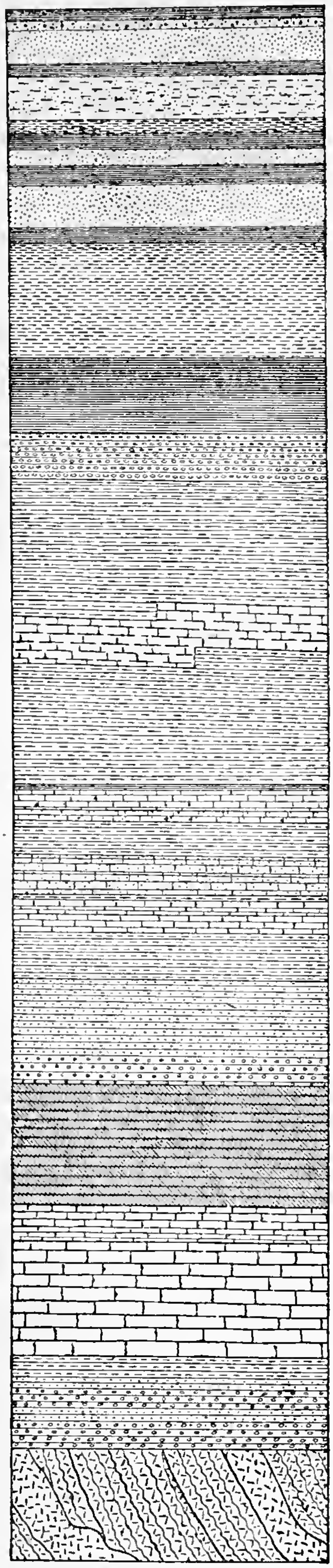
The geology of the clay district will be best understood by a general review of the geology of the State in which it occurs, and of the geological formations which are associated with it.

For this reason we here present a condensed statement of the geology of New Jersey.

Nearly all the great geological classes of rocks and earths are represented in this State. Its oldest rocks make up the mountain range which crosses the northern part of the State from northeast to southwest in parts of Sussex, Passaic and Bergen; Warren and Morris; Hunterdon and Somerset; and which is known in New York as the Highlands, in Pennsylvania as South Mountain; and is here without any general name, but its individual ridges are known as Ramapo Mountain, Hamburg Mountain, Schooleys Mountain, Trowbridge Mountain, Watnong Mountain, Musconetcong Mountain, Scotts Mountain, Marble Mountain and others. The newer geological formations lie upon each side of this central ridge, and run parallel with it; the Silurian and Devonian limestones and other formations being mostly in a broad belt upon its northwest side, and a little in its valleys; the Triassic red sandstone adjoins it in a broad belt on its southeast side; the Cretaceous clays and marls stretch across the State in a belt just southeast of the red sandstones; and the Tertiary and the Recent formations lie southeast of the marls. The columnar section of New Jersey formations here inserted shows their order and relative position, as they have been proved by measurement and comparison at the various places where they occur in different parts of the State. It does not however give the relative thickness of the different formations, those in the lower part being much thicker in proportion to the higher; and the layers or strata are not level as represented here, but are almost all of them slanting or *dipping* downwards towards the northwest or southeast. The Azoic, Cretaceous, Tertiary, and most of the Recent have a prevailing dip towards the southeast; while the Silurian, Devonian, and Triassic mostly dip towards the northwest.

GEOLOGICAL SECTION,

SHOWING THE FORMATIONS OF NEW JERSEY IN ORDER AND THEIR EQUIVALENTS.

Geological Ages.	Equivalents.	Section.	New Jersey Series.
Post Tertiary.	Post Pliocene.		Alluvium and Drift.
	Pliocene.		Glass Sand and
Tertiary.	Miocene.		Sandy Clays.
	Eocene.		Upper Marl Bed.
Cretaceous.	Maestricht Beds.		Middle Marl Bed.
	Upper White Chalk.		Lower Marl Bed.
	Lower White Chalk.		Laminated Sand and Clay Marls.
	Upper Green-sand.		
	Gault.		
	Lower Green-sand.		Plastic Clays.
Triassic.	Keuper.		Conglomerates.
	Muschelkalk.		Shales,
			Red Sandstone and
	Bunter Sandstein.		Trap Rocks.
Devonian.	Marcellus Shale.		Marcellus Shale. Cherty Limestone.
	Corniferous Limestone. Cauda-Galli Grit.		Cauda-Galli Grit.
	Oriskany Sandstone.		Oriskany Sandstone.
Silurian.	Lwr. Helderberg Limestone and Water Lime.		Lr. Helderberg Limestone and Wat. Lime.
	Medina Sandstone.		Red Slates and Sandstone.
	Oneida Conglomerate.		Sandstone and Cong. of Kittatinny Mt
	Hudson River Slates.		Shales, Roofing Slates and Slaty Sandstones.
	Trenton Limestone.		Fossiliferous Limest'e
	Calciferous Sandrock.		Magnesian Limestone
	Potsdam Sandstone.		Sandstone, Slaty Grit and Conglomerates of Green Pond Mt.
Azoic.	Laurentian.		Gneiss, Crystalline Limestone Granite.

The sketch map of New Jersey, which faces the title page, gives the outlines and location of the most important geological divisions of the State. The plastic clay formation is shown on it. It is that part of the Cretaceous which is northwest of the dotted line drawn through it, and the clay district of Middlesex county is marked by a dotted line, inclosing a rectangular space.

The boundaries of the formation are as follows: The northwestern boundary, beginning at Woodbridge Neck, on the shore of Staten Island sound, passes just north of the villages of Woodbridge and Bonhamtown, to the Raritan river, a few rods below the mouth of Mill brook. Then crossing the Raritan, it is easily traced along the south side of Lawrence brook, and at distances varying from a few rods to a quarter of a mile from the stream, to the bend of the brook a mile west of Dean's pond. From there it can be traced in almost a straight line to the Delaware and Raritan canal, half way between Clarksville and Baker's Basin, and then near the line of the canal to Trenton and the Delaware river. From Trenton to Salem the Delaware marks the northwestern and western boundary, with the exception of some limited patches of marsh and alluvium along the river. Its southeast border can be traced from the shore of Raritan bay, a little south of Chesquake creek, in a southwesterly direction, in a line passing north of the village of Morristown, and on just south of Jacksonville; then across the country by the house of the late Parker Brown to the little village called Texas, on the Matchaponix creek; and from thence directly on, passing about a mile south of Jamesburg station, and crossing the Camden and Amboy railroad near Cranbury station, it passes about a half-mile north of Hightstown, and thence in a line a half-mile north of the railroad to the mouth of Crosswicks creek, on the Delaware at Bordentown. It follows the bank of the river to Kinkora, from which place it is extremely difficult to trace it with accuracy, the characteristic clays being entirely hidden by superficial deposits and soil, except in the banks of the streams. Guided by these marks the line has been drawn. It follows near the line of the railroad east of Florence; a half-mile east of Burlington, crosses the Rancocus a mile above Bridgeboro', and the Pensauken some distance above Cinnaminson bridge; it comes to the bank of the Delaware again at

Gloucester City; it passes back of Red Bank, crosses Woodbury creek a mile above its mouth, Mantua creek near Paulsboro, and Raccoon creek a mile above Bridgeport; thence it continues in the same direction to the Delaware near Pennsgrove.

The area comprehended within this formation is three hundred and twenty square miles.

The materials of the clay formation are earthy; and no rocky or stony layers or beds are to be found in it. There are some small places in which the sand and gravel have been cemented with oxide of iron sufficietly to form a rough building stone, and concretions of clay and oxide of iron of a stony hardness are found in some of the clay beds; but the layers of sand and clay, of which the formation is made up, are all earthy, and so soft that they can be dug with a spade.

The whole formation is composed of a series of strata of fire clay, potter's clay, brick clay, sand and lignite. The details of these with their order, thickness, and qualities will be given farther on in this report. The thickness of the series of strata is nearly 350 feet. The strata are generally parallel to each other, and are all inclined downwards towards the southeast, with an average dip of about forty-five feet per mile. The direction or *strike* of the outcropping edges of the strata is south 46° west, true bearing.

The geological age of this formation is determined entirely from its fossils—the series of earlier formations between this and the Azoic period being wanting here, and this lying directly upon the crystalline gneissic rocks. Fossil wood is abundant in many places, and the roots, leaves and fruit of plants are sometimes found. Shells, and remains of animals, are rare.

Fossil leaves from the clay banks at Washington and Sayreville, from the clay pits at Burts creek, from Mrs. Allen's pit at South Amboy, and from the clay in the bluff bank of the Delaware two miles below Trenton, were collected. These were submitted to the examination of Prof. Leo Lesquereux, of Columbus, Ohio, who makes a special study of Vegetable Paleontology, and is one of the most eminent authorities upon the subject. He reports as follows: "The specimens, very numerous, badly preserved, from Sayreville and other localities in the leaf-bed overlying the Woodbridge fire clay bed, have, so far as they are determinable, the characters of the flora of the Dakota group, or of the lower Cretaceous of Nebraska and Kansas. This is lower Cretaceous for this country equivalent to a lower member of the upper Cretaceous of Europe. The species identical to both formations in New Jersey and Kansas are *Magnolia Capellini*, Heer; *M. alternans*, Heer; *Persea Nebrascensis*, Lesqr.; *Salix protæfolia*, Lesqr.; two species of *Proteoides; Glyptostrobus gracillimus*, Lesqr.; *Sequoia condita*, Lesqr.; I noted some other species as new, but they are not named or described, indeed from the bad state of preservation of the leaves, it would not be possible to make a diagnosis, without a comparative study of specimens with those I have on hand. Among others there are fragments of an Araliopsis, the basilar part of a leaf only, and we have from the Cretaceous of Kansas and now also from that of Colorado numerous species of the same genus.

"The flora of South Amboy, as collected from Mrs. Allen's clay pit, totally differs in its character as far as represented by the few species known as yet, from that at Sayreville.* It has one, a single species, a Sterculia (new species) in common, and it is the only one. Most of the leaves of the lower Cretaceous stage have entire borders; on the contrary those of this upper stage are serrate or denticulate on the borders. As said above, these upper Cretaceous leaves represent mostly new species referable to the genera, Salix, Proteoides, Andromeda, Myrica, and perhaps a Prunus. There are many specimens of small cuneate flabellate leaflets referable to a new genus of ferns; also leaves of *Quercus*, of the section *Dryophyllum*, and another narrow denticulate, apparently a *Lomatia* or a *Myrica*. The leaves of *Salix* are like those of *S. protæfolia* of the lower stage but are covered with a coating of carbonaceous matter which renders their nervation obsolete. One of the leaves is referable to *Andromeda* like *A. parlatori*, Heer.; another to *Cinnamomum Heeri*, and two species of conifers, *Sequoia rigida.*, Heer, and *S. Reichenbachi*, Heer., the leaves being shorter and narrower.

Resuming.

1. *Pettits' clay bank near Washington, S. R.*

    Sterculia, undetermined species.
    Rootlets of equisetum.
    Andromeda.
    Proteoides Daphnogenoides.

* It is comparable to an upper Cretaceous bed of southwest Colorado, (see Ann. Rep. of Dr. F. V. Hayden, 1874, p. 360.

Platanus Heerii, Lesqr.

2. Sayre & Fisher's clay bank, at Sayreville.
   - Glyptostrobus gracillimus, Lesqr.
   - Sesquoia ~~Sequoia~~ condita, Lesqr.
   - S. Smithsiana, Heer.
   - S. Subulata, Heer.
   - Araliopsis—undeterminable.
   - Magnolia alternans, Heer.
   - M. Capellini, Heer.
   - Cinnamomum Heerii, Lesqr.
   - Laurus—species.
   - Persea Nebrascensis, Lesqr.
   - Daphnophyllum ?
   - Salix protæfolia, Lesqr.
   - Proteoides Daphnogenoides, Heer.
   - P. undeterminable.
   - Sterculia—species.
3. J. K. Brick's clay bank, Burts creek.
   - Sassafras (Araliopsis).
   - Seed of Conifer.
   - Rootlets.
   - A Sequoia with thick leaves.
   - Sequoia Reichenbachi.
4. Mrs. Allen's clay pit, South Amboy.
   - Quercus, dentate leaves.
   - (Dryophyllum.)
   - Sterculia, same as above.
   - Myrica or Lomatia.
   - Salix protæfolia.
   - Andromeda
   - Cinnamomum Heerii; Lesqr.
   - Sequoia rigida, Heer.
   - S. Reichenbachi, Heer.
   - Leaves of a peculiar new kind of fern.

"These specimens are few and poor, and therefore the determinations are not positively ascertained."

Two specimens only of shells have been collected from the clays during the surveys. These are not very well preserved, but they have been examined by Prof. W. M. Gabb, of Philadelphia, and by him determined to be the *Cucullæa antrorsa*, a species common in the green sand marl bed. It is undoubtedly of the Cretaceous age.

Pebbles containing fossils are not uncommon in the gravel found in all parts of the clay district. Several small lots submitted to Prof. R. P. Whitfield of the American Museum of Natural History, Central Park, New York, were reported on as follows: "The fossils in the various lots are nearly all from the Upper Helderberg limestone group. Those from Martin's dock contain three species of Favosites, several fragments of *cyathophylloid* corals, a *Michelina*, also allied to *Favosites*, *Atrypa reticularis*, *Strophodonta parva* and some other shells, fragmentary, also several specimens of an undescribed *Stromatopora* (spongoid).

"Those from Everett and Fish's clay banks are mostly cherts and jaspers and many, likely, from the Corniferous.

"The pebble with fish tooth is most likely Upper Helderberg. One other lot contained a curious pebble of sandstond composed of a white matrix and rounded quartz and on being broken open revealed a large fragment of *Orthis hipparionyx*, Vanuxem.

"Another lot reveals *Atrypa reticularis*, Spiriferae (species?) and several fragments of Devonian brachiopods and corals and an impression of the dorsal side of a Gyroceras, or Cyrtoceras, very like C. ——— Hall, from the Schoharie Grit.

"There is no evidence of anything in the lot of more recent age than the Hamilton and that only on two fragments, the others being Upper Helderberg, Oriskany and perhaps some of the *Favosites* Lower Helderberg, possibly though not probably."

The source from whence the materials for this formation originated must be looked for to the southeast of the present strata. Though bordering upon and overlying the red-shale and sandstone which lies to the northwest of it, there is not a fragment of those rocks to be found in any of these beds, nor any of their striking and characteristic red color to be perceived in them. On the contrary, the materials of these beds are white, grey, or blackish, and if at all tinged with the reddish color of oxide of iron, it is a yellowish red, and not a purplish red like the red-shale and red sandstone. The appearances all indicate that they have originated from the materials of disintegrated and partially decomposed feldspathic granite or gneiss. In some places these products of disintegration have been sorted by water, the fine particles of clay deposited by themselves to make the present clay beds; in others, the quartz has been deposited as sand in beds by itself; and in still other places, the finest of the sands, with a little mica almost in powder, has been deposited to make the so-called *kaolin* beds. In other beds the materials are deposited in their original mixed condition—clay and quartz together constituting the so-called *feldspar* beds of this district.

There does not appear to have been any violent or irregular movements since the deposit of the clay beds, which has disturbed or distorted them. But there must have been high ground to the southeast and outside the present line of sea coast, from which the materials for the clay and sand could have been washed and deposited on the lower ground upon which they still lie. And this high ground, besides what wore away to make these beds, must have gradually settled down till it was hidden beneath the ocean, and the beds of the clay formation have risen along their northwestern border till they were above the sea level, and till the beds had so altered their inclination as to slope down towards the southeast instead of towards the northwest, as they did when first deposited.

PART II.

CHAPTER I.

GEOLOGICAL STRUCTURE OF THE CLAY DISTRICT OF MIDDLESEX COUNTY.

THE PLASTIC CLAY FORMATION here described consists of the following members, or sub-divisions, beginning at the top, viz.:

	Feet.
Dark colored clay (with beds and laminæ of lignite)	50
Sandy clay with sand, in alternate layers	40
Stoneware clay bed	30
Sand and sandy clay (with lignite near the bottom)	50
South Amboy fire clay bed	20
Sandy clay (generally red or yellow)	3
Sand and *kaolin*	10
Feldspar bed	5
Micaceous sand bed	20
Laminated clay and sand	30
Pipe clay (*top white*)	10
Sandy clay (including leaf bed)	5
Woodbridge fire clay bed	20
Fire sand bed	15
Raritan clay beds—Fire clay	15
Sandy clay	4
Potters clay	20
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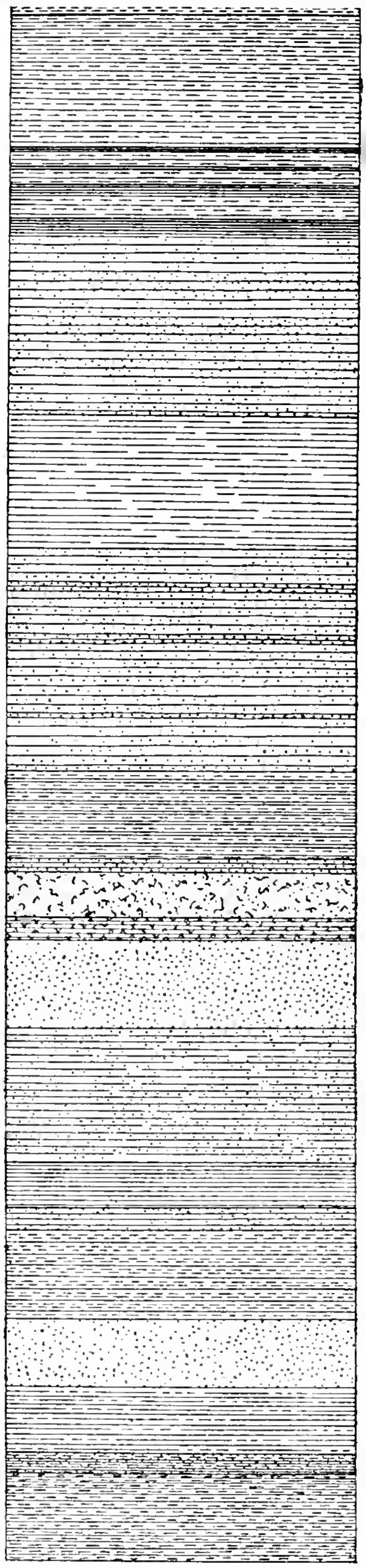
The columnar section here given shows the position and relative thickness of the several members of the Clay Formation. These several members of the Plastic Clay Formation are not equally well defined and clearly marked by characteristic features; neither do they always appear of uniform thickness, corresponding to the figures as stated in the above general section and order of superposition. The series here given represents the succession of the several sub-divisions, or beds, and their average thickness, as observed in localities where they appear fully developed and have not been subsequently eroded or otherwise diminished in thickness through the action of outside agencies. The order of succession, or superposition, is made up from a survey of the whole.

COLUMNAR SECTION

OF THE PLASTIC CLAY FORMATIONS.



Clay Marl.	
Sand and Sandy Clay with Lignite Beds.	50 feet.
Sandy Clay and Sand.	40 feet.
Stoneware Clay Bed.	30 feet.
Sand and Sandy Clay.	50 feet.
South Amboy Fire Clay Bed.	20 feet.
Sandy Clay.	3 feet.
Sand and *Kaolin*.	10 feet.
Feldspar Bed.	5 feet.
Micaceous Sand Bed.	20 feet.
Laminated Clay and Sand.	30 feet.
Pipe Clay—Top White Clay.	10 feet.
Sandy Clay.	5 feet.
Woodbridge Fire Clay Bed.	20 feet.
Fire Sand Bed.	15 feet.
Raritan Fire Clay Bed.	15 feet.
Sandy Clay, with Lignite.	4 feet.
Raritan Potters Clay Bed.	20 feet.
Red Shale.	

In this district there are no high hills with steep slopes, neither river or shore bluffs, nor any natural cuts or banks of sufficient elevation to exhibit this aggregate thickness of individual beds. Nor are any of the excavations made in working the clays, or borings made in the course of exploration, deep enough to show the whole series. Scarcely any of these exceed eighty feet in depth, or little more than one-quarter of the whole thickness of the formation. The general section and the sub-divisions given above, may be considered as a combination representing and including over one hundred local sections, which are distributed all over the district. Some of these are quite short, scarcely showing more than a single bed and its relations to the one over or under it. Others include several entire beds and parts of others. Taking into account all these features and peculiarities, the position, extent and character of each bed have been determined as the result of this general comparison. There are many characters or phenomena which are merely accidental, peculiar to a locality and of limited extent. These, however, when carefully examined, are found to conform to the general arrangement described above, and a reasonable cause can be found for the apparent variation.

In the consideration of this part of the subject the superficial beds of earth, loam, sand, gravel and boulders are omitted, inasmuch as they have already been described in Part I, page 14, on the geology of the surface. The discussion here considers the geological structure, or skeleton of the district stripped of its superficial or later covering, though in many cases this is of great importance in the economy of mining clay. We look at it as it existed just before the drift of sands, gravel and boulders came in successive floods and covered it.

Strike.—The strike of the beds in the plastic clay series is in a general northeast and southwest line, or more accurately, north 46° east, and south 46° west. This is ascertained from a comparison of heights of the Woodbridge fire clay bed, South Amboy fire clay bed and of the stoneware clay bed, taken at nearly all the points where they have been seen. The vertical sections properly referred to these standard levels or elevations of these more prominent and persistent beds give further data for comparing the elevations of other and intermediate beds, and consequently additional lines of equal heights or *strike*. Each layer or bed thus furnishes one or more of these, but since they all agree in direction and are simply parallel to one another, one represents all these beds, or the whole formation. Any given bed or member of the series is at the same elevation on this line of strike. And proceeding from any given point on one of these beds in the direction of this line either northeast or southwest, that bed is to be found at the same elevation throughout the extent of this district. A reference to the map will show a remarkable correspondence between this line of strike and some of the natural features of the surface. First, it will be observed to coincide with the trend or direction of the tidal valley along the Raritan river, from the South river at Washington and Petit's clay bank to the upland at the Crossman Clay and Manufacturing Company's works and at Kearney's dock, where the wide border of meadow on the north side of the river ends. Second, the broad valley of the Chesquake creek from Jacksonville to the Raritan bay also runs in this same direction. There are, of course, other streams and valleys and depressions, as well as ridges of hill and lines of elevation, which do not agree with this general trend. But these two valleys, above mentioned, are large and the most characteristic features of the surface and their coincidence with the line of strike is at least remarkable. The banks opened along the Raritan from near Bonhamtown to the tract of the Crossman Clay and Manufacturing Company, in what is known as the Woodbridge fire clay bed approximate to the line of strike. The several banks in the South Amboy fire clay bed between Washington and South Amboy border the tide valley of the Raritan *on the south* and their general direction coincides with the line of strike of the clay beds. In the same way the openings along the Chesquake creek in the stoneware clay bed correspond to the trend of this tidal valley and to the line of strike. The Woodbridge clay banks are all in a comparatively limited area and the length of this group of openings is from northwest to southeast, or across the strike. The elevation at the several points in this group shows that going from northwest to southeast the line of strike is crossed at right angles.

DIP.—From the *strike,* or line of level along or in any given bed the line of maximum descent gives the inclination, and this descent is termed the *dip.* It is always at right angles to the *strike.* From the elevations of the clay beds this descent or dip towards the southeast is evident. And as the line of the *strike* is north 46° east, the direction of the dip, being at right angles to the strike, is, therefore, south 44° east. An examination of these elevations at a few points illustrates this statement. Beginning with the lowest member of this series, the Raritan potters clay bed—the bottom of the bed in Mundy's pits, north of Bonhamtown, is 60 feet above mean high water level; in Charles M. Dally's pits along the Raritan river meadows it is about 18 feet below the same datum plane, showing a difference in elevation of 78 feet in a distance of 1.3 miles (measured on the line of dip) equivalent to a descent, or dip, of 60 feet to a mile.

In William P. Edgar's bank, north of Woodbridge, the bottom of the Woodbridge fire clay bed is 69–75 feet above high water mark; in James Valentine's pits, south of Woodbridge, the same bed (bottom) is 36 feet above the same datum plane, a difference of 36 feet, taking the mean of the two measurements in Edgar's bank. These pits are on the line of dip and the distance between them is two-thirds of a mile. This would, therefore, show a descent or *dip*, of 48 feet to the mile. Again, in David Flood's bank, northwest of Woodbridge, the height of the bottom of the fire clay is 61 feet; in William H. Benton's pits, near Spa Spring station, the bottom of the same bed is 25 feet below high water level, showing a difference of 86 feet in a distance of 1.7 miles, which is equivalent to 50.6 feet per mile. In the clay banks along the Raritan, those of P. Neukumet and the Woodbridge Clay Company, near the mouth of Crows mill creek, are on the line of dip, and the distance between them is just one mile. The mean elevation of the clay bed (bottom) in the former is 30 feet, while in the latter the bottom is about 22 feet below high tide—a difference of 52 feet, or here the dip of the bed is 52 feet per mile.

In the South Amboy fire clay bed the average height in E. F. Robert's pits near Eagleswood, north of the Raritan, is at the bottom 65 feet; in George Such's pits near Burt's creek, south of the Raritan, the bottom of the clay is 11 feet above high tide level. The distance between these two points, on the line of dip, is one and a quarter miles, and hence the dip is 42 feet per mile. Between the average elevation of the fire clay in the bank of the J. K. Brick estate and that of George Such's bank there is a difference of 9 feet—a distance of a quarter of a mile, equivalent to 36 feet to a mile. In the stoneware clay bed the dip is less than in the South Amboy or Woodbridge beds. At the pits of E. R. Rose & Son, near the Camden and Amboy railroad, the bottom of the clay is 55–64 feet high; at Otto Ernst's clay mines on Chesquake creek the bottom of this bed is a little below mean tide, making a difference of about 65 feet in 1.5 miles, equivalent to a dip of 43 feet per mile. Again, the heights of this bed in Theodore Smith's pits and Noah Furman's western mine are 32 feet and 13 feet respectively—a difference equivalent to a descent of 30 feet to a mile. Other examples might be cited, showing the uniformity in the dips of the Woodbridge and South Amboy beds, but more variation in that of the stoneware clay bed. The average of all the measured dips in any given bed is taken as its representative. This average or mean inclination of the several beds has been ascertained more accurately and readily from a general or combined section, upon which all the openings and outcrops at their respective elevations have been placed and all referred to their proper position with respect to each other.

This section may be understood as coinciding with the direction line of the dip, S. 44° E. To it every outcrop of clay or of other associated beds has been projected, each carried on the line of strike to this section line and there represented at its proper height. We have in this way the whole district represented on one plane and by a single section; and on it the several clay beds appear within certain parallel lines, which correspond approximately to the top and bottom of each bed. These are observed to have quite a regular descent or *dip* to the southeast, corresponding in amount to the figures given above. As this section includes in the comparison all the outcrops, pits and openings, it furnishes a more nearly correct mean or *average* dip than any comparison which could be made, using any less number of points of observation.

This section will be found folded and accompanying this report. The horizontal scale is six inches per mile; the vertical scale, one inch, equivalent to one hundred feet. The observer is supposed to be looking in the direction of the strike, towards the northeast—the northwest end being to the left hand and the southeast to the right hand. The Woodbridge and South Amboy beds will be observed descending quite regularly towards the southeast and at nearly the same angle of dip, while the stoneware clay bed descends more gently in the same direction.

From this section the Woodbridge fire clay bed is found to have a dip of 51 feet per mile; the South Amboy fire clay bed, 48 feet per mile; and the stoneware clay bed, 28 feet per mile. These figures indicate a slight difference only between the rate of descent of the two fire clay beds. Practically, they may be assumed to be parallel, although the more gentle dip of the South Amboy bed, together with the still more gentle dip of the stoneware clay bed, show that the strata of this clay formation gradually become flatter, approximating to the horizontal position, or level, in going from northwest to southeast. And the amount of the dip of the stoneware clay bed agrees with that of the greensand marl beds which lie on its southeastern border, although in these latter the *direction* of the dip is about 10° more towards the south. The strata which lie between the Woodbridge and South Amboy beds conform to them in the amount of dip, that of the *feldspar* bed, which is clearly marked and easily traced, being 48 feet to the mile. The strata above the South Amboy bed and under the stoneware clay bed are not so plainly marked as to be capable of identification at many points, and, consequently, it is not possible to give their rate of dip, or to indicate the line where the dip changes its angle and these beds become flatter. From an isolated outcrop of an inferior fire clay on the beach at South Amboy, about 25 feet higher than the regular dip of the South Amboy bed would put it at that point, it is reasonable to suppose that this bed bends a little upwards somewhere between this point and Burt's creek clay banks, or near the line where the bed strikes the level of tide water. The curve may be near this level, not only in this bed, but upwards through the overlying beds to the stoneware clay bed.

RARITAN CLAY BEDS.

RARITAN POTTERS CLAY BED.

This is the lowest member of the Plastic Clay Formation and lies unconformably upon the red and shaly rocks of the Triassic age. Its contact with the shale can be seen at nearly all the localities where it has been opened and worked. The shale appears with its uniform northwest dip at the bottom of the pits which are dug through this clay bed. From the elevations of the bed at its several localities its dip is ascertained to be towards the southeast and at the rate of 60 feet per mile. It is slightly more than that of the following and higher beds of this formation. The strike corresponds to that of the rest of the clay formation. The bed has been designated as the *Raritan* Potters' Clay Bed, on account of its occurrence on both sides of that river, having a greater length of outcrop on the northern side of it than any of the other clay beds of the series. And from the topography of the country this outcrop and its localities will in all probability be considerably extended and increased, and will make it pre-eminently the Raritan bed. The extreme western outcrops now known are near Silver lake, half a mile south of the village of Piscataway, and north of Martin's dock. The bed has been opened on the property of J. Conway west of the Silver Lake brook and in the pits of W. N. Weidner on the east of the same stream. At the latter the bed had a maximum thickness of 18 feet and rested upon a greenish grey shale. This locality is especially interesting on account of the several relations between the clay, shale and the drift over the former. These are illustrated and described fully in the local descriptions given in the chapter succeeding this. Proceeding eastward this clay crops out in the upland bank, bordering the tide meadows, on John Van Horn's farm. It was also found in digging the well at his residence and was there reported to be 13 feet thick. It has also been found on the lands of Morby & Brown, east of Van Horn's. Charles M. Dally's clay near and in the tide meadows belongs to this bed. On the adjoining farm of B. Ellison it has been uncovered in pits dug in the low grounds south of his residence. Nearer the house and in a southwesterly direction from it a pit was recently dug through a sandy clay, which is considered the equivalent of W. B. Dixon's clay at Woodbridge, and is named the Raritan fire clay bed, then through about 4 feet of clay with lignite and a layer of "hard pan," or cemented sand, and then 4 feet into this Raritan potters clay bed. East northeast of Ellison's, a pit dug near the Crossway brook and the road which leads southward to the meadows from Bonhamtown, is also supposed to have opened this bed. Still further towards the northeast some of the clay dug by David Flood in one of his southwest pits may also belong here.

This bed appears north of Bonhamtown at Carman's brick yard, and in the pits of W. C. and E. Mundy and George Phœnix. At the first named of these places the clay was mottled red and white, and was said to lie on the shale. On it there was the clay containing lignite. In Mundy's pits the same relation between the clay and shale was observed. The top of the bed hereabouts has an average elevation of 78 feet above mean high tide level. This bed has been struck by the auger in borings in the Pennsylvania R. R. Co.'s gravel pit at Bonhamtown and on the farm of Harrison Martin, northeast of the same place. Going northeastward the next locality where this clay bed is recognized is at the pits of George W. Ruddy, one mile northwest of Woodbridge. Here also the red shale is found at the bottom of the pits, underlying the clay. The mottled clay dug at Edgar station on the Woodbridge and Perth Amboy railroad, is the most northerly outcrop of this bed. At Ruddy's the elevation of the bed top is 36–38 feet.

Southwest of the Raritan river the white clay on the Island farm and that on the adjoining Devlin farm, being on the lines of strike passing through Charles M. Dally's and B. Ellison's clay pits, and at about the same level, are included in the limits of this bed, and they are its most southern outcrops thus far discovered. A reference to the map will show that the area, within which this clay bed may be found at workable depths beneath the surface, is large, reaching from the Sand hills to Martin's dock, and southwest beyond the Island farm at the mouth of Lawrence's brook. In consequence of the gentle slope of the surface throughout much of this distance the breadth of working territory will probably be found to be greater than it is in the outcrops of either of the other beds of this formation. Up to this time this bed has not been developed to the same extent as the others, and future explorations and working must add largely to the list of localities and our facts concerning it.

This clay bed has been recognized still further west, beyond the limits of the clay district, near Ten Mile Run, on the farm of Isaac Webster. Its elevation there is nearly 200 feet, and it there also lies immediately upon the red shale. The descriptions of these western localities appear in Chapter II. of Part II. of this report. The composition of Webster's clay is included in the table below with the others of this district—for purposes of comparison.

This bed appears quite irregular both at the top and at the bottom, lying upon and conforming to the inequalities of the shale beneath, and having its surface marked by inequalities, some of which are so great that the continuity of the bed is apparently broken in places, and some of the outcrops seem more like local pockets or deposits than the parts of one continuous bed. The red shale surface has given character to the bottom, receiving as a great sloping floor the clay as it was deposited upon it. And this rocky basis, by its greater elevation in some places, may have interfered with the deposition of the clay and thereby occasioned the formation of some isolated bodies or masses. But these separate outcrops, if there be such, will all be found having the same general dip towards the southeast and the same elevation on given lines of strike. The top of the bed has been in most places towards the north, very much exposed to the denuding agency of the northern drift, and after that to the wear of the natural drainage of the country, and by them has been very much modified, so that in places, as at Edgar's station and at Carman's brick yard, only a thin layer of clay—a remnant of the bed—has been left. Along Mill brook, from Mundy's pits to the Raritan river, the bed has been eroded so that none of it remains. In consequence of the modifying agencies that have acted upon it, the thickness of the bed varies considerably, from a few feet to a maximum of about 20 feet. The latter, as the limit, corresponds to the requirements of the general section (appended to this report), in order to include all the localities represented upon it. The northwest edge or outcrop of this bed may be a natural *thinning out* of the formation in that direction, and not a result of the drift denudation.

This clay bed has been recognized at the several localities by its immediate contact with the shale and by its elevation, as referred to planes corresponding to its top and bottom, drawn from known heights at given localities. It has, however, some characteristics that are generally seen. Most of the clay in it shows, on close examination, a laminated structure and a lack of homogeneity, as if the materials of which it was formed were of somewhat diverse origin. This seems particularly true of the lower part, near the shale; and in some of the pits, as at Charles

M. Dally's, it looks like a mixture of blue clay, alternating in very thin layers and laminæ with fine shaly material or earth. This latter may be largely from the wash of red shale or earth tinged by it. In general, there does not seem to be the same uniformity in material which is so characteristic of the best portions of the higher fire clay beds. At Ruddy's pits some of the clay has been found containing traces of copper, which is evidently from the copper-bearing beds of the Triassic shales. Red and mottled colors are also common, and almost characteristic. Another observed character is the low degree of plasticity. The rich white clays of Weidner's pits, near Piscataway, and of the Island farm, as well as the laminated specimens from Dally's pits, all exhibit this want of plasticity as compared with the rich clays of the other beds of this district. Another character of nearly all the clay of this bed is the larger percentage of potash than in the fire clays, varying from one to two per cent. Specimens containing much less can be found, and there may be less in certain horizons, or portions of the bed; but taken together, from top to bottom, all the clays of the Raritan potters' clay bed have it in amount sufficient to render them fusible at high temperatures and unfit for refractory purposes. In short, they are not properly fire clays. This does not, of course, prevent their use nor lessen their value for other purposes. By careful selection it might be possible to get some fire clay from some of the localities.

The results of chemical examinations of some of the clays of this bed are here given. These are representative specimens:

	1	2	3	4
Alumina	39.04	35.80	35.09	....
Silicic acid (combined)	45.61	46.44	38.20	....
Water	10.90	14.10	12.10	4.90
Quartz sand	0.71	0.51	8.60	....
Ferric oxide	1.10	1.44	1.89	....
Magnesia	....	traces	0.21	....
Lime	....	0.25	....	....
Potash	2.26	0.12	2.44	1.71
Soda	0.25	traces	0.21	....
Titanic acid	....	1.~~[illegible]~~ 30	....	....
Totals	99.87	100.10	~~[illegible]~~ 100.04	

1. Best white clay, Weidner's pits, Martin's dock.
2. White clay, Island farm.
3. White clay, Isaac Webster, near Ten-Mile Run, Somerset county.
4. Best clay, Charles M. Dally's pits, south of Bonhamtown.

In Nos. 1 and 3 the titanic acid was not determined. It is weighed with the alumina in these analyses. The other blanks show that no determinations were made where they appear. The Island farm specimen here seems to be exceptional, but as only a foot or so of it was dug and that in a single small pit, it cannot be considered as representing the locality. The others exhibit the potash present in quantity.

The Raritan clay bed is interesting geologically on account of its position at the bottom of the plastic clay series and as the *first* of the deposits of the Cretaceous age in New Jersey. And it marks the changed conditions that followed the deposition of the shales and sandstones of the Triassic age. Instead of the shallow waters and sandy flats of the former age there was a general subsidence, deeper water, and sheltered seas in which was silted down the suspended matter carried hither by the gentle currents from the surface degradation of gneissic and granitic rocks which lay to the southeast.

The Raritan potters clay bed is separated from the Raritan fire clay bed in B. Ellison's pits, southeast of Bonhamtown, by a layer of sandy clay, which has in it considerable lignite, and a layer of so-called *hardpan*, or cemented sand. The clay layer is 2 feet thick and the *hardpan* 1 to 1½ feet thick, making, together, nearly 4 feet. The lignite bearing clay is seen at Carman's pits, north of Bonhamtown. These are the only localities where it has been observed and they are hardly sufficient to allow any definite conclusions being drawn from them, regarding the space between these two clay beds. On the general section this interval is scarcely noticeable. In William B. Dixon's pits at Woodbridge there is a sandy clay at the bottom, but nothing is known of its thickness or of the beds under it. More facts are needed to determine the nature and extent of these intermediate layers. For the present they are assumed, as a provisional arrangement, to be 4 feet thick and to consist mainly of clay and lignite, according to the section at Ellison's pits.

RARITAN FIRE CLAY BED.

As has already been stated this bed follows, ascending in the series, the Raritan potters clay bed, and is separated from it by a thin layer of lignitic clay and a cemented sand, or *hardpan.* This bed was first recognized, as a distinct and well defined member of the plastic clay series, at the pits of William B. Dixon, in Woodbridge. From this locality it was for a time known as the Dixon bed. The identification of the clays at the pits of David Flood and B. Ellison, southeast of Bonhamtown, as belonging to this bed, has extended its limits and proved it to be more or less uninterrupted from Woodbridge southwest to the Raritan river, and probably beyond this stream, corresponding in direction and extent with the Raritan potter's clay bed and the Woodbridge and South Amboy fire clay beds. Continued exploration and clay mining will undoubtedly discover and open new localities of this bed. The map and appended section suggest these.

Beginning at the southwest, this bed is opened in the southwest pits of B. Ellison, where it is 8 feet thick. In a pit west of his house it was found 15 feet thick. The next locality, going northeast, is the clay of David Flood's pits, about one mile southeast of Bonhamtown. Here the bed is covered by the fire sand bed, and that by yellow, sandy and gravelly earth. The elevation of the bed (top) here is 47 feet. It is a little lower at Ellison's. The only other locality is in Woodbridge, at the closely adjoining pits of Wm. B. Dixon and Lewis Potter. Here it is covered by drift, and is of varying thickness—from 5 to 15 feet.

The clay of this bed is characterized by its drab color, its containing very fine sand, and its small percentage of potash. The specimens examined show from 29 to 50 per cent. of fine-grained quartz sand. The composition of specimens taken as representing the three separate localities, is as follows:

	1	2	3
Alumina	27.13	....	15.70
Silicic acid (combined)	31.32	....	18.13
Water	9.63	9.60	4.90
Quartz sand	29.00	....	58.09
Ferric oxide	1.26	....	1.21
Magnesia	0.08	....	....
Lime	traces.	....	....
Potash	traces.	0.42	0.17
Soda	traces.	....	....
Titanic acid	1.93	....	1.61
Totals	100.35		99.81

1. William B. Dixon's clay.
2. David Flood's clay.
3. B. Ellison's clay.

In No. 2 the percentage of water shows the amount of sand to be quite small.

In No. 3 the percentage of quartz sand is a little higher than in some of the clays from that property. It is a varying constituent.

FIRE SAND BED.

This sand is seen at the bottom of the pits dug in the Woodbridge fire clay bed; and as the openings in the bed are numerous about Woodbridge and along the Raritan river, the localities of this sand are also many, and in several places borings, made in search of clay, have gone nearly through it. As the Raritan fire clay bed has not been discovered at any point under the Woodbridge bed, there is no vertically measured section giving the thickness of the sand separating them, but from the general section, accompanying this report, the vertical distance between them is found to be fifteen feet, which, of course, must be the thickness of the fire sand bed. At the bank of A. Hall & Son, in Mutton Hollow, a boring is reported as going 14 feet into this sand. It was said to be mixed with streaks of reddish, sandy earth and fine gravel. In Loughridge & Powers' pits, near the Woodbridge and New Brunswick road, a boring 21 feet deep went 13 feet into yellow sand and then 8 feet into a sandy clay.

This latter is probably the Raritan fire clay bed. At the bank of the Salamander Works a boring, made several years ago, is reported to have passed through 27 feet of sand from the bottom of the clay bed as then opened and worked. This must have reached the level of the same fire clay bed, but the earlier borings were not so skilfully nor so carefully made as now, and a sandy clay might have been overlooked or not recognized in the small pieces brought up by the auger. Under the fire clay in J. R. Watson's bank, borings show 20 feet of sand. The sand under the clay in William P. Edgar's bank, B. Kreischer's bank, and the east bank of the Crossman Clay and Manufacturing Company, has been found containing lignite and, occasionally, pyrite.

The fire sand in the pits of R. N. & H. Valentine, M. Compton, Charles A. Campbell & Co., and David Flood, north of the Raritan, is in each of these localities lower than the horizon of the Woodbridge fire clay bed and in that of this bed.

The material of this bed, as already referred to, is generally a white quartzose sand. In places it contains a little fine gravel. Fragments of lignite also are common in it. Thin layers of yellowish and reddish earths are occasionally seen in it. In general, its characters are not so clearly marked or so persistent as those of the clay beds above it, and hardly decided enough to admit of easy recognition, unless the accompanying and overlying clay bed be present to enable one to identify it by its position.

WOODBRIDGE FIRE CLAY BED.

This is one of the most important members of the plastic clay formation. On account of the great commercial value of much of its material and the important uses to which it is put, this bed has been excavated at many points, and widely explored for additional workings. There are, in consequence of these openings and explorations, the best facilities for studying its geological relations, structure and character. It has been named from its development and the many pits where it has been opened and worked, in the vicinity of Woodbridge. Excepting the clays of George W. Ruddy, L. Potter and William B. Dixon, all the fire, ware and paper clays dug about Woodbridge and southward as far as Anness' and Benton's pits, near Spa Springs, belong to this bed. But this is only one group of openings or outcrops. Separated from these by the high ridge (which is a continuation of the Short hills), running from Poplar hill to Perth Amboy, are the several clay banks on the north side of the Raritan river, from Eagleswood westward to Bonhamtown. These are often termed the *Raritan river clays.* The pits on the J. H. Manning farm and the pits of John De Bow and Edward F. Roberts do not, however, belong to this bed, but are in the higher South Amboy fire clay bed. The position, association and character of the materials in these pits along the Raritan show their intimate relation to the Woodbridge group, as parts of the same bed. Whether these two groups of outcrops and workings are connected under the high ground lying between them, or are separate bodies or deposits of the same age and origin, is at present unknown. And this question can only be solved by further exploration in this intervening territory. It may be that this ridge has in it a core of red shale rock *in place,* of which the little hill of D. Watrous, two miles northwest of Perth Amboy, is an isolated outcrop, that has not been covered by drift. The more probable explanation is that the ridge is a continuation of the Short hills, and is a part of the great terminal moraine, which here covers deeply the Woodbridge fire clay bed and the higher members of this formation, and by thus concealing, divides, as it were, the outcrop of this bed into two distinct groups of localities. The existence of the *feldspar* bed near the top of this *dividing* ridge also indicates the presence of the lower members of the series beneath it. Future exploration and excavations will probably soon prove the continuity of these outcrops and dispel the prevailing belief in their separation. The general section appended to this report and described on page 38 exhibits nearly all the localities where this clay bed is opened, or seen, and these are represented in their relative position as determined by the lines of strike, in the thickness of the bed, as cut in these several localities and in their elevation above the level of mean high tide. In thickness there is considerable variation, as observed in the different pits. And this is more generally due to inequalities in the surface, or top, than in the bottom of the bed. And these changes of level or irregularities of the surface are frequent, within short distances, and there are many instances known where the top line has abruptly fallen from five to fifteen feet. Wherever a considerable area of the bed has been uncovered, this undulating character appears to a greater or less extent; sometimes rising and falling quite gently, forming ridges and 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, resembling on a smaller scale, the uneven surface so characteristic of much of the drift areas of the Short hills and other moraine ridges. These irregularities are characteristic of the top, or surface of this bed very generally throughout the district. There are, however, pits where the bed is more uniform and the top approximates to a plane surface. This irregular surface has been observed very marked in some of the pits west of Woodbridge; for example, in those of Loughridge & Powers, a difference of 17 feet has been seen within a few yards. And here, the bottom, also, being quite uneven and not corresponding to the top, the clay has been found in places 40 feet thick. In Hampton Cutter's bank, south of Woodbridge, the top line has been seen running in nearly a straight line for several rods. In the banks along the Raritan river this bed seems to be more uniform in thickness and less irregular in its surface line. This regularity in stratification is very beautifully exhibited in the bank of A. Weber and the east bank of the Crossman Clay and Manufacturing Company. But in these this bed is covered by the overlying members of the series in their regular order of succession and these in their turn by the drift beds. It may be stated as a fact of general occurrence that there is more inequality in the surface of the fire clay in the lower ground, or wherever the bed is not covered by the dark colored sands and clays that belong geologically over it, but by drift only. In such localities the surface features are to be regarded as the results of denuding agents which have removed the higher beds of the series and worn down the clay into furrow-like depressions and sink holes, and left it to be subsequently covered by deposits of the glacial and post-glacial epochs. This wear or denudation may have occurred in the time of the glacial drift or long before it in Cretaceous or Tertiary times, and it may in the latter case have been the wear of natural drainage rather than the work of any extraordinary floods sweeping over the land of those ages. This difference between localities where the bed is covered by dark colored sands and clays or by a thin layer of drift, is well exhibited in the banks of Charles A. Campbell & Company, at Sand hills, along the Raritan. In the old bank near the Perth Amboy and New Brunswick road, the fire clay is covered by these higher clays and sand; in the southern pits, in the lower ground, about two acres of the clay bed stripped of the top dirt, show the inequalities of such surfaces. The high bank of R. N. & H. Valentine near the same road, and the southern pits of the same firm also illustrate this difference in the surface. In Isaac Flood's bank, east of that of Valentine Brothers, the fire clay bed is covered at the east end by white sand, while at the west end the black clay lies upon it, and there the top of the bed is five feet higher than at the east end where the covering is drift. For additional facts illustrating these general statements the reader is referred to the chapter on detailed descriptions of localities.

The continuity of this bed is in places wholly interrupted by breaks or gaps, which show that it was not deposited uniformly, or that there was a considerable wearing away, or erosion after its deposition. That there was such erosion is evident in the clay pits worked on either side of such depressions which are lower than the general level of the clay bed. This can be seen in the pits along the valley of the brook between David Flood's clay and that of the Salamander Works, also along the branch of Heards brook between the pits of Melick Brothers and B. Kreischer & Son on the east side and those of William H. Berry and others on the west side. The valley along the Metuchen road between David Flood's clay on the west and William H. Berry's on the east, is another example of an eroded valley, cut out after the deposition of the beds of this clay formation. Northwest of David Flood's fire clay bank borings show black sandy clays, but no fire clay. Here is an example of erosion in the interval of time between the deposition of the latter and that of the former and higher, or more recent, strata. Many other localities could be given where the older strata appear to have been replaced by the more recent. More frequently we see the hollows and depressions and breaks filled by drift materials, evidences that these inequalities in the surface belong in the more recent age of the drift or diluvium. The bottom of this bed approximates to a plane, descending to the southeast. It has some inequalities making it in places higher and in others lower, but not rising and falling with the surface. This could not be so when it is considered that the *bottom* of this is the *top* of an older bed, or beds, upon which, as a great floor the fire clay was gently laid down. And hence the uneven upper surface of that older bed is represented by the bottom which is reached in the fire clay pits.

As the top and bottom of the bed are not generally parallel planes or conformable to one another, the thickness of this member of the clay formation is subject to the inequalities of both, and is, consequently, more varying than it would be if one or both were more regular, or plane surfaces. And it is seen ranging from a few feet to 40 feet thick. The average of all the pits, where the bed appears well developed, is about 20 feet. The general section appended to the volume shows, by its parallel lines following the dip, that this agrees with the mean or average of all thereon represented. For the exceptions, the reader is referred to the descriptions of localities.

This bed is mainly a bluish-white refractory clay, mixed with more or less fine white quartz sand. Its composition is represented by the following eight analyses of good specimens of as many No. 1 fire clays taken from different banks:

	1	2	3	4	5	6	7	8	9 Average.
Alumina	40.14	37.94	38.87	36.49	37.92	35.95	36.34	36.78*	37.55
Silicic acid (combined).	42.88	44.26	44.77	42.82	42.40	38.18	36.60	40.28	41.52
Water	13.59	14.10	12.97	12.42	14.60	12.38	12.23	13.06	13.17
Quartz sand	0.50	1.10	0.80	5.80	1.41	10.50	12.33	8.10	5.07
Ferric oxide	0.51	0.96	1.14	0.78	1.05	0.96	0.97	1.02	0.92
Magnesia	....	0.11	0.11	0.11	....	traces	....	0.04	0.09
Lime	0.10	....	....	....	....	....	....	....	0.10
Potash	0.41	0.15	0.16	0.45	0.35	0.37	0.08	0.15	0.26
Soda	0.08	....	....	....	0.37	....	....	....	0.22
Titanic acid	1.42	1.30	1.30	1.12	1.41	1.61	1.52	....	1.38
Totals	99.63	99.92	100.12	99.99	99.51	99.95	100.07	99.43	100.28

*includes titanic acid

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.
6. Crossman Clay and Manufacturing Company's fire clay, north shore of Raritan river.
7. Charles A. Campbell & Co's *white* fire clay, north shore of Raritan river.
8. R. N. & H. Valentine's fire clay, north shore of Raritan river.
9. An average, 1—8.

While this may be taken as representative of the whole, there are many exceptions. The following order in the nature of the material from the top downward shows the more common character of these variations:

Sandy clay.
Alum clay.
Fire clay.
Spotted or red clay.
Sandy clay.
Extra sandy clay.

These are not to be understood as separate layers, but simply parts of one continuous bed. This shows that both at the top and at the bottom there is a larger proportion of sand and very frequently the bed is found more and more sandy until it is lost in the sands above and below. Especially is this true at the bottom and the gradation is so gentle that it is difficult in some places to fix the limit between the clay and the sands. The alum clay is not so well marked nor so common. It may be defined as that portion of the bed which contains some pyrite, or sulphide of iron with some sulphates of iron and alumina and which is not good for refractory purposes, whereas it answers quite as well for the manufacture of alum. It is distinguished by these little nodules or lumps of pyrite and by its yellow and dark colored or dark mottled color on weathered surfaces.

The best clay of the bed is commonly in the central portion, or about half way between top and bottom, but these variations have so wide a range that it is impossible to be definite upon this point. The spotted and red clays are those which contain a large percentage of iron and which exists in them as ferric oxide, giving them a red or spotted (red and bluish) color. They are termed mottled clays, and also, simply red clays. The line of separation between these red, spotted and blue clays is always exceedingly uneven and the clay often appears to be one mass, which has been made by the most irregular mixture of large and small masses and fragments of these different shades of color. In some places these colored, or more properly discolored, clays are not found and the whole bed is blue or bluish white clay. In others the red clay is at the top, as if this part of the bed had been in some way thus discolored by agencies from above; in still others it is found at the bottom, but it is more generally found towards the bottom, as in the order of arrangement given above. Some of these latter seem to indicate an original uniform percentage of ferric oxide throughout the whole bed which has been removed from the upper part.

The sandy and extra sandy clays contain such varying percentages of sand that their composition can be given only approximately. A typical specimen from Loughridge & Powers' pits contains 52.6 per cent. of quartz sand.

From the Woodbridge fire clay bed upward to the *feldspar* bed there is a distance of 65 feet, which is occupied by sandy and dark colored clays with irregularly interbedded layers of sand Some of these beds are largely worked for common red brick and pipe materials, and these excavations, together with those necessary for the removal of these higher beds in many of the fire clay banks, afford good opportunities for the examination of the lower of these strata, but the whole series is not to be seen at any one locality or in any one vertical section. In the Woodbridge group of pits the overlying black clays run up to 40 feet in thickness Along the Raritan also they are very well exposed both in the clay banks and also in the high bluff at Florida Grove. The sub-division, as given in the columnar section above, see page 34, is not everywhere equally plain and well marked. It may be regarded as provisional, particularly towards the top, subject to alteration and further sub-division after extended workings have made the order more clearly defined.

SANDY CLAY, INCLUDING LEAF BED.

This bed is easily traced by its contact with the fire clay and by the leaf prints, or impressions so numerous in it. These are occasionally seen in other strata of this formation; but not in such numbers as here. This leaf bed, with its fossil remains, appears in David Ayers' pits, S. A. Meeker's pits, Hampton Cutter & Sons' pits, in Isaac Inslee's pits, near Woodbridge, in the Woodbridge Clay Company's pits, in the east bank of the Crossman Clay and Manufacturing Company, and at the bottom of the brick clay bank of Sayre & Fisher, on the Raritan river. Elsewhere the sandy layers appear, but they have not been examined for such organic remains. Careful explorations will no doubt result in their discovery in nearly all places where the bed is found. And this may be considered as the immediate accompaniment of the fire clay, and a guide in exploring for the underlying Woodbridge fire clay bed. It is difficult to determine accurately the thickness of this leaf-bearing sand bed. At the bank of the Crossman Clay and Manufacturing Company, where it lies between the *top white* clay and the fire clay, it is six feet thick. In R. N. & H. Valentine's bank there is five or six feet of such sandy layers between the pipe clay and the fire clay. In some of the banks it is only one or two feet thick, while in others its limits cannot be fixed with any certainty. 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 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, and at Sayreville, the bed seems like a great herbarium, with its specimens nicely pressed and preserved in the sandy layers.

PIPE CLAY.—(TOP WHITE CLAY).

This subdivision, as well as its name, comes from the fine section seen in the adjacent banks of the Crossman Clay and Manufacturing Company and A. Weber. It is made to include both the so-called *top white clay*, and the clays over it, which are used as pipe material. The best of the top black and dark colored clays in the bank of the Salamander works, and in those adjoining it, along the Woodbridge and New Brunswick road, and also those in Mutton Hollow, as in J. R. Watson's, S. A. Meeker's, and Melick Brothers' banks and in Isaac Inslee's pits south of Woodbridge, H. Cutter & Son's, and the pipe clays in the banks along the Raritan, and the hard clay stratum at Sayre & Fisher's brick clay blank, used for front brick, are all in this member of the clay series.

The stiff blue clay stratum in W. S. Petit's brick clay bank on the South river, and the five-foot blue clay layer in Willett & Yates' bank, at Washington, are also to be referred to this member of the clay formation, although in neither of these banks has the lower Woodbridge fire clay bed been identified.

It has been represented in the columnar section as 10 feet thick, but like the sand bed underneath, its thickness varies in different localities. In Watson's bank there is 8 feet of pipe clay; at the Salamander Works' bank the pipe clay, including three feet of sandy clay, is 11 feet thick. At Weber's bank and in the east bank of the Crossman Clay and Manufacturing Company there is 12 feet, including a blue pipe clay 3 feet thick; then 2½ to 3 feet of black sandy clay; 3 feet of black pipe clay; then the top white clay 3 to 4 feet thick. Near Crows Mill creek, in the pit of the Woodbridge Clay Company, this bed is 9 feet thick. At R. N. & H. Valentine's bank there is a layer of dark colored pipe clay 4 to 5 feet thick, which belongs in this subdivision. The front brick clay at Sayre & Fisher's bank is about of the same thickness. These examples show that there is in this, as in the lower strata, the same moderate range of variation from certain fixed limits, which are to be taken as the mean or average of many localities.

As has already been stated, this sub-division in some places consists of two to four distinct layers or strata. Generally there is a thin and sandy stratum interposed between two layers of pipe clay, as if the middle of the bed had received a larger percentage of sand. A more detailed survey of localities may find additional facts sufficient to justify a triple or four-fold sub-division of this member of the series. The material of this bed, as here limited and described, shows a wide range in character. The *top white clay* of the Crossman and Weber banks may be taken as typical of the purer clay of the bed. This contains about 50 per cent. of sand, and about one per cent. ferric oxide and 2.64 per cent. of potash. The equivalent of this layer—in Sayre & Fisher's bank—the front brick clay, has the following constituents, as determined by analysis:

Alumina	28.24
Silicic acid	29.15
Water	6.60
Quartz sand	28.63
Ferric oxide	2.76
Magnesia	0.19
Lime	....
Potash	2.87
Soda	....
Titanic acid	1.03
Totals	99.47

These figures represent the best portion of this bed, although there is probably less potash in some of the black clays that are included in it than in these clays whose analyses are here given. Some of them are certainly more sandy. This gradation from richer to poorer, or more sandy clays, is seen here as in all the other clay beds, and this not only in going vertically, but also horizontally, from point to point, thus explaining the differences which are to be seen in corresponding sections of the same layers taken from different banks, or even from points in the same bank. There is the general correspondence running through the varying details of each locality. Lignite is not so abundant as in the beds above and below this one. It occurs more commonly in the sandy layers, and not in the richer portions of the bed. There is some carbonaceous matter in all the clays of darker shades of color. In one from the bank of H. Cutter & Sons—a black clay—it amounts to 6.73 per cent. This is exceptionally large. The average is estimated to be 4 per cent. It is distributed quite uniformly through the mass, and gives it the dark blue to black color so common. As this is consumed in the kiln, such clays burn white. Pyrite is another quite common constituent of the clays in this bed, but nearly always in the more sandy portions which are not used. It is generally associated with the lignite. It is seen in the thin layer separating the black pipe and the blue pipe clay layers of the east bank of the Crossman Clay and

Manufacturing Company. The *top white* and the best pipe clays are free from it. No leaf impressions are known to have been found in it, but they may exist in some of its sandy and lignite-bearing layers. This bed has furnished the few shells and casts of shells which up to the present time have been found in the plastic clay formation. These are of one species only, viz.: *Cucullea antrorsa.* They were found in Valentine Bros.' bank, on the Raritan river. Additional localities and specimens of this shell, as well as of other species, are anticipated as the results of further diligent search for such fossil remains.

LAMINATED CLAY AND SAND.

This member of the clay series is well developed in many of the banks about Woodbridge and also in those along the Raritan, especially where the *bearing*, or top dirt, is thick. At many of them it is the uppermost clay in the bank, since none of them as yet are high enough to reach the next higher member of the series. The bottom sandy clay of Isaac Inslee's pits, near the Woodbridge and Perth Amboy railroad, is referred to this subdivision. The lower half of the brick clay bank of Sayre & Fisher is also placed here. Most of the upper part of W. S. Petit's red brick clay, on South river, very probably belongs to this bed. The black clay and sand dug by Willett & Yates in their bank at Washington, and the clays dug along the South river for the red brick yards, are also here included.

This bed crops out at Florida Grove, in the north bank of the Raritan, and is seen in the south bank also, near Kearney's dock, and thence southwest along that bank to Mount Ararat, near George Such's residence. It will be observed that this, with the micaceous sand bed which rests upon it, furnish nearly all the clay which is dug in this district for the manufacture of red or common brick; and the extent of these beds is quite equal to the largest demands.

As implied in its name, this bed consists of thin layers of sand and sandy clay, alternating quite irregularly. Some of these are less than an inch, while others exceed a foot in thickness. Both lignite and pyrite abound, more, however, in some than in other layers, and disseminated irregularly in all of them. The carbonaceous matter gives the dark color to much of the clays in this sub-division. The sandy layers are almost all white quartz, although in places blackened by small fragments of lignite. In consequence of this sorted character of these layers and laminæ and the lack of homogeneity, as well as the very general prevalence of both pyrite and lignite, the materials found in them are only used in the manufacture of red brick. Some of the layers might be used for more valuable purposes. The division plane between this and the overlying sand cannot be located accurately. There are but few sections showing the whole thickness of the two, and consequently it is impossible to define exactly their limits. As nearly as can be determined, the thickness of this laminated clay bed is put at 30 feet, leaving 20 feet (the interval between this and the *feldspar* bed) as the thickness of the sand bed.

MICACEOUS SAND BED.

While the laminated clay and sand has been most studied at the top of the clay banks, where alone it is worked, this sand bed is best known from the excavations that go down through higher beds and stop in it. In other words, it is best known as a *bottom* bed, whereas the other is generally at the top of the section. The localities where this is seen are comparatively few, partly owing to its position with reference to other beds, partly to its having no present use, and, possibly, in part to its lack of decided marks or character whereby to identify it. Lying next under the *feldspar* bed, the pits in that material have in most of the banks gone down to it, and borings and explorations have then gone further into it. At the bank of Charles Anness & Son this dark colored sandy bed has been penetrated twenty feet in borings. On the adjoining Forbes farm, a pit and boring went through 20 feet of this bluish sand and micaceous clay. It appears in Edgar Bros.' bank also. On the line of the New York and Long Branch railroad, near Woodbridge creek, and under the *kaolin* of James Valentine, there is 14 feet of black, sandy and micaceous clay, containing lignite and pyrite. Here this sub-division appears more clayey than it is under the *feldspar* in the above-mentioned banks. This bed, or this portion of the clay series, crops out in the hillside at Florida Grove. It was dug years ago on B. Valentine's place, south of his residence, and down the hill below the *feldspar* pit. The black clay under the sand at the fire sand bank on the property of the Knickerbocker Life Insurance Company, from its relations to the overlying *feldspar*, must also be placed here. The top clays at Isaac Inslee's pit, near the Woodbridge and Perth Amboy railroad, also belong here. South of the Raritan, the top clays in W. S. Petit's bank, in Willett & Yates' bank at Washington, and those in Sayre & Fisher's bank at Sayreville, also belong here. As the division plane between this and the laminated clay and sand under it is unsettled, some of these localities here separated may belong to both. In our section 20 feet has been assigned as the thickness of this bed.

Micaceous sand and sandy clay, dark-colored to black, make up the mass of this bed, not uniformly mixed, but more or less in layers of varying thickness; but the sand predominates over the clay and gives character to it, distinguishing it from the more clayey beds under it. Mica also appears more abundant here than in some of the lower strata of this formation. It occurs in the form of very minute flakes or scales. Pyrite and lignite are also common in it. No organic remains other than those of plants occur in it.

FELDSPAR AND KAOLIN BEDS.

The columnar section represents these as distinct beds. They are, however, so intimately connected that for the purposes of description these layers, and the thin sandy clay stratum which is found generally accompanying them, are here included under one head—one sub-division, as it were, of this formation. This three-fold division is plain at nearly all the localities, but there is such a variation in the thickness of the respective layers that the figures on this part of the section cannot be considered as representative of any one locality, but as typical of what is seen at all of the openings and outcrops. These strata lying on the black sand and sandy clay, are not seen in the vicinity of Woodbridge. The sections there do not reach high enough to include them. Nor are they seen in any of the Raritan river banks west of Crows Mill creek. There, also, the drift lies upon the laminated clay and sand bed, or upon even lower members of the clay series. The higher ground between these two groups of clay banks includes the higher strata under a considerable thickness of drift, and the most extensively worked *feldspar* localities are in this dividing ridge. At the bank of Charles Anness & Son, the *feldspar* varies from 3 to 10 feet in thickness, sometimes in two layers, which are separated by a bed of white quartz sand, and covered by a sandy clay bed 1 to 5 feet thick. At the neighboring large bank on the Forbes tract there is, in most of the pits, a sandy clay at the top, which is between a few inches and 3 feet thick; then there is a fire sand and a sandy clay, resembling *kaolin*, from 2 to 8 feet thick; then the *feldspar*, 2 to 8 feet thick; and at the bottom the bluish, micaceous sand bed. A little further to the southeast, this bed is opened on the farm of the Knickerbocker Life Insurance Company. Still further southeast it is cut in the *kaolin* pits of James Valentine, and by the New York and Long Branch railroad near Maurer's brick and tile works. At the last mentioned place the *feldspar* occurs in a thin layer, scarcely a foot thick, resting on the black, sandy clay and under the *kaolin*. On the Forbes farm the *feldspar* bed is 90 feet (bottom) above high water level; in James Valentine's pits it is 38 feet, and at the latter place the *kaolin* is 6 feet thick. At Merritt's pits, one mile northwest of Perth Amboy, the *kaolin* varies between 4 and 12 feet in thickness, and there is no clay or *feldspar* of any extent accompanying it. In Perth Amboy and its vicinity the *kaolin* is dug in the pits of A. Hall & Son, where it is 8 to 10 feet thick, and also along the Easton and Amboy railroad. It also appears in the cut of the New York and Long Branch railroad, near the depot, besides several other places within the limits of the city. The *feldspar* is wanting in these pits and excavations in Perth Amboy. West of this, and on the southwestern slope of the ridge, Edgar Brothers dig the *feldspar* near Crows Mill creek. It has been found in the clay shaft on the J. H. Manning farm, and in a boring under the clay at Ed. F. Roberts' pits, and also on B. Valentine's lands, near Florida Grove. These localities are between one and two miles west-northwest of Perth Amboy. In Roberts' boring, on the Manning farm, the three layers were penetrated as follows: reddish yellow, sandy clay from 2 to 3 feet thick; *kaolin* and white sand, 10 feet thick; *feldspar*, 4 feet thick, and at the bottom, sand. South of the Raritan river this *feldspar* bed has been opened by J N. Coleman, about half a mile southeast of Kearney's dock. The *kaolin* stratum has been recognized under the South Amboy fire clay bed in all the fire clay pits on that side of the river. At the pits of E. F. & J. M. Roberts, on the Kearney tract, it is found at the bottom, but is not taken out, the work stopping as soon as the clay is removed. In George Such's pits the red clay under the blue fire clay is presumed to lie directly upon the *kaolin* or on an equivalent bed of sand. On the J. K. Brick estate the pits are dug through the fire clay and into the *kaolin*, and this is at least 7 feet thick. At Whitehead Brothers' bank, at Sayreville, it is 8 feet thick. At Washington the *kaolin* crops out near the top of the hill above the brick clay and it is there opened and dug extensively by Whitehead Brothers. The layer there appears higher than the natural dip would put it at this point, occupying the horizon, which the South Amboy fire clay bed would be expected to fill. The general section illustrates this statement. Some of the fire sand and clay of J. N. Coleman's pits between South Amboy and Kearney's dock is referred to this place in the vertical geological section. From these preliminary notes of localities and from the fuller description of all the outcrops, given further on in this report, it will be evident that the strata of *feldspar*, *kaolin* and the associated clay layer are subject to much variation in their thickness and character of materials. The average aggregate thickness of the three beds is 18 feet, of which the *feldspar* occupies 5 feet, the *kaolin* 10 feet, and the sandy clay, 3 feet. The surface is marked by its unevenness, the inequalities being more characteristic and common than they are in any of the clayey beds of this formation.

The names *feldspar* and *kaolin*, as used everywhere in this clay district to designate these strata and their materials, are applied incorrectly. The *feldspar* is more properly a *kaolin*, although not answering fully to all the characters implied in that well known term. It is a mixture of a rich clay with white quartzose sand and fragments of quartz, nearly all of which are slightly rounded on their edges and lack the sharp grained character of the quartz in most of the true kaolins. Both the clay and the quartzose portions are of a *secondary* origin, that is, they are not the result of rock disintegration *in place*. Nor are they sorted as the materials of the clay and sand beds. There is no lamination in its structure nor any arrangement other than a most intimate mixture of these two constituents, somewhat similar to the blending of quartz and *feldspar* in some of our granitic rocks. Whence it came and how it was deposited, in this unsorted condition over comparatively so large an area, and so uniformly, are difficult questions. If there were gneissic or granitic rocks immediately under it, the explanation would be easy. Instead of such a rock basis it reposes on a sand bed, which is one of a series of sedimentary strata and these too of earthy materials, such as clays and sands, all of which appear to have been sorted by the action of water during their deposition. The mixture is so intimate that there is not the slightest trace of lamination or stratification in it. As it does not show any wave action or evidences of deposition in water it may be considered as a drift of the Cretaceous period probably of quite local origin and extent.

The chemical composition of this anomalous mixture varies somewhat in the different horizons of the layer, according as there is more or less quartz in it or oxide of iron stains through it. In places it is quite sandy and by gradations, not marked, passes into a coarse, clayey fire sand. In others it is discolored by the iron oxide and this appears in the analyses of such specimens. The following analyses * represent the average composition of the typical *feldspar*, viz:

	1	2	3
Alumina	18.95	17.55	16.07
Silicic acid	16.99	16.59	....
Water	4.90	6.30	4.30
Quartz sand	58.89	57.41	† 77.40
Ferric oxide	0.49	0.54	0.53
Magnesia	....	....	0.25
Lime	....	....	....
Potash	0.15	0.12	0.15
Soda	0.21	0.21	....
Titanic acid	....	0.90	....
Totals	100.58	99.68	98.70

† Including the silicic acid.

1. *Feldspar* from the Forbes' farm, bank worked by W. N. Weidener.

* In the chemical examination of these specimens the magnesia and the lime were not weighed. They are very small in amount, hardly more than traces. The titanic acid was determined in one only. In the other analyses it is weighed with the ~~silicic acid~~
alumina.

2. Edgar Brothers' *feldspar*.

3. *Feldspar* from bank on farm on the Knickerbocker Life Insurance Company.

These analyses show a remarkable agreement among the several constituents. They show also that the sand and quartzose fragments or pebbles amount to about sixty per cent. of the weight, which, allowing for the greater density of the quartz, would make it about one-half of the mass by volume.

The specific gravity of the *feldspar* is 2.283—2.321, being considerably greater than that of the fire clays and a little less than than that of pure quartz (2.5—2.8).

The so-called *kaolin* is a micaceous sand, consisting of 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, however, is conspicuous and gives the mass a glistening appearance and a somewhat soft and soapy feel, but the sand is very largely in excess, constituting from sixty to ninety per cent. of the mass in the more clayey and micaceous specimens. The ultimate chemical composition of some of these *kaolins* is as follows:

	1	2	3
Silicic acid and sand	77.10	89.40	92.70
Alumina and ferric oxide	17.10	7.80	5.70
Water	4.50	2.60	0.70
Potash	1.30	....	0.35

1. Is from Mrs. Merritt's pits, near Perth Amboy.

2. From Whitehead Brothers' pits, Washington.

3. A typical specimen from Charles A. Campbell & Co., Staten island.

These analyses were partial, made for comparing the *kaolins* with the fire sands, but they indicate the large proportion of sand and show that they are simply *mica-bearing sands.*

The upper layer of sandy clay is not seen everywhere accompanying the *feldspar* and *kaolin.* It is quite often wanting. It is very sandy and in most places has a reddish or yellow color and contains a considerable amount of ferric oxide. Some of it is used, mixed with other clays in the manufacture of lower grades of fire bricks and also in saggars.

East of Staten Island sound this bed of *kaolin* is worked extensively in several large pits north of Rossville, Staten island. It has been worked to a depth of 18 feet without finding bottom. It occupies the same relative position as in New Jersey, a little below the South Amboy fire clay, which latter bed is seen in the pits of Storer & Brothers, B. Kreischer & Co. and William H. Berry.

SOUTH AMBOY FIRE CLAY BED.

This bed of fire clay is best developed on the south side of the Raritan river and within the limits of the township of South Amboy, as these ran before its division two years ago. This name, then proposed, has been retained as appropriate inasmuch as the bed comes to the shore near the town of South Amboy. Like the Woodbridge bed this fire clay bed has been worked extensively at several points and these large excavations have afforded very good facilities for studying its relations and structure. The configuration of the surface south of the Raritan river does not favor a wide development in working, such as is seen north of that stream, in the Woodbridge fire clay. In the latter the slope of the surface descends southward, making a small angle with the line of the dip; and as this slope is in some places quite as steep as the dip of the clay, the belt of available or working territory—that is, land where the clay is within an accessible depth beneath the surface—is wider than it is on the south of the river, where the slope of the country is towards the north and northwest, or in an opposite direction from that of the dip of the clays. As the ground here rises quite rapidly, going southward the edges of the strata are soon passed over, and the covering, or top dirt, becomes too thick for removal, precluding profitable working and exploration. This explains the narrow belt in which the several banks of fire clay south of the Raritan are located. Looking at the map, we see this belt bending south in the low ground along Burt's creek, then turning north again in the banks on the J. K. Brick estate and that of Whitehead Brothers, where the land rises. This bed has been identified north of the Raritan river at three points, near the New Brunswick road, 1½ miles northwest of Perth Amboy. The most important one of these localities, where the bed has been best opened and most extensively worked, is in the pits of E. F. Roberts, on the Manning farm. Here the bottom of the fire clay is 60 to 69 feet above high water level, and is between 7 and 13 feet thick. Under it there is a sandy clay 2 or 3 feet thick, and under this the *kaolin* and *feldspar*. These pits and the neighboring river bluff, south of them, together make a vertical section of 80 feet, including nearly all the strata between the Woodbridge and the South Amboy beds. Until the true place of this fire clay was recognized it seemed altogether exceptional, being, as it were, an isolated outcrop on the top of the hill, and much too high to be classed with the other Raritan river clays. By reference to the general section, it will be seen that its elevation is that which would be assigned to it, knowing the dip of this fire clay bed and its correct geographical relations to the other localities of this bed. The pits on the De Bow farm, west of Roberts', are also in this bed. The remaining locality is on the north of the New Brunswick road, on the J. H. Manning place. A deep pit or shaft was here sunk through this into the *kaolin* and *feldspar*, confirming its geological position, as indicated by its elevation. In addition to these three localities, of which there is no question, some of the reddish clays found in the Easton and Amboy railroad cuttings, near the Florida Grove road crossing, very probably belong in this horizon. It is also reported as existing north of the Manning farm, in some of the higher ground running thence to the Forbes farm.

All of the fire clay which is dug south of the Raritan river comes from this bed. It has been very extensively mined in the large excavations made by E. F. & J. M. Roberts, on the Kearney tract. It has in these pits an average thickness of 8 feet and is underlaid by quartzose sand, the equivalent of the *kaolin* bed. In most of these it has evidently suffered some loss at the surface by wear, or denudation, and afterwards has been covered by the yellow sand and gravel drift. In George Such's bank it is generally found covered by sand and sandy black clay, in irregularly alternating layers. And here the bottom of the bed is red and not properly a fire clay. Proceeding west, it appears in the Brick estate bank, under a heavy bed of sand and gravel drift and lying on *kaolin*. The same association of layers is seen at Whitehead Brothers' bank, at Sayreville, although in some of the pits of this bank there is a sandy bed at the top,

which is called *kaolin*, as well as that under it. The same sand drift covers it in Sayre & Fisher's (westernmost) bank and it in turn lies on the *kaolin*. Here it is from 5 to 16 feet thick. This bed has been opened on F. Van Deventer's land near the South river, one mile southeast of Washington. The diggings were not of sufficient extent to test the locality. At James Bissett's red brick clay bank on the South river, a thin layer of tough and refractory white clay, near the top of the bank, has been supposed to belong to this bed. Its elevation corresponds to that of the fire clay horizon, but the layers associated with it do not appear to confirm this position. The white clay which crops out on the shore in South Amboy near William Allen's pits may also be a part of this bed. Its elevation and place
39 have been discussed above (see page 34.) The fire clays dug on Staten island, near Rossville, by William H. Berry, Storer & Brother and B. Kreischer & Co., from their relations to the *kaolin*, near the same place, their elevation and their location in reference to the fire clays of this district, are also in this bed. The general section shows these relations and their elevation and illustrates this statement. Judging from the localities where this bed appears best developed and not greatly worn or denuded on the surface, its thickness has been estimated to be about 20 feet. This exceeds the measurements in most of the pits, but in many of these there are evidences that at these points the thickness has been diminished by much surface wear. The inequalities in both the surface and at the bottom are very considerable, as can be seen in the pits of E. F. Roberts near Florida Grove; in George Such's and in the Brick estate banks at Burt's creek, and very finely in those of Whitehead Brothers and Sayre & Fisher, at Sayreville. So also on Staten island this clay is 15 to 29 feet thick in Storer & Brothers pits, while in Kreischer's it is only 6 feet. Notwithstanding all these variations the general section shows the mean thickness to be about 20 feet.

The South Amboy bed, like the Woodbridge bed, shows much variation in the character and in the percentage of its several constituents. The order of succession, or changes vertically in this bed, is as follows, beginning at the top:

Sandy white to buff-colored clay.
Blue fire clay.
Sandy mottled-red clay.

These are not distinct layers, but gradations from top to bottom in the one bed. This order is not always apparent. For exceptions the local descriptions must be consulted. This bed, like the Woodbridge bed, has its upper and lower portions more sandy than the intermediate part; and here, also, the lower part is found, in most pits, colored by ferric oxide, making a red or mottled, or (as often styled) a *spotted clay*, according as the clay is wholly or in part impregnated with this coloring oxide. "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 and fine fire clays, just as in the inferior red clays. These are from one to four 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. It appears more common in this than in the Woodbridge bed. Small pieces of lignite are also found here and there in it. A filmy coating of vivianite (phosphate of iron) has also been seen in one locality. Amber is another foreign mineral, but of much more rare occurrence. The rich and purest clays of this bed do not differ essentially in chemical composition from those of the Woodbridge bed. For the comparison the following table of analysis is here given:

	1	2	3	4	5
Alumina	37.49	39.93	38.76	39.05	38.81
Silicic acid	41.33	43.45	43.36	41.51	42.41
Water	12.66	13.42	13.64	13.68	13.35
Quartz sand	5.27	0.71	1.51	3.13	2.65
Ferric oxide	1.21	0.41	0.87	0.75	0.81
Magnesia	0.25	....	....	....	0.25
Lime	0.22	0.20	....	....	0.21
Potash	0.59	0.47	0.26	0.28	0.40
Soda	....	0.42	0.18	0.18	0.26
Titanic acid	(1)	1.63	1.21	1.21	1.35
Totals	99.02	100.64	99.79	99.79	100.50

(1) Undetermined, weighed with alumina.

1. E. F. Roberts' pits, Manning farm, northwest of Perth Amboy.

2. E. F. & J. M. Roberts' pits, Burt's creek.
3. George Such's, (washed clay,) Burt's creek.
4. Sayre & Fisher's fire clay, Sayreville.
5. An average of analyses, 1 to 4, inclusive.

There appears to be a slight difference in the density, those of the Woodbridge bed being more solid and their specific gravity a little greater. This difference does not, however, exceed one-tenth (0.1), which is equivalent to 150 pounds, nearly, per cubic yard. These clays thus compared contain nearly the same amount of quartz sand. The more sandy specimens are more dense.

The interval between the South Amboy fire clay bed and the stoneware clay bed is not so well known as the lower part of the clay formation. The thick beds of drift which make the surface of the slope skirting the clay banks along the Raritan river from South Amboy to the South river, have hindered, to some extent, exploration, and there are very few outcrops, or cuts, where these intermediate strata appear. The sandy, dark-colored clays of E. F. & J. M. Roberts' pits, near the South Amboy road; that over the fire clay in the old Kearney bank, and in the bank worked by the Messrs. Roberts in 1865, all on the Kearney tract; the black clay in George Such's bank, and the black sandy earth on the same clay bed in Brick's pits, constitute the lower of these strata. In the last-mentioned locality leaf impressions and lignite occur. The sandy, dark-colored clay in W. C. Perrine's pits, east of Roberts' pits, and near the old South Amboy and Burt's creek road, from its elevation, is supposed to be near the top of this intermediate series, and not far below the stoneware clay. The laminated, sandy clay dug in Mrs. Clark's pits, on the shore at South Amboy, and in which, also, leaf prints and lignite are abundant, is another exposure of these layers, but close down to the fire clay bed, the latter cropping out a little lower on the beach and seen at low water only. One of the best localities for seeing a part of these intervening beds is in the cut of the Camden and Amboy railroad, west of South Amboy and just north of and under the crossing of the Washington road. In this cut there is a considerable thickness of the dark-colored to black sandy clays, containing lignite and pyrite. Under the stoneware clay bed in the pits of E. R. Rose & Son, near the Camden and Amboy railroad, a dark-colored, sandy earth is found; in

Theodore Smith's pits, a laminated, sandy clay; in the Morgan bank, on the shore of Raritan bay, sand; in Otto Ernst's clay mines, the bottom is sandy clay, with lignite in places in it; in Noah Furman's mine, white sand. These several localities taken together show that between these beds the predominating material is a sandy clay of dark color, with alternating layers of quartz sand, and all containing some lignite and pyrite; and near the top of the fire clay bed—that is, near the bottom of this series—there appears to be a layer characterized by the presence of leaf impressions, more plainly marked and better preserved specimens and of species differing from those found in the more sandy layer which lies immediately upon the Woodbridge fire clay bed.

The thickness of these sandy clay and sand layers from the South Amboy bed up to the stoneware clay bed, as measured on the general section, assuming the dip of the former bed to be constant as it descends under the latter, is 50 feet. If the descent, or dip grows less, as is indicated by the height of the clay on the shore at South Amboy, this interval is scarcely 40 feet. The distance from the fire clay outcrop at South Amboy to Morgan's stoneware clay bank is one mile and in the direction of the dip. At these two points the two beds are at the same height respectively. According to this distance and at the dip as observed in the stoneware clay bed these clays are 30 feet apart measured vertically or at right angles to the planes of the beds. Again, the difference in the elevation of George Such's clay (bottom) and that of E. R. Rose's (bottom) is 45 feet and these are one mile apart on a northwest and southeast line. From these statements and examples it is evident that these layers do not exceed 50 feet in aggregate thickness and more probably range between 30 and 45 feet. On the columnar section and in the tabular statement of the members or sub-divisions of this formation a thickness of 50 feet, as a *maximum*, has been assigned to them.

STONEWARE CLAY BED.

This designation is taken from the material of the bed, nearly all of which is particularly well adapted to the manufacture of stoneware. Its outcrops are seen southeast of the South Amboy fire clay bed and in Sayreville and Madison township. The thick beds of sand and gravel, forming the surface in all the higher ground south of the Washington and South Amboy road and extending to the Raritan bay shore and the tide meadows along the Chesquake creek, cover this clay so deeply that it has been opened at one point only on this higher level—or territory—all the other openings are on the steep slopes of this area. The most northerly pits are those of W. C. Perrine and E. R. Rose & Son, southwest of South Amboy and near the Camden and Amboy Railroad. The bed here is covered by drift sand and gravel. In some of the pits of this locality the bed has been 15 feet thick. Along the bay shore the bed has been extensively worked on the Clark property and on the Charles Morgan estate. Here it is covered by a laminated sand and sandy clay and it has a maximum thickness of 25 feet. In the deep and narrow valley of Crossway or Back creek the bed has been opened at three points on the southeast side of the stream. On the southern edge of the high upland where it descends to the Chesquake creek meadows this bed has been opened by N. Furman, Otto Ernst and on the Morgan estate. These openings are at the head of this creek and near Jacksonville. This high ground descends more gently towards the west and southwest and on this slope there is but one opening, viz., the pits of Theodore Smith. The clay of Charles Reynolds near Tennent's brook, west-southwest of Jacksonville, should probably be included in this list of localities, although it wants some of the characteristics belonging to the others. From this enumeration it will be at once remarked that this bed has not been opened at as many points as either of the fire clay beds. There are consequently, fewer localities and sections for the examination of its geological relations and structure and these are not so well understood.

The vertical extent, or thickness of this bed varies exceedingly in these several banks where it is worked. At Reynold's pits there is only 5 feet of clay; in Theodore Smith's the bed is 8 feet thick; in Noah Furman's mines it is from 7 to 12 feet thick, including a sandy layer at the top; in Ernst's mines it appears to be somewhat thicker, being 12 feet in one shaft, 15 feet in another, and in a third, the shaft and borings are reported by Mr. Ernst to show 31 feet of clay, passing through two distinct layers of good clay, separated by 6 feet of sandy and red to dark colored clays. At the salt works dock the clay appeared in pockets, one of which was found to be 18 feet thick and 20 feet below tide level, while near this in the side hill the clay was got 18 feet above that level and 5 to 7 feet thick. Morgan's bank on Raritan bay also shows much inequality and variation in the thickness of the workable clay. Measured from extreme top to bottom, at deepest, it here approximates to 30 feet in thickness. Some of these figures and the general section, appended to this report, indicate a mean thickness of 30 feet. Wherever it is found covered by the laminated sand bed which succeeds it in the geological order, it is generally found to be thicker. Elsewhere it seems to have been diminished in size by agencies operating at the surface. The upper part of it has very probably, in these places, been carried away by floods of water or ice. More extensive working in it may yet show considerable irregularity and, possibly, that it is more of a series of pocket-like deposits than a regular, continuous bed, like the fire clays of Woodbridge and South Amboy.

This bed rests upon a sandy stratum and, in turn, supports a laminated sand bed. Approaching these limits, towards the top and bottom, it grows sandy. And the top part, which is more sandy, is not generally recognized by *clay miners* as the *stoneware* clay, but is sold for inferior uses. In the vertical dimensions, given above, this has been put in as a part of the bed, as there is not generally any well marked plane of division between this and the *stoneware* clay, of the *miner*, which is beneath it. In one of Ernst's shafts a dark colored clay comes in between them. The stoneware clay, proper, is a white to greyish white clay, marked by numerous small spots or specks of ferric oxide and hence, sometimes, termed "fly specked." It is quite dense, having a specific gravity of 1.97–2.15. It contains from one-third to one-half its weight of fine, white quartz sand. Its chemical composition appears in the following analyses of typical specimens:

	1	2	3
Alumina	21.07	20.45	21.29
Silicic acid (combined)	29.95	29.14	29.46
Water (combined)	7.22	5.87	6.81
Quartz sand	36.75	40.43	38.14
Ferric oxide	1.47	1.46	1.71
Magnesia	0.30	0.51	0.30
Lime	0.11	traces	0.11
Potash	1.56	1.61	1.82
Soda	traces	0.48	0.18
Titanic acid	1.15	0.91	1.01
Totals	99.58	100.86	100.83

1. Stoneware clay from E. R. Rose & Son's pits.
2. Stoneware clay from Otto Ernst's clay mines.
3. Stoneware clay from N. Furman's clay mines.

Foreign minerals are less common than in the fire clay beds, and no leaf impressions or other organic remains have been found in it. At Ernst's mines small pieces of amber have been discovered, but they are comparatively rare. It differs from the fire clays in the large amount of sand and in the much larger percentage of potash. The latter constituent, coupled with the sand, makes it fusible and adapted to the making of stoneware. At Morgan's bank the lower part of the bed is found very commonly stained red by oxide of iron (ferric oxide), or sometimes spotted, red and white, and then, locally, termed, from its color, "peach blossom clay." Other spotted clay, from its use, is called "door knob clay." In this phenomenon there is some correspondence between these several beds. Whatever may have been the causes which produced these like effects, they seem to have acted uniformly in affecting the lower rather than the upper parts of these beds.

LAMINATED SAND AND CLAY.

This sand and clay, succeeding the stoneware clay bed, crops out at several points along the Chesquake creek valley and in the bluff along Raritan bay. The best locality for seeing it is on the stoneware clay in Morgan's bank and on the Clark property adjoining, and thence southward along the line of the New York and Long Branch railroad to Morgan station, near the mouth of Chesquake creek. At Morgan's bank it rises nearly to the top of the hill, and there attains a maximum thickness of 40 feet. From this point to the creek it appears in the side cut of the railroad, above the track level, and downwards to the tide water line. Here it is covered by yellow sand and stratified gravels. At the salt works dock it lies on the stoneware bed. Near Mr. Ernst's mines it crops out in the hillside, and here it is quite full of pyrite and lignite, and is covered by yellow sand and gravel drift. Some of the sandy earth, or so-called "black stuff," was found in sinking the mine shafts at this place. This, together with the strata, seen in the neighboring ravine where the strata are well exposed by surface wash, makes a total thickness of about 40 feet. The proportion of white quartz sand seems here to be greater than it is at Morgan's bank. At N. Furman's old bank, south of Ernst's mines there is 10 to 15 feet of this black sand and clay. At the more recently worked mine of Furman, near the head of Chesquake creek, there is 3 to 6 feet of this bed, and here as at Ernst's the section made up of this and the outcrop in the adjacent hillside, is somewhat longer. The Chesquake creek is approximately the southeastern limit of this laminated sand, as south of that, in the cuts on the New York and Long Branch railroad, and also along the Bay Shore there is more clay and less sand and very little of the laminated structure. It is estimated to be at least 40 feet thick. The very plainly marked lamination is a characteristic of this bed. It is made up of drab to black, sandy clay, generally in moderately thin layers, separated by much thinner layers, and in some instances by mere filmy partings of white sand. There is, however, some variation in the size of these layers. Lignite occurs in this bed, but most commonly in small pieces and fragmentary masses.

CLAY AND LIGNITE.

This is at the top of our columnar section, and extends upwards to the greensand marl, or the clay marl bed, which is at the bottom of the greensand series. The line of division between this and the laminated clay and sand cannot be fixed accurately, but its top is clearly defined by the greensand, or *glauconite*, which appears irregularly disseminated through the drab and dark-colored clay of the clay marl. Two good sections of this lignite-bearing clay are seen, one along the Raritan bay shore, from Chesquake creek southeast to a point a little beyond the Monmouth county line; the other in the several cuts on the New York and Long Branch railroad, from the same stream to the Cliffwood station, in Monmouth county. There is about 40 feet of this bluish-black clay in the bluff on the shore of the bay, east of the Travers house. Southeast of this, and near N. Furman's brickyard and Whale creek, the bluff is 40 feet high, and consists of a solid bluish-black clay, excepting gravelly earth a few feet thick at the top. Lignite, in the form of branches and even sections of large tree trunks, is abundant. On the railroad line, south of the Chesquake creek, there is a cut 45 feet deep, and in this there is at least 30 feet of this clay, covered by a little sand and gravel at the top. The sandy and micaceous layers at the level of track, and seen at the north end of the cut in the upland bank, are supposed to belong to the laminated sand and clay. A little above the track level there is a layer largely made up of lignite in small pieces and other carbonaceous materials. This is very black. It is the bottom of this clay, and is 25 feet above tide level. It is about 15 feet thick. Higher, and extending to the gravel, the clay is of a lighter shade of color, and apparently faded. Lignite was discovered several years ago in this clay, east of the railroad line and north of Whale creek, on the Hodge farm. A bed of it, 4 feet thick, was struck 35 feet from the surface and at about tide level. West of the railroad line, and on the south side of the Chesquake creek meadows, beds of it have been opened at several points. On the farm of George C. Thomas a great deal of exploring and mining work was done. On the farm of the late Sheriff Gordon it was found 20 feet above tide level. This lignite crumbles on exposure to the air and soon falls to pieces, and then looks like a heap of very black clay. The clay and lignite is about 50 feet thick, judging from its outcrop, as measured from the northern border of the Chesquake tide meadows, where the stoneware clay bed is about at tide level, to the Cliffwood road crossing, or Cliffwood station on the New York and Long Branch railroad, a distance of 1¾ miles, and assuming the dip to be the same as that of the stoneware clays and the green sand marls—about 30 feet per mile. On Enoch Hardy's farm, near Jacksonville, there is above the lignite layers a yellowish white sand about 30 feet thick. This is not seen either on the shore of the bay or along the railroad line, although the cuts on the latter are hardly deep enough and so continuous as to exhibit anything, excepting a few feet of the top. If this sand be persistent it forms the upper layer of the plastic clay series and then the lignite-bearing clay is only 20 feet thick. This subdivision is as yet involved in somewhat of uncertainty. The materials of both of these subdivisions, if they be made, are quite largely used in the manufacture of common red brick in two or three yards on Raritan bay. The lignite is combustible, easily kindled and burns with a blaze like wood. It has been called brown coal, or simply *coal.* A good specimen of it analyzed some years ago in the laboratory of the Geological Survey, yielded of volatile matters, mostly combustible:

Gases	50.2
Coke	34.6
Ash	15.2
Total	100.0

On account of the pyrite in it there is always a disagreeable odor in burning, and the sand and clay mixed with it make it difficult to get in large and workable amount and sufficiently clean for an economical fuel. Several attempts have been made to mine it, but thus far without success or profit.

This lignitic clay is considered to be the equivalent of that seen at Bordentown and White Hill, on the Delaware river bank. At the latter place the laminated clay and sand, with the latter in excess, appears just under the clay marls, but the beds there are not so well defined nor so largely developed as on Raritan bay.

The green sand of the clay marls seen in the marl pits of Enoch Hardy and on the Gordon farm (near the farm house), or the Conover farm near the head of Whale creek, and in the cuts on the New York and Long Branch railroad, near the Cliffwood road and station, marks the southeastern limit and the top of this plastic clay series.

SECTION I.

1. LOCAL DETAILS OF BEDS NORTH OF THE RARITAN RIVER.

The description of the several outcrops and openings of these beds of clay, *kaolin, feldspar* and sands, occurring in the clay district of Middlesex county embraces all the local and particular facts attaching to them with such references to the general geography and geological structure as are necessary to define more precisely their relations, and in turn illustrate the general statements of the preceding chapters. The arrangement of these local descriptions is geographical. Beginning at the northeast, near Woodbridge, proceeding thence south and southeast to Perth Amboy, and from that point westward, to the extreme western openings near Martin's dock, all the outcrops and localities *north* of the Raritan river are grouped together in the first section of this chapter. Property lines mark the limits of these localities, with few exceptions, as, for example, where the openings on the same property are quite separate and show some marked differences. Generally the individual openings are described as *banks*, in distinction from *pits*, which are restricted in their meaning to smaller excavations, such as may be made in a few days. The *pits*, as here understood, are, therefore, *parts* of *banks*.

In the arrangement of the matter, descriptive of any given locality, an attempt has been made to put the facts, as nearly as possible in the following order:

1. Geographical relations.
2. Columnar section of the strata.
3. Elevation above *mean high tide level.*
4. Character of the materials, beginning at the surface, or with the top clay, &c.; with analyses.
5. Historical notice of openings.
6. Modes of working, handling and transportation, with uses and values of materials.

Constant reference is made to the map and the accompanying general section. On the latter the localities are numbered, and by this means any given one can be found readily and certainly.

The numbers in the text correspond with those on the section. In this chapter nearly all the local designations for beds, clays, &c., are used, as properly belonging in a full account of the facts and peculiarities pertaining to the several localities. The frequent repetition of some of these has prevented explanation in each case. It is hoped that they will be understood from a comparison of the facts presented, if not plain on first reading.

The arrangement of the beds in their natural order is shown by numbers, and these tabular statements are intended, unless it is otherwise mentioned, to be representative of that locality or opening.

The analyses were generally of the best specimens of the kinds described. Exceptions are mentioned in place. These specimens were nearly all collected by the Geological Survey and with reference to their use as the basis for microscopical, chemical and physical examinations and tests and comparisons. These examinations have furnished many of the facts regarding their physical characters, and all of those relating to their chemical composition, which are included in these detailed descriptions. The specimens analyzed were all well air-dried. The analyses give the composition of the clays, *kaolins*, *feldspars* and sands as they dry in summer air. The specific gravity* of the specimens represents their weights as compared with the weights of equal volumes, or bulks of water. Many of the specimens were examined under powers of 75 to 150 diameters of the compound microscope, and the descriptions often refer to such examinations.

On account of the length of time during which this report has been in course of preparation, many localities have been visited several times, so that the notes of these examinations at intervals of one, two, and, in a very few cases, of three years, show differences such as would be expected to appear in such a length of time in the steady working and further opening of localities. Wherever practicable, the descriptions have been brought up to date, but this could not be done in all cases, since in many of them little work and, in a few of them, nothing has been done since 1874. The very general working of all the banks and lo-

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* The method of getting these was as follows: A cube or other convenient form was cut out of the solid mass. This was covered by a film of paraffine, and then weighed, first in air and then in water. By this method the *openness* or porous condition was considered as affecting the density, while by the common method this is neglected, and the specific gravity is that of the *clay*, sand, &c., without reference to the spaces or interstices between the particles of solid matter.

calities in that year made observations easy and very full, and these are incorporated in the report as more applicable than some of those of the succeeding years.

Where not expressly stated, the facts regarding the strata, character of materials and other general geological observations, are from the field notes of personal examination or verification. The modes of working, expenses, uses, and other facts more related to the business of mining and using the materials, are in most cases the statements of proprietors, or other practical men acquainted with these facts. So far as possible these have been verified by corroborative testimony, and a general judgment obtained as authority for what is here given. Where this has not been obtained, the fact is credited to its author.

DESCRIPTION OF CLAY BANKS IN GEOGRAPHICAL ORDER.

EDGAR'S STATION CLAY.

At this place some white and reddish-white, or mottled clay has been dug for making red brick, but the layer is quite thin and the clay not suited for such use. The red-shale drift, including large boulders, lies upon it. This is the most northerly clay outcrop in this district, and it is the most eastern locality of the Raritan bed, to which it is referred by its elevation above high water level and by its evident nearness to the red-shale, the underlying rock.

Nothing was learned of the refractory quality of this clay. It has not probably been tried, excepting for common brick. It is not now worked.

WILLIAM B. DIXON'S CLAY PITS.

These pits are about 30 rods north of Mr. Dixon's residence, in the village of Woodbridge. The top dirt here is from 8 to 12 feet thick and largely of red shale earth. The bed of clay varies somewhat in thickness, and its surface is quite uneven. This inequality corresponds with the varying amount of top dirt. The top spit of the clay is yellowish. Under this there is the best clay of the bed, and from 3 to 10 feet thick. Towards the bottom it is more sandy. It is underlaid by sand. The thickness of this sand, or the nature of the strata, deeper are not known. The clay is said to run deeper in the most southern part of the pits. The average elevation of the top of the clay bed is 31 feet. This clay belongs to the Raritan fire clay bed. It appears as number 27 on the general section.

This clay is more sandy than the rich fire clays dug about Woodbridge. The selected or crucible clay is greyish white; some of it has a reddish or faint purplish tinge, and some is quite red in color. This latter is owing to oxide of iron in considerable quantity present in it. And this red clay is very irregularly distributed in the bed. Commonly it appears in pockets and layers over the best white clay. Some of the clay thrown out of these pits is covered by a greenish yellow efflorescence of sulphate of iron, indicating the presence of this salt with sulphide of iron in parts of the bed. All of it is remarkable for its compactness and density. And its specific gravity is 1.994–2.047. An analysis of the best of it gives the following percentages:

ANALYSIS.

Alumina	26.95	
Silicic acid	31.12	
Water (combined)	9.63	
		67.70
Silicic acid (sand)	28.81	
Titanic acid	1.90	
		30.71
Potash	traces	
Soda	traces	
Lime	....	
Magnesia	0.07	
Sesqui-oxide of iron	1.24	
Water (moisture)	0.57	
		1.88
Total		100.29

These figures exhibit a close correspondence in composition to that of the German clays, which are imported for making glass house pots, and also with the best English crucible clays. This clay is not quite so dense as they are. It has been tried in a few glass houses for making pots, but the results have been rather experimental in character. It stands fire well, and burns without much shrinkage or checking, and the burned clay is dense and strong, properties which give it special value for making crucibles, glass pots and the more silicious fire brick.

But few pits have been dug by Mr. Dixon, and the limited extent which its uses have reached are hardly sufficient to establish its character in the great industries where such a clay is needed. In view of the increasing demand in our country for such clays, nearly all of which are now imported at very high prices to the consumer, this promising clay deserves a careful and thorough trial.

LEWIS POTTER'S CLAY PITS.

These pits are a few rods west of Dixon's and in the same bed of clay. The top dirt is said to be 4 to 8 feet thick, and the clay bed 5 to 6 feet thick. The surface of the latter is not more than 10 feet lower than that of Dixon's clay. Very little has been dug on this place. This opening is in the Raritan fire clay bed.

GEORGE W. RUDDY'S PITS.

These are near a small tributary of Heards brook, a mile north of Woodbridge, and about 200 yards west of the Uniontown road. The overlying beds are red shale drift and, at the north end, a yellowish white fire sand. This is quite coarse grained and is mixed with a little white clay and streaked reddish in places by oxide of iron. The clay is said to have had a maximum thickness of 20 feet. White, greenish white and mottled clays were obtained. Red shale, in place, underlies the clay. From the large proportion of shale found on the top of one of the heaps, this statement appears altogether reasonable. In the most southern pits the top of the clay is 35 feet above high water level. Near the road, and a few rods from the house of Mr. Ruddy, a pit was dug under a bearing of 4 feet of reddish earth and 4 feet of sand. This clay had a greenish tinge. Carbonates of copper occur in it. Here the clay bed is reported as 12 feet thick. Of the character and value of this clay of Ruddy's pits, nothing definite is known, although several hundred tons are said to have been sold. While this pit is near the group of openings about Woodbridge it does not belong in the same bed, but to the lower Raritan potter's clay bed. Its position being near, if not altogether upon, the red shale and in contact with it, and its elevation somewhat lower than any of the clay worked about Woodbridge, refer it to this geological horizon. See the general section, No. 6.

These pits have not been worked in several years, excepting for the sand. This is supposed to belong to the fire sand bed underlying the Woodbridge fire clay bed. But it may belong to the drift. Some of the sandy clay of the Raritan fire clay bed ought also to be found here, as this lies next under the fire sand bed.

WILLIAM P. EDGAR'S CLAY BANK.

This bank is the most northerly locality in the clay district where the Woodbridge fire clay bed is opened and worked. It is about a mile north of Woodbridge village and east of the Metuchen road. It furnishes the following section at the northwest, viz.:

(1) Yellow sand and gravel	30 feet
(2) Retort clay	4 feet
(3) Sandy clay (for pipe)	5 feet
(4) Fire clay, No. 1	2 feet
(5) Black clay, No. 2	2 feet

A black sandy clay, containing much lignite and pyrite, is at the bottom. The top of the clay in this bank, as measured at two points, is 83 and 89 feet high, respectively.

At the east the clay bed is sandy at the top for 2 feet downwards; then there is 3 to 4 feet of red or spotted clay; next, fire clay, 2 feet; and, at the bottom, black, pipe clay, 2 feet—in all, a thickness of 10 feet.

The sand at the top is very plainly stratified, and the gravel is generally in thin layers in it. The sand shows the compound ebb and flow structure. Towards the bottom of this drift covering the gravelly layers are thicker than at the top, and there are a few stones, from three inches to a foot in diameter, in them. In places there is a very thin layer of red, shaly earth at the top on this sand.

The top layer of clay is very tough, and is sold for making gas retorts. The next layer (~~2~~ 3) is more sandy and not so tenacious nor so dark-colored as (~~1~~ 2). This is used in sewer and drain pipe, and is known as "pipe clay." The best fire clay, or *fine clay*, is white, and nearly free from gritty matter. It is sold for fire brick, etc. The black clay at the bottom (5) is not so sandy as that at the top. It also is used for pipe. The sandy bed under this and at the bottom is quite full of lignite, and pieces five feet long are very common in it; but no leaf impressions have been found in it, or in the overlying clays which are dug. This clay bank appears as No. 7 on the general section. The clays are carted to docks on Woodbridge creek, where they are loaded on vessels.

WILLIAM H. BERRY'S CLAY PITS.

These are on the farm adjoining the Edgar place on the west, and near the Metuchen road. There are two separate openings. *That east of the house* is but a few rods from Edgar's bank. In this the red-shale drift forms the surface, and is several feet thick. Under it there is the yellow sand and gravel, which is stratified and of varying thickness. The clay surface has here an elevation of 73 feet above mean high water level, and it is said to be 15 feet thick. Some of it is bluish-black in color, and very tough and without any sand or gritty matter, but it is not so refractory as the best white fire clay. It burns white, and makes a very superior sewer pipe. Its composition is as follows:

Alumina	20.11
Silicic acid and sand	68.38
Water	5.55
Oxide of iron	1.71
Magnesia	0.73
Potash	2.58
Titanic acid	1.01
Total	100.07

The potash shows that it is not refractory as a true fire clay. The alumina and water indicate nearly one-half of it to be clay proper and the rest sand. Quartzose sand is at the bottom in this bank.

Northwest Pits.—Here the overlying beds vary greatly from point to point. Generally there is about 6 feet of red-shale drift. Under this the yellow sand and gravelly layers are of varying thickness, up to 25 feet in some places. This latter is not always continuous, and in some parts of the bank the red-shale drift reposes immediately upon the clay. This bank gives the following section, beginning with the surface of the clay bed, the elevation of which is 81 feet.

(1) Saggar clay	1 foot
(2) Bluish-black clay (for retorts)	5 feet
(3) Slate-colored clay (for pipe)	2 feet
(4) Black clay	3 feet
(5) Black clay, full of lignite	8 feet
Yellow sand at the bottom.	

The surface of the clay is very uneven, hence the height is varying. The bottom is more regular. The best clay of the pits is (2) that used for retorts. It is remarkably tough. Its specific gravity is 1.743—1.789, and its composition as follows:

ANALYSIS.

Alumina	36.52	
Silicic acid	41.18	
Water (combined)	11.30	
		89.00
Silicic acid (sand)	6.51	
Titanic acid	1.32	
		7.83
Potash	0.28	
Soda	0.16	
Lime	......	
Magnesia	......	
Sesqui-oxide of iron	1.11	
Water (moisture)	1.50	
		3.05
Total		99.88

This clay burns white and is very refractory.

These banks, together with that of Edgar's adjoining, show finely the varying character and thickness of the top dirt, consisting of the two well marked drift beds. These banks appear at number 8 on the general section.

FIRE SAND PIT OF THE SALAMANDER WORKS.

This sand pit is a few rods south of the Woodbridge and Metuchen road and south of the clay pits described above. The bearing, or top dirt on the sand is red-shale drift, and is 5 to 10 feet thick. In it there are some large boulders of gneiss, trap-rock, indurated shale, &c., &c. The top of the sand is 60 to 64 feet above high water level, and it is said to be 8 feet thick. This elevation agrees with the horizon of the fire sand bed, and its place on the general section is at number 12. The sand of this locality is white and almost exclusively of quartz.

The pit is worked for the supply of the Salamander Works in Woodbridge, where it is used in fire bricks.

DAVID FLOOD'S CLAY PITS.

These pits open the Woodbridge fire clay bed, a short distance west of the Uniontown or Metuchen road, and west of Mr. Flood's residence. They are the most easterly of a group of pits or continuous openings belonging to several landowners, whose property lines take in the little valley which is a tributary of Heard's brook, and which heads about one mile west of Woodbridge, near the residence of Ed. Thompson. Flood's pits have been worked profitably for many years, and have yielded a large amount of valuable clay. The top of the fire clay at the north-east is 76 feet above mean high water level. About 100 yards west of that the elevation of the clay (sandy) bed is 89 feet. According to Mr. Flood's statements the following section may be taken as an average of the pits. It has the following subdivisions and thickness, beginning with the surface of the ground:

(1) Red-shale drift	10 feet
(2) Yellow sand and gravel	
(3) White, sandy clay (for pipe)	2 feet
(4) Blue fire clay	2 feet

(5) Mottled or spotted clay.. 8 feet
(6) Bottom sandy clay.. 2 feet
Sand at bottom of pits under the clay.

No. 3, the top clay, which is quite sandy is sold for making drain pipe and tile.

The blue fire clay, or, as it is here designated, *fine clay*, is the best of the bank, and commands the highest price for manufacture into white ware. It is bluish white, and contains scarcely any sand or other foreign matter. The mottled or spotted clay derives its name from the irregularly mixed red and white masses, the red color being due to a comparatively large percentage of sesqui-oxide of iron. This is not an essential constituent of the clay, but is to be considered as a foreign or accidental constituent, which enters irregularly into its composition, amounting sometimes, in the deeper red portions, to seven per cent. of the mass. Slight digestion in dilute hydrochloric acid removes it, leaving a white or blue fire clay, somewhat more valuable than the original mottled or spotted clay. This method of treating such clays, in practice, will be extensively carried on whenever the prices of pure clay shall make it profitable to do so. These iron stained masses in this clay are not in any way separate from the remaining portion, nor are they in any orderly arrangement. This mottled clay is at present used in making a No. 2 fire brick, and is also adapted to mixtures for pipe or tile. The bottom, sandy clay, No. 6, is a bluish white clay, becoming dirty yellow in the heaps. It also is used in mixtures for fire brick. Mr. Flood says that in borings southwest of his bank he did not find any good white clay. It is possible that these explorations have been at points where the fire clay bed has been entirely removed by erosion, and its place filled subsequently by beds of drift, or, as elsewhere in this clay district, replaced by other members of the plastic clay formation. The fire clay bed appears, in the workings, to thin out, going west and northwest. Some of the borings seem to show an increased thickness of black clay towards the west. For the position of this clay bank on the general section see No. 9.

WILLIAM H. BERRY'S CLAY BANK.

Adjoining Flood's bank on the west is that of William H. Berry, but it has not been worked in six or seven years. Mr. Berry says that he got a considerahle proportion of alum clay, pipe clay and some fire clay. And in the first pits that were dug there some paper clay was obtained.

J. H. CAMPBELL ESTATE.

This property adjoins Berry's on the west. The bank, as worked three years ago, showed the following beds in a descending order, viz:

(1) Red-shale drift..	
(2) Dark blue, sandy clay..	3 feet
(3) Sand	3 feet
(4) Fire clay..	8–16 feet

In places a part of the latter was mottled, or spotted, red and white. The sand layer (No. 3) is wanting in some of the pits, and the fire clay is in one continuous mass or bed. The top of the clay in this bank is 78 feet high. This bank has not been worked steadily, having until very recently been idle for about three years. Work in it has been resumed by Mr. Loughridge. The three banks of Messrs. Flood and Berry and the Campbell estate are all on the north side of the valley of the little stream. As they are all within a radius of a quarter of a mile, the general features of both the surface and the underlying beds are much the same in all.

DAVID AYERS' CLAY BANK.

This bank is near the head of the valley, or *run*, and adjoins that of Ed. Thompson on the west, and B. Kreischer's on the east. The top of the clay has an elevation of 80 feet, as seen on the general section, No. 10. The section of this bank, as it was worked in 1875, includes the following beds:*

(1) Red-shale drift..	10 to 20 feet
(2) Black clay, with layers of sand, and containing lignite and pyrite....	
(3) Top sandy clay...	2 feet
(4) White quartz sand..	8 inches
(5) Alum clay...	2 feet

*The figures are by Mr. Ayers.

(6) Fire clay..	7 feet
(7) Red clay..	6 feet
(8) Extra-sandy clay..	5 feet
Yellow, shaly earth, containing lignite, at the bottom.	

The black clay and sand at the top (No. 2) is made up of irregularly alternating layers of dark-colored, sandy clay and white, quartzose sand, varying greatly in thickness, and horizontally stratified. In it there is much silver mica, lignite and pyrite, and some leaf impressions have been found, but these latter are of rare occurrence. Fish bones are also reported, but nothing is known of them. Below this, the Nos. 3 to 8, inclusive, are geologically parts of the Woodbridge bed, although not all fire clays.

The top-sandy clay is of uneven grain, and quite full of little particles of red oxide of iron. It is used in pipe. The fire clay (No. 6) is very white, and does not fade on exposure. There is scarcely any gritty matter in it. It is used in fire brick. Selected lots of it are sold for white ware; and its reputation is among the best of any of the Woodbridge clays used for this purpose.

The red clay is a little sandy, but the sand in it is fine grained. It contains a little pyrite and a very few scales of white mica. On account of the iron oxide it is unfit for No. 1 fire brick. It is used in No. 2 brick, in stove linings and in drain and sewer pipe.

The extra sandy clay is more than half fine and white quartz sand. It is a good refractory material, and, as such, is used in fire brick mixed with richer clays, for the purpose of tempering them.

This bank has been worked steadily, and a large proportion of its products have been high priced fire brick and ware clays, obtained at a moderate cost for the labor spent in extraction.

ED. THOMPSON'S BANK.

This bank is next west of that of David Ayers, and is the furthest opening in that direction in this little, subordinate valley. It was not worked when visited. As it is really nothing more than an extension of Ayers' bank, any details would be little more than a repetition of the description which has been given above of this latter.

CHARLES M. DALLY'S BANK.

This adjoins Campbell's bank, on the south, and is on the south side of the stream. No work has been done here recently, so that the details of the place are scanty. The red-shale drift, as seen in the bank, varies up to 10 feet in thickness, and lies on a thick bed of black clay. The upper part of the fire clay bed is sandy. The maximum thickness of the clay in this bank is 20 feet, of which that suitable for fire brick manufacture is said to range from 4 to 8 feet. At the bottom there is a yellowish sand.

CLAY BANK OF THE SALAMANDER WORKS.

This property is west of the village of Woodbridge, and on the north side of the New Brunswick road. The work of excavation goes westward and northward into the hill, which is here 100 feet above mean high tide level. The elevation of the workable clay bed (top) is about 80 feet. See general section, No. 17. This bank has a long working face, and consequently exhibits considerable variation in the vertical sections taken at different points. One observed in the summer of 1874 showed the following strata :

(1) Red-shale drift	8–10 feet
(2) Yellow sand and gravel	11 feet
(3) Black, sandy clay	3–6 feet
(4) Black clay (for pipe)	2 feet
(5) Very sandy clay	5 feet
(6) Sandy clay	5 feet
(7) Fire clay	7 feet
(8) Spotted clay	6 feet

Another section, seen in 1875, and further towards the northeast end of the bank, showed—

(1) Red-shale drift	8 feet
(2) Yellow sand and gravel	6 feet
(3) Clay and sand	6 feet
(4) Black pipe clay	2 feet
(5) Sandy clay	3 feet
(6) Light blue and red clays	6 feet
(7) Alum clay	4 inches
(8) Fire clay, No. 1	3 feet
(9) Fire clay, No. 2	2 feet
(10) Red or spotted clay	3 fee.

Red, sandy clay at the bottom.

The red-shale drift, as here shown in the cut face of the bank, contains many large boulders of indurated shale and trap rock. Some thin layers of very sandy white clay are seen in it. These are short and unconnected. No other evidences of stratification are to be seen in it. The bed of sand and gravel under it is very irregular, sometimes thinning out entirely and leaving nothing between the dark-colored clay and the red-shale drift. Generally this sand is very beautifully laminated, the thin pebbly sheets separating the thicker sand layers. Some of this sand is uniform in grain and has enough loam with it to be used in moulding. Towards the bottom there is more gravel, and the pebbles are larger. The clay and sand (No. 3) also shows stratification in irregular, alternate layers, or laminæ. Scattered throughout this bed there is much lignite and some pyrite. The lignite occurs very generally in certain horizons, or layers, and in some of these it makes up the bulk of the mass. No leaf impressions have been found at this bank. The pyrite and lignite and the excess of sand in this layer make it practically worthless. The black clay (No. 4) is slightly gritty, but very tough. It is used in the mixture for drain and sewer pipe. An analysis of a specimen of this gave the following results:

Alumina	*22.20
Silicic acid and sand	61.25
Water (combined and moisture)	8.00
Potash	2.44
Soda	......
Lime	......
Magnesia	0.94
Sesqui-oxide of iron	5.30
Lignite	0.30
Total	100.43

From the percentage of alumina and water here given, it follows that there is comparatively a large percentage of quartz sand. The amounts of potash and iron also are large, and indicate a clay of low degree of refractoriness.

No. 5 of the section above is too sandy to be of use.

No. 6 is also quite sandy. In places it is stained reddish by sesqui-oxide of iron. It is used in making sewer pipe. The

* Includes titanic acid.

alum clay contains some coarse grained sand in small aggregates, also pyrite in little nodules. On exposure to the weather it fades to a yellow-buff color. It has a decidedly astringent taste.

The fire clay is of two grades—one, the upper part of the bed which is used in No. 1 fire brick, and is from this fact known as No. 1 clay; the other being slightly inferior in refractory properties is considered a No. 2 clay, and is made into No. 2 brick. The No. 1 fire clay has a little very fine sand, a few small flakes of silver mica, and on weathering shows a cream colored surface. The *spotted* or mottled clay, resembles in general that described above, found in David Flood's bank. This also is of inferior grade and is used for pipe, or for No. 2 fire brick. In the pits this layer grows sandy towards the bottom, and at last ceases to be sufficiently *clayey* to be worth extraction, and at this depth the digging is stopped. A boring made several years ago, in the bottom of a pit, is reported to have gone 27 feet below this clay, all in quartz sand. Nearly the whole product of this bank is worked up into drain and sewer pipe and fire brick, at the Salamander Works in the village, one mile from the bank. A little of the inferior sort has been stocked in heaps at the bank awaiting future demands.

LOUGHRIDGE & POWERS' BANK.

This bank adjoins that of the Salamander Works on the south and runs to the New Brunswick road. The locality has been sometimes called "China Hill." The section made up from observations at this locality in 1874 and 1875, includes the following subdivisions, viz:

(1)	Red-shale drift	
(2)	Yellow sand and gravel	
(3)	Black clay, containing lignite and pyrite	20–30 feet
(4)	Top, sandy clay	0–10 feet, average 4 feet
(5)	Alum clay	1–6 feet
(6)	Fire clay, including ware clay	6 feet
(7)	No. 2 fire clay, sometimes mottled or red	4 feet
(8)	Fire clay (lead colored)	
(9)	Mottled or spotted clay	
(10)	Extra sandy clay	4 feet
(11)	Yellow sandy clay	

These figures except in Nos. 3–5 inclusive, are average thicknesses. In some pits Nos. 8 and 9 were wanting.

A boring 21 feet below the bottom of the pits passed through 13 feet of the yellow sandy clay and earth, and then into a sandy clay—8 feet. Under this a fine grained *feldspar*-like substance was reported as the material at the lowest point ever reached at this locality. This sandy clay must have been the Raritan fire clay bed. See number 24 of the general section.

The top of the white clay here (No. 4) is 73 feet, but this elevation varies greatly on account of its remarkably uneven surface, and a difference of 17 feet of level has been observed in a horizontal distance of as many yards. There appear to be bunches, or *bunks*, as here termed, of clay with intervening hollows or sinks in its surface, caused either by very irregular deposition, or by subsequent erosion. As the bed is about 20 feet thick, the bottom has a mean elevation of 53 feet. But these inequalities of the surface do not correspond with those at the bottom, and sometimes the clay goes deeper in one of these so-called *bunks*. And in one of them which rose up 12 feet above the surrounding clay surface, there was said to be a thickness of 40 feet of marketable clay.

The great thickness of the top black clay here, and in the adjoining pits of William H. Berry and David Ayers, is exceptional. There is more or less pyrite disseminated irregularly through it, and some mica in very small white scales, but much of it is tolerably free from the former constituent. It is very dense and tough, and slate colored, drying quite white on weathered surfaces. The best of it will do for pipe making, but it is at present all thrown back into the pits, where it gets mixed with the earth from the surface, and is thus spoiled for all future uses. In this manner thousands of tons of this clay are annually wasted. It could be used for common red brick, if for nothing of more value. As it is improved by weathering, thereby gradually losing its sulphur through the decomposition of its pyrite, it might be well to stock it by itself in heaps on the dump or waste, and there let it undergo the amelioration of nature, or await, possibly, the coming practicable methods of treating such clays so as to render them fit for more valuable uses than those known at present. When it is considered that the valuable clay beds of this district are being gradually worked back, under thicker beds of drift and worthless clays and sands, it will be evident that the demand for better qualities must stimulate the invention of methods whereby these top clays, now wasted, can be made available. The existing practice forever puts them beyond the reach of improvement. It is a matter deserving the attention of all prudent clay proprietors and miners.

The top sandy clay is light colored and contains much rather coarse-grained quartz sand. It is used in pipe. The alum clay is nearly always found just over the fire clay. It is generally somewhat streaked with darker shades and contains pyrite in small crystalline aggregates and nodules, which show plainly in specimens freshly dug. This clay after short exposure to the air turns greenish yellow.

The ware clay is really a part of the fire clay, which, in appearance, differs from it, in being more brittle and friable, breaking with conchoidal fracture and crumbling quickly and readily to a soft, pulverulent mass. The fire clay is harder and more solid, and show an irregular fracture. It does not fall to pieces so readily as the ware clay. Both are very fine, and scarcely any gritty matter can be detected in them. The following analysis of the ware clay of these pits may be taken as representing the composition of the best of the fire clay layer :

Alumina	39.53	
Silicic acid	42.23	
Water	13.59	
		95.35
Silica (quartz sand)	0.50	
Titanic acid	1.40	
		1.90
Potash	0.41	
Soda	0.08	
Lime	0.10	
Sesqui-oxide of iron	0.50	
Hygroscopic water	1.21	
		2.30
		99.55

The specific gravity of this fire clay varies from 1.731 to 1.809.

Underlying the best fire clay there is an inferior grade, or No. 2 fire clay, which is sometimes white and at others appears mottled, red and white. This, with the clays found under it, including Nos. 8 to 10, as given above, are sold for No. 2 fire brick. No. 9 is used in stove linings, saggars and drain pipe. The lead-colored clay apparently differs little from the white fire clay, except in color. The extra sandy clay, the lowest clay dug here, is of uneven texture, being quite coarse-grained in some portions. No mica flakes are perceptible in it. It is more than half quartz sand, as appears in the following analysis:

Alumina (1)	18.92	
Silicic acid	20.00	
Water	6.70	
		45.62
Silica (sand)	51.80	
		51.80
Potash	0.48	
Sesqui-oxide of iron	0.88	
Hygroscopic water	0.50	
		1.86
		99.28

This clay answers well in tempering rich or "fat" clays.

The bank has been worked steadily until within a year. Although the thickness of top dirt to be removed has been great, the amount of good clay, which has commanded high prices, has more than paid for the heavy expense of uncovering.

East of Loughridge & Powers' pits, the old site of the New Brunswick road has been dug up by David Ayers and William H. Berry. South of this road, in the bank of the latter, there is nearly 50 feet of covering on the fire clay bed, of which about 30 feet is a dark-colored clay, with some interstratified layers of sand. At another point the yellow sand and gravel drift above the clay is very distinctly stratified, the thin layers of white and yellow quartz pebbles alternating with rather coarse yellow sand. These pebbly layers are thicker and the pebbles are larger towards the bottom of the bed. In the overlying red-shale drift

(1) Includes titanic acid, which was not determined. Sp. gr. 1.813—1.897.

a thin and very uneven layer of white sandy clay appears, but of limited extent. The fire clay bed of these pits being only a few rods from that of Loughridge & Powers, which has been described above, does not differ materially from that, and the descriptions of the latter apply in general to the former.

SAMUEL DALLY'S BANK.

South of the New Brunswick road and south of William H. Berry's line, Samuel Dally owns the next bank. It is properly the continuation of the same general arrangement of strata as already described, varying, as everywhere in this district, in the details, so that the vertical sections of openings, but a few rods apart, do not exhibit complete parallelism in all their subdivisions. As this property has not been worked within the time of our survey of the district, no full description can be given of it.

PITS OF FLOOD BROTHERS.

This property joins Dally's on the south, and is on the northwest side of the Mutton Hollow brook and between the roads. When visited two years ago, the digging passed through black sandy clay and white quartz sand at the top, then a dark colored sandy bed, in which there was much lignite and one thin seam of sandy white clay; next a greyish pipe clay resting upon a sandy earth where the pits stopped. No fire clay was then got here. The black clay and sand bed found here near the surface must be the laminated clay and sand bed, and the pipe clay layer the equivalent of the *top white clay*, so well marked in the banks along the Raritan river. If this be so, the fire clay would be found about 6 feet below it. This property has been worked during the past year, but with what results is not known.

CLAY BANK OF A. HALL & SON.

This bank is at the head of Mutton Hollow, and the most westerly opening for clay in it. The New Brunswick road at present runs along side of it on the north; the original line of the road being directly across the present diggings. The section which this bank gives shows considerable variation in the several layers from the surface to the bottom of the pits. The following one represented the bank as exposed in 1875. The working since does not show any important changes:

(1) Red-shale drift, varying up to	20 feet
(2) Yellow sand and gravel not continuous over the whole working area...	
(3) Black clay and sand, varying up to	15 feet
(4) Blue and buff colored clays	3–8 feet
(5) Black, sandy earth containing lignite and pyrite	1–2 feet
(6) Fire clay	8–20 feet
(7) Sandy clay (bottom sandy)	3–6 feet
(8) White quartz sand (boring)	14 feet

In some of the pits at the bottom there is a gravelly earth with some shaly materials mixed with it.

The red-shale drift here includes many boulders of trap rocks, indurated shales, quartzites, &c., some of which exceed 6 feet in diameter. Wherever the yellow sand and gravel is wanting this lies immediately upon the black clay and sand. The two drift beds are well exposed in this bank for the study of their relation to each other and their structure.

No. 3 (of the section) is characterized by the abundance of lignite and some pyrite found in it. It contains some mica in fine scales or plates. It is thrown back into the pits as *filling*, or carted out on the dump as waste material.

The top clay—blue and buff colored clays—is a little sandy, the grains of sand being rather coarse and unevenly mixed through the mass. Some pyrite, in small lenticular nodules, occurs in it. It is considered good enough for mixture in No. 1 fire brick. The next layer is worthless, and is thrown aside as waste.

The fire clay bed presents the usual inequalities in its surface, and its elevation of 67 feet above mean high water level is the average of several measurements. These inequalities make the thickness also to vary from point to point. A maximum thickness of 28 feet of fire clay has been seen at this bank. The top *spit* is of a greenish yellow color and contains some pyrite, and is sold to chemical works for alum making. The pyrite appears in it in small nests or aggregations of crystalline masses. This clay weathers yellowish, on long exposure to atmospheric agencies. Sometimes a large part of the bed is sold as alum clay. The top clay is very solid, and is said to burn *tight* or close. The best of the fire clay is very fine, having a conchoidal fracture, and containing but little fine quartz sand. Its composition as shown by the analysis of a good specimen, is as follows:

Alumina	35.83	
Silicic acid	42.05	
Water (combined)	12.20	
		90.08
Silica (quartz sand)	5.70	
Titanic acid	1.10	
		6.80
Potash	0.44	
Soda	......	
Lime	......	
Magnesia	0.11	
Sesqui-oxide of iron	0.77	
Water (moisture)	1.50	
		2.82
Total		99.70

The soda and lime were not determined. They cannot amount to much, judging by the analyses of the fire clays from other localities in this district, and also by the difference between this total and 100.

The sandy clay at the bottom, or as it is sometimes called *extra sandy*, contains some quite coarse grained quartz sand in irregularly shaped aggregates in the sandy clay mass. No mica was perceptible in it. For mixture with *fat* clays it is liked, and is considered to be a good refractory material. This is properly a part of the fire clay bed. Below this layer comes the white sand, into which the superintendent of the work says he has bored 14 feet. The shaly earth seen at the bottom in some of the pits may indicate the red-shale *in place* a little deeper—although this is not so likely to be found as the sand—and then the lower beds of this plastic clay formation. The general section, number 23, shows the relative position of these clay pits and this boring.

Most of the fire clay got out of this bank is used in the works of the proprietors at Perth Amboy and at Buffalo, N. Y. A considerable amount is sold to other fire brick factories, chemical works, &c., particularly to some in the northern part of Ohio and western New York. The product has in some years amounted to 12,000 tons.

JOHN R. WATSON'S BANK.

Watson's bank is south of the Mutton Hollow brook and east of Hall's. The *bearing*, comprising the red-shale drift, the yellow sand and gravel and the black, laminated clay and sand, varies greatly in different parts of this bank. On the east, next to William H. Berry's line, it is between 5 and 20 feet thick; while on the west and southwest, the working has penetrated the upland or hill, until it has become 40 feet. On the east, near the property line, the successive strata, beginning at the surface, are:

(1) Red-shale drift	4 feet
(2) Sand and yellow clay (varying greatly)	
(3) Dark colored, pipe clay	8 feet
(4) Sandy clay (used in stoneware)	4 feet
(5) Fire clay (No. 1)	6 feet
(6) Sandy fire clay (No. 2)	3–5 feet
(7) Extra-sandy clay at bottom	

The elevation of the clay at this bank is 59 feet. That is the top of No. 4. Towards the southwest this bank shows quite a thickness of sand and gravel, under the true boulder drift. Here, at the east, the sand is associated with a yellowish clay, or clayey earth, and little gravel.

The black clay under the sand is not used, except as waste, for filling the pits. The best of it, if sorted, could be used in making pipe. The sandy clay (No. 4) is a mixture of fine quartz sand and clay in about equal proportions, and resembles the top sandy clays of other banks. Some of it is sold to potteries for stoneware mixture, and hence its local name of stoneware clay. That which is dug in the more southerly pits and under the thicker *bearing* is not so sandy as that of the east pits where the superficial beds are not so thick. A part of this clay is used by Mr. Watson in his fire brick. Geologically it is a part of the fire clay bed, and cannot be considered a well defined layer or persistent member of the clay formation. The same is true of the sandy and extra sandy clays under the No. 1 fire clay of this bank. (See general section, No. 34.) In some of the pits an alum clay, one to three *spits* thick, is dug on the top of the fire clay. All of these are parts of the Woodbridge bed. They are modified somewhat by the existence of more or less sand and pyrite, although retaining somewhat of their refractory nature. The *fine* or No. 1 fire clay dug at this bank is white to bluish white, fading a little on weathering; has very little grit in it; breaks with a conchoidal fracture; and belongs in the class of fine clays dug in Mutton Hollow. Towards the bottom it is of inferior quality and is considered as a No. 2 clay. Borings at this bank, which go down 40 feet from the top of the clay, passing through the whole of the fire clay bed, show 20 feet of sand under it, and do not strike the Raritan bed.

Most of the clays dug here are carted to the Watson Fire Brick Works, at Perth Amboy, and made into fire brick.

This bank was one of the first opened in the vicinity of Woodbridge, and has been worked, with some interruptions, since 1820.

WILLIAM H. BERRY'S BANK.

This bank, east of Watson's, has not been worked lately. As it lies between Watson's and Meeker's, something may be learned of it from the descriptions of those on either side of it. Clays for sewer pipe, stoneware, and retorts were got here.

S. A. MEEKER'S BANK.

This opening occupies the southeast angle of the Mutton Hollow group of clay pits; and, being farthest to the southeast, it opens this fire clay bed at a less elevation than that of the other banks, which are north and northwest of it. Its height is 56 feet. This dip and the position of this bank is represented on the general section as No. 39.

The vertical section representing the bank, as made from observations on the ground and the figures of Mr. Meeker, includes the following layers, viz.:

(1) Red-shale drift	5–8 feet
(2) Yellow sand and gravel	0–6 feet
(3) Black, laminated sandy clay	4–7 feet
(4) White, sandy clay (for stoneware)	4 feet

(5) Drab-colored, pipe clay	3 feet
(6) Retort clay	1–4 feet
(7) Fire clay	6–8 feet
(8) Sandy fire clay	4 feet
(9) Coarse yellow sand at the bottom	

Of this section, the layers 6, 7 and 8 may be considered as making the Woodbridge fire clay bed. The *bearing*, which consists of the layers above the stoneware (No. 4), varies somewhat, according as the pits are nearer the bottom of the valley or further in the bank. It is 20 feet thick in the southwestern pits. The sand and gravel drift is very beautifully laminated. On the west side the *bearing* consists of the dirt of an old dump, then the black clay and sand. Under this there is a clay dug for stoneware, 3 feet thick; pipe clay, 1½ feet; retort clay, 2 feet; then a black sandy earth.

The so-called stoneware clay of this bank is white and sandy, the sand in it being fine-grained, and it contains some white mica in small flakes. Its composition is as follows, viz.:

Alumina (1)	21.83	
Silicic acid	19.44	
Water (combined)	5.90	
	———	46.17
Silica (quartz sand)	48.40	
	———	48.40
Potash	2.24	
Soda	......	
Lime	0.28	
Magnesia	0.24	
Sesqui-oxide of iron	1.57	
Water (moisture)	0.80	
	———	5.13
Total		99.70

Its specific gravity is 2.047—2.077.

From this it will be seen that the amount of quartz is large, and also that the potash is sufficient to make it vitrify the mass, and hence its use in the manufacture of pottery. It corresponds to the analysis of the *top white* clay found in the banks of the

(1) Including titanic acid.

Crossman Clay and Manufacturing Company, and it appears to belong to that layer of the clay series. The lower part of this layer is more sandy, and is of inferior quality. This *stoneware* clay is used in mixture with the South Amboy stoneware clay for pottery.

The pipe clay (layer No. 5) is quite sandy, but the sand in it is fine. It is of a drab color.

The retort clay also is rather dark colored and quite sandy, but tough—a fire clay.

The fire clay restricted to its narrow limits, as it is by these local names, is fine, white and free from grit, becoming sandy towards the bottom. The latter is used in mixture for tempering fat clays, or for No. 2 brick.

Some of the best of the top clay and sand layer (3) is very hard and solid, and is used in pipe. It contains scattering fragments of lignite.

B. KREISCHER'S PITS.

This property is east of the Mutton Hollow brook and north of the road. The beds overlying the clay here are:

(1) Red-shale drift	5 feet
(2) Mottled, red and white, micaceous sand, resembling *kaolin*, and in places containing a whitish clay	5 feet
(3) Laminated sand and clay, sometimes containing impressions of leaves...	4 feet

The clays show the following succession, beginning at the top:

(4) Clay for stoneware	4 feet
(5) Clay for smoking pipe	1½ feet
(6) *Kaolin*-like sand	9 inches
(7) Fire clay	4 feet
(8) Black, sandy earth, containing lignite and pyrite at the bottom	

Layer (4) called *stoneware* clay is sandy, of light bluish color.

The next layer (5) is compact, dark colored, but drying white, and burning white. It is used with a more sandy clay for the pipe mixture. The fire clay of these pits is bluish and hard, but crumbling on exposure to the weather.

Some of the overlying clay and sand layer (No. 3) is good enough for common brick, but it is not now used except to fill up pits.

Further north the pits go through a bluish-white fire clay into a light-spotted and red clay; and the total thickness of clay there was 12 feet. Under this the sandy clay with lignite and pyrite was found. No. 36 on the general section shows the position of this clay bank. A little of the clay dug at this bank is sold, but nearly all of it, and all the *fire clay*, is worked up in the fire brick and clay retort works of the proprietors, B. Kreischer & Son, at Rossville, Staten Island.

In 1873 the product of these pits is said to have been 17,000 tons of clays.

The pits of S. A. Meeker, across the road, east of Kreischer's bank, have not been worked lately, and no data respecting them is at hand, and their description is omitted.

MELICK BROTHERS' CLAY PITS.

These pits are south of the straight New Brunswick road and just east of the old road, and near the village of Woodbridge. The red-shale drift and yellow sand and gravel cover the clay from 10 to 20 feet thick. At the north end of the bank the latter bed is wanting, and the shale drift is in contact with the clay. A granite boulder, 10 feet in diameter, was found here, lying half in this drift and half imbedded in the clay. Its upper surface was polished, while the under side was rough. The clay surface in these pits is marked by inequalities. The top clay is dark-colored, and is used for pipe making. This is thin at the north, but 3 to 6 feet thick in the southernmost pits. In the latter there is a layer of sand 2 feet thick between the pipe clay and the fire clay. The latter is about 6 feet thick, and its surface in the northern pits is 57 feet above high tide level. It is underlaid by a white quartz sand. It is white, with very little gritty matter, and very refractory. The clays of these pits are carted to the dock of the proprietors, on the creek southeast of the village, whence they are shipped as orders require. The same firm own clay lands north of these pits and north of the straight New Brunswick road, adjoining the Salamander Works' clay bank, but they have not worked there recently.

This completes the description of the Mutton Hollow group of clay pits, consisting of several ownerships whose openings are all connected, so that it is in reality one great excavation. which has taken out nearly all the accessible clays of value in this hollow, or valley, and filled it partially with great, flat-topped mounds of waste clays and top dirt.

CLAY PITS SOUTH OF WOODBRIDGE.

Going east on the clay docks road from Mutton Hollow there is, on the north side of this road, a group of pits which have been so worked that they are almost united, although they are distinct in ownership, belonging to three proprietors, viz: S. A. Meeker on the west, Isaac Inslee in the middle, and James Valentine on the east.

S. A. MEEKER'S PITS.

The succession of the layers seen in Meeker's pits, beginning at the surface, is as follows:

(1) Red-shale drift	9 feet
(2) Light greyish clay	3 feet
(3) Sandy, white clay	2 feet
(4) Dark colored clay	5 feet
(5) White, quartz sand at bottom	

Leaf impressions are said to occur in this dark colored to black clay at the bottom, but no lignite or pyrite. It is very hard and solid and is said to burn white, and is used, together with the greyish white and sandy white clays, in pipe. According to the elevation of the Woodbridge bed on the line of strike passing through this opening, which is 48 feet, and the heights of this bed in the adjoining pits of Isaac Inslee and James Valentine, 42 and 41 feet, respectively, these pits do not get deep enough to reach it. The bottom of the above described section is at 51 feet. (See general section, Nos. 40 and 41.) The existence of leaf impressions also identifies it as the leaf layer which lies over the Woodbridge bed.

ISAAC INSLEE'S PITS.

These pits showed when visited, and when worked in 1874, the following strata, viz:

(1) Red-shale drift	8 feet
(2) Yellow gravelly sand	
(3) Sandy, white clay	2 feet
(4) White sandy bed (called *kaolin*)	4 feet
(5) Dark colored, sandy, pipe clay	3 feet
(6) Black, sandy earth	2 feet
(7) Fire clay	3 feet
Dark colored sand at the bottom	

The bottom of the fire clay layer has an elevation of 38 feet. Leaf impressions have been found at the bottom of the pit and in the white fire clay. This is the only locality where they have been seen in that bed.

These pits have not been worked since 1875.

JAMES VALENTINE'S PITS.

Mr. Valentine finds that both the top-dirt, or *bearing*, and the clay bed are very uneven, showing much variation from point to point. The stratification generally exposed is as follows:

(1) Red-shale drift	4–6 feet
(2) Sandy clay (white, greyish and streaked)	3 feet
(3) Sand	1 foot
(4) Dark-colored, pipe clay	2 feet
(5) Fire clay	8–10 feet
(6) Sand and sandy clay, with lignite, at the bottom	

Some of the greyish-white sand and sandy clay found on the pipe clay is sent to steel foundries as crucible linings. In places this makes up nearly all of the top-dirt below the shale drift. It is almost all quartz, although there is some clay streaked through it in some of the pits.

The fire clay layer appears to be very irregular, lying in bunches, or pockets. Its elevation (top) is 42 feet. This clay is white, very tough, quite free from sand or gritty matter, breaks with a conchoidal fracture, and is highly refractory. In burning, it shrinks considerably, like all the pure or aluminous clays of this fire clay bed. Mr. Valentine says that he has bored 30 feet in the level ground north of his pits and found no fire clay. Towards the northwest he found black clay only. Southeast of the pits the auger brings up a sandy clay. These explorations indicate a want of regularity in the bedding in this locality greater than is generally observed where the surface is so smooth as it is here. The thinness of the fire clay in Inslee's pits, on the west, also points to unevenness in the original deposition, since it appears there to be covered by beds that belong above it, in their regular order of succession, although their complete identification is not certainly made out. A large part of the clay of these pits is used in the fire brick and drain pipe works of M. D. Valentine & Brother, about a half a mile east of the pits.

ISAAC INSLEE'S PITS—(PERTH AMBOY ROAD.)

These pits are on the road side a few rods south of Mr. Inslee's residence. There is much variation in the bedding which has been exposed in this opening, and hardly any section is a representation of the whole. Generally there is red-shale drift at the surface, then black clay, very hard and showing a jointed structure; then the fire clay bed becoming sandy towards the bottom of the pits. The top dirt varies from 4 feet upwards in thickness. The black clay at the top is in places 12 feet thick. It has a laminated structure, including filmy layers of white quartz sand. It contains a considerable amount of carbonaceous or coaly material, which gives it a very black shade, besides small fragments of lignite. The lower part of it is very hard, and breaks with a clean, sharp fracture into square, flattened, plate-like masses. Small, nodular masses of amber are occasionally found in it. Leaf impressions also occur in it. This clay is sold for making pipe. The best of it is destitute of the laminated structure. The fire clay has a mean height of about 30 feet, judging from the elevation of the surface of the ground as given by the contour lines of the map, but its surface is quite uneven. Some of it near the top of the layer is stained by oxide of iron in filmy coatings on cracked surfaces, apparently caused by infiltration from above. This also goes into drain pipe. It is improved by weathering. Some is sold to foundries. The fire clay is very hard, breaking up under the pick, with a conchoidal fracture.

Both at the top and the bottom it is sandy. The *top blue*, which is sandy, is sold as a pipe clay. It is further sorted into No. 1, or fine clay, for fire brick ; No. 2 also for fire brick, retort clay, and *bottom sandy* clay. In the latter small quartz pebbles are occasionally found. And this contains a large percentage of very fine sand. It burns without shrinking or *checking* much. The total thickness of the fire clay bed may average 10 to 13 feet.

Thus far no water has interfered with the digging, and this lessens the cost of extraction. The small amount of top dirt has also favored the locality. But the clay being dry and hard it is not so easily or cheaply dug. These pits have been opened about a year, and the sales are reported as encouraging, even in these times, for new localities, which, like this, can furnish good and marketable clays.

These pits are interesting geologically, as having been opened since the publication of the map of this district, according to which they are in *clay territory*, and the bed here is within accessible distance from the surface. The general section appended to this report also shows its position (No. 50) within the limits of the Woodbridge bed as there drawn. A careful study of the map shows further that the area of *workable* clay territory extends east of this a short distance, also a little further south and west and southwest to the clay pits above described and to those of Hampton Cutter and Sons. And a fire clay is said to have been got in digging Hampton Cutter's well at his house on the hill, but this was quite deep, probably too much covered for profitable extraction.

FIRE CLAY BANKS OF HAMPTON CUTTER AND SONS.

These are south-southwest of Woodbridge and west of Mr. Cutter's residence. The openings are properly in two groups of pits, separated by a short space of ground that has not been touched in the work of excavation. The northern pits are in lower ground and not more than 200 yards south of James Valentine's pits, described above. At these the top dirt of sandy earths and clays is, on an average, 6 feet thick. The clay bed is 10 feet thick, and 32 feet (top) above mean high tide level. It is stained by oxide of iron in places, and is rather sandy, becoming more so at the bottom. It is sold as a No. 2 fire clay.

Under it the pits stop at a sand, which is full of water. This may be the fire sand bed. (See general section, No. 46.) These pits have not been worked in two or three years.

The main bank is a few rods southwest of that described. A large area of ground has been worked over, and many thousands of tons of valuable clay have been taken from it. On account of its extent and the inequality of the ground, the stratification varies somewhat in different parts of the bank. The following vertical sections, one at the east and the other at the west, illustrate this difference and show the several beds:

Eastern Face of Main Bank.

(1) Sandy and gravelly earth	6 feet
(2) White quartz sand, including thin layers of earth	9 feet
(3) Sandstone (sand cemented by oxide of iron)	3 feet
(4) White quartz sand	1 foot
(5) Black, pipe clay	1 foot
(6) White ware (and paper clay in some pits) clay	6 feet
(7) Red clay	7 feet
(8) Sandy fire clay	7 feet

The sand bed in this bank (No. 2) is very plainly stratified, and much of the material in it is clean quartz sand. The stone layer (3) is in some places 6 feet thick. This stone is really a part of the sand bed, which has been cemented into a quite solid, stony mass by a very little reddish oxide of iron. It serves a useful purpose in working the bank by holding up the overlying beds, thus preventing slides and accidents from falling top dirt. It is not firm enough for a very desirable building material, although good enough for rough and light structures. It is thrown out on the waste heaps. Some of this top sand is sold to fire brick makers for moulding. This sand bed is supposed to belong to the drift. The clay under it begins the top of the regular series here. Southward this black clay grows thicker and is remarkably uniform on the top, running nearly horizontal through the bank. Some of the pits do not get any red clay, the ware clay in them lying upon the extra-sandy white clay.

The western face of the bank affords the following section, viz.:

(1) Red-shaly dirt	2 feet
(2) Dark-colored sandy clay and layers of sand	20 feet

(3)	White quartz sand	2–3 feet
(4)	Bluish-white sandy clay	4–5 feet
(5)	Dark-colored sandy clay	4 feet
(6)	Retort clay	2 feet
(7)	Fire clay, No. 1	6 feet
(8)	Extra-sandy fire clay	

The black clay and sand bed (No. 2) of this bank is not used, although much of it, if sorted, could be put into pipe, and some into retort. It is quite dark colored, almost black in the bank, and contains a great deal of lignite and coaly or carbonaceous matter. Its composition according to an analysis of a good specimen, is as follows:

Alumina	20.75
Silicic acid and sand	56.00
Titanic acid	0.95
Water (combined)	10.67
Potash	0.91
Soda	....
Lime	0.22
Magnesia	0.18
Sesqui-oxide of iron	1.60
Water (moisture)	2.40
Carbon	6.73
Total	100.41

This analysis shows nearly seven per cent. of woody matter but this is not in the usual form of lignite, but rather fine carbonaceous material distributed uniformly through the clay. As this is removed in burning, the mass is left open, and uninjured as a fire material. Its combustion also gives heat, and amounts to so much fuel in the kiln. The percentage of potash is comparatively low. It may, therefore, be considered as a *fire clay*, but of inferior quality. The great thickness of this bed in the western part of the bank, all of which has to be removed to get at the retort and fire clays, makes the work of extraction expensive—and such clay should find other uses than filling pits. The present practice at this bank is to put it *by itself*, in heaps outside, where, if wanted, it can be easily reached. In some of the layers of this bed there is a great deal of sand and much pyrite and lignite. These are worthless. About 10 feet above the fire clay bed there is an apparent accumulation of lignite—in the form of flattened twigs, limbs, and trunks of trees, and leaf impressions. For a thickness of 2 to 4 feet the mass is mainly made up of these vegetable remains. All lie with their flattened forms in the plane of the bedding, evidently compressed by the great weight of the overlying clay and top dirt.

The blue, sandy clay (No. 3), dries white, is very sandy, and contains many scales of mica. It is sold as a sort of sandy clay or *kaolin* for fire brick and pipe mixtures.

Of the dark colored clay overlying immediately the fire clay the bottom two spits, or two feet, is used for retorts and saggers. It is very tough and plastic. It dries light in color.

The fire clay of this bank is quite remarkable for its freedom from sand and its high character for fire brick, ware and paper glazing. The several varieties, as defined by these several uses, are dug at different points, one pit yielding more of the *ware clay*, another a *paper clay*, &c., but they all belong to the same continuous Woodbridge fire clay bed, and their differences in physical and chemical characters are apparently slight. Generally the easternmost pits have furnished the paper clay; the western and northern, the ware and brick clays. These clay banks appear on the general section as Nos. 46 and 52. The clay for fire brick is harder, more solid and breaks with a straight fracture. The ware clay is softer, more friable, crumbling readily on exposure to the atmospheric agencies, and has a very decided conchoidal fracture. The specific gravity of the former is 1.764–1.769; that of the latter is 1.791–1.893, showing the ware clay to be a little denser. In the kiln the ware clay is said to burn more open than the brick clay. The composition of these two varieties is not materially unlike; in fact it does not differ enough to justify any such variations as their uses intimate. The analyses of good, typical specimens are as follows:

	1		2	
Alumina	38.24		38.81	
Silicic acid	43.90		44.14	
Water (combined)	14.10		12.97	
		96.24		95.92
Silica (sand)	1.10		0.80	
Titanic acid	1.30		1.30	
		2.40		2.10
Potash	0.15		0.17	
Soda	0.00		0.00	
Lime	traces		traces	
Magnesia	0.11		0.11	
Sesqui-oxide of iron	0.96		1.14	
Water (moisture)	0.70		1.23	
		1.92		2.65
Totals		100.56		100.67

1. Fire brick clay.
2. Ware clay.

In these analyses the lime was not determined. From what is known of other like clays it is scarcely a weighable constituent, rarely amounting to as much as the magnesia.

The red clay, got in some pits, under the fire clay is quite hard, breaking with a conchoidal fracture, and contains some fine sand unevenly distributed through it. This is sold for stove linings. The sandy clay, below this red layer, is used in fire brick.

This bank is drained by underground, covered ditches that carry the water from the lowest pits. This naturally easy and cheap drainage, with the thinness of the top dirt over much of the clay which has been dug, and the high prices realized for a large part of the clay mined, have made these pits a source of wealth to the proprietors. No other equal area of ground in the clay district has yielded so large an aggregate of net returns as these. The total number of tons of clays sold from these pits amounts to thousands of tons, and their sale has realized a fortune.

WILLIAM CUTTER'S CLAY BANKS.

The main bank of William Cutter is connected with that of Hampton Cutter & Sons, lying immediately south of it. The geological relation and chemical and physical characters of the clays are so like those of the former that no additional, separate description seems needed. It is not worked now. About 80 yards southwest of it, and in the woods, a new opening was made in February, 1876, which has been worked by Messrs. William H. and Josiah Cutter. A vertical section observed recently exhibits the following layers:

(1) Red-shale drift earth	2–10 feet
(2) Black, sandy clay, streaked horizontally and irregularly with thin layers of sand	6 feet
(3) Top, sandy clay	3–4 feet
(4) Blue, pipe clay	1 foot
(5) Yellowish, streaked (alum) clay	2 feet
(6) Fire clay and ware clay	5 feet
(7) Fire clay, partly No. 2	5 feet
(8) Sandy clay, containing lignite, at the bottom	

The top of the clay is quite uniform and is about 30 feet above high water level, judging from the contour lines of the map, on which the surface here is 40 to 50 feet. The ware clay is sorted from the fire clay bed. This latter bed is more sandy towards the bottom, and this is sold as a No. 2 fire clay. The fire clay bed proper includes (5) to (7), inclusive, of the section given above, and is therefore about 12 feet thick.

Going west from the Cutter banks, the next openings are the *kaolin* and clay pits of H. Cutter and Isaac Flood. In that of the former, a sandy clay and a so-called *kaolin* was obtained. It was not worked when visited. West of it, and connected with it, are

THE CLAY PITS OF ISAAC FLOOD.

The beds here when visited were as follows, beginning at the surface:

(1) Red-shale drift	3–5 feet
(2) White, pipe clay	4–5 feet
(3) Yellow, laminated sand	4–5 feet
(4) Black, pipe clay	4 feet
(5) Black, sandy earth, containing some lignite and pyrite	5 feet
(6) Sandy white clay, used in stoneware	6 feet
(7) Sandy *kaolin*	
Black clay	

Of these layers, No. 2, which is sold for pipe mixture, is really a fire clay of inferior grade. It is light drab-colored, and has some iron oxide stains through it.

The next bed (3) consists of drab-colored and white, thin layers of sand.

No. 5 of the above section contains much lignite in small fragments. The *stoneware clay* of these pits is white and sandy, and is said to burn brown. It is used to mix with the South Amboy stoneware clays. The top of this bed is 38 feet above high tide level. There is some uncertainty as to the proper place of these beds in the geological series of this clay district, inasmuch as no fire clay is recognized here as belonging to the Woodbridge bed. The general section at No. 48 shows that the upper layers dug here belong above that bed, and that the stoneware clay is in it. If this be so, then the sandy, *kaolin*-like layer underlying it corresponds to the fire sand bed just under the fire clay, and the dark-colored pipe clay (4) is the equivalent of the top-white clay. The next bed below this, in which there is much lignite and pyrite, must include the leaf horizon. Near the line of the property on the east a retort clay was formerly dug, 30 feet beneath the surface of the ground, and separated from the *kaolin*-like sand by a stratum of black, sandy clay. Nothing further is known of it, and no specimens were seen.

Cutter's pits are in the low ground east of Flood's.

E. CUTTER FARM.

This property is south of William Cutter's lands, west of the Perth Amboy road, and lying along the head of Spa Spring brook. Clays have been dug at several points in the lower ground near this stream. At the most westerly openings (old *kaolin* pits of the map), there was said to be a thickness of top dirt of 18 feet, then a pipe clay 3 feet thick overlying the sandy bed—here called a *kaolin*. Its elevation, according to the height of the ground here and the above figures, may have been 15 feet (top); and this is about the height at which the Woodbridge bed should be found. The *kaolin* may lie on it.

A short distance from these *kaolin* pits, down the valley of the brook and on the east of the stream, there is a pit where a white fire clay is said to have been dug. Its surface was about 7 feet above high tide level. Still further on down this valley, and an eighth of a mile or so from the Cutter farm house, a dark-colored clay for yellow ware, and also for pipe, was dug. There were 8 or 9 feet of red-shale drift over it. This latter clay appears where the fire clay would be expected if the elevation and the thicknesses given above are correct. (See the general section, No. 58.) It is possible that the stratification is more irregular along the valley of this brook, and that the fire clay has, in part at least, been replaced by more sandy layers, either as dark-colored clays and such as are suitable for pottery, or by *kaolin*-like sands. Such variations and localities like this are to be expected where there seem to be exceptions to the persistence and uniformity observed over so large a territory and in so many openings. More careful explorations are needed here to test this property and to settle these questions.

S. G. PHILLIPS' PITS.

These are newly opened pits east of the Woodbridge and Perth Amboy road and a few rods west of Spa Springs station. The vertical section partly from observation and partly from the statements of the foreman of the pits, is made up of the following layers:

(1) Red-shale drift	9 feet
(2) Dark-colored clay, containing pyrite and lignite	4–5 feet
(3) Dark-colored to black, pipe clay	9 feet
(4) Fire clay	4–5 feet
(5) Sandy fire clay	2 feet

The top of the fire clay bed here is about at the level of mean tide, and the bottom of the same about 9 feet below high water mark. Number 65 on the general section exhibits this opening.

The top black clay (2) is thrown away as waste. Of the succeeding dark-colored clays, that in the middle of the bed (3) is nearly black. All of it is suitable for pipe mixture. There may be some of it adapted to more valuable uses.

Since these pits have been opened a considerable amount of clay has been taken out and sold.

This is another locality opened since the publication of this clay district map, and within the limits of clay territory represented by *it.*

Over the hill, south of these pits and southwest of Chas. Anness' residence, and just west of the Perth Amboy road, several small pits in fire clay have been dug by Mr. Phillips. North of this and on the hill across the road from Anness' house, there is an old pit where a little dark-colored clay was dug some years ago for making red brick at the Spa Springs yard. This belongs in the laminated clay and sand bed, which is the great source of the red brick clay for the several yards along the Raritan and South rivers.

W. H. P. BENTON'S CLAY PITS.

These pits are in the low ground west of the Perth Amboy road and the railroad, and south of those above mentioned. The first opening here was made about three years ago. The surface of the ground is a few feet only above high water and the top of the fire clay bed, as leveled, is 7 feet below that datum plane. The relation of these pits to this bed is shown by the general section, No. 67, being the columnar section of these openings. The following section, made from the observations of Mr. Benton, shows the several strata, descending:

(1) Red-shale drift	12 feet
(2) Sandy, blue clay, for pipe	8–9 feet
(3) Fire clay, No. 2	5 feet
(4) Blue, fire clay	2 feet
(5) Best, white, fire clay	5–6 feet
(6) Black sand and sandy clays at the bottom, into which boring has gone	7 feet

The top sandy clay (No. 2) is not uniform, the sand in it being irregularly mixed with the more clayey portions. It contains a little pyrite. An analysis of a good specimen of it showed the following constituents:

Alumina	23.80	
Silicic acid	33.00	
Water (combined)	6.70	
		63.50

Silica (Quartz sand)	29.10	
Titanic acid	1.70	
		30.80
Potash	2.01	
Soda	0.76	
Lime	traces	
Magnesia	0.57	
Sesqui-oxide of iron	1.60	
Sulphuric acid	......	
Phosphoric acid	traces	
Water (moisture)	1.00	
		5.94
Total		100.24

This is a tough clay, but not refractory. It answers well in mixtures for pipe.

In some of the pits there is 2–3 feet of sharp, clean, white quartz sand over the fire clay and under this bed.

The fire clay bed proper includes Nos. (3) to (5) inclusive, and is, therefore, about 13 feet thick. Some of the last pits dug are said to have had a greater thickness than this, and of superior clay at the bottom. The best of the white fire clay dug here is bluish white; has a conchoidal fracture; contains very few gritty particles, and crumbles readily on exposure to the air, falling down into a fine lumpy mass. And the best of it is said to answer for white ware equally as well as for fire brick. The composition of the best of this fire clay is given in the following analysis:

ANALYSIS.

Alumina	37.56	
Silicic acid	42.00	
Water (combined)	14.60	
		94.16
Silicic acid (sand)	1.40	
Titanic acid	1.40	
		2.80
Potash	0.35	
Soda	0.37	
Lime	......	

Magnesia	......	
Sesqui-oxide of iron	1.04	
Water (moisture)	0.80	
		2.56
Total		99.52

The lime and magnesia were not determined. They are inconsiderable in quantity, probably, together less than a half of one per cent. of the whole.

Some of the dark-colored clay of these pits has been called a retort clay, but as to its composition or reputation nothing can be said.

The depth of the fire clay bed in these pits under the top earth and clays and below tide level, necessitates the removal of much waste and the raising of all the water flowing into the pit. The cost of pumping this out added to that of stripping and digging the clay, makes mining in these pits more expensive than the present slow market justifies, even for fine clays. No work has been done here in over a year. The pits are now filled with water.

Nearly a half a mile southwest of these pits, and also in low ground near the brook, Mr. Benton dug a single pit and went through :

(1) Top dirt (sandy)	5 feet
(2) Yellowish white clay	3 feet
(3) Yellow sand	3 feet
(4) Sandy clay	3 feet
(5) *Kaolin*-like sand	2–3 feet
Dark sandy clay at the bottom	

This pit was not deep enough to strike the fire clay, as the ground rises in that direction, and the clay is about on the same level as in the pits on the roadside, judging from the strike of the formation.

PITS OF CHAS. ANNESS & SONS.

Anness' clay pits are south of his residence, east of the Woodbridge and Perth Amboy railroad, and at the border of the tide meadow. The clay bed here, as at Benton's pits, is wholly below tide level, its surface being somewhat uneven, but from 5 to 10 feet below that level. The strata observed here were the following:

(1) Red sandy earth (for red brick)	10–18 feet
(2) Gravelly loam and earth, in alternating layers	
(3) Pipe clay	2 feet
(4) Fire clay	4 feet
(5) Sandy clay and sand, dark-colored, at the bottom	

The top earth here is very fine and sufficiently clayey for red brick material. This has been stored by itself for such use whenever it is wanted. It lies upon the gravelly drift, and is probably of alluvial origin—a meadow mud. It is from 6 to 8 feet thick.

The gravelly loam and earth (No. 2) varies greatly in thickness. It is waste.

No. 3 is an inferior fire clay that is used in pipe. It is a little sandy, dark streaked, but dries white. The best fire clay of these pits is bluish-white, solid; having a specific gravity of 1.861—1.864. It contains some fine sand, which with the other constituents appear in the following analyis:

Alumina*	31.66	
Silicic acid	34.30	
Water (combined)	10.50	
		76.46
Silica (quartz sand)	20.60	
		20.60
Potash	1.53	
Soda	......	
Lime	......	
Magnesia	......	
Sesqui-oxide of iron	0.74	
Water (moisture)	0.60	
		2.87
Total		99.93

Towards the bottom the bed is sandy.

Another section, seen in a pit more recently dug than that which the above figures illustrate, is as follows:

* Titanic acid with the alumina.

(1) Soil	1 foot
(2) Sandy clay, bluish, in places yellow	6 feet
(3) Sandy gravel and cobblestones	1–5 feet
(4) Red, sandy earth	4 feet
(5) Clay and sandy gravel, in alternating layers	2–6 feet
(6) Sandy clay	12 feet
(7) Fire clay	4–10 feet
(8) Black clay	1 foot
(9) Quicksand, black and underlaid by black clay	6 feet

This last is depth of boring from the bottom of the pits.

The layer No. 2 furnishes a superior red brick material.

The next lower layer (No. 5), is quite remarkable for its uniformly fine-grained texture and its deep red color. Thus far no use has been found for it, although from its fineness of grain it seems adapted for some purposes of value.

The clay of layer (6) is used either for pipe or for some kinds of pottery or stoneware. It may be regarded as the upper part of the fire clay bed.

The fire clay has been found 10 feet thick in some borings west of the pits. In the latter, it was 4 feet thick. It is shown by the columnar section No. 71 on the general section.

The water was raised from these pits by a centrifugal pump, worked by steam power. This, of course, was attended by considerable expense, as the amount of water is large, particularly towards the bottom.

All the clay of these pits is worked up in the National Fire Brick Works of Charles Anness & Son, into fire brick, drain pipe and land tile.

FELDSPAR AND KAOLIN PITS OF CHARLES ANNESS & SONS.

These pits are one mile south of Woodbridge, and in Woodbridge township, near the line road which separates this township from Perth Amboy. In these pits there is considerable irregularity and variation in the thickness of the several layers, and the vertical section of any given pit is not always representative of that immediately adjoining it. In the southernmost pits the following layers were observed:

(1) Red-shale drift	18 feet
(2) Yellow sand and gravel	6 feet
(3) White, sandy clay	3 feet
(4) *Feldspar*	4–5 feet

Here the top of the *feldspar* bed was 91 feet above high water level. About 100 feet from the above section, and in the eastern pit face, there was:

(1) Red-shale drift	8 feet
(2) Whitish sand	7 feet
(3) *Feldspar*	3–5 feet

And here the latter bed was 99 feet high. The unstratified red-shale drift, and the underlying sorted sand and gravel drift, are very finely exhibited in these pits. The former is much coarser at the top, and includes some large boulders, scattered irregularly through it. It is seen here from 3 to 18 feet thick.

The yellow sand and gravel is nearly all quartz, and some parts of this drift bed are clean and sharp grained and good enough for common mortar. The pebbles and cobble stones are generally in thin layers in the sand, marking very distinctly the lines of stratification.

The top clay varies from a yellowish white to buff, and to a deep red color. It is quite sandy and the sand in it is often of uneven grain. It is, however, refractory enough for admixture with other clays, for No. 2 fire brick, and also for pipe. Its thickness varies from 1 to 5 feet. In some of the pits there is a thin layer of reddish sand, with balls or concretionary masses of iron-cemented sand, between this clay and the *feldspar* bed.

The *feldspar* ranges from 3 to 10 feet in thickness. In some of the more westerly pits it is in two beds, separated by a bed of white quartz sand, which is 2 to 3 feet thick. Here the upper layer is of inferior quality and is considered a No. 2 *feldspar*. In the main layer or bed the material is in places varied by the presence of small irregular masses of white sand surrounded by the *feldspar*. The material does not differ much from that dug on the Forbes tract, and for the composition of the No. 1 *feldspar* reference is made to the analysis in the description of that locality. The finer-grained portions and also that which is at all yellowish, or stained by oxide of iron, or which has any earth with it, are graded as No. 2.

Under this bed there is a dark-colored clayey sand, containing some lignite and a little pyrite. Mr. Anness says he has bored 20 feet into this sandy bed. Occasionally there is a layer of yellow sandy clay, 1 to 2 feet thick, slightly mixed with *feldspar*, between the sand and the *feldspar* beds. This *feldspar* opening is represented as No. 57 on the general section.

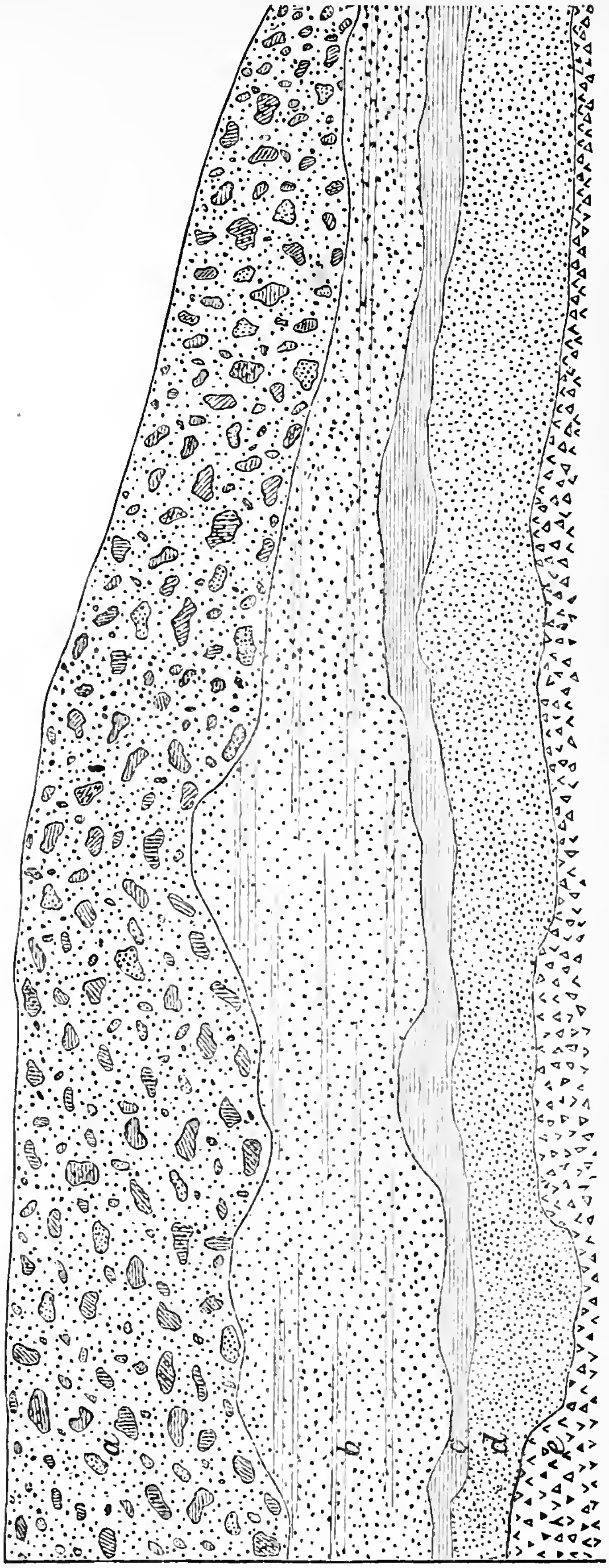
The materials dug in these pits are carted to the proprietors' works, on Woodbridge creek and near Spa Spring station. They are used in the various grades of fire brick, sewer and drain pipe and land tile.

The *kaolin* pits are about 200 yards north, northeast of the *feldspar* opening. These have not been worked in several years. They are in lower ground, and the *kaolin* did not exceed the height of 80 feet, or about 10 feet lower than the *feldspar* bed. This is probably a sandy material belonging to the micaceous sand bed underlying the latter. The so-called granite pits of I. Flood are a few yards south of Anness' *feldspar* bank, and on a little higher ground—near the top of the ridge. *Feldspar* was dug in them.

FORBES FARM—FELDSPAR BANK.

This bank is in Perth Amboy township near the Woodbridge line road and a few rods southeast of Anness' pits. This large opening has shown much variation in the thickness of the *feldspar*, and also in that of the overlying beds of drift, and a single vertical section fails to represent the whole area here opened. The general character of the beds over the *feldspar* in their relative super-position, varying thickness and inequalities are shown by the accompanying sketch (Figure 1.) This represents the order and the thickness of the several beds, not however in exact correspondence with the bank in its whole length. It is rather a combination of three vertical sections, as observed at different parts of the bank.

FIG. 1.



Forbes Farm Feldspar Bank.—The upper bed *a* is the glacial drift, termed in the local descriptions the *red-shale drift*. The yellow sand and gravel, or *modified drift*, appears as *b*; then the red clay as *c*, the fire sand *d*, and the *feldspar e*, at the bottom.

The following is a tabular statement of the strata:

(1) Red-shale drift	6–20 feet
(2) Yellow sand and gravel	0–15 feet
(3) Red and white, sandy clay	1–3 feet
(4) Fire sand and sandy layers	2–10 feet
(5) Feldspar	3–8 feet
(6) Micaceous sand bed (boring)	20 feet

The irregularities are such that thicker and thin beds are brought together. That is neither the minimum nor the maximum thicknesses are always together in any given vertical section of the bank. For example in a recently measured section of the *bearing* there was of the

(1) Red-shale drift	10 feet
(2) Yellow sand and gravel	8 feet
(3) Red clay	2 feet
(4) White quartz sand (fire sand in part)	10 feet
Or in all above the *feldspar*	30 feet

The two drift deposits are very finely seen here, and are sharply defined by a very uneven divisional plane.

The clay bed (No. 3) is occasionally wanting. It is sometimes white, sometimes red, and always sandy. It is thrown away as waste.

The next bed is a white quartz sand, some of which is considered a fire sand. Some of it that is of finer grain and contains a little mica is sold under the name of *kaolin*. And it represents the *kaolin* bed of the clay series, being the equivalent of that which is found under the South Amboy fire clay bed in the several pits where that clay is dug. Some of this sand is yellowish and, in places, it shows oxide of iron stains. Here and there it seems to replace in part the *feldspar* or it is split into thin layers that alternate with like strata of feldspar.

The height of the *feldspar* in this bank is on an average 96 feet. Its thickness has been from 2 to 14 feet; the average has been put at 5 feet. The material of this bed also varies greatly, according as it is more sandy, or more clayey, or contains more or less of oxide of iron *stains* or other foreign matters. That which is most free from these foreign constituents and which contains the most clay is selected as No. 1; while inferior grades are marked Nos. 2 and 3, the latter being little else than a clayey fire sand. The best of it is very white, solid and a mixture of nearly equal parts of clay and quartz grains. These grains are from fine sand to those half an inch in diameter and are slightly rounded. The composition of the No. 1 *feldspar* is as follows:

Alumina and titanic acid	18.80	
Silicic acid	16.85	
Water (combined)	4.90	
		40.55
Silicic acid (sand)	58.40	
		58.40
Potash	0.15	
Soda	0.21	
Lime	......	
Magnesia	......	
Sesqui-oxide of iron	0.49	
Water (moisture)	0.80	
		1.65
Total		100.60

These figures show this strange mixture is a good fire material, being quite as pure as the best clays of this district, and, excepting the quartz, quite as refractory as they are. In any comparisons of this kind the only material difference, chemically, is between quartz and clay. Physically, the texture of the *feldspar* is different from the sandy clays, and from any fire brick mixture, where fire sand is used, in the more uneven grain and greater coarseness. The *feldspars* of the several grades are sold for tempering clay for fire brick mixture. They command a quite ready sale at good prices.

The fire sand in this bank is in spots, contaminated by ball-like masses of pyrite crystals. Neither the sand nor the *kaolin* sell as well as the *feldspar*, and there is a large stock of them in great heaps about the opening.

The sandy earth found in boring under the *feldspar* contains quite a conspicuous amount of mica in very fine scales, and it resembles *kaolin*. It is the micaceous sand bed of the plastic clay series. The general section, No. 59, gives the position of this opening and the boring in relation to the strata. On account of the excessive quantity of water in it, the pits stop at the bottom of the *feldspar.*

The excavation at this bank has worked over several acres. In the deeper pits at the west, the *bearing* on the *feldspar* has been 40 feet thick, making the cost of stripping very large; but the height of all the beds above easy, natural drainage down to the bottom of the pits compensates largely for the expenses of removing so much from the top. This mode of drainage is very important, as there is a great deal of water in the lower strata, none of which are like the clay, wholly impervious to water, but rather water bearing beds, allowing all the waters from above to run through them; and when very wet they become soft, and slide or fall down very easily.

North of this bank *feldspar* has been dug in one or two small pits near the barn on this property, and within a few yards of the road. In these there was about 8 feet of yellowish, buff-colored, sandy earth; then 2 to 4 feet of No. 1 *feldspar*, and sand at the bottom.

The same bed has been found in trial pits and borings west of the main bank and also north of it and east of the farm house. It thins out in that direction, as the ground rapidly descends below its *level.* South and southwest of the bank the ground rises and as the bed descends in that direction it soon reaches the limit beyond which practicable or economical working becomes impossible.

At Kinsey's corner a half a mile south southwest of the Forbes' *feldspar* bank, a well dug about thirty years ago, is said to have reached the *feldspar* bed at a depth of 38 feet. The surface here is 130 feet above tide level, and the height of this bed is 92 feet at this place. No. 62 of the general section shows its relative position and elevation.

On this Forbes property, southeast of the *feldspar* bank, 100 yards, or thereabouts, a light-colored, sandy clay has been dug and used in pipe. It is at an elevation of 55 to 57 feet (top) above tide level, or 35 feet below the *feldspar.* According to these figures it belongs in the horizon of the laminated clay and sand. Borings near the old pits, and on the eastern part of the tract, along the road indicate the same clay stratum as extending in that direction, but thin and of no economic value. Lower a dark-colored, sandy clay, full of lignite, abounds, cropping out along the brook, south of the road and seen in borings made near it. This is at 20 feet above tide level and is the equivalent of the sandy, leaf bearing bed, which lies immediately upon the Woodbridge bed. Some of the light-colored clay found on this tract may answer in the manufacture of yellow ware.

D. WATROUS' FELDSPAR.

Within a year or so considerable digging has been done on the farm of D. Watrous, a half a mile east of the Woodbridge and Perth Amboy road and 150 yards northeast of his house. The pits are in the low ground, near the head of a wet, swampy run. Only thin seams of *feldspar* have been found, interstratified with yellowish white sand and covered by a red, shaly earth and a bluish black, sandy clay. The total thickness of this top dirt does not exceed 6 feet. The little *feldspar* obtained is much stained by oxide of iron. It is rather clayey and the quartz in it is quite fine grained. On account of this association in such thin strata with ferruginous sands, the separation of marketable grades of *feldspar* is scarcely practicable. A small heap has, however, been thus sorted out, but rather as an experiment. The height of the bed here is estimated from the contour (surface) lines to be between 80 and 90 feet.

Borings in the low ground west of this opening have failed to discover any extension of the bed in that direction.

FELDSPAR AND CLAY BANKS OF THE KNICKERBOCKER LIFE INSURANCE COMPANY.

Feldspar and Fire sand.—These banks are from 200 to 300 yards west of the Perth Amboy and Woodbridge road, and one and a half miles north of the former place. The old bank, not worked lately, is mainly a fire sand with thin seams of *feldspar*. The following layers were observed here in 1874:

(1) Yellow sand and gravel	12 feet
(2) Chocolate-colored clay	2 feet
(3) Yellow, sandy earth	2 feet
(4) *Feldspar*	2 feet
(5) Fire-sand	1½ feet
(6) *Feldspar*	6 inches
(7) Yellowish, sandy earth at bottom	

But these layers are not persistent for any distance. They show the interstratification of sand and *feldspar*. Even in the sand at the top there are thin layers of *feldspar* and fire-sand. And the whole bank seems very much mixed in character. The highest outcrop of the fire sand is 71 feet. East of this bank a black clay crops out in ground a little lower than the bottom of the bank, or at an elevation (average) of 50 feet. This is quite sandy, and belongs under the *feldspar* bed. Some of it was tried in a kiln near the pit, for making red brick, but it did not burn easily, and the bricks were pale and tender, falling to pieces in the air. Some of them are still at the site of the kiln, near the road.

Another bank, on this property, for *feldspar* and fire-sand has been opened within a year or two. This is a little over 100 yards northwest of the old bank, and in ground of about the same height. This has the following beds:

(1) Red, shaly earth with small boulders	0–3 feet
(2) Yellowish-white sand and fine gravel	20 feet
(3) Fire-sand	3–5 feet
(4) *Feldspar* (average)	5 feet
(5) Brown, chocolate-colored, sandy clay	2 feet
(6) White quartz sand	5 feet

Black, sandy clay only found at bottom of deepest trial pits.

The red-shale earth at the top is here a part of the true northern drift, which appears in the hollows only, as a very thin superficial sheet. In places this is wanting, and the sand and gravel bed forms the surface.

The sand and gravel bed is very finely laminated, some of its layers show very plainly what is known as an *ebb and flow structure*, that is sands obliquely laminated as if deposited by the changing currents of tide waters. Some of the sand in this part of the bank is very clean, but sorting is impracticable where the layers of it are thin and lie between those which are worthless. The surface of the fire sand is very uneven and its thickness is varying. It is in places streaked by oxide of iron. The *feldspar* bed also varies a great deal in thickness, and has an irregularly undulating surface. Its average elevation is about 60 feet. The material is very white, consisting of a white clay matrix which holds the grains of white quartz, most of which are somewhat rounded on the edges and range in size from fine sand to pebbles half an inch in diameter. Most of these are opaque and crumble easily; some of them are bluish; others translucent. Throughout some portions of the bed there are scattering earthy specks that slightly affect its appearance and quality. The best, selected material contains the following constituents:

ANALYSIS.

Alumina and titanic acid	16.07
Silicic acid (combined and sand)	77.40
Water (combined and hygroscopic)	4.30
Sesqui-oxide of iron	0.53
Lime	......
Magnesia	0.25
Potash	0.15
Soda	......
Total	98.70

The composition is very much like that of the No. 1 *feldspar* of Weidner's and also that of Edgar Brothers' pits. It is used quite largely by William H. Berry & Co. in their mixture with clay for fire brick and is much liked. A little clay has been dug on this property, south of the farm house and near the corner of the road. The clay was said to be yellowish white and quite sandy, but as it was not seen, nothing further is known of it or its relations. The ground hereabouts is between 90 and 100 feet high, and from the combined section the height of the South Amboy fire clay bed is found to be between 65 and 85 feet, which would put that clay within reach of pits of moderate depth. And it may be that the clay dug there was a part of that bed. but of an inferior quality. On the same section these *feldspar* openings are represented by No. 73. Another clay pit is reported on the same tract, near the line between it and W. P. Benton's lands, and northerly from the *feldspar* banks. It must belong to the laminated clay and sand bed overlying the Woodbridge clay bed. Such clays as this bed furnishes, sufficiently refractory for many purposes, are to be found not only on this tract, or farm, but also in all of the territory lying between the outcrop of the Woodbridge fire clay bed and the *feldspar* bed.

KAOLIN AND FIRE-SAND PITS OF ISAAC INSLEE.

These are east of the above-described *feldspar* banks, and a few rods east of the Woodbridge and Perth Amboy road. The *kaolin* was got in the north pits, and found near the surface, at an elevation of 65 feet, which corresponds to the height of that layer here, as shown by the general section, No. 79. The fire-sand was dug a little south of the *kaolin* opening, and where the surface of the ground is a little higher. No work has been done here since the survey of this district has been in progress.

CLAY PITS OF ISAAC INSLEE, JR.

These pits are between the Perth Amboy road and the Woodbridge and Perth Amboy railroad, northeast of the last-described locality. One of the pits went through the following strata:

(1) Red shale drift	10 feet
(2) Blue clay	5 feet
(3) Black, sandy clay, containing lignite	5 feet
(4) Sandy clay, resembling *kaolin*	5 feet
(5) Dark blue clay, containing leaf impressions	5 feet
(6) Sand and clay	3 feet
(7) Light-colored sand (boring)	15 feet

The ground here is about 55 feet high, so that this pit and boring reached within 10 or 15 feet of tide level. The section is referred, from its position and height (see general section, No. 77), to beds lying below the *feldspar*.

The top clay (No. 2 of the section) is considered the best of the pit, although not sufficiently refractory for fire-brick, as it is said to vitrify in the fire-holes of the pottery kilns. It might do for yellow, or for Rockingham ware. An analysis of it gives the following results:

ANALYSIS:

Alumina	28.80
Silicic acid and sand	54.80
Water (combined)	7.80
Titanic acid	1.00
Potash	2.97
Soda	....
Lime	0.20

Magnesia	0.64
Sesqui-oxide of iron	2.20
Water (moisture)	1.50
Total	99.91

The aggregate of alkalies and of lime, magnesia and oxide of iron, amounting to five per cent. of the clay corresponds with the practical tests, indicating a somewhat fusible material.

The layer, No. 4 of this section, is very sandy and not of value. Throughout all the layers of this pit scattering fragments of lignite appear, hardly enough in some of them to be characteristic, in others abundant. Leaf impressions have been found in No. 5—a dark blue and very tough clay.

The clays of Nos. 2, 3 and 5 are all quite good enough for pipe. That of the latter has been thought fit for retorts, but all of them are as yet, in a measure, of undecided character and the pits are rather more to test the ground than as clay producing localities.

East of this pit the dark-colored clays and sandy beds, marked by the presence of more or less lignite and pyrite, are cut by the Woodbridge and Perth Amboy railroad, and some of these have been dug at the side of that road for pipe mixtures.

JAS. VALENTINE'S KAOLIN PITS AND NEW YORK AND LONG BRANCH RAILROAD CUT.

This cut is through the rising ground south of the Woodbridge creek. The dark-colored clays and sands and the overlying *kaolin* and *feldspar* are all traversed by it. The following are the layers exposed here, beginning at the surface:

(1) Yellow sand and gravel with red-shaly earth	4–8 feet
(2) *Kaolin*—average	5 feet
(3) *Feldspar*	1 foot
(4) Yellow sand	1 foot
(5) Black, micaceous clay, lignite and pyrite	20 feet
Bluish, sandy clay at bottom, at level of track	

The *kaolin* has been dug on each side of the railroad cut—on the top of the ridge. It has an average thickness of 5 to 7 feet, varying, it is said, from 2 to 18 feet. The *feldspar* is not over a foot thick, and in most of the pits it has appeared at or near the bottom, under the *kaolin.* The top dirt on the east of the railroad has an average thickness of 8 feet, and the height of the *kaolin* bed (top) is about 48 feet. It may be a little higher on the west side. This is rather low, as the general section shows it (No. 82), although we may here see the bottom of the bed only. The upper part of it may have been washed away or worn down previous to the deposition of the drift bed, which now covers it. The *feldspar* here is finer grained than that of Weidner's or Anness' pits and contains some scales of mica, looking more like a mixture of fire sand and *kaolin.* It can be considered as the geological equivalent of that bed ; practically it is unimportant and is dug with the *kaolin.* The bed seems to thin out in this direction, and it does not appear either at Merrit's pits, southeast of this, or in the *kaolin* localities in and near Perth Amboy. In some of the western pits there is a thin stratum of yellowish, sandy earth at the bottom of the pits, under the *kaolin* and *feldspar.* But more commonly they occur, lying directly on the dark colored micaceous and sandy clay. This is, at the top, full of lignite and pyrite, and is valueless. Some of it contains much mica in very small scales. The lower part of this bed, near the bottom of the cut, is quite free from pyrite and lignite, and has a bluish shade. Some of it is reported to be suitable for Rockingham ware. It has not been used. Previous to the opening of this clay by the railroad cut it was supposed that there was a valuable clay bed under the *kaolin* pits. A reference to the combined general section will show that this ground is occupied by these dark colored clays and sands only, and that the fire clay is here too deep for working. Some of the clay in the bottom of this cut may, however, be valuable for pipe, or some kinds of ware.

The sides of the cut have slid down somewhat, thereby mixing the layers and presenting sections that may mislead observers on a first inspection.

The products of these pits are carted to the works of M. D. Valentine & Brother, near Woodbridge, one mile from these pits. They are used in the mixtures for fire brick.

MERRITT'S KAOLIN PITS.

This opening for *kaolin* is in Perth Amboy township, a mile north of the town, and a short distance west of the New York and Long Branch railroad. The top dirt is red-shale earth mixed with sand, gravel and some thin layers of red and white sandy clays, and is 8–17 feet thick. This bed is *modified drift.*

The *kaolin* bed is (top) 53 feet above tide level, and is from 4 to 12 feet thick. There is considerable variation, and the surface is undulating. Near the top it is streaked by yellowish oxide of iron stains and some little earthy masses. Its composition is, in part, as follows:

Alumina and sesqui-oxide of iron	17.10
Silicic acid and sand	77.10
Potash	1.30
Water	4.50
Total (determined)	100.00

According to these figures there is clay in this *kaolin.* The quartz grains are very small, most of them less than 1–200 of an inch in diameter. The mica is in very fine white scales, and this may furnish a part, if not most, of the potash given in the analysis.

It is sold for mixing with fire-clay in making fire-brick, stove linings, &c., &c. A large area has been worked over at these pits. As in most *kaolin* pits there is some water, particularly towards the bottom, and the digging is sometimes interfered with by the excessive amount of it, although good drainage is here practicable quite to the bottom of the *kaolin* bed.

KAOLIN PITS OF A. HALL & SON.

Hall's pits are about a half a mile northwest of their works, and between the Woodbridge and Perth Amboy railroad and the Easton and Amboy railroad. The *kaolin* is 8–10 feet thick, and is underlaid by a dark-colored, sandy earth, occasionally called "black kaolin." The *kaolin* got at these pits is coarser grained than that of Merritt's, and is regarded as of inferior quality. Very little of it has been used lately.

KAOLIN IN PERTH AMBOY.

This bed is cut in several places in Perth Amboy. On the line of the Easton and Amboy railroad, a few rods east of Hall's pits, and near the railroad hotel, it was found in the low cut, and that under the track line was dug out. Streaks of reddish and of yellowish earths run through it, and affect slightly its quality. Its elevation here is (top) about 30 feet above tide level. Over it there was a thickness of 10 feet of red-shale drift.

In some of the streets of Perth Amboy, near the sound, a *kaolin* like sand appears at an elevation of about 25 feet, covered by red-shale drift. In the western part of the town it is seen near the freight depot of the New York and Long Branch railroad, at the level of the track. Over it there is the red-shale drift. Its elevation is here also about 30 feet. The thickness of the bed and the underlying strata are not known. The relative positions of these several openings for *kaolin* in and near Perth Amboy are exhibited on the general section by Nos. 88, 97 and 101. Some of the *kaolin* from Perth Amboy was formerly used in the Watson fire brick works. But of late its use has been discontinued.

This *kaolin* bed extends northeast beyond the sound into Staten island, and it is extensively worked in several large openings one-fourth of a mile northeast of Rossville. The bed there has a maximum thickness of quite 30 feet, although generally the pits stop at 20 feet in it. This *kaolin* is very white and the grains of quartz are from 1-200 to 1-400 of an inch in diameter. The mica is in small white scales. For purposes of comparison the following analysis is here inserted. It is of a representative specimen from the pits of the Staten Island Kaolin Company and sent to the State Laboratory by Hon. Charles A. Campbell:

ANALYSIS.

Alumina and sesqui-oxide of iron	5.70
Silicic acid and sand	92.70
Potash	0.35
Water	0.70
Total (determined)	99.45

SAMUEL DALLY'S FIRE SAND PIT.

This pit is a mile northwest of Perth Amboy, close to a cross road which connects the Woodbridge and Perth Amboy and the township line road. The material dug here was found near the surface and resembled a coarse fire sand, excepting a little more clay than is common to such sands. Its height, 110 to 120 feet above tide level, is much too great for the fire sand or the *feldspar* beds of this clay formation, and it can only be referred to the sand drift.

Nothing was learned of its thickness. Only two or three small pits were dug, and the material thrown out was seen in a little that was left about them.

EASTON AND AMBOY RAILROAD CUT—FELDSPAR.

Feldspar has been seen cropping out in the Easton and Amboy railroad cut, one mile west of Perth Amboy and east of the Eagleswood road. This was in the bottom of the cut.

J. H. MANNING'S CLAY PIT.

This locality is one and a half miles west of Perth Amboy, near the New Brunswick road. A single, shaft-like pit was sunk in 1874, more for testing the ground than for the extraction of materials. In it the layers were:

(1) Top earth—soil and subsoil	2–3 feet
(2) Clays (red and white)	10 feet
(3) Black, sandy clay	2 feet
(4) Fire sand	10 feet
(5) Buff-colored clay	4 feet
(6) Fire sand	4 feet
(7) *Feldspar* (boring)	10 feet

The surface of the ground at this pit is 103 feet high, consequently the top of the clay is at 100 feet, and the bottom of the *feldspar* at 60 feet above high tide level. The elevation of the latter corresponds with the horizon at which its heights at other pits and its proper dip would indicate for the bed at this point. The fire sand of this pit is the equivalent of the *kaolin* bed, and overlying it there is the buff sandy clay closely resembling the clay in the *feldspar* banks. The top clay, red and white, belongs to the South Amboy fire clay bed. It is several feet higher than the same bed as opened in E. F. Roberts' and in John De Bow's pits, even allowing for the proper dip in the distance between them. The general combined section exhibits this locality (No.

72) and the difference between the mean surface line of the South Amboy bed and the top of the clay at this place. The so-called *fire sand* layer under this clay and above the buff clay, is, possibly, a part of the South Amboy bed, which is at the bottom sandy.

The white clay at the top is almost free of gritty particles, and *apparently* a rich and fine clay. Some parts of this bed are stained reddish.

Some of the fire sand approaches a *feldspar* in composition, containing small lumpy masses of hard clay.

The *feldspar* bed here was dug into about a foot, below which it was bored 10 feet. Specimens from it show more sand, and are finer grained than the average No. 1 *feldspar* of this district.

Working was suspended here shortly after this deep trial pit was dug. The locality is more interesting geologically than practically, as it shows the relative positions of the *feldspar* and the clay beds. It is also a proof of the existence of these beds in this high ground north of the Raritan river, and, probably, in extent sufficient for further opening and mining.

Northward, and also eastward, borings are reported, which have reached this fire clay bed. Northeast of this point, and near S. Dally's pit, a clay crops out in the road side, which is, probably, of the same bed. A study of the map, and the general section, will show a wide area wherein exploration is feasible and hopeful.

EASTON AND AMBOY RAILROAD CUT NEAR THE FLORIDA GROVE ROAD.

At the west end of this cut a variegated, reddish and sandy clay appears, about 4 feet above the level of the track. It is covered by a beautifully laminated, yellowish-white sand. Further east, in the middle of the cut, a dark-colored, sandy clay is exposed. The height of the red clay, in this cut, is about 90 feet, which puts it in the South Amboy fire clay bed. The only clay dug here was in the cutting for the railroad grade, and none of it has been put in the market.

E. F. ROBERTS' CLAY PITS.

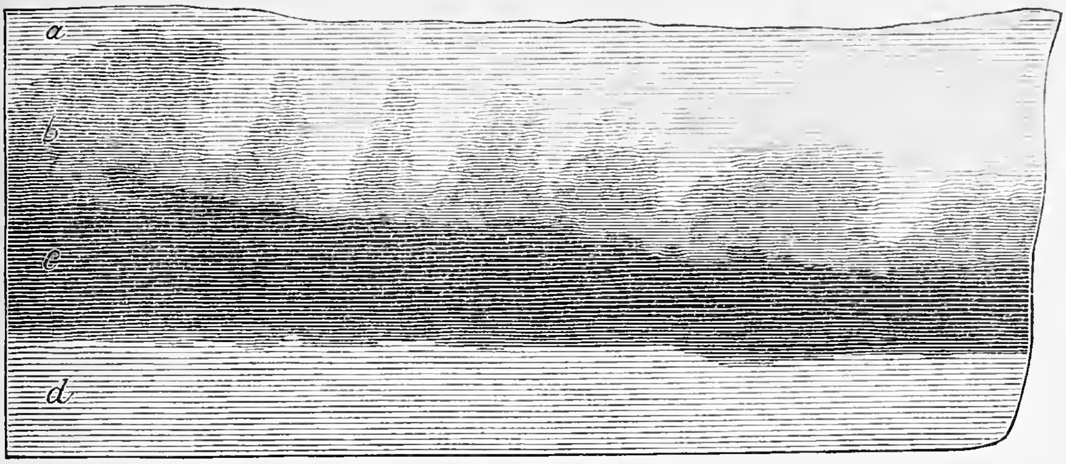
These are south of the Easton and Amboy railroad, near the Woodbridge and Perth Amboy line, and a third of a mile north of Florida Grove.

The pits and borings made in the bottom of the diggings, furnish data for the following scheme of stratification, beginning at the surface:

(1)	Red-shale drift, (at west)	10–18 feet
	Yellow sand and gravel, (at east)	
(2)	Buff-colored fire clay	7–13 feet
	Bluish fire clay	
	Dark-spotted fire clay	
	Light-spotted fire clay	
(3)	Sandy clay (for saggars)	2–3 feet
(4)	White sand and *kaolin*	10 feet
(5)	*Feldspar*	3–4 feet
(6)	White sand	
	Black clay at the bottom.	

In the western part of this excavation red-shale drift is the *bearing* on the bed of clay; while towards the east, yellow sand and gravel is found at the top. Both the top and the bottom of the clay bed show great inequalities, and there are differences of 9 or 10 feet within a few yards, the elevation of the surface varying from 80 to 89 feet. Its thickness ranges between 7 and 13 feet. The variation in color also is considerable. Generally the upper part of the bed is buff; then comes a blue; next a mottled, red and white, of which the upper portion is of a darker shade, and is termed "dark spotted," and the lower portion, which is lighter in color, "light spotted." A buff-colored clay is found in some of the pits under these mottled varieties. But this order is not invariable. The lines of division between these different colors, as seen in the walls of the pits, are exceedingly irregular. The accompanying sketch illustrates this fact.

FIG. 2.



a. Buff and yellow clays.
b. Blue clay.
c. Mottled, or spotted clay.
d. Buff clay.

The superintendent, Mr. English, reports finding, occasionally, masses of blue clay *entirely* enclosed in buff-colored clay, showing a change from above, descending and working into the clay mass. The *spotted* clays appear to consist of red and bluish masses irregularly intermingled. The dark spotted, as its name implies, is darker colored, containing more of the reddish masses, while in the light spotted there is a preponderance of the blue. The blue clay is considered as No. 1 fire clay, and has very little sand in it. It is solid, breaking with an irregular fracture. Its composition is given by the following

ANALYSIS.

Alumina	38.40	
Silicic acid	40.40	
Titanic acid (with alumina)	......	
Water (combined)	12.50	
	———	91.30
Silicic acid (sand)	5.20	
	———	5.20
Potash	0.59	
Soda	......	
Lime	0.22	
Magnesia	0.25	

Sesqui-oxide of iron	1.20	
Water (moisture)	1.30	
		3.56
Total		100.06

According to these figures, this clay is like most of the best fire clays of the Woodbridge and South Amboy beds in general composition, differing from some of them in having a little more of the alkalies, oxide of iron and sand, and, *possibly*, not quite equal to some in refractory qualities.

The buff clay is faintly streaked by pale reddish lines of iron oxide. It has very little grit, but contains a little more sand than the blue.

The *spotted* clays are more sandy. The shades of red are due to a larger percentage of oxide of iron than is to be found in the blue or light-colored masses, and in these there is more sand also.

The blue, buff and some of the *light spotted* clays are sold for fire bricks and other refractory materials. The *dark spotted* and the *lower*, more sandy, buff clays are used for saggars.

Under the clays borings have gone 20 feet into a white sand, some of it a sort of *kaolin*, 10 to 15 feet thick; then into a *feldspar*, 3 to 4 feet, and stopped at the top of a black, sandy clay, resembling that which is so well developed in the river bank at Florida Grove. The several strata here opened and their relation to the clay formation, are illustrated by the little section, No. 78, of the general section appended to this report. A narrow gauge railroad to Roberts' dock, on the river, serves for the transportation of the clays of these pits to that point, whence they are shipped by boat.

The first digging at this locality was in the fall of 1872, since which date work has gone on steadily until very recently.

JOHN DE BOW'S CLAY PITS.

These are across the road, about 200 yards west of Roberts' pits. Here the top dirt is red-shale drift, and is about 10 feet thick. The top of the clay bed is 80–83 feet above high tide level. The average thickness of the clay is said to be 10 to 12 feet. A portion of the top of the bed is white; lower it becomes mottled, red and white, while at the bottom red is the prevailing shade of color. All of it is quite sandy. The red clay contains some iron oxide. These make it worthless for more refractory uses, and hence its sales have been limited and the area dug over has been small. A white quartz sand is found at the bottom of the pits.

FELDSPAR PITS OF EDGAR BROTHERS.

This opening is on the William Watson farm, in Woodbridge township, two miles northwest of Perth Amboy, and a quarter of a mile north of the Perth Amboy and New Brunswick road. When visited two years ago the following vertical section was observed, showing the several strata there dug:

(1) Red-shale drift	3–16 feet
(2) Yellow sand and gravel	
(3) Red clay	2–3 feet
(4) *Feldspar*	1–13 feet
(5) Yellow sand	1 foot
(6) Dark-colored *kaolin*-like sand at the bottom	

The *top* of the *feldspar* bed has a mean elevation of 83 feet above high water level, corresponding to the heights of the same bed at Anness' bank and to that on the Forbes' farm, when the proper allowance for dip is made. (See general section, Nos. 63, 59 and 57.) There is here a wide range in the thickness of the *bearing* (layers 1 and 2 of above section), and also in its character. In some of the pits there is a red, sandy clay stratum, 2 to 3 feet thick, between the sand and gravel and the *feldspar*. It is thrown away as waste. As elsewhere, the *feldspar* bed is very uneven, appearing in pockets thinning out here and there to less than a foot. The material is very solid, cutting like clay. The grains and lumps of quartz in it are from a quarter of an inch downwards in diameter, and on the average a little smaller than those of the *feldspar* dug in the pits northeast of this opening. They also appear less rounded, or more angular. The following analysis shows the composition of the best of the pits:

ANALYSIS.

Alumina	17.46	
Silicic acid	16.50	
Water (combined)	6.30	
		40.26

Silicic acid (quartz sand)	57.10	
Titanic acid	0.90	
		58.00
Potash	0.12	
Soda	0.21	
Lime	......	
Magnesia	......	
Sesqui-oxide of iron	0.54	
Water (moisture)	0.50	
		1.37
Total		99.63

These figures show a great similarity to the analyses of the same material as dug elsewhere in this clay district.

The more sandy and finer grained portion of this bed, together with any which may be stained by oxide of iron, is selected as a No. 2 article. It is underlaid by the thin layer of yellow sand, and that by the dark-colored sandy earth which is said to resemble *kaolin*.

About 200 yards north of the pits, and in ground about 15 feet higher than that about the pits, Mr. Edgar reports boring through 9 feet of red earth, 5 feet of fire sand, 1 foot of spotted clay, 1 foot of white sand, and then 8 feet of *feldspar*.

Edgar's *feldspar* pits were first opened three years ago. A very large amount has been dug. It is carted direct to fire brick works in the vicinity, or to tide water for shipment to more distant points.

W. N. WEIDNER'S CLAY.

This opening is one mile southeast of Ford's Corners, and just at the south side of the road to Perth Amboy. It is little more than a trial pit dug in the hollow close to the brook. In the bank of this stream a sandy white clay crops out covered by a dark-colored clay, full of pyrite and lignite. In the pits there was red-shale drift at the surface and 3 feet thick. Under this a dark blue clay 8 feet thick, then a greyish clay 12 feet thick, and at the bottom a greyish sandy earth. As the surface of the ground here is between 60 and 70 feet high, this clay has an elevation of 45 to 65 feet, which places it below the *feldspar* bed and in the horizon of the laminated clay and sand and the micaceous sand beds. For its exact location in the series and its relations to the neighboring pits see the general combined section, and in particular, No. 64 of that section.

B. VALENTINE'S FIRE SAND, FELDSPAR AND KAOLIN PITS.

These several pits are all near Mr. Valentine's residence, about a quarter of a mile northwest of Florida Grove. The southern slope to the river allows of easy access to these beds, beginning at the top with the fire sand and descending to the dark-colored clay at the bottom, and at the river level.

Fire sand.—This is dug a few rods southeast of the farm-house. The bed appears about 5 feet thick, and is 70 feet high. It is underlaid by a hard, indurated sand. This sand is yellowish-white, and the grains of opaque, white quartz range downwards from ¼ and 1-16 inch in diameter to fine quartzose dust. There are in it a few lumps cemented by oxide of iron, but no mica. It is most probably drift.

Feldspar.—Nearer the river, and at a height of 50 feet above it, a *feldspar* has been dug. It is covered by a thin layer of top dirt, and is 2 to 5 feet thick, resting upon a black, micaceous sand. This latter bed is reported to be 10 feet thick. This *feldspar* has more quartz and less clay than that of Weidner or Edgar Brothers, and is stained reddish by oxide of iron. The clayey portion is unevenly mixed with the quartz, and the latter is in smaller grains. Neither this nor the *kaolin*, which is found a little to the southeast of it, can be considered as first-class in character.

This bed appears as No. 75 on the general section.

Lower in the hillside the dark-colored clay appears. A little of this was dug years ago, but it is not good enough for refractory uses. Its favorable situation for easy and cheap extraction and its nearness to water transportation make it a good site for the location of red brick works.

Deeper and further excavation on this property may show that the *feldspar* and *kaolin* beds improve in character further in the hillside, where they are covered more deeply. So far the whole amount of excavation here has been comparatively small. Of late years the work has been in the fire sand pits alone.

Southwest of the house and 150 yards east of the Woodbridge

Clay Company's dock, at the level of high water, two borings were made about 50 years ago in search of coal. These struck a blue, slaty rock, at a depth of 100 feet. This is supposed to have been hard shale or slate-like rock of the Triassic formation. One of these holes was sunk 23 feet further in this rock; the other, 9 feet below the top of the slate, struck upon what was supposed to be coal. In the absence of any notes or data, other than the memory of the land owner, these *opinions* are little more than conjectures. But the fact of so much rock, said to be slate, and its depth below tide water level, lead to the inference that it was triassic shale, the flooring of this whole clay district. This depth agrees with our estimate, taking the descent of the Raritan clay bed (60 feet per mile), as that of the rock upon which it rests, and having the elevation of the red-shale on the northwest border, at Edgar's station, Ruddy's pits, on Mill brook and at Weidner's pits (near Martin's dock) at 15 to 30 feet—that is, 120 feet in about two miles, the distance measured on the *line of dip*. This existence of the shale at such depth seems to prove that it is the *bottom rock* under all of these clay beds, and also that it has a general slope towards the southeast, with which they correspond. The general section illustrates these statements.

WOODBRIDGE CLAY COMPANY'S PITS—(EAST).

This company has three separate localities or groups of pits where clay has been dug. The easternmost of these is at the border of the tide meadows, a half a mile west of Florida Grove, and not far from the Raritan river. The top dirt here consists of red-shale drift a few feet thick, then a weathered, laminated and sandy clay. According to the workmen of the pits, the following beds are found, and have the thickness given in the accompanying figures:

(1) Red-shale drift	up to 20 feet
(2) Laminated, sandy clay	
(3) Dark-colored pipe clay	9 feet
(4) Dark-colored sandy clay	7–9 feet
(5) Bluish fire clay	7–9 feet
(6) Sand at bottom, full of water	

The thickness of the top dirt (1 and 2) varies here according as the point of measurement is nearer or further from the level of the tide meadow. On the northeast and in the bank the material is not properly a red-shale drift, but more of gravel, with shaly earth and a few small boulders and cobble-stones. And here it may be 10 to 15 feet thick, and the total thickness of the two beds (1 and 2) about 20 feet. The pipe clay surface corresponds very nearly to the level of high water; and this is apparently the equivalent of the *top white clay* of the banks northwest of this locality. The sandy clay under it is worthless. The fire clay bed (bottom) is, on an average, 22 feet below high water. It is represented by No. 69 on the general section.

In working these pits all the water, as well as the clays, have to be raised to the meadow level, and there is, consequently, considerable expense attending the working of these pits. Partly as a result of this no digging has been done since 1874, and the pits have filled with water. The nearness to the river and the comparatively small thickness of *top* partly compensate for the drawbacks from water.

AUGUSTINE CAMPBELL'S PITS.

These are about 150 yards west of the pits above described, and not quite a half a mile east of the Crossman Clay and Manufacturing Company's works. They were formerly worked for the firm of Maurer & Weber, but have been idle for some time. The beds are said to correspond to those found in the pits east of the brook, and the bottom of the fire clay is about 20 feet below high w ter level.

WOODBRIDGE CLAY COMPANY'S PITS—(WEST).

These are west of the last mentioned pits, and about a quarter of a mile north of the works of the Crossman Clay and Manufacturing Company. The surface of the ground immediately about the pits ranges from 10 to 30 feet above tide water. The top dirt varies quite as much in thickness, but in this there is 3 feet of pipe clay. The fire clay is between 3 and 11.5 feet below high water. Sand is found at the bottom. Mr. Hope, the superintendent, reports leaf impressions in the pipe clay, just over the fire clay.

This company works pits a quarter of a mile north of these, and east of the Crossman bank railroad line. This locality was opened between two and three years ago. This also is at the tide meadow border. Mr. Hope reports the following beds, beginning at the surface:

(1) Sandy earth and red brick clay	4–14 feet
(2) "*Specky*" *clay* varying considerably	
(3) Fire clay, (No. 1)	2–6 feet
(4) Fire clay, (No. 2)	1–2 feet
(5) "*Seamy*" *clay*	
(6) Extra-sandy clay at the bottom	

The so-called *specky clay* is quite white but a little sandy, although free from earthy streaks. It is sold for stove linings.

The fire clay, No. 1, is without grit, bluish white and solid. The No. 2 fire clay is not so white as No. 1, and more friable, crumbling easily. It is sandy. On weathered surfaces its color is a yellowish buff.

The "seamy" clay, which is under the fire clay bed, is sandy and streaked with yellow earth. It is sold for pipe, or sometimes, after weathering, for No. 2 fire brick mixture. The extra-sandy clay also is sold for pipe making.

All of these clays, geologically, are one bed, whose upper and under portions are more or less impure on account of earthy and sandy admixtures.

The clays of these northernmost pits of this company are not considered quite as good as those got in the southernmost, nearer the Crossman company's works. This company sells its clays.

The present working bank of this company joins that of A. Weber on the west side, and the stratification corresponds in general to that seen in both Weber's and the Crossman Clay Company's (east) banks. The red-shale drift is here thin, lying upon the black clay. The top white clay layer is here recognized, although partially replaced by a very dark-colored clay in which there is much lignite in small fragments scattered through the clayey mass. A chemical examination of an average specimen gave seven per cent. of lignite or carbonaceous matter. In the kiln this amounts to as much fuel, besides rendering the product more open. In practice this clay is said to burn as white, as the best No. 1 clay of the bank. A red clay is found under the fire clay, and under that a sand. On the west, close to Weber's line, the top of the fire clay bed is white and stained on fissure surfaces by thin films of oxide of iron. This occurs where there is less top dirt and overlying clays. It is not seen as yet in the bank.

A. WEBER'S CLAY BANK.

This bank together with the several banks of the Crossman Clay Company and that of Philip Neukumet, are all quite close together in places adjoining, and they are all in the side hill where the upland level falls to the low ground immediately bordering the tide meadows. They are within a quarter of a mile of the Easton and Amboy railroad, and between three-quarters and one and a quarter miles of the Raritan river, at the dock of the Crossman Clay and Manufacturing Company, to which their clays are carried by railroad lines running from the several banks.

At Weber's bank the stratification is very distinct, and following beds are seen :

(1) Red-shale drift	10–11 feet
(2) Blue, pipe clay	2 feet
(3) Black, sandy earth	3 feet
(4) Black, pipe clay	3 feet
(5) Top white clay	3 feet
(6) Dark-colored, sandy bed	4–5 feet
(7) Fire clay, No. 1	5 feet
(8) Extra-sandy fire clay	6 feet

The top of the fire clay (No. 7) is 20 feet above high water level, making the top of the section nearly 50 feet high. These subdivisions are represented by No. 56 on the general section.

The drift at the top includes some sand and gravel, but unsorted. The blue clay at the top (No. 2) is a little sandy, tough, and dries quite light-colored. It is used in making pipe, and also for beer bottles, from which use it is known as *blue bottle clay.* The next bed is sandy and is not used.

The *black, pipe,* or *bottle clay,* (No. 4) is dark, lead-colored on drying ; it is more sandy than the *blue bottle clay,* but the sand in it is fine grained. Its name indicates its uses.

The *top white clay* bed is here distinctly defined. This clay dries nearly white, although not like the fire clay proper. From this circumstance it gets its name—distinguishing it from the *lower* white fire clay. It contains considerable quartz sand and some very fine scales of white mica. It is sold for pipe.

The fire clay is white, slighty gritty, although no sand can be seen with small magnifying glass, quite hard, breaking with a conchoidal fracture. The extra-sandy fire clay is white, quite sandy, but very fine grained, solid, and is used in fire brick.

The clays of this bank are loaded on cars which run on a narrow gauge railroad from the bank to the dock at the Crossman works, whence they are shipped to the proprietors' works, the " Manhattan Fire Brick and Enameled Clay Retort Works," East Fifteenth street, New York City.

CLAY BANKS OF THE CROSSMAN CLAY AND MANUFACTURING COMPANY.

The three banks of this company, on account of their nearness to one another and closely similar position, show a correspondence and uniformity in the relations of the several layers and their thickness. As they cut the clay on a northwest and southeast line the elevations of the fire clay bed show a dip towards the southeast. Thus, in the west bank, this bed is 25 to 37 feet high ; in the east bank it is 10 to 21 feet, a difference of 15 or 16 feet in a distance of one-third of a mile, corresponding to a dip of 45 to 48 feet per mile. The horizontal section from Ford's corner to Whale creek, at the bottom of the map, cuts through these banks and shows their location and the dip of the clay bed. And the general section, Nos. 45, 53 and 55, shows the same dip.

East Bank.

This bank joins that of Weber on the west. Being so close to it the vertical sections of the two are very much alike. The section of this bank includes the following beds :

(1) Red-shale drift	10 feet
(2) Clay with sand layers (for red brick)	10 feet
(3) Blue, pipe clay	3 feet
(4) Black, pyritiferous clay	2½ feet
(5) Black, pipe clay	2½ feet
(6) Top, white clay	3–4 feet
(7) Clay and sand (leaf layer)	6 feet
(8) Fire clay, (sandy towards the bottom)	10–11 feet
(9) Sand, with much lignite, at bottom of pits	

The red-shale drift at the top of the bank includes many boulders of gneissic, granitic and quartzose rocks. One of feldspar and quartz, 4 feet in diameter, was lately observed here.

The laminated sand and sandy clay is used in the red brick yard near the bank.

The blue, pipe clay is very tough, but a little sandy. Its specific gravity is 1.689 to 1.699. This is used for pipe.

The black clay (No. 4) is sandy and contains too much pyrite for use.

No. 5, of this section, is a dark slate colored clay, and is used in the manufacture of pipe, stove linings and beer bottles. The *top white clay* is rather sandy, yellowish white, and contains a little mica in the form of small scales. The bottom eighteen inches of this layer, or bed, is chocolate-colored, and, in places, almost black. According to a partial analysis, it contains of:

Alumina and titanic acid	29.08 per cent.
Silicic acid and sand	64.00 per cent.
Combined water and moisture	6.80 per cent.
Sesqui-oxide of iron	1.12 per cent.
Potash	2.64 per cent.

From the percentage of water the clay is calculated to be about one-half of the mass, leaving nearly one-half of sand. The large percentage of potash, and the iron oxide, show that it is not a good fire clay. It is said to burn white. Its use is almost exclusively for mixing with No. 2 fire clay for stove linings. With other clays it has been put into fire brick, No. 2, and is said to give strength to the mixture. Between this and the fire clay bed there is a bed, 6 feet thick, made up of sand and sandy clay, in alternating layers, these varying from an inch to two feet thick. Just at the bottom of this, and on the top of the fire clay, leaf impressions occur quite abundantly. This bed has a great deal of lignite in it, scattered irregularly through it. It is utilized by mixing with the top clay and sand for red brick. In the western part of this bank there is, between this and the fire clay bed, a layer of clean, white quartz sand, 1 to 2 feet thick, probably belonging to this bed.

The fire clay is very solid, breaking with a conchoidal fracture; it has in it a few scattering quartz grains which are somewhat rounded. An analysis of an average of the bed shows the following percentages:

Alumina	35.75	
Silicic acid	37.85	
Water combined	12.30	
		85.90
Sand (quartz)	10.50	
Titanic acid	1.60	
		12.10
Potash	0.37	
Magnesia	traces	
Sesqui-oxide of iron	0.95	
Water	1.00	
		2.32
		100.32

The sandy clay at the bottom is considered a No. 2 fire material, although it is said that this will stand a more intense heat than the *fat* No. 1 clay. A partial analysis gives, of

Water (total)	7.00 per cent
Potash	0.21 per cent
Sesqui-oxide of iron	0.78 per cent

These figures indicate about 40 per cent. of sand. The potash and oxide of iron are each less than they are in the No. 1 clay. This sandy clay is generally mixed with the rich, or fat clay for fire brick, or sometimes with the top white clay for other purposes.

This bank shows quite a long working face, and the regularity and persistence, as well as the evenness, of the several beds is remarkable.

Middle Bank.—The order of arrangement of the beds at this bank is substantially the same as that already described in the eastern bank, although it is not quite so easy to make out all of the sub-divisions which appear in the latter. The clay at the top of this bank has a greyish shade of color, as if the original *blue* had faded. Under this there is a blue, pipe clay, 4 feet thick, then a bed, 8 feet thick, of dark-colored clay with thin sand partings, and containing lignite and pyrite. This bed is not used. The *top white clay* is not so well marked here as in the east bank. The main fire clay bed is 9 feet thick, and has an elevation (bottom) of 17 feet. Here, also, the top of this bed is very even.

West Bank.—This bank is about a quarter of a mile south of Ford's Corner, and 100 yards or thereabouts from the Easton and Amboy railroad. Here the top dirt is not heavy, and is mostly sand and gravel. Next under it is a blue clay 8 feet thick. It is quite sandy, and the sand in it is fine-grained. It also contains much mica in fine scales. It is used in drain pipe and in land tile, and, with fire clay, for gas retorts. Descending, there is a bed of black clay 8 feet thick. This is quite free from the presence of lignite, but it is rather sandy, and has a laminated structure. One layer in it, 2 feet thick, contains much pyrite; otherwise it is entirely free from this constituent, so common to the dark-colored clays. The selected clay of this bed is used in pipe making.

The fire clay in this bank is 11 to 12 feet thick, and has an average elevation of 25 feet. It is bluish white, solid and is considered the best of this company's banks. At the bottom there is said to be a hard, red, ochrey clay.

South of this bank, and in the lower ground, this company has another clay opening. In it a white fire clay was got, 11 feet thick, and covered with 2 to 3 feet of top dirt. The fractured surfaces of this clay are coated by red films of oxide of iron, probably deposited by waters from above carrying this oxide. This clay bed is the same Woodbridge clay bed, which is ordinarily blue, or bluish white, which on account of its thinner covering has been more discolored by atmospheric agents and by drainage from the surface. It is not thought to be as good a refractory material as the blue clay. At all the banks of this company the clays are above tide level, and consequently the drainage is thorough and not expensive, through covered drains that open south of the banks in the lower ground. No pumping is needed, and digging is possible at all seasons of the year. This is offset in part by the increasing thickness of the *top dirt* as the work of excavation advances further into the upland bank. In consequence of the use made of much of this *top*, especially of the clayey beds, in the making of common red brick, the cost of removal is much lessened, or at least partly counterbalanced. This use of these clays in works so near the banks, is an economy in management worthy of the serious consideration of many of the clay proprietors and miners of the clay district, and also of the attention of capitalists who may be seeking new locations for the manufacture of common brick. The cost of the material is almost nothing, since these top clays have to be removed, and generally the fire clay miner is glad to get rid of them at the cost of digging.

By means of a railroad about a mile long, the clay of these banks is sent to the company's works on the Raritan. This road also carries the coal to the red brick yard and their brick to vessels at the docks.

On the line of the Easton and Amboy railroad, north of the Crossman Company's middle bank, and 870 feet southeast of the Stingtail brook, at its intersection with the railroad line, a boring 57 feet deep, combined with the strata seen in the same railroad cut, affords the following vertical section.

(1)	Red-shale drift	20 feet
(2)	Yellow sand and gravel	
(3)	Sandy, slate colored clay	10 feet
(4)	Clay (for red brick)	23 feet
(5)	Blue, pipe clay	7 feet
(6)	Clay (for red brick)	8 feet
(7)	Black sand and clay, pipe or bottle clay	6 feet
(8)	*Top white clay*	5 feet
(9)	Clay, (suitable for red brick)	7 feet
(10)	Black clay	5 feet

The Boring was through Nos. 4 to 10 inclusive. The thickness of Nos. 1, 2 and 3 are from the cut, at its deepest point. The elevation of the track is 94 feet, so that the boring stopped at 37 feet above high water level. According to the combined general section the Woodbridge bed has at this point an elevation of 42 feet, which is 5 feet above the point where the boring stopped. The existence of the *top white clay* and the general correspondence of the boring with the general columnar section, indicates the fire clay bed as probably very near the bottom of this boring. This section is also interesting as it includes nearly the whole series of beds between the *feldspar* bed and the Woodbridge fire clay bed. It appears on the general section as No. 47.

South of the railroad 250 feet, and 20 to 40 feet east of the brook the fire clay has been uncovered at depths of from 13 to 24 feet, and this locality has been worked during the past summer, (1877).

JOHN NEUKUMET'S ESTATE CLAY BANK.

This bank is a few rods west of the west bank of the Crossman Clay and Manufacturing Company, and about a quarter of a mile south of Ford's Corner. In the western face of the bank the following beds are seen:

(1) Sand and gravel and sandy clays	30–35 feet
(2) Black clay (for pipe)	5 feet
(3) Sand	5 feet
(4) Fire clay	6–13 feet
Sand at bottom of the pits	

The top part of the bank was so fallen down at the time of our visit, that the subdivisions of the upper 30 to 35 feet could not be seen.

Towards the east and southeast there is a less thickness of top dirt. In the eastern face there is only a little red-shale drift on the fire clay. This is interesting as marking the western and southwestern limit of this red-shale drift and the glacial drift. West of this the yellow sands and gravels (sorted or stratified drift) appear as the surface deposits.

The best fire clay of this bank is bluish white in color and remarkable for its density and hardness, requiring the use of a pick in getting it out. Its density is 1.798–1.814, which exceeds the average of this clay by one-tenth at least. In it there are scattered grains of white quartz varying in size up to 1-32 inch in diameter and slightly rounded. The bottom of this bed is a mottled red clay, also hard and solid. This rests upon a yellow sandy earth. The whole bed is also remarkably dry and free from water. An eighth of a mile or so southeast of this bank and in the lower ground, there is another opening in which a fire clay is dug by the same proprietor. At this point the top dirt is about 3 feet thick, and the bed of white fire clay is 6 feet thick. Under it there is a red or mottled clay. This clay resembles in location and character that of the southern pits of the Crossman Clay and Manufacturing Company.

The clays of these banks are carried by rail to the dock of the Crossman Company, and thence shipped to Neukumet's Fire Brick and Clay Retort Works, Twenty-third and Vine streets, Philadelphia.

RARITAN CLAY COMPANY'S BANK.

Going west from Neukumet's bank, there is only a short interval to this bank. As this has not been worked in several years, no data are at hand for descriptions.

CLAY BANKS AND PITS OF CHARLES A. CAMPBELL & CO.

Here the work of excavation has cut away the hillside quite to the Perth Amboy and New Brunswick road at the Sand Hills. A very large area has been dug over, and the large quantity of top dirt has accumulated in huge waste heaps. No work has been done at this bank in several years. The average thickness and the general succession of the layers seen in this bank, as reported by Mr. Mundy, the foreman, are as follows:

(1)	Sandy earth (drift)	8 feet
(2)	Black, pipe clay	4 feet
(3)	Sand (thinning out entirely in places)	
(4)	Blue, sandy clay	3 feet
(5)	Black, sandy earth, containing lignite and pyrite	7 feet
(6)	Fire clay	8 feet
(7)	Red clay	5 feet
	Sandy blue clay at bottom	

The top of the black clay in this section is about 70 feet high. This would make the elevation of the fire clay bed about 50 feet. The pits now worked by this firm are about 300 yards southwest of this bank, and not quite a half a mile south of Sand Hills. They are in two groups, or separate openings. The more northerly of these is known as the *blue clay bank;* the other as the *white clay bank.* These local names arise from the color of the clays found in them.

Northern, or Blue Clay Bank.—In this opening the top dirt, or *bearing* on the fire clay, consists of yellow and white sands and gravels, with some sandy, dark-colored clays in places, and is from 3 to 12 feet thick. The average height of the surface of the fire clay is 40 feet. It is 10 feet thick. Under it there is a red, or mottled clay 8 feet thick. The total thickness of these two sorts of clay has been as much as 26 feet. Some of the bed is variegated, red and white, but there does not appear to be much order in the arrangement of these shades of color, although generally the top and bottom are bluish white and the middle portion red or mottled. Long, irregular shaped lenticular masses, or bodies of clean, white quartz sand are sometimes found, enclosed in the fine clay, analogous to the *horses* of rock which are seen in the bedded ores of older rock formations. The bottom clay is quite sandy.

The White Clay Bank is a short distance south of the blue clay bank. About an acre of clay has here been *stripped,* and the inequalities of the clay surface show finely. These are gently undulating, but without order; ridges, furrows, small basins and little, rounded knolls succeeding one another. The top dirt, or *stripping,* was 3–10 feet thick, and mostly yellowish, sandy and gravelly earths. The clay is from 5 to 8 feet thick, and the average elevation of the surface is 38 feet. This *white clay* is the same bed as the blue clay of the northern opening, and of the old bank, which has lost its bluish shade of color by the oxidation of its iron (ferrous oxide), by the action of atmospheric agents that have worked more easily through the lighter surface covering. Underneath this fire clay there is a sandy clay 4 to 5 feet thick, and under that a sand. The *blue* fire clay of these pits is slightly gritty, crumbling quite easily. The *white* fire clay is white, but stained by very thin films of iron oxide ; it is a little softer than the blue and crumbles more easily, and has a rather shaly structure. Its composition is represented by the following percentages:

Alumina	35.94	
Silicic acid	36.20	
Water (combined)	12.10	
		84.24
Sand (quartz)	12.20	
Titanic acid	1.50	
		13.70
Potash	0.08	
Soda	......	

Lime	......	
Magnesia	......	
Sesqui-oxide of iron	0.96	
Water (moisture)	1.10	
		2.14
Total		100.08

While these figures show some sand, they also indicate scarcely more than traces of alkalies, and not much iron oxide. Its composition is that of a very refractory clay, and quite equal to any of the *blue* clay dug in these Raritan river banks. The red, or mottled clay of Campbell's banks, is more sandy, and also of uneven texture. The lines of color are very sharply defined, and the red is of several shades. Both the blue and the white clays are sold for fire brick manufacture. The red clay goes for saggars, sewer pipe and No. 2 fire brick. The clay is loaded on cars in the banks, the tracks being moved from pit to pit, so that the workmen throw it directly into the cars. These run on Campbell's clay railroad to the docks on the Raritan, whence it is shipped by boat. A large amount is sent to Troy, N. Y.

Fire Sand Pits.—About 150 yards southeast of Campbell's blue clay bank, a fire sand is dug from a bed 5 feet thick. The top of this sand bed is 17 feet high, or 3 feet below the bottom of the Woodbridge fire clay bed at this point, as determined by the lines of strike and dip. This is supposed to belong to the fire sand bed which separates the Woodbridge and the Raritan fire clay beds, and to be the bottom of that bed. In the ditch leading up to the clay banks the sand crops out higher up, under the clay, and is much finer-grained. This deposit of fire sand is said to thin out towards the west. East and south its limits are undetermined. The general section in Nos. 38, 42, 44 and 49 exhibits the relative position of the several pits of this firm.

CLAY BANK OF ISAAC FLOOD & SON.

This bank is at Sand Hills, one and a half miles east of Bonhamtown, and close to the New Brunswick and Perth Amboy road. The clay is covered at the eastern end of the bank by 6 to 8 feet of yellow sandy loam and earth, and then by 15 feet of fine, white quartz sand, some of which contains a little earth, and is sold for moulding. Further west this sand is replaced by a dark-colored clay containing lignite and pyrite, interstratified with thinner layers of sand. The whole series of dark-colored sandy and clayey beds appear to have been eroded down to the fire clay, and the latter subsequently to have been covered by the sand and gravel drift, which filled up the excavated space to the general level of the surrounding country. This erosion seems to have been continued a little way into the fire clay, as this bed is highest at the west end of the bank where the upper beds of the series were undisturbed. The top fire clay (6 feet) is white, the lower portion (4 feet) is blue. The height of the *bottom* of this clay is 51 feet above tide level. A yellow clayey sand is found at the bottom, under the fire clay.

This bank was opened ten years ago, and has yielded a large amount of good clay.

The products of this bank are sent into market over Campbell's clay railroad, and thence by boat, and also over the Easton and Amboy railroad, which is about half a mile distant at Sand Hills.

CLAY BANK OF R. N. & H. VALENTINE.

This clay bank is separated from that of Flood & Son by a roadway which leads into these banks, branching from the main road that runs just north of them. The several layers of sand and dark-colored clays above the fire clay are very plainly marked and well exhibited in the long face of the extended workings of this bank, and the following vertical section, from observation and from data contributed by the Messrs. Valentine, presents these several sub-divisions in their order and relative thickness. (See general section also, No. 25):

(1)	Yellow sand and gravel	10 feet
(2)	Slate-colored, sandy clay	10 feet
(3)	Grey, sandy clay	2 feet
(4)	Black sand	3–4 feet
(5)	Dark-colored pipe clay	4–5 feet
(6)	Black, sandy clay, with layers of fine sand	3–4 feet
(7)	White sand	2 feet
(8)	Sandy clay	1 foot
(9)	Blue fire clay	7 feet
(10)	Red or mottled fire clay.	
	Sandy clay and sand at bottom	

The top dirt here, mainly a yellow sand and gravel mixture, is from 4 to 10 feet thick. The next layer, the slate-colored clay, becomes darker in shade towards the bottom. It is carted away as waste. The grey sandy clay is in places good enough for drain pipe. The sand underlying this clay (No. 4) is also waste. No. 5 of this order is a tough black clay, and includes an occasional cast of a fossil shell known as the *Cucullea antrorsa*. These casts are of much geological interest, as they are almost the only marks of animal life which have been found in the clay formation of this county, and they help to determine its age. Leaf impressions are also reported as occurring in this layer, but none were seen. It is possible that they may have come from the more sandy layers just over the fire clay. This clay is probably the equivalent of the pipe and top white clays of the banks east of this. Under this there is a dark-colored, very sandy clay in thin layers, separated by thinner, white sand layers, which gives the whole a laminated structure. Pyrite occurs in it, but not sufficient to injure selected portions for drain pipe. Lignite is abundant, and the fine, coaly matter in it makes it almost black. On burning it becomes white. The more sandy layers between this and the fire clay bed are carted to the dump as waste, or used in filling pits.

The fire clay bed has an elevation of 51–54 feet (top), but its surface is slightly undulating. The clay of this bed is blue, quite firm, breaking up readily, and showing a conchoidal fracture. No mica or quartz appear in it under a low magnifying glass, although containing some sand. Its composition, according to an analysis of an average specimen, is as follows:

Alumina and titanic acid	36.34	
Silicic acid	39.80	
Water (combined)	12.90	
		89.04
Silicic acid (sand)	8.10	
		8.10
Potash	0.15	
Soda	......	
Lime	......	
Magnesia	0.04	
Sesqui-oxide of iron	1.01	
Water (moisture)	1.20	
		2.40
Total		99.54

The pits are dug through this blue clay into a red, or mottled and sandy clay, and generally stop in that.

In the low ground at the southwest end of the bank, a white fire clay is dug under 1 to 3 feet of soil and sub-soil. This is said to be 14 feet thick. The average elevation of its surface is 50 feet. This white fire clay has some iron oxide stains in it, but not sufficient to injure it as a refractory material. It appears a little more sandy than the best blue clay of the high bank. Some of it is sandy, and has some admixture of yellowish earth. This latter is sold as a No. 2 clay.

The fire clay bed of Valentine's bank is not so irregular or uneven in surface as it is in many banks and pits. This is clearly exhibited in the long stretch of excavation from east to west, and in the sub-divisions above the fire clay also, all of which run nearly level from one end to the other.

The figures of the several layers, or beds, given above, show how much top has to be removed, and how large a part of it has to be thrown on the dump as waste. And here, as at nearly all the clay banks of this district, there are tall and large heaps of refuse clays and sands. Some of these stand upon *clay ground*, so that the working of such ground will require their removal first. The height of the clays in this bank is considerably above the natural drainage, permitting their extraction without need of pumping any water. Such a bank can also be worked by driving the carts quite to the bottom level of the clay beds, and the loading is then more easy than by throwing upwards from planking in the pit.

The clays of this bank are nearly all used in the fire brick and drain pipe works of M. D. Valentine & Brother, at Woodbridge, and are carted thither by teams.

Fire Sand Pits.—A quarter of a mile southwest of this bank the same firm digs a fire sand. The pits go through 3 to 5 feet of sandy top dirt; then 16 feet of white quartz sand. This bed is plainly laminated and the layers dip gently towards the south-east. Some of the layers contain a little whitish clay. At the bottom there is a clayey sand, 1 to 3 feet thick, which looks like *feldspar*, excepting the larger proportion of sand, and is not so coarse-grained. Trial pits sunk still deeper show a continuation of quartz sand, but of fine grain. The top of this fire sand is 49 feet high, which is a few feet higher than the strike and dip would require it at this place. According to the combined general section the bottom of the fire clay bed would here be 44 feet high. These figures show some inequality in the stratification.

This fire sand consists of slightly rounded grains of white, opaque and translucent quartz of varying sizes, from one-quarter inch downwards. There is a little clayey matter attached to some of these grains. A partial analysis showed of:

Quartz sand	96.00 per cent.
Alumina and sesqui-oxide of iron	4.20 per cent.

It is used with the clays of this bank by the same firm in their works at Woodbridge, and is regarded by them as a very superior sand.

Kaolin.—Valentine Brothers dig a sort of *kaolin* in the low ground south of their clay openings, but the work done there has not been very great as the same and other like manufacturing firms have other and more accessible *kaolin* pits nearer their works. This deposit belongs near the fire sand horizon and cannot be much above the Raritan fire clay bed.

The property was opened as a *clay tract* eleven years ago. As a matter of record in the history of the clay district and its development, it was purchased at that time for $3,800. Since that its market value has been multiplied several times.

EDGAR BROTHERS' CLAY BANK.

This locality was discovered by C. S. Edgar and opened by him this year (1877). The *bearing* is a stratified, gravelly and sandy earth and is 3 to 10 feet thick, averaging thus far about 5 feet. The surface of the ground here is about 75 feet above the level of tide water, so that the *top* of the clay bed has an elevation of about 70 feet.

This corresponds with the height of the Woodbridge fire clay bed here. (See general section, No. 18.) The bed is about 20 feet thick. The best of the clay is found near the top and in the middle of it. Towards the bottom it is reddish, spotted red and blue, and a little gritty. The upper part is a good fire clay, bluish-white, and quite solid and compact. The finest of it is sorted for paper glazing. The spotted clay may answer for No. 2 fire brick, saggars, or stove linings.

This bank is interesting geologically, as it is a discovery following the hints given by the map of this district, and another confirmation of its accuracy and the correctness of the geological structure of this country as thereon indicated.

SAMUEL DALLY'S PITS.

These pits are close to the New Brunswick and Perth Amboy road, about a quarter of a mile from its junction with the Woodbridge road. The surface of the ground here has an elevation of about 80 feet. The clay is found a few feet only beneath the surface, covered by the soil and a reddish, gravelly earth. The top of the clay has an average elevation of 74 feet above high water level. A comparison of this height with that of the same bed in the bank of R. N. & H. Valentine shows the dip of this bed towards the southeast, or, as it is sometimes locally termed, the *rise* going northwestward. (See general section, No. 15.)

The thickness of the fire clay dug here was not ascertained, as no work has been done in these pits in several years. The heaps show clays of several shades of color—some yellowish-white, others bluish, and still others reddish and mottled. On some of them there is a yellow efflorescence of sulphate of iron and alumina. None of them appeared to be very pure or fine clays. They might answer for saggars, pipe and in No. 2 fire brick.

South of the road there are several pits, and the clay surface has an average elevation of 66 feet. Here also both the red and the blue clays are seen.

Very little clay seems to have been carted away from these pits. The pits were dug by R. J. Wiley, and his name appears on the older map.

CLAY PITS OF THE NEW JERSEY CLAY AND BRICK COMPANY.

These pits are also near the Perth Amboy road, west of Dally's pits, and three-quarters of a mile east of Bonhamtown. At the most northerly pit, at the side of the road, there is but a few feet of top dirt on the fire clay, and the elevation of the latter (top) is 64 feet. It is 6 to 7 feet thick. It is white, a little sandy, and slightly stained on some of the fracture surfaces by oxide of iron, especially near the surface. A yellow, sandy earth, also stained by iron oxide, is found at the bottom of the pits, underlying the clay.

West-southwest of this pit, about 250 yards, several small pits have been dug in the lower ground, near the head of a ravine. The top of the clay here is 45 feet high, which corresponds to the surface line of the Raritan fire clay bed at this point, as seen on the combined section, No. 13. The clay here is sandy, bluish-white on the top and red at the bottom. It is said to be 11 feet thick.

A yard for making front brick was started here a few years ago, and there was a considerable outlay of capital for this manufacture. A railroad 1½ miles in length, from the yard to the river, was built for the transportation of clays and brick. The greater heat necessary to burn these clays (properly fire clays) was not given them, and as a result the brick produced by the ordinary kiln constructed here were pale, tender, crumbling and of little value. This part of the enterprise proved a failure, and the work was abandoned. Since the yard went down very little clay has been dug on the property. Further exploration and the use of these lower clays for refractory purposes promise to be successful.

The property is interesting geologically from the possession of both the Woodbridge and the Raritan beds, in outcrops that are quite near one another, and also near the surface of the ground. It ought to be made more productive than it is at present.

DAVID FLOOD'S FIRE SAND AND CLAY PITS.

These pits are about three-quarters of a mile southeast of Bonhamtown and a quarter of a mile west of the New Jersey Clay and Brick Company's pits. There are two separate openings for clay. At the most northerly and the working locality there are the following beds:

(1) Gravelly earth and sand	4–6 feet
(2) Fire sand (average)	4 feet
(3) Fire clay	5 feet
Sandy clay at the bottom	

The *top* of the clay bed is 47 feet above mean high water level, and that of the sand 51 feet.

This fire sand is mostly coarse grained and sharp. Its structure is laminated. In places it is streaked with oxide of iron and yellowish earthy sand. It is an excellent article and commands a steady market.

The drab colored clay is rather sandy. A partial analysis gave 9.60 per cent. of water, and 0.42 per cent of potash. The general resemblance of this clay to those of the Raritan fire clay bed and its elevation (see general section No. 22) refer it to that bed. Its relation to the overlying fire sand bed also indicates its place.

The clay of the southwestern pits was near the surface and 43 feet (*top*) above tide level. This is streaked with earth and of inferior quality. That from the bottom was said to be the best of these pits. In the valley of the brook and in the lower ground, between these two clay openings, borings show sand. It seems highly probably that the Raritan potters' clay bed will yet be found in this lower ground, and below the level of these clays here described.

Northwest of the clay pits and near the road, a pit of sand has been dug, which is called *kaolin*. Properly it is a sand containing a little mica in fine flakes or scales, and also a little clay. Its surface is 50 feet high, or above the level of the fire clay, and corresponding to the horizon of the fire sand bed, and belongs to that bed. (See general section No. 20). But little of it has been dug. The materials from these pits are carted to a loading platform at the side of the railroad of the New Jersey Clay and Brick Company, whence they are taken in cars to the river and there shipped as desired.

M. COMPTON'S FIRE SAND BANKS.

These banks are one mile southeast of Bonhamtown, and near the New Jersey Clay and Brick Company's railroad. The *bearing* is yellow, sandy earth, and reddish gravel, and is 3 to 6 feet thick in the westernmost pits. The sand is white, and almost wholly of quartz, but varies considerably in the size of grain. These varying sizes appear generally in different layers, which are thin, and give to the whole a laminated structure. In some of the northwest pits the sand is as much as 13 feet thick. Under this there is a reddish, sandy clay layer 6 inches thick, and under that *quicksand.* The top of the sand bed is generally of finer-grained quartz. These grains are angular and quite uniform in size, being about 1–30 inch in diameter. Under this there is a coarser-grained layer, some of the grains being as large as a pea, and a part of it, properly, a fine gravel. The grains in this are sharp, or but slightly worn, and mostly of opaque quartz. The more frequent sizes are from 1–16 to $\frac{1}{8}$ inch in diameter. In some of the thinner layers of it there is a very little white clay mixed with the quartz. Near the bottom some of the fine-grained sand is very clean and white, consisting of white, translucent quartz grains of nearly uniform size—about 1–30 inch in diameter. This grade has been thrown aside, as too fine-grained for a fire sand. Partial analyses of these fire sands gave the following results:

	1	2
Silica (quartz)	98.00	96.40
Titanic acid	0.25	....
Alumina and oxide of iron	1.45	2.10
Potash	0.20	....
Soda	traces	....
Lime	traces	....
Totals determined	99.90	98.50

1. Coarse-grained fire sand.
2. Fine-grained fire sand.

According to those figures the first is a little better than the fine-grained. The alkalies and alkaline earths were not determined in 2.

The elevation of the fire sand bed in these banks is not known, excepting approximately from the contour lines that run near them. The bottom of the bed, as ascertained in this way, is about 15 feet above tide level. This, according to the section (No. 35), puts it partly in the horizon of the Raritan fire clay bed, and partly in the fire sand bed, as there drawn.

This property is leased and worked by Thomas Aiken, of Bonhamtown, and the sand is sold to J. R. Watson, B. Kreischer & Co., A. Weber, and other fire brick manufacturers. By a short branch tramway cars are run from from the banks to the railway of the New Jersey Clay and Brick Company, and thence to the dock on the river. As the *bearing* is light and easily handled, the sand bed thick, and the facilities for loading and transporting are good, the cost of putting this sand in the market is comparatively low. The annual sales have been large, and steady excavation for eighteen years has worked out a large area of ground.

These banks and the lower grounds near them should be further examined for the Raritan fire clay bed, which belongs under the fire sand. The wet and swampy character of much of the surface south and east of the banks, indicates a tight bottom and probably a bed of clay.

Northeast of M. Compton's residence about a quarter of a mile, and near the Sand Hills road, there is an old fire sand pit not worked in several years.

CLAYS, &C., IN THE VICINITY OF BONHAMTOWN.

Nearly a mile southeast of this village a white clay is said to have been opened in a trial pit near the Crossway brook, and north of a house belonging to Ex-Sheriff Acken. This is in low ground, much of which may be considered available territory in which to discover the lowest clay bed—the Raritan potter's clay. The map illustrates this and the inquirer is directed to it.

South of Bonhamtown and near the village, the Woodbridge bed has been opened in several places. On Jerome B. Ross' lands, 150 yards southeast of John Courter's residence, C. S. Edgar reports a pit which passed through white clay at the top, then blue clay and at the bottom a red clay, in all a thickness of 24 feet of clay.

Clay is also reported on Benjamin Tappan's lands, southeast of the village.

There is also said to be fire clay on the property of L. J. Tappan, southwest of the village.

There are very probably other points in this vicinity where trial pits have found this bed and of which we have not heard. But none of these have amounted to more than exploring work.

Just north of the village a white clay has been found under the gravel at the gravel pits of the Pennsylvania Railroad Company, and 7 feet beneath the bottom of the excavations made for the gravel. This was found in boring. This is at about the proper height for the Raritan potter's clay bed.

A similar clay is said to have been struck in borings on Harrison Martin's farm, northeast of the village and near the Mill brook. This also belongs to the Raritan potter's clay bed, which has been opened and worked in the pits of Messrs. Mundy, Phœnix and Carman to the northwest.

West of the village, at the road forks and the chapel, a fire clay was found in digging a well. It was 40 feet beneath the surface of the ground, which has an elevation of 80 feet. This agrees with the horizon of the Woodbridge bed at that point.

T. L. CARMAN'S CLAY.

This clay is near the old brick yard, two-thirds of a mile north of Bonhamtown and west of the Metuchen road. The top clay is dark drab-colored, and contains a few lumps of lignite. The red and white or mottled clay under it, is said to be 4 to 6 feet thick and to lie upon red-shale. An attempt was made to use it for making red front brick, but the location was bad, and the clay was too hard to burn for profitable manufacture. The top of the clay here is 78 feet above mean high water. This clay is a part of the Raritan potters' clay bed.

W. C. & E. MUNDY'S PITS.

These are only a few rods southwest of Carman's brick yard. The strata here, according to the statement of the proprietors, is as follows:

Earth and gravel	6–8 feet
Yellow, clayey earth	2 feet
White clay	6–8 feet
Red clay (in places only)	8 feet

At the bottom red-shale was found *in situ*. These figures are of maximum thickness of the several layers as passed through in these pits.

The surface of the white clay has an elevation of 77 feet above high tide. On exposure some of the heaps show a considerable coating or efflorescence of the sulphates of iron and alumina. Most of this clay is a little gritty. Some of it was burned in tile at adjoining works, and some of it was sent to Trenton for use in the potteries.

GEORGE PHŒNIX'S CLAY PITS.

These are about 200 yards west of Mundy's and near the gravel pit railroad. The clay bed is reported to be 8 feet thick under a few feet thickness of top dirt. Both the red and the white varieties were found here also. The mean elevation of the surface here is 78 feet above high water level. Some of this clay is said to have been sold in Trenton for use in the potteries, but how it was used, and with what results, are not known Both Phœnix's and Mundy's clays belong to the Raritan potters' clay bed. They are shown at Nos. 2 and 3 on the general section.

JACKSON TAPPAN'S CLAY AND FIRE SAND.

This tract of J. Tappan lies southwest of Bonhamtown, between the Piscataway road and the road leading due south from this place. A single small pit of clay has been dug. Nothing was learned of the character of the clay. It was probably in the Woodbridge bed, although the Raritan beds ought to be found on the lower part of the property nearer the marsh.

The fire sand pit is a few rods south of the road which runs in a southwest course across the place, passing Freeman & Vanderhoven's pits. This digging is in a very sandy knoll, one of a series of low, rounded knolls of very loose and coarse sand. Much of the sand dug here is yellow, and some of it contains a little yellow earth. Its structure is very plainly laminated. A large amount has been dug. There is said to be a coarse sandy clay under it. This pit is in the horizon of the fire sand, between the Woodbridge and the Raritan fire clay beds. Its place on the general section is numbered 13½.

CLAY PITS OF FREEMAN & VANDERHOVEN.

These pits are one mile southwest of Bonhamtown and a third of a mile east of the road leading to Freeman's dock on the river. They are close to the by-road which runs northeasterly from the last-mentioned road to the Red Root creek road, and on the southern slope of the ridge near its summit. At the most northerly pit there is 8 to 10 feet of *bearing*. This is clay loam and gravelly earth, with a layer of black, sandy clay just over the fire clay. The latter is, on an average, 10 feet thick, although it has been found 14 feet thick in places. Under this there is a sandy clay, probably the bottom of the fire clay bed. This clay is bluish-white, and has very little grit in it. An analysis showed the following percentages:

Alumina	36.33
Sand and silicic acid	47.10
Titanic acid	1.60
Water (total)	13.60
Sesqui-oxide of iron	1.07
Potash	0.20
Total	99.90

The percentages of alumina and water show that this is a rich and pure clay. The amounts of potash and oxide of iron are small.

The elevation of the bed at this pit is about 60 feet, which corresponds with the elevations at pits on and near this line of strike between this point and Woodbridge. The southwest pit is about 100 yards from this one. At that point the covering is but a foot or two thick. The clay is white at the top and of a peach-blossom shade at the bottom; and it is 4 to 9 feet thick. Only the two or three *spits* at the bottom are of the reddish, or peach-blossom shade. This is more sandy.

In this pit the clay is at nearly the same elevation as in the northeastern, although the ground is about 10 feet lower than it is about the former. On the ridge northwest of the pits the borings go through dark-colored clay and then into a blue fire clay, showing that the *white* variety is only a part of the bed where it has not been so deeply covered, or not covered at all. In one of these borings on the hill, where the surface altitude is about 90 feet, the section penetrated was:

(1) Clay, loam and gravel	6 feet
(2) Black, clay and sand	8–9 feet
(3) Blue, fire clay	10 feet

Mr. Freeman says that this blue clay burns white and close. It has been tried in small lumps by the fire brick manufacturers, with good indications.

In some of the borings on the hill there was 25 feet of *bearing*, but the range was found to be from 8 to 25 feet. Generally the extreme thickness was in the higher ground. Towards the southeast, beyond the pits, and also towards the southwest, between the two pits, there appeared, from many borings, to be breaks or partial interruptions in the continuity of the fire clay bed.

The location of these pits is such that an open ditch drains off all the water and the clay is very dry. The clay is carted to Freeman's dock, a mile and a half distant, on the Raritan river.

These pits make the most southwesterly outcrop or opening of the Woodbridge fire clay bed, on the north side of the river. Reference to the map shows the extension of the clay land a little further towards the west.

B. ELLISON'S CLAY.

This property borders the tide meadows of the Raritan, and is about a mile south-southwest of Bonhamtown. The surface slopes quite gently from a maximum elevation of 70 feet, on the north, near the farm house, towards the south and the meadows. This slope being greater than the dip of the clay formation, both the Raritan fire clay bed and the Raritan potter's clay bed are found at workable depths, the first towards the north and on the higher ground, and the latter on the lower portion of the farm, near the meadows. At the spring, about 75 yards west of the house, a boring strikes the clay under 12 feet of top dirt They have gone into this bed about 11 feet, not reaching the bottom. This clay is light drab colored and quite sandy. A partial analysis of carefully selected borings and taken as representative of the bed penetrated, gave:

Sand and silicic acid	77.90
Alumina and titanic acid	15.60
Oxide of iron	1.00
Potash	0.25
Water	5.20
Total	99.95

This analysis shows the sand as probably about half of the mass, by weight. The titanic acid, which is weighed with the alumina, may be less than one per cent., leaving nearly fifteen per cent. of alumina. The small amount of potash and the general apperance of the clay, show a close resemblance to that of Dixon's pits at Woodbridge. The line of strike of this formation connects the two localities and the heights correspond closely. These facts of similarity in character and position seem to prove that these belong in one bed, and this clay is here placed in the Raritan fire clay bed.

Recently a pit was dug 100 yards northwest of the spring. The top dirt here is yellow sand and gravel, and about 5 feet thick. The bed of clay is 15 feet thick. Its height, ascertained by reference to the contour lines of the surface, is (top) 40 feet above tide level. The general section, No. 19, shows its elevation and relation to other clays. Both its character and its height indicate its place in the Raritan fire clay bed.

The top spit of the clay dug in this pit is white streaked a little with yellow, oxide of iron probably. It is sandy, but the sand is very fine-grained.

The clay, 6 feet from the top of the bed, is of a light drab color, and without any streaks of yellow or red. It feels quite gritty to the touch. A complete analysis of this shows its composition to be as follows:

ANALYSIS.

Alumina	20.45	
Silicic acid	29.14	
Water (combined)	5.87	
		55.46
Silicic acid (sand)	40.43	
Titanic acid	1.61	
		42.04
Potash	0.17	
Soda	0.48	
Lime	traces	
Magnesia	0.51	
Sesqui-oxide of iron	1 21	
Water (moisture)	......	
		2.37
Total		99.87

The clay from the bottom of this pit is a shade darker in color, but otherwise much like that above described.

At the bottom, and under the clay bed, there was sand. On account of the water in this bed the auger could not be got more than 2 feet down into it. And, consequently, the Raritan potters' clay stratum was not reached.

Sand Field Pits.—On the same property, and in what is known as the "sand field," from fire sand occurring in its surface, and southwest of the house, about a quarter of a mile, two pits have been dug. One of these, a few rods west of the meadow lane, passed through the following layers:

(1) Sand, coarse, and, in part, a fire sand	7 feet
(2) "Hard pan" of sand, cemented by oxide of iron	1 foot
(3) Clay	8 feet
(4) Clay and lignite	2 feet
(5) "Hard pan" layer (cemented sand)	1½ feet
(6) Clay	4–4½ feet

The pit was stopped in this latter bed of clay.

The upper clay (3) of this pit is white, or light drab-colored, and sandy. It resembles closely the clays of the pit above described, excepting that these contain more yellow streaks.

This is an interesting section, as it presents both of the Raritan beds and gives the distance between them; and it is the only place where both have been seen in one vertical section—or one above the other. The clay and lignite must be the equivalent of that seen on the top of the white clay at Edgar's station and at Carman's pits.

Some of the clay from the top of this pit has been tried for stoneware, but it did not fuse. It is a fire clay, and not adapted to making ware. The lower clay was said to be like that of Dally's pits, and without grit. It belongs to the Raritan potters clay bed.

A pit was recently dug in this sand field, east of the above mentioned one and near the lane. Here sand was found at the top 3 feet thick, then earthy and sandy clay. The specimens from this pit, from Mr. Ellison, are a little more sandy than those of the western pit, and the top clay is streaked reddish. Those from 3 and 6 feet down, respectively, are less sandy, of light drab color, and streaked red and yellow.

Southeast of the farmhouse a little digging has been done and a white clay obtained. These pits are in lower ground than the sand field, the surface being about 20 feet above tide level. The top clay got here is a faint buff color, with yellow streaks through it. That lower down in the bed is bluish-white and of faintly mottled shades of white and greenish-white. It has a laminated structure, and is not so homogenous as the clays of the other pits on this property. Its place is certainly in the lower Raritan bed. For its location on the general section, see No. 26.

Up to date the diggings and openings on this property have been of an exploring character, and no considerable amount of clay has been sold. Some of this lower clay has been tried for ware, and is said to answer for such use. It is also thought to be suitable for alum making. One drawback of this bed is its want of uniformity in quality; hence there is constant need of careful sorting. The fire clay bed is much more promising, both in its extent and character.

A tramway about a half a mile in length is now being constructed to the river for the transportation of these clays to a dock on the river front. This necessary work must lead to the development of the property.

CHARLES M. DALLY'S PITS.

These pits are near the salt meadow, southwest of Ellison's, and 1½ miles southeast of Piscataway, in Raritan township. The first opening for clay on this property was made in 1870 and 1871 by Edgar Brothers. One of the pits then dug was about 300 yards northwest of the farmhouse and near the woods. The ground here is between 20 and 30 feet high, and the clay is covered by several feet of sand and gravel. That which was seen on the bank is partly white and partly mottled. Some of the latter looks as if it had been tinged by red-shale, or had been derived from the wash of that rock. It is said to vitrify in the fire, fusing to a mass of very pretty shade of color. Nothing as to the value or uses of what was dug here was learned.

In the pits southwest of the farmhouse and at the border of the meadow, there is an average thickness of 10 feet of yellowish-white sand and sandy gravel in thin layers. The surface of the clay is quite uneven, varying from 6 to 13 feet below the level of high water. It may have an average thickness of 9 feet. In one pit it exceeded 11 feet. The upper three spits (equivalent to $2\frac{1}{2}$ feet) is bluish-white, very tough, and contains a little pyrite in small crystalline masses. On exposure to the air it is soon coated by a yellow efflorescence. This clay is said to be fusible at a moderately high temperature. Below this the clay is free from pyrite and almost without gritty matter. This is said to be quite refractory, and to burn tight and close. A partial analysis of it gave 1.71 per cent. of potash, which indicates fusibility at a high temperature. By judicious mixture it might be used as a fire clay. The seventh and eighth spits down are mottled with bluish and pinkish streaks, and the clay seems to be a mixture, in very thin layers, of a blue clay and a very fine reddish earth, which latter is probably detrital or silted matter from the wash of red-shale. This mixture melts in the fire. In the bottom of the pit the clay has a very plainly laminated structure, and is more solid. Under this there is a flaky clay, out of which the water flows very freely, and the digging stops when it is reached. Mr. Dally says that in the low ground east of these pits he has bored and found the clay from 9 to 18 feet beneath the surface, or 5 to 12 feet below high water level. About 350 yards east of the above described pits, a single pit was dug in 1874, and the clay was found 14 feet thick, under 11 feet of top dirt.

Some of the clay on this property could be improved in character by washing, and so made valuable for some uses; and for this purpose there is a good stream near the pits and the flat tide meadows, convenient for settling vats. But the position of the bed—wholly under tide level—necessitates the raising of all the water from the pits, and this adds considerably to the cost of extraction. The nearness to the Raritan river, and the short distance to reach transportation by vessels, may counterbalance this drawback from water. The outlay necessary for working such a locality, and the slow market for such grades of clay, have prevented the development of the property.

This is one of the interesting localities in this part of the clay district. The mixed reddish earth and clay near the bottom of the pits belongs evidently to the lowest and first layers of this plastic clay formation, the Raritan potters' clay bed, deposited upon the shale. Its structure and composition indicate an alternate mingling of currents, carrying the blue clay and those flowing from red-shale areas, charged with shaly materials, as if it were a border region, where for a time neither prevailed, and consequently in the resulting quiet and slow shifting of materials, there was the deposition of the more or less mixed sediments. The old shore line must have been near this southeast boundary of the present red-shale outcrop, and this shale may have been the land whose drainage thus mingled with the muddy currents of the water wherein the clay was deposited.

CLAY WEST OF FREEMAN'S DOCK ROAD.

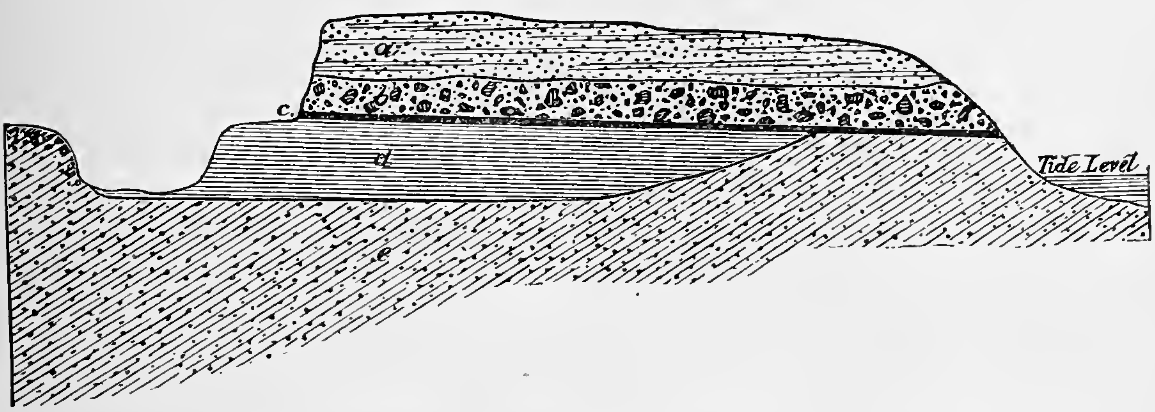
Near this road and west of Charles M. Dally's place, some white clay was formerly dug by Nelson Martin. As the pits are caved in, and none of the clay is seen, nothing of its character or extent. is known to the survey. According to the map, this wet ground along the brook from this point, both eastward and westward, is of the elevation indicating the existence of the Raritan beds at workable depths. White clay is said to have been found on the lands of Morby & Brown, southwest of the old pits of Martin West of this property and east of Mill brook and lake, a white clay crops out in the upland bank, bordering the tide meadows, on John Van Horn's farm. In digging his well it was found 9 feet beneath the surface, and the bed was 13 feet thick. Borings reported on the same property passed through rich clays. All of these localities are within the limits of the Raritan beds. The important question is as to their quality. Further exploration will, doubtless, find workable amounts of good clay and other localities along this shore—westward to Martin's dock.

W. N. WEIDNER'S CLAY PITS.

These pits are near Silver lake, a half a mile south of Piscataway, and about a quarter of a mile northeast of Martin's Dock, on the Raritan river.

The locality was opened about eight years ago by C. S. Edgar. It is one of the most interesting in this district, on account of its relations to the red-shale, and the overlying and newer beds of modified and true drift. The accompanying section, running from the pits southward, through a cut, for a proposed railway to the tidal meadows, represents the geological features of the place.

FIG. 3.



a. Yellow sand and gravel, with red-shale fragments.
b. Glacial drift.
c. Bottom of cut.
d. Clay.
e. Red-shale.

At the south end of the cut the red-shale is seen, dipping towards the northwest. Following this there is a red-shale drift, which, in the cut about midway, is 8 feet thick. In this the shale predominates, both in an earthy form, as a matrix, and in irregularly shaped and slightly rounded fragments and masses, of all sizes—up to blocks two feet in diameter, mixed with boulders of trap and other rocks, and sand and gravel. This is a true drift, and shows no stratification. The overlying bed of yellow sand and gravel has a maximum thickness of 12 feet. It is plainly marked by lines of sorting, and these lines dip gently towards the northwest. In some portions of it, a beach structure is plain in the lamination of its layers. Red-shale is seen in this drift also, but only sparingly, and nearly all of it is confined to a single very thin layer, which is interstratified with the gravel and sand. Many fossiliferous pebbles occur in this upper gravel and sand drift. Both of these drift beds lie above the clay. The relations and ages of these are discussed in the chapter on the Geology of the Surface. (See page 30.)

The clay, as it has been uncovered, has been very uneven, but the average elevation above tide water may be put at 45 feet. This appears a little low for the Raritan bed, when compared with the other localities where it has been opened and measured, and as illustrated by the general section No. 5.

The greatest thickness of clay observed here was reported to be 18 feet. Towards the bottom there are streaks of yellowish earth in it. And underneath it a greenish grey shaly rock is struck. This is probably *in place.* Most of the clay dug in this pit is very white, although there is some of a bluish shade. A little copperas is detected in some of it. Selected lots are remarkably clean and free from sand, and very white. And this does not change color on long exposure. Its tenacity is not as great as that of the Woodbridge clays. It also appears to be less plastic. The fracture is not so clean and sharp as in the fire clays. Its density is less than that of the latter, being 1.528–1.542. An analysis of a sample, taken as the average of several tons of this sorted white clay, shows its composition to be as follows:

Alumina	39.04	
Silicic acid	45.61	
Water (combined)	10.90	
		95.55
Sand	0.71	
		0.71
Oxide of iron	1.10	
Magnesia	......	
Lime	......	
Potash	2.26	
Soda	0.25	
Titanic acid	......	
		3.61
Total		99.87

In this analysis the titanic acid is weighed with and included in the alumina. The magnesia and lime were not determined. They do not probably amount together to one per cent. The titanic acid may be a little over one per cent. From these figures it will be observed that this clay is remarkably free from sand. The potash is large, comparatively, and makes it unfit for any refractory purposes. It is said to fuse readily. It may do for glazing paper, or for certain kinds of ware, if the quality can be got uniform through enough of it to pay for working. The blue clay here is more sandy. A few yards west of the pits, on the road to the dock, the red-shale crops out on a level with the outcrop of the same rock at the south end of the cut, giving to the clay mass the appearance of being a pocket lying in this red-shale basin.

Extensive preparation was made here in cutting through the ridge and building a causeway on the meadows to the dock on the river, for the removal of the clay to vessels at this dock, but nothing has been done since 1874. The locality has the advantage of easy and efficient drainage and of short transportation to boats on the river. The want of uniformity in quality throughout large masses may offset these advantages of location.

CONWAY'S CLAY.

A short distance west of Weidener's pits, and on the west side of the Silver lake outlet, two or three small pits were dug some years ago, on the Conway farm, by George Phœnix. The clay was found quite near the surface of the sloping field. That seen in the old heaps left by the pits, has a pinkish shade of color. But nothing further of its occurrence or character is known. From its elevation and location there can be no doubt of its place in the Raritan bed. It may be remarked of it that it is the most westerly outcrop of this bed on the north side of the Raritan river. The general section shows this clay at No. 4.

SECTION II.

2. LOCAL DETAILS OF BEDS SOUTH OF THE RARITAN.

The order of the descriptions in this section is geographical, and proceeds from west to east, beginning near Lawrence brook, first the pits and outcrops along the South river; next, those along the Raritan slope, Sayreville and Burt's creek to South Amboy; then the pits south and southwest of South Amboy to the southern limit of the district. This arrangement corresponds in general with the geological succession of the more important beds, in putting the stoneware clays at the end, following the South Amboy fire clay bed and the most of the outcrops of the latter after those of the Woodbridge and the Raritan beds. There are, however, exceptions which can be seen by a reference to the map.

DEVLIN FARM.

This property lies south of Lawrence brook and west of the Island farm, between that and the Old Bridge turnpike. The pits dug to test the ground, are near the meadows, on the eastern side of the tract. The surface is about 20 feet above tide level at the pits. Some bluish white clay was got in a bed 6 or 7 feet thick, under which there was a red clay. The top of the bed was about 12 feet above high water level.

Southwest of these pits C. S. Edgar reports borings in a sandy blue clay near the surface of a hill, the highest point of which is 70 feet above tide level. This latter would appear to be of a higher and different bed, perhaps the Woodbridge fire clay bed. That of the pits in the lower ground, is referred to the Raritan potters' clay. (See general section No. 21.)

ISLAND FARM.

On this tract the red-shale outcrops are seen on the north and northwest, in the low, upland banks, bordering the tide marsh. They are covered by a thin deposit of yellowish sandy loam. On the central and highest part of the island the sand and gravel drift was found quite thick in the several trial pits dug by the Pennsylvania Railroad Company, in search for gravel. In two of these, white clay is said to have been found at the bottom, under about 15 feet of the drift sand and gravel. On the eastern side of the island a large amount of fire sand has been taken from the bank of Whitehead Brothers. At this place the yellow sand and gravel is 1 to 8 feet thick. Under this there is a layer 2 to 3 feet thick, consisting of alternating laminæ of sandy clay and fine grained, angular, quartz gravel. If these materials were mixed and not thus sorted, the mass would be a *feldspar.* This layer is quite hard and compact, capping, as it were, the sand below. This latter extends down nearly to the level of tide water, and is about 20 feet thick. The sand is nearly all quartz, moderately fine grained and yellowish white. A very little clay is mixed with it in some of the thinner layers. In digging no attempt was ever made to sort the different grades of sand. It was carted to the dock on the river and there loaded on vessels.

North of the fire sand bank a few rods, white clay has been uncovered in two small pits, dug in the lower ground near the marsh border. In these the *bearing* on the clay was only a few feet thick. The clay was at the level of tide, and in these trial pits was not more than 6 feet thick. Towards the bottom there were ferruginous stains in it. A sample of the best found in this digging was analyzed. The analysis shows the following components:

Alumina	34.85	
Silicic acid	45.20	
Water (combined)	13.60	
		93.65
Silica (quartz sand)	0.50	
Titanic acid	1.40	
		1.90
Potash	0.12	
Soda	trace	
Lime	0.25	
Magnesia	trace	
Sesqui-oxide of iron	1.35	
Water (moisture)	2.80	
		4.52
Total		100.07

These figures show that this is a very pure clay. The percentage of alkalies and alkaline earths is unusually small. The oxide of iron is above the average of the best of the fire clays of this district. The ratio of silicic acid to the alumina is different from that of the best clays. The alumina in this is relatively smaller and the silicic acid larger than in most fire clays.

Too much stress must not be put upon this analysis, inasmuch as this small pit was the first one dug, and this single specimen may not be an average or representative of the bed here opened. Its elevation corresponds with the horizon of the Raritan clay bed, as is shown by the general section. (See No. 32.) In composition it does not agree with the analyses of other specimens from this bed; but this is not sufficient of itself to offset the argument from elevation. The potters clay layer is characterized by its want of uniformity in physical properties, and by its variation in character in its different parts, so that this unusually pure clay may belong in it, being of limited extent and of little practical value. The position of the fire sand of this tract appears on the general section at No. 37.

W. S. PETIT'S CLAY BANK.

This bank is near the South river, and a half a mile north of Washington. It is worked for the supply of the red brick yard near it, and on the river. The following is the order of the several beds seen in the bank, and in the face of the hill above it, on the road leading west to the Old Bridge turnpike:

(1) Reddish gravel and sand	10 feet
(2) Light-colored, sandy clay, with layers of sand	25 feet
(3) Clay and sand, alternating	20 feet
(4) Cemented sand (stone)	3–5 feet
(5) Black clay	5 feet
(6) Laminated sand and sandy clays containing lignite, at the bottom	

This level, or working floor of the bank, is 18 feet above high water. Of the above-mentioned sub-divisions only 3, 4 and 5 are excavated, and of these No. 4 is thrown aside. The black clay (No. 5) is very tough and solid, and is the best of the bank. It contains a very little lignite and pyrite. Mr. Petit dug a small pit in the bottom level, and found a light-colored, sandy clay, which burned hard and appeared to be quite refractory—like a second quality fire clay.

Northwest of the main bank there is an excavation for white sand, which is used in moulding. This lies below the level of the main bank, not more than 10 feet above high tide. Just over it there crops out a dirty white, sandy clay. This may be the equivalent of the Woodbridge fire clay bed. Below the level of this sand, in the ditches northeast of the bank, there is sandy, black clay, which goes down to tide level.

The pits across the road, and south of the main bank, furnish a light-colored clay, which burns to a paler shade. The bluish and the black clays of the main bank make a deep-colored, red brick.

The position of these clays, with reference to the fire clays, is shown on the general section (No. 60.) This shows the clay at the bottom to be at the height of the Woodbridge fire clay bed. Hence, from its character and its elevation, it may be regarded as a part of that clay bed. Nothing definite is known of its thickness, or of its character, beyond what has been learned from the surface specimens.

The clays worked in these banks all belong in the laminated clay and sand bed—the source of nearly all of our best red-brick clays dug in the State.

In the old bank south of the kilns a black, pyritiferous and lignitic clay is seen.

CLAY BANK OF NEWARK COMPANY.

This is at the side of the New Brunswick road, close to and northwest of the village of Washington. The excavation has been confined within the 10 and 30 feet contour lines above tide level, corresponding to the heights at Petit's bank, and the clays dug here are geologically the same as those at the latter place. It will be observed that the line of strike runs through this opening and the brick clay bank of Sayre & Fisher, at Sayreville, and this shows them to belong to the same bed—the laminated clay and sand. This bank has not been much worked in several years past.

Northwest of this bank *kaolin* and a clayey sand crop out in the hill on the New Brunswick road. The top of this outcrop is 85 to 90 feet above high water mark. This height is the same as that of the *kaolin*, which is worked on the Whitehead estate, southwest of the village of Washington, but it is one third of a mile northwest of that locality and does not, therefore, show any dip in the bed. It corresponds more with the elevations of the bed, as opened north of the Raritan and shows the Whitehead bank to be exceptionally high. This outcrop is placed on the general section as No. 63½.

KAOLIN, WHITEHEAD ESTATE, WASHINGTON.

This *kaolin* bank is in the village of Washington, at the side of the Hardenburg Corners road, near the top of the hill. It is covered by a reddish, sandy gravel, which is thicker westward in the higher ground near the top of the hill. In the excavation for road material this gravel appears in layers of irregular extent and thickness with thicker strata of coarse sand. The *kaolin* (*surface*) has an elevation of 82 feet above mean high water level and the workable bed is on an average 6 feet thick. Under it there is a fine white sand and then the black clay of the brick clay bank. This *kaolin* is very white and rather coarse-grained, and it contains more white mica than is commonly found in the *kaolins* of other localities in this district. It is not regarded as a first class article. According to a partial analysis it has of

Alumina and sesqui-oxide of iron	7.80 per cent.
Silicic acid and sand	89.40 per cent.
Water	2.60 per cent.
Total (determined)	99.80 per cent.

As the stripping is light and the drainage easy and natural this bank is cheaply worked.

BRICK CLAY BANK OF WILLETT & YATES.

This is almost connected with the above described *kaolin* bank, being a few rods east-southeast of the latter, in the village of Washington. The strata between the top of this bank (59 feet elevation) and the bottom of the *kaolin* (76 feet) are not seen, excepting in the gentle slope of hill and as to these there is some uncertainty. The several sub-divisions of the bank and their relations to the *kaolin* are expressed in the following order, beginning at the top of the hill, at the gravel pit:

(1) Reddish sand and gravel	10–15 feet
(2) *Kaolin* (workable bed)	6 feet
(3) Black clay with layers of sand (partially obscured)	35 feet
(4) Yellow, loamy clay	1½ feet
(5) Black, pyritiferous clay	6 feet
(6) Bluish clayey *kaolin*	4 feet
(7) Slate-colored clay	5 feet
(8) Clay full of pyrite	1½ feet
(9) Bluish *kaolin*	1 foot

Blue clay at the bottom of the digging, which is 22 feet above the level of high water. No. 3 occupies the interval between the *kaolin* near the top of the hill and the top of the working face of the clay bank. In No. 8 there is very much of both lignite and pyrite, and it is sometimes called pyrites clay. Layers 6 and 9 are sands, which are known in the bank as *kaolins*. They are mixed with the clays for brick. The slate-colored clay (7) is very tenacious and burns *hard*, and is quite refractory. It is free from pyrite and it is considered the best clay of the bank. The working face of the bank stops at the bottom of this, although in the drains and in the eastern part of the bank, nearer the yards, lower clays have been dug. The several clays and sands are mixed together in using them for the brick.

The clays and sands of this bank belong to the laminated clay and sand bed. The height of the *kaolin* in the top of the hill, west of the bank, is shown on the general section (No. 81) to be 20 feet above the horizon of that bed. The *feldspar* is wanting here unless it is to be found in the intervening 35 feet under the *kaolin*, that is, in No. 3 of the above section. It is probable that it is here replaced by sand, and also that the greater height of the several beds here is owing to a flattening of the strata and a gentler dip, which would account for these apparent exceptions. And if this be so, the Woodbridge fire clay bed should be found higher and somewhere near tide level. Or, it is possible, that the intervening beds between the fire clay and the *kaolin* have a greater aggregate thickness here than eastward and the former is at the horizon which the section indicates, viz., about 25 feet below high tide level.

JAMES BISSETT'S CLAY BANK.

This is on the west bank of the South river, one mile southeast of Washington. There is here at the top, yellow sand and gravel 8 feet thick, then a greyish clay 1 foot thick, then a *kaolin*-like sand, which is about 8 feet thick. Then comes the black clay, thick layers of which alternate with very thin seams of white sand and sandy clay. One of these thick layers of clay is traversed by planes of bedding and joints, which divide it into large brick-like massess. This curious structure facilitates its extraction and handling. This is a very solid, tenacious clay and has a specific gravity of 1.778—1.812. It is a very superior brick clay. The top of the black clay outcrop is at the height of 22 feet above high tide level, and the bottom of the diggings 10 feet above the same datum plane. At the bottom the clay is more sandy. This burns very red. The materials of the several layers are generally mixed together and all put into common red brick. At the top there is, over the black clay and the *kaolin*, a greyish streak of *clayey sand*, which is said to be hard to burn. This may be the bottom of the South Amboy fire clay bed and the *kaolin* under it, that bed being here in place. The general section, No. 108, exhibits this bank as partly in the horizon of this fire clay bed. The flattening of the whole formation on this side of the South river, or going southeast will also explain the apparent discrepancy in the section. Such a flattening would elevate the fire clay bed here and so place this brick clay under it, where it most probably belongs.

Neither the top clay nor the *kaolin*, above mentioned as over the black clay, are used. Mr. Bissett reports finding a whitish clay in a pit and boring about 100 yards west of his residence, at a depth of 22 feet beneath the surface. This was in ground 40 feet high, and this clay was therefore nearly 20 feet above high water level.

A. J. DISBROW'S CLAY.

From fifteen to eighteen years ago about 3,000 tons of potters' clay were dug near Old Bridge, in the side of Snake Hill, and at the level of tide, by A. J. Disbrow. As worked, the bed was eight feet thick, and was underlaid by sand. Over it there was about 25 feet of top dirt. The clay was greyish slate-colored. A specimen obtained at time of visit, from the outcrop near the river, is white, solid and sandy, but the sand in it is very fine-grained. An analysis of this specimen gave the following percentages:

ANALYSIS.

Alumina	19.85	
Silicic acid	24.55	
Water (combined)	5.70	
		50.10
Sand (quartz)	44.80	
Titanic acid	1.00	
		45.80
Potash	1.90	
Soda	0.32	
Sesqui-oxide of iron	1.00	
Water (moisture)	0.90	
		4.12
Total		100.02

These figures indicate a composition suitable for pottery, corresponding as they do quite closely with the stoneware clays of this district. This outcrop from its elevation appears too low for the stoneware clay, unless there is a curve in the line of strike of that bed, which is not sustained by any other fact. Hence it seems more reasonable to consider this clay as a part of the South Amboy fire clay bed, although in composition and character it is allied to the stoneware clays. It will be observed that this outcrop is very nearly on the line of strike with that dug on the shore at South Amboy, and they are much alike. This similarity in position and character may indicate one bed, of which these are the only outcrops thus far discovered; and it may be a distinct bed intermediate to the South Amboy and the stoneware clay beds. Additional localities are necessary to settle these points. Knowing the horizon at which this is to be found, it may be desirable for landowners and clay miners to look carefully after it, since this question has a practical as well as purely geological interest. The South Amboy clay and this outcrop are to be seen on the general section, Nos. 114 and 115.

Higher up in the side of this (Snake) hill and 50 feet above the level of the tide water, there is another layer of light-colored, sandy clay. It has not been worked, and none of it has been examined.

Northwest of this and nearer the New Brunswick road, on the same property, clay has been dug in two small openings at intervals during the past 40 years. These pits are about 100 feet above tide level. The clay has been used in making drain pipe. Specimens from near the surface of the ground are drab-colored, sandy and streaked with yellow earth. The same clay has been struck, as is supposed, in several wells on the high ground in this neighborhood. Its geological place is not plain, unless it be of the drift.

The potters' clay bed, at the river level, is seen up the stream in the bank in the village of Old Bridge. There it is 2 feet thick. Mr. Disbrow thinks it can be traced to the southwest as far as Outcalt's mills, above Spotswood. These outcrops in the low and flat valley of South river may also be of drift or even of alluvial origin.

BRICK CLAYS EAST OF SOUTH RIVER—WASHINGTON.

The laminated clay and sand bed is worked for brick clay in the pits of Service & Tuttle, north of the Amboy road, in those of Peter Fisher, just south of the same, and in H. F. Worthington's, still further south. Those at the side of the road go down a few feet below tide level, and their working necessitates the pumping of the water. The clay of these pits is all dark-colored and very tough, and it makes strong and good building brick.

H. F. WORTHINGTON'S BRICK CLAY.

At the northernmost pits of Worthington, the bottom of the excavation is about 10 feet below tide level or high water mark. At the southern end of the opening the bottom of the digging is about at tide level. Here the clay runs up to the top of the ground, so that there is no waste material to be removed. The thickness worked is about 15 feet. At the botton there is a sandy, laminated bed, and over it a tough, bluish-black clay layer. The layers are all mixed together for the brick.

A short distance northwest of the pits and near the yard, a well 65 or 68 feet deep was dug about eight years ago. This went through. It was six feet in diameter for a depth of about 30 feet, and was then bored 32 feet, in six holes each 2½ inches in diameter. From one of them water rose in abundance, and filled the well quite up to the overflow drain. Mr. Worthington in a recent letter says: "In descending the first four or five feet we passed through impure surface clay, known by brickmakers as yellow-white, and containing large quantities of sulphuret of iron. From that on we passed through nothing but blue clay, which, however, grew gradually darker in color as we descended, until at last the clay was, when damp, almost jet black. We came to no sand, but at the depth of thirty-five feet we struck a clearly defined stratum of clay, which was almost white, and contained but very little sand. The contrast was very great between this and the stratum immediately over it." From the description, it is safe to infer that this white clay belongs to the Woodbridge fire clay bed. And it is equally safe to conclude that the water comes from the underlying fire sand bed; and, of course, that the bottom of the well represents the bottom of the Woodbridge bed at this place. According to the general section, the bottom of the Woodbridge bed at this place should be sixty-two feet below high water mark. The boring makes it a few feet less than this, but the difference is not greater than is frequently found in the inequalities of the bed; and the result is a confirmation of the regularity of the beds, and of the general accuracy of the sections as previously deduced from the various surface workings.

Another boring, made by the Lehigh Valley Railroad Company at their docks, at Perth Amboy, since the early part of this report was written, is so much like this in its confirmation of the geological structure given in these pages, that a description of the latter is here given:

1. The well started at 26 feet above tide, and just at the bottom of the *kaolin* bed; there was 25 feet of surface materials,

2. The boring then passed 36 feet of black clays and sands, the various layers next over the Woodbridge bed.

3. Then light-colored clay in the place of the Woodbridge bed for 25 feet.

4. Fine white sand, representing the fire sand, 11 feet.
5. Thick layers of light-colored clays, representing the Raritan clay beds, 30 feet.
6. A thin stony layer, and red mud in which the auger sunk 17 feet.

The whole depth was 130 feet. Water should have been found in 4, but the sand is very fine and yielded none.

Both of these wells are southeast of the outcrop and all the openings in the Woodbridge bed. They prove the extension of that bed under the higher and more recent beds of brick clay.

BRICK CLAY.

About a mile southeast of Washington, a red brick clay was formerly dug near the Van Deventer place and at the side of the Jacksonville road. The yard was on the meadows near the river. Nothing has been done at this place for several years. The pits were not of much extent, and the business was limited to a few years. The strata here are probably equivalent to the higher beds at the bank of Willett & Yates, or to the clays above their working bank and under the *kaolin*.

FREELAND VAN DEVENTER'S CLAY.

This property is one mile southeast of Washington, and on the east side of the South river. There is a red brick yard at the border of the tide meadows, and from it a canal to the river. Here Mr. Van Deventer made brick for several years. The clay was obtained from pits near the yard. The works are now down.

White fire clay has been found at several points on the tract. It lies within 2 feet of the surface, about 50 yards northwest of the farm house, on the Washington road. The clay here is sandy, and contains some quite angular grains of white quartz, which give it the appearance of some of the *feldspars*. The same bed is said to have been struck in a pit dug a few rods east of the house. It also appears close to the surface in the swampy ground northeast of the house.

By reference to the map, it will be observed that the line of strike of the clay beds runs from George Such's banks, across this property, to the South river, and the general section shows the elevation of the South Amboy fire clay bed, on this line, No. 107½, to be 30 feet. And this is about the height of the ground where the white clay has been discovered. The map also indicates this as available clay land. The clay dug at the brick yard is lower than this white, fire clay, and belongs, most likely, close under the *kaolin.*

None of the fire clay of this tract has been tested. The diggings have been for exploration, and not for getting clay for use.

BRICK CLAY BANK OF SAYRE & FISHER, SAYREVILLE.

This large bank affords a very fine section of the strata overlying the Woodbridge fire clay bed, and extending upwards nearly to the horizon of the *feldspar.* The vertical section, from the top of the bank to the tide water in the river, shows the following strata:

(1) Laminated clay and sand layers, about	40 feet
(2) Laminated sand, containing some leaf impressions	$1\frac{1}{2}$–5 feet
(3) Drab-colored clay (for front brick)	4–10 feet
(4) White sand	5 feet
(5) Black, sandy bed, very full of lignite and containing some leaf impressions	6–7 feet
(6) Sand (leaf bed) at low water mark	

The *bearing* on (1) is nothing more than the clayey soil—really a part of it changed by atmospheric agents and by cultivation.

Towards the top of the bank the clay is somewhat faded, and of a greyish color. Pyrite and lignite occur throughout all the strata of the bank. No order is recognized in the succession of the layers of clay and sand, nor do they run in an unvarying thickness from one end of the bank to the other, but vary from point to point.

Near the bottom of this thickness (1) there is a very tough and fat, black clay, about 4 feet thick. Then comes the sand (No. 2.)

The sand (No. 2 of the above scheme) is of clean quartz, and beautifully laminated.

No. 3 is a drab-colored clay, very persistent in all parts of the bank, and 4 to 10 feet thick. Its average elevation (top) above high water is 15 feet. It is very hard, compact and finely laminated, and splits on these lines into flat sheets and masses. Its specific gravity is 1.705–1.732. That of the more sandy, common brick clay of the bank is 1.860–1.882. Under a magnifying glass of low power it appears quite full of very small plates of mica. Its composition is as follows:

ANALYSIS.

Alumina	27.42	
Silicic acid	28.30	
Water (combined)	6.60	
		62.32
Sand (quartz)	27.80	
Titanic acid	1.00	
		28.80
Potash	2.71	
Magnesia	0.18	
Sesqui-oxide of iron	2.68	
Water (moisture)	2.90	
		8.47
Total		99.59

A *very little* lignite and occasional small nodules of pyrite are in it. On burning it becomes pale yellow to white, and it is used with excellent results in the manufacture of pressed front brick.

Geologically this bed is considered the equivalent of the *top white* clay, seen in the banks on the north of the Raritan river, and the pipe clay of other banks. A very thin, stony layer of sand, cemented by oxide of iron, separates this from the sandy beds below. In the more clayey portion of this latter and a few feet above tide level there is a great deal of lignite in the form of twigs, limbs and trunks of trees, and leaf impressions are very abundant, frequently being so crowded together as to form a "leaf bed." For a fuller notice of the species found here see pages 27–29. Mr. Fisher says that under this sand and leaf bed, and a few feet below tide level he has found a white clay, which is sufficiently refractory to make a No. 2 fire brick. This latter bed of white clay was struck 25 to 30 feet beneath the surface, in a well dug near the office and store of the firm. These discoveries confirm the *dip* of the Woodbridge bed, as above stated, according to which it should be found here at a depth of 10 to 15 feet below high water level.

At the west end of the brick yards a driven well passed through sand only for over 60 feet from the level of high tide. This probably belongs to a more recent formation, which has filled up valleys and gaps in the clay series. Pits or borings at the east end of the bank, where the brick clays remain, would be likely to strike the lower members of the clay series, and the Woodbridge bed. The *leaf bed* and the sandy layer here resting upon the latter shows the correspondence in the order of the beds between this locality and the pits north of the Raritan. The space here between the front brick clay and the fire clay seems to be greater than that between the top white and the fire clay in the Raritan river banks.

The relation of the strata as seen in the bank of Sayre & Fisher to the plastic clay formation is graphically presented on the general section, No. 70.

The whole of the thick bed of clay from the surface to the front brick clay layer is tumbled down by partial undermining and is mixed together. The bank has a working face over a quarter of a mile long, and a very large amount of clay is dug every year.* Cars running on narrow gauge railways carry the clay to the yards.

WOOD'S CLAY BANK.

Less than a quarter of a mile east of the bank of Sayre & Fisher, James Wood digs a similar clay for his red brick yard. The strata are like those above described, and are their eastward extension. The general section, No. 80, gives the location of this bank. The digging does not go down quite so deep, the bottom being about 10 feet above tide level, but as the bank is further to the southeast the dip of the strata compensates for this less depth, and the same brick clay is obtained as in Sayre & Fisher's bank. As the bank is not so high—about 20 feet at the back—there is a less thickness worked. Mr. Wood uses his clay in his yards, adjoining those of Sayre & Fisher on the east. Here, as in the latter, the light amount of waste material to be removed, the natural drainage, the location upon navigable waters and the nearness to the banks, all favor these manufacturers.

* The annual product of the yards of Sayre & Fisher is reported to be 22,000,000 bricks, to make which would take at least 50,000 tons of raw material.

The dark-colored brick clay has been found 15 feet beneath the surface on the line of Sayre & Fisher's railway, about half way between the brick clay bank and the fire clay pits; and Mr. Higbee (of Sayre & Fisher) reports finding it 60 feet under their fire clay. These occurrences at such depths would be in entire agreement with the structure of this country, as indicated by the general descriptions and the map, and the reader is referred to them for further details.

FIRE CLAY BANKS OF SAYRE & FISHER.

Fire clay has been dug at several points on the large tract belonging to this firm. The banks formerly worked are between a quarter and a third of a mile northeast of the one now occupied, and they are all north of the Washington and South Amboy road. At the latter there is much variation in the stratification, but the following order is generally observed:

(1) Gravelly earth and loam	3–4 feet
(2) Sand with earthy layers	18–20 feet
(3) White fire clay	1–4 feet
(4) Blue fire clay	4–9 feet
(5) Sandy fire clay	2–3 feet
(6) Clayey *kaolin*, containing pyrite	5 feet
(7) Fine *kaolin*	6 feet

The gravelly earth at the top evidently is a part of the drift which covers most of this country.

The sand over the clay is beautifully laminated, and the thin, gently undulating layers have a slight dip towards the southeast, although in places they are horizontal. Through it there are some thin loamy layers, in which the sand is mixed with a yellow earth. Towards the bottom, and near the clay surface, the sand is very clean, sharp and fine-grained, resembling glass sand. Under the microscope it appears to be nearly all white, translucent quartz of uniform grain, about 1-100 inch in diameter; no mica in it. As it has to be removed in mining the clay, and can be carried cheaply to the river, it can be sold at a low rate if wanted for any such uses. At present all the top dirt is tumbled down together, and is used in tempering the clay for the yards at Sayreville. A railway connects these with this bank.

The fire clay is here exceedingly uneven, and sometimes there is as much as 15 feet difference in the heights of the surface in a horizontal distance of 30 feet. The mean elevation above the datum plane (high water level) is 65 feet. This is the *top* of the bed. As lately worked, the highest point has been near the middle of the bank, and from this its surface has descended east and west. In places there is a thickness of several feet of white clayey *kaolin*, or a very sandy clay, between the top drift sand and the fire clay bed. The white fire clay at the top is probably blue clay which has faded, or has been altered by the oxidation of the slight amount of protoxide of iron in it. Sometimes a little lignite is seen in this, just over the blue clay. Towards the bottom of the bed the fire clay becomes more sandy, and grades into what is termed here a "clay *kaolin*." The best of the fire clay of the bank—the blue—is a homogenous, compact mass, having a specific gravity of 1.657—1.705. Its fracture is decidedly conchoidal. It does not fade or become discolored on exposure to the air. An analysis shows its composition to be as follows:

ANALYSIS.

Alumina	38.66	
Silicic acid	41.10	
Water (combined)	13.55	
		93.31
Sand	3.10	
Titanic acid	1.20	
		4.30
Potash	0.28	
Soda	0.18	
Lime	......	
Magnesia	......	
Sesqui-oxide of iron	0.74	
Water (moisture)	1.00	
		2.20
Total (determined)		99.81

The *kaolin* at the bottom (layer No. 7) is very fine grained, and contains a little white mica. The pits are generally stopped in this bed, as the water comes in quite freely, but borings have gone through it and into a dark-colored sand, and then stopped in a dark-colored clay, probably the equivalent of some of the layers in the bank on the river. For the relative position of these strata, reference is made to No. 91 on the general section.

All of the clays and the *kaolin*, and also the top sand dug in this bank, are used by this firm in their own works on the Raritan. The *kaolin* is largely used in the mixture for front brick. The fire clays are carted to the fire brick works by team; the sands and kaolin are sent to the brick yards by cars.

The large tract of this firm has been explored by digging pits and boring, and much valuable fire clay has been discovered. Mr. Higbee reports such discoveries northeast of the bank now worked. On some of the higher points the covering seems to have been too thick for these pits or borings to reach the clay bed. A careful study of the contour lines of the surface together with height of this bed will show that these results are in accordance with the geological structure as above set forth. Future need will develop these available clay areas as they are wanted. A practical question of constant importance is the thickness of *top* to be removed.

A half a mile southwest of this bank and near the Washington and South Amboy road, fire clay was formerly dug. Its character and the thickness of the bed were not learned. Its location is within the outcrop lines of the South Amboy bed, as is shown by the map.

CLAY BANKS OF WHITEHEAD BROTHERS, SAYREVILLE.

These are a half mile from the Raritan, along the old road to Burt's creek. They extend a quarter of a mile from northwest to southeast, and on the line of the dip. And this extent of openings shows considerable variation in the character and arrangements of the several strata. The first digging was at the southeast, in what is known as the Bolton pit. In this there was about 16 feet of top dirt, and then the fire clay bed, 20 feet thick, having an elevation (top) of 70–72 feet and lying upon *kaolin*. The bank, as now worked, shows at the south end the following order of strata:

(1) Sand (yellowish white) in places, including some sandy clay layers	25–30 feet
(2) Yellow buff-colored clay (3) Blue fire clay	1–20 feet
(4) Sand and *kaolin*	8 feet

There is, in places, a thin layer of reddish gravel at the surface, overlying the sand.

In the northern part of this bank the strata appear in the following order and thickness:

(1) Reddish-yellow gravel (2) Yellowish white sand with streaks of clay	20–25 feet
(3) Sandy bed (called *kaolin*)	6 feet
(4) Blue fire clay	4 feet
(5) *Kaolin*	4 feet
(6) Black, pipe clay at the bottom.	

Both the gravel and the sand, which form the *bearing* on the clay bed, are very plainly marked, particularly in the middle of the bank. The reddish-yellow earth and gravel at the surface, make up together 5 to 8 feet, the gravel stratum being on an average 2 feet thick.

The sand has an average thickness of about 25 feet. It is in nearly horizontal, gently undulating, thin layers, and is almost all clean, white quartz, excepting an occasional thin layer in which some yellow sandy earth is mixed with it. Some of it is sold to foundries and for building purposes, bringing $1.25 a ton, on the boat. In the northwesternmost pits there is, between the sand and the clay, a sandy layer (No. 3), which is sold as a *kaolin*. In some of the pits there is a thin stratum full of wood, on the clay. It has not yielded any leaf impressions.

Both the top and the bottom of the fire clay bed are very uneven. The height of the top, northeast of the Burt's creek road, is 76 feet; south of this, and west of the road, it is only 60 feet. The general section, Nos. 84 and 85, show these heights.

Towards the northeast the top clay is generally bright red, and of two shades of this color, presenting a mottled appearance. A partial analysis showed as much as seven per cent. of peroxide of iron in it. This did not seem to be in combination, but simply as a foreign constituent, which gave color to the mass. Dilute hydrochloric acid dissolved it readily. Yellow and also a buff-colored clay occur at the top, in some of the more southern pits.

In a pit, at the extreme northwest, and which was dug quite recently, the following order was observed in the clay bed: Sandy white; blue; dirty yellow; blue; red and blue. These colors appear in irregular, thin bands running, in general, horizontally across the pit. All of these facts show the remarkable variation in the fire clay bed, as opened in the different parts of this bank. And in the alternations of color no order is discernible. Near the top of the blue clay there is, in some of the pits, much pyrite, occurring in irregularly rounded aggregations of crystals, which are popularly known as "sulphur balls." They are from two to five inches in diameter, and many of them are oxidized on the exterior to a reddish-yellow ochrey mass, while the centre or interior consists of unchanged pyrite. They seem to be confined to the blue and yellow clays, and are not seen in the red clays.

The best blue fire clay of this bank contains a little fine sand. Its specific gravity is 1.837–1.883. This greater density is an index of some sand. The red clay is more earthy and also more crumbling. Its specific gravity is 1.745–1.771. The buff-colored variety is generally specked by oxide of iron and some undecomposed pyrite.

The layer under the fire clay is not so sandy as that over it, and it is the *kaolin* bed of the clay series. It is used in fire brick.

The black clay at the bottom is not generally reached, or dug. It is sandy, and contains both pyrite and lignite. Only the best of it is of value as pipe material.

The red clay of this bank is sold to foundries and is known as "foundry clay." Some of the blue clay goes into fire brick and some of it is used for boiler linings. The general practice in working this bank has been to dig the clays of the several colors and grades of quality together and sell them unsorted for inferior uses and at lower prices, rather than to select the varieties and sell at prices varying according to quality. The economy of labor in this method of working may more than counterbalance the slight loss in prices obtained.

The elevation of the clay in this bank and the rapid descent of the ground towards the east and north allow the water to run off without much trouble or expense and the down grade for the half mile of cartage to the dock on the river are material advantages favoring it.

Northwest of Whiteheads' bank, near the Methodist Episcopal

Church, fire clay has been dug, but the top dirt has fallen down so much that it cannot be seen and nothing was learned of its extent or character. It is within the fire clay territory. And a study of the map and general section will show that much of this higher ground to the west of this bank and south of Wood's brick clay pits is available clay land. East of this bank there is an interval of three-quarters of a mile in which there are no openings. There is no reason to suppose that there is any break in the bed in this space and explorations at the proper height in the ground south of the Burt's creek road should discover clay at workable depths from the surface.

EAST BANKS OF WHITEHEAD BROTHERS.

These openings are from 50 to 300 yards south of the Sayreville and Burts' creek road and near the head of a small stream running northward to the Raritan. The west group of pits has been dug within a year. These are nearest to the road. The surface of the ground is between 40 and 60 feet high and the yellow sand on the clay ranges from 6 to 8 feet thick, in a pit near the road to a thickness of 20 feet in the main bank, 100 yards from it. The top of the clay is, therefore, 35–40 feet, which corresponds with the height of this bed at this point as given on the general combined section, No. 95. The top clay of these pits is sandy. About five feet down there is a layer 18 inches thick, streaked by oxide of iron. It dries white and the amount of iron is small. Under this the clay is blue and better. Towards the bottom it becomes sandy. These pits are dug 8–9 feet in clay and do not go through it. The best of the clay got here is a little sandy, but this does not materially affect its refractory quality.

A short distance east and southeast of these pits, there is an older opening which has not been worked recently. The top of the clay bed in the southeastern part of this opening was measured and found to be 54 feet high. This was probably above the average elevation. As the fallen top dirt had everywhere else covered the clay, no other heights were obtained, and no further data respecting it were got. As the ground south and east rises quite fast, the *bearing* on the clay bed is probably thicker in those directions, and this location is not so favorable for getting at the clay as that of the newly opened pits west of this and described above. The clay of these pits is carted to Whitehead's dock on the river a half a mile north of them.

WHITEHEAD BROTHERS' FIRE SAND PIT.

This pit is by the side of the road about a quarter of a mile east of the above described clay pits. It shows at the top:

Gravelly earth	1–4 feet
Yellow fire sand, with streaks of loam	8 feet
Very sandy clay in thin layer; then sand and a "clayey kaolin" at the bottom	

The sand of this pit is mostly quite coarse and sharp grained. As the height of the surface here is about 50 feet, the sand bed has an elevation of 34 to 46 feet, which is the horizon of the fire clay, according to map and general section (see No. 96½ in the latter.) The explanation of this occurrence of sand is that the clay has been removed from this point, and its place subsequently filled by the drift sand, and the *kaolin* at the bottom is of the clay series and *in place*—undisturbed. This sand is nearly all quartz. Some very small black grains appear in it, which may be earthy and colored by organic matter. It is carted to boats, which, load at the proprietors' dock on the river, and is sold to foundries and iron furnaces.

About half way from this pit to the dock and west of the road, the same firm dig a moulding sand in the eastern side of a round hill, which rises 50 feet above the surrounding surface and 70 feet above tide level. A long excavation exposes to view about 30 feet of quite clean white quartz sand. It is very finely laminated and is covered by a yellow, sandy earth, a few feet thick, thinning away on the sides of the hill. Examined by the microscope, this sand is found to be fine grained (grains 1-100 to 1-200 inch in diameter.) Mostly transparent quartz, and most of these quite angular. Some crusts of cemented sand and oxide of iron are observable.

This sand is sold to foundries, and also for building purposes.

It is said that there is a dark-colored clay underneath this sand hill, which latter appears to be a drift mass of modern age. If there, it belongs, probably, to the laminated clay and sand bed.

CLAY BANK OF THE J. K. BRICK ESTATE.

This bank is at Burt's creek, in Sayreville township. The digging has been along the eastern and northeastern side of a ridge, and has exposed the strata along this for a quarter of a mile from north to south. This length of continuous opening in the clay has, of course, shown the inequalities of its surface, the range of its variation in character, and the varying nature of the layers associated with and contiguous to it. The top of the fire clay is between 28 and 36 feet high, but these heights appear within a few yards of one another. The following vertical section gives the several layers in their order and thickness:

(1) Yellow sand with some gravelly layers through it	15–40 feet
(2) Buff-colored fire clay	6–14 feet
(3) Blue, fire clay	
(4) Sandy fire clay	
(5) Extra-sandy clay, and sand	7 feet

The sand at the top is nearly all fine white quartz, and its layers are gently undulating, and dipping slightly southward. This sand alternates with very thin layers of quartz pebbles. It is all thrown aside or used in filling up the pits. At the south end of the bank there is more gravel and less sand, and the *bearing* is not so thick as to the north, where the ground is higher.

In some parts of the bank there is a thin layer of black, sandy earth between this sand bed and the fire clay, and in this, lignite is abundant. Some leaf impressions have been found in it. At other points the sand just over the clay for 2 to 8 inches is cemented into a sort of stone by iron oxide.

A red clay is got at the top of the more southeastern pits, and very frequently the top of the bed is buff-colored. The upper portion of the blue clay of the bed is considered the best, and is here designated as XX clay, or No. 1. The paler blue portion, lower down, is marked X clay, or No. 2. Towards the bottom the bed is more sandy

The best clay is bluish white, compact, having a specific gravity of 1.760—1.773, and contains an occasional scale of white mica. The No. 2 grade is a little sandy and its specific gravity is 1.852—1.901. It crumbles more readily than the No. 1 clay.

The buff variety is also a little sandy and crumbly. It shows streaks of oxide of iron.

The *kaolin* consists of fine quartz sand and a little white clay and without mica. It is rather a clayey sand than *kaolin*, as this term is understood in this clay district. It is considered a first class article and is used with the clays of this bank in fire brick. The clays and *kaolin* of this bank are used by the proprietors of the same, E. D. White & Company, in their works, which are known as the Brooklyn Clay Retort and Fire Brick Works, Van Dyke street, Brooklyn.

A few rods northwest of the main bank and near the residence of S. Gildersleeve, the superintendent, there is another clay bank worked by the same firm. This opening shows the following layers:

(1) Yellow sand	10–15 feet
(2) Dark-colored, sandy clay	4 feet
(3) Black clay, full of lignite and pyrite	2–3½ feet
(4) Black clay, used for ware or No. 2 brick	4 feet
(5) Yellow sand (boring)	6 feet

The clay layer (No. 2) is sandy, but the sand in it is fine-grained, and it dries nearly white. It is used in the manufacture of yellow ware. The next layer is quite full of leaf impressions. Its only use is as a substitute for Albany slip, in glazing pipe. The next lower clay is another potters clay stratum, although generally put in the mixture for No. 2 fire brick. The sand at the bottom has not been dug. Borings have gone 6 feet in it.

The place of these clays in the clay series and their relation to the fire clay bed of the adjoining bank are unsettled. Their elevation, between 29 and 40 feet above high tide level corresponds with the horizon of the fire clay. As a practical opinion it may be stated that Mr. Gildersleeve thinks these potters clays here replace the fire clay and he hopes to find the latter further in the bank, south and southeast. Another explanation may be in the reference of these layers to a place in the series just below the fire clay. For the better illustration of these points the reader is referred to Nos. 99 and 102 on the general section.

The materials of these banks of the Brick estate are carted about a quarter of a mile to the dock, at the head of a long slip or canal, which opens northward into the Raritan river. Thence they are shipped to the works in Brooklyn.

GEORGE SUCH'S CLAY BANKS.

These are on the Ridgeway tract, east of Burt's creek, and two and a half miles west of South Amboy. A large area has been dug over, but it is all comprised in two groups of pits, or openings. The eastern, east of the old Burt's creek and Jacksonville road, is not now worked. The western bank is much larger, and is the scene of present operations. In so large an area there is considerable variation in the stratification, although all within the range of the general order of arrangement of the members of the plastic clay series. The representation of all of these, by any one vertical section, is impossible. The following order is presented as an approximate expression, and, as such, fairly representative of the bank.

(1) Yellow sand, with thin layers of gravel	5–35 feet
(2) Dark-colored sandy clay	0–10 feet
(3) White fire clay (average)	10 feet
(4) Mottled clay	up to 10 feet
(5) Red clay	

The sand at the top is nearly all white and yellowish white quartz, and of varying degrees of fineness. It has a gently undulating structure. There are a very few thin layers of pebbles in it. No dip is apparent in the complex arrangement of the laminae, or layers. In much of the area worked over this sand bed lay immediately upon the fire clay, but on the southeast side of the opening a black clay (2) comes in between them. This is sandy, and includes some thin layers of white sand. It contains more or less lignite, and some trunks of trees, 3 feet across, have been found in it. Pyrite is also common in it. Amber is another mineral found occasionally in it. At present, no use is made of this clay, excepting to fill up pits or to pile up heaps of waste on the dump. Some of it is said to be good enough for drain pipe, but the cost of sorting prevents its employment for such uses.

The fire clay bed in this bank has an average elevation (top) of 25 feet above mean high tide level, but its surface is full of inequalities, rising and sinking from 5 to 10 feet in almost as many yards, or within the compass of a pit, so that the track level is in places 5 or 6 feet below the top of the clay, while in others the black clay line runs as many feet below the same horizon, following, as it does, the sinuosities of the fire clay line, and by its contrast sharply defining the surface of this bed.

Mr. Armstrong, superintendent of the bank, says that towards the southwest the fire clay bed thins out and is wanting, and that the black clay appears to replace it, although this is not considered the end of the former bed in that direction. These facts, brought out in the very extended area here excavated, confirm the observations made elsewhere—that the fire clay beds have been worn away in places, and these hollows of denudation have been afterwards filled by the more recent beds of black clay, sand, &c., deposited upon them. The average thickness of the fire clay is 10 feet, ranging from 2 to 13 feet. White, buff and red clays are got. Generally the top of the bed is white, lower down it is spotted, or mottled, red and white, and at the bottom red; but this order of colors is not uniform nor everywhere observed. Some of the white clay contains pyrite in very minute aggregations of crystals disseminated through its mass. This clay is washed, and thus freed from this injurious constituent. Probably one-third of the total amount dug is thus treated. Some of the white clay is very pure and of superior quality. This is sold for fire brick. The so-called "paper clay," used for paper glazing, is all washed. By a proper mixture of clays of different colors any desirable shade from white, buff, yellow, to red is obtained. A sample of washed white clay was analyzed, and found to contain:

Alumina	38.34	
Silicic acid	42.90	
Water (combined)	13.50	
	———	94.74
Sand (quartz)	1.50	
Titanic acid	1.20	
	———	2.70
Potash	0.26	
Soda	0.18	
Lime	......	
Magnesia	......	

Sesqui-oxide of iron	0.86	
Water (moisture)	1.10	
		2.40
Total (determined)		99.84

These washed samples are lighter than the crude clays, the specific gravity of a buff (paper) clay being 1.530—1.571. That of the unwashed white clay is 1.716—1.751. The fracture is conchoidal, but not so smooth and clean as in the original specimens. The unwashed clays turn yellowish on exposure to the air; the washed remain unchanged in color. These changes are due, probably, to a trace of sulphate of iron in the crude clay, which is removed by the washing. The mottled and red clays are more sandy. Some of these are sold for making saggars and other uses where less refractory clays can be employed. The red clay where it crops out in the exposed bank, or when lying for some time in heaps, is soon covered by stony crusts of clay cemented by ferric oxide. These seem to be due to atmospheric agents. Some of the white, and also some of the yellow and buff clays, turn brown on exposure, and this efflorescence has a very astringent, or *inky*, taste, indicating the presence of copperas or sulphate of iron. These are not considered of any value for refractory purposes, as they do not stand high heat. They are thrown out on the dump. Some of the richer white clays, containing some pyrite, are sold for the manufacture of alum.

All of these varied phenomena of arrangement, extent and character give a peculiar interest to this bank, and make it a favorable place for observations, both of a geological and of a practical nature.

A track runs from the bank to the washing works near by and to Such's dock, one mile distant on the Raritan. This in the bank is shifted to suit the digging, and top dirt and clays are readily carried in cars that are drawn out by team to the works, dock or to the dump for waste. These arrangements show a comprehensive management, and the economy in the handling and in the transportation is a strong argument for similar modes of working at other places in the clay district.

In the old "blue clay bank" east of the one now worked, the yellow sand *bearing* is seen. The fire clay dug in it is bluish white. No digging has been done there in several years past.

The washing works are north of the clay bank, and about them are the large drying vats. The description of these works is given further on in this report.

CLAY PITS OF LAIRD & FURMAN.

This pit is a half a mile east southeast of Such's clay works. But little clay has been dug here, and it has not been worked in several years. There is a yellow sand bed, 10–15 feet thick, on the clay, and the latter is about 30 feet high, or nearly the same level as Such's clay. Its extent or character was not learned, nor any reason for the abandonment of the locality. It is, as the map and section show, within the available clay territory.

KEARNEY TRACT.—CLAY PITS OF E. F. & J. M. ROBERTS.

This large tract of about 700 acres borders the Raritan river, northeast of Burt's creek, and one to two miles west and northwest of South Amboy. Pits have been dug at several points, but inasmuch as their relative location is more easily learned from the map, than from any extended geographical description, the reader is referred to it, and only some of the local details are given here.

Western Pits.—These are on both sides of the old Burt's creek and South Amboy road, and about a quarter of a mile east of Such's greenhouses. The diggings here have left a narrow strip for the roadway, and this may be said to divide it into two groups of pits, one to the north and the other south of it. The length of opening from northwest to southeast, on the line of dip, shows the descent to the southeast in the greater height of the fire clay bed north of the road than in the pits south of it. Thus, on the north, the top of this bed has an elevation of 32–36 feet; on the south its height is 29–35 feet. But a difference of several feet is common within short distances. And these inequalities appear at the bottom as well as in the top. For example, at one point, where the top was 35 feet high, the bed was 20 feet thick, appearing both higher than the general surface and going below the average bottom, or flooring. In the lower ground, and on the south of the road, the *bearing* on the clay consists of a yellow sand with some gravelly layers, in all, from 6 to 12 feet thick. The average thickness of the clay bed is 8 feet. Under it there is fine sand and *kaolin*. At the top a spit or two of the clay is white, next comes the blue, or bluish white, and, at the bottom, a red clay. But these are not to be understood as separate layers or beds. They are shades of color all in one bed, and the color line is the only one to be seen.

South of these pits the ground is still lower, descending more rapidly than the clay bed. This, with the known thickness of the alluvial and diluvial beds there, precludes the probability of finding much clay in that direction. It may be found beyond the low and swampy ground, where the surface again rises, going southward. Borings and trial pits have confirmed these geological conclusions, and shown the absence of a workable thickness of valuable clay in this low ground, immediately adjoining the pits on the south.

North of the road the digging has got into higher ground, and there is a thicker bed of sand on the fire clay, varying from 10 to 30 feet. In this there are a few streaks of white gravel. Although much of this sand is clean, sharp grained quartz, and is excellent for mason's use, it is carted off as so much waste material. The clay bed here also presents inequalities, quite as great as in the more southern pits. The upper part of the bed is a buff-colored clay. Below this it is bluish white, the line between the two shades of color being distinct and clearly marked. Concretionary, or ball-like masses of pyrite crystals, one to three inches in diameter, and which are generally oxidized on the surface into a brownish, ochrey shell, are quite abundant in the top of this buff clay. Each spit of this pyritiferous clay is examined, and the pyrite cut out and thrown aside. The clay thus sorted is sold for alum making. The lower part of this buff clay is very rich and free from impurities, and is sold for glazing paper, commanding a high price. The blue, or bluish white clay, is esteemed the best of the bank. This is very rich in alumina, and contains scarcely any sand or foreign matters. Its composition is given in the following analysis of a selected specimen, which can, however, be taken as representative of this clay:

ANALYSIS.

Alumina	39.24	
Silicic acid	42.71	
Water (combined)	13.32	
		95.27

Sand (quartz)	0.70	
Titanic acid	1.60	
		2.30
Potash	0.47	
Soda	0.42	
Lime	0.20	
Magnesia	......	
Sesqui-oxide of iron	0.46	
Water (moisture)	1.58	
		3.13
Total		100.70

The small percentages of quartz sand, alkalies and oxide of iron show the purity of this clay, approaching a pure kaolinite in composition. It dries very white, and, unlike most of the fire clays of this clay district, does not show any discoloration on the surface, but retains its whiteness. It is the most refractory of the clays dug here, and is sold for fire brick.

The best clays of these pits all appear of very uniform texture and homogenous. Their specific gravity varies between 1.702 and 1.742. They exhibit a conchoidal and clean fracture. Under the microscope there is seen occasionally a very small scale of white mica or a particle of white quartz. The red clay is a little sandy, and is sold for making into saggars.

No attempt has been made in these pits to dig or utilize the fine sand or *kaolin* found under the fire clay. There is so much water in the stratum that its extraction is not practicable while digging the clay, as it would soon rush up and fill the pits.

Northeast Bank.—This is the most eastern opening along the road, and is less than a quarter of a mile northeast of the pits just described. It is an older bank, in which work has been resumed within a year. At the side of the road the pits pass through sand 6 feet thick, then through a bed of black, sandy clay, also several feet thick, into the fire clay. North of this, 100 yards or thereabouts, there is none of the black clay, but the sand bed attains a maximum thickness of 40 feet. A very few thin layers of white gravel occur in it. The whole has a plainly laminated structure, and much of the bed is a very clean, sharp sand. The removal of so great a thickness of *bearing*, which is waste material, is costly, and is compensated only by the superior quality of the clays which it covers. The top of the clay bed here also has its characteristic inequalities of surface. At the top there is a white to faint buff clay, reaching down 4 feet. The top spit of this contains a few of the "sulphur balls" (above described), which are cut out. The remaining mass is very rich and a fine clay. The lower portion of this buff clay is free from almost all impurities, and is considered the best clay of the tract. A fair specimen of it was carefully analyzed, and the following results obtained:

ANALYSIS.

Alumina	39.14	
Silicic acid	44.20	
Water (combined)	14.05	
		97.39
Silica (sand)	0.20	
Titanic acid	1.05	
		1.25
Potash	0.25	
Soda	......	
Lime	......	
Magnesia	......	
Sesqui-oxide of iron	0.45	
Water (moisture)	0.90	
		1.60
Total		100.24

The purity of this clay is apparent at a glance at these figures, there being less than three per cent. of foreign matter, and of this nine-tenths of one per cent. is moisture.

The blue portion of the bed under the buff is thought to be equally good, but it burns a little darker shade of color than the buff. Selected lots from this bank are sold for ware, the buff going as a paper clay. The rest is good enough for fire brick. Sand underlies the clay in this bank. The digging stops when it is reached.

Kearney Clay Bank.—What was known under this name is three-quarters of a mile north northeast of the Roberts openings and a half a mile southeast of Kearney's dock. The ground about this opening is 70–80 feet high and the top of the clay, as ascertained by levelling done in 1855, by the geological survey, is 57 feet high. The fire clay bed was 17 feet thick, of which 13 feet of the top was of good quality, and 4 feet at the bottom of spotted clay. The pits stopped at a sandy clay at the bottom. Resting on the fire clay bed there was, in places, a black, lignite-bearing clay, but most of the top or *bearing*, which was 10–18 feet thick, was yellow sand. A *kaolin* was dug in the lower ground about 200 feet from this clay bank and at the side of the road. Its height was 44 feet.

In Roberts' bank (worked in 1855, but not lately) a few rods east northeast of the Kearney bank, there was yellow sand, 15–30 feet thick, then 14 feet of fire clay. And the surface of this latter was found to be 58 feet above mean tide level. These differences of level observed in the several banks on this property are explained by the dip of the fire clay bed towards the southeast and they show it in a very striking manner. The general, combined section also shows these banks in their respective places on the lines of strike and the heights of the clay bed at these several points. (See numbers 103, 100, 93 and 92).

In working these banks of Messrs. Roberts the customary practice is to throw the spits in heaps upon a board flooring at the side of the pit, sorting them into paper, ware, fire brick, and alum clays according to their quality. The white and buff varieties are sold for paper; the blue and some of the buff for fire brick; that containing a little pyrite, for alum; the reddish and inferior sorts, for saggars, &c., &c. A great deal of care is here given in the handling and sorting, thus keeping up the several grades to a high standard of purity and excellence, as well as maintaining the character of the clays from these banks. They are carted to Roberts' dock on the river, less than half a mile distant, whence they are shipped wherever ordered. Most of the clays go either to Jersey City or to Trenton, although some are sent as far as Baltimore and Boston. The fire brick clay is sold to manufacturers in Philadelphia, Reading, Lehigh Valley and at other points. A very small amount is used (it is said) by manufacturers of white lead as an adulteration or *diluent*.

The aggregate production of the banks on this tract, worked steadily for so many years, is very large. And of this amount an unusually large proportion has been of very superior quality and has commanded high prices, although here, perhaps more than elsewhere in the district, very much fine clay suited for ware, or for paper glazing, has been sold for making ordinary fire brick and thus used, where lower grades of clay, or such as were not quite so rich and pure, would have done nearly, if not quite as well.

J. N. COLEMAN'S ESTATE PITS.

Fire sand, *feldspar* and sandy clay have been dug at these pits, one mile northwest of South Amboy and near the road to Kearney's dock. At the most westerly pit a sandy material resembling *feldspar* is found a few feet beneath the surface. The top of this layer, as here opened, is about 30 feet high. This agrees with the horizon of this bed as determined by the dip. The general section illustrates this statement in its No. 94. In the pit southeast of the *feldspar*, some clay has been dug, but it is said to have been in thin layers and of limited extent. A yellowish white quartz sand forms the *bearing* in these pits. The fire sand pit is in lower ground northeast of the road.

Further exploration of the higher ground adjacent to these pits on the west and southwest may discover a thicker bed of better *feldspar* than that which has been dug. And in this ridge which starting here, runs southwest, passing the several pits of E. F. & J. M. Roberts, the South Amboy fire clay bed ought to be found. The clay in the southeast pit cannot belong to that bed as it is too low, the surface there being 35 to 45 feet high, whereas the top of the fire clay bed there should be 50 feet above high water level. Allowing a few feet for superficial beds or *bearing* there is no *margin* left for this clay. Both the fire sand and clay dug on this property are very probably of drift origin—a part of the great sheet of sand, gravel and clays which cover the members of the plastic clay beds in this part of the clay district. The clays nearer the shore and southeast of these pits appear to be of like character.

CLAY IN SOUTH AMBOY.

A white clay crops out in South Amboy, near the wharf at the end of Bordentown turnpike. It appears about 5 feet above high water level. A few rods southwest of this point, and also along the shore, a dark, drab-colored clay crops out in the upland bluff, rising 8 feet above tide level. This appears to lie above the white clay. In Mrs. Clark's pits, near the shore, this clay is seen 10 feet above the same level. The clay dug in these pits is very sandy, as is seen in the following analysis of a specimen from them :

Alumina and titanic acid	17.58	
Silicic acid	19.50	
Water (combined)	4.50	
	———	41.58
Sand (quartz)	53.20	
	———	53.20
Potash..	2.24	
Soda	......	
Lime	traces	
Magnesia	0.43	
Sesqui-oxide of iron	1.42	
Water (moisture	1.20	
	———	5.29
Total (determined)		100.07

Its composition is much like that of the stoneware clays of this district. It is used in making yellow ware. Towards the bottom it is not so sandy, and is said to be too refractory for ware. In some of this drab-colored clay there is much lignite and many leaf impressions. Their outlines are well preserved and clearly marked. For a notice of their age, species, &c., see page 29.

As has been referred to on page 180, there is a close correspondence between this clay and that of Disbrow's bank, at Old Bridge, both in position and in chemical composition. And, as there stated, the place of these clays is still doubtful. They are certainly below the horizon of most of the stoneware clays. And they are too high for the South Amboy fire clay bed, unless there is a change in the rate of dip of the latter, and that is here higher than it would otherwise be. The whiter portions resemble the fire clays in external appearance. The leaf layer over this would also correspond with that seen over the fire clay in the bank on the Brick estate. If it be a part of that bed, the drab-colored clay at the top, and that dug for ware, are hardly parts of the same stratum. Deeper diggings may discover the more refractory clay of the South Amboy bed.

FIRE SAND BANK OF MAXFIELD & PARISEN.

Sand is dug at the side of the New York and Long Branch Railroad in South Amboy. It is on the east side of the road, and about a quarter of a mile southeast of the station. There is at least 30 feet thickness of this bed. At the top there is a thin layer of loam. It shows fine lines of stratification, which descend at an angle of 10° towards the southeast. Along some of these lines there is a little yellowish earth. These alternate irregularly with the sand. The sand is very firm and solid in the bank, requiring the use of a pick to cut it down. And the bank stands up nearly vertical. The digging goes down to tide level. And the sand is loaded on boats off the shore.

CLAY PITS OF EVERETT AND PERRINE.

These pits are in South Amboy near the Jacksonville road. The ground is 90 to 100 feet high and rises rapidly on all sides, excepting towards the east. The top of the clay as opened in the several pits is 82, 84, 85 and 88 feet high. In some dug quite recently there is 1 to 6 feet of yellow sand and gravel at the top; then 1 foot or about that of black sandy earth quite full of wood; then 4 to 10 feet of clay, light-colored and rather sandy, becoming more sandy and of a darker color towards the bottom. Also pyrite occurs towards the bottom. It is underlaid by sand. This clay is dug for the supply of the pottery in South Amboy, belonging to the Fish estate. It is used in making yellow ware.

Southeast of the above openings clay was formerly dug at several points by Mr. Parisen. Sandy clay of a dark color and containing lignite and pyrite appears in the old bank, but as no work has been done here in some years, the lower strata have not been seen.

East of the Parisen bank there is another opening in the side hill, worked by Messrs. Everett and Perrine. The clay is covered by 5 feet of sand and gravel. At the top it is slightly stained on seams by oxide of iron. The main body is drab-colored, drying bluish white and is very sandy. It is only a few feet thick and is underlaid by sand. It is inferior to the clay of the western pits. It goes to the pottery on the Bay Shore, a half a mile east of this opening.

W. C. PERRINE'S CLAY PITS, NEAR SOUTH AMBOY.

This locality is about a half a mile south of South Amboy and about 200 yards northwest of the old Bordentown turnpike. A shaft was sunk to a depth of 46 feet, of which 32 feet was through sand and gravel, and then 14 feet in a dark-colored, tough clay, containing a little lignite and pyrite. From this, horizontal drifts were cut, all in the same clay bed. This shaft is square with its sides planked, and the materials are hoisted in buckets by means of horse power. The clay passed through would probably do for yellow ware, but it is not a *stoneware* clay. This shaft has been abandoned. Other trial pits are being put down near it, in hopes of finding a good material for stoneware. The height of the ground at the mouth of this shaft is about 130 feet. The clay met with in it is, therefore, 84 to 98 feet above tide water.

In the pits, a short distance north of the shaft, there is 8 feet of sand and gravel, then the dark-colored clay 8 feet thick, below which sand is struck. Mr. Perrine reports boring 25 feet in this sand, mostly white quartz, with some streaks which are dark-colored. All of the materials appear very dry. Here the surface is at least 20 feet lower than at the shaft, and the clay of the pit is 94 to 102 feet high.

The geological position of these clays of W. C. Perrine, and those of Everett & Perrine, nearer South Amboy, is involved in some doubt, arising from their elevation and their exceptional character. While they may *all* answer for yellow ware, they are not adapted to the manufacture of stoneware, nor do they have the peculiar speckled and characteristic appearance which belongs to the stoneware clays proper. The clay at the pits of Messrs. Everett & Perrine is very near the height required for this stoneware clay bed, going northwest, being a few feet above the height of the same bed as opened near the Camden and Amboy railroad, in the pits of E. R. Rose and W. C. Perrine; but the clay struck in Perrine's shaft appears a little too high for that bed. If this be the case, sinking this shaft deeper should strike the latter. This shaft and the pits along the Camden and Amboy railroad (above referred to) are on the same northeast and southwest line of strike, and assuming the dip to be uniform and the strike to continue the same direction through this intervening space, the bed of stoneware clay should be found at the same elevation—that is, 55 to 70 feet above mean high tide level, or 14 feet below the bottom of said shaft. The advisability of sinking such shafts rather than digging pits in the lower ground towards the north and east, is very seriously questioned. It must, however, always be kept in mind that on the slopes and side hills the superficial covering may be thicker and more uneven, having been subject to the modifying effects of surface drainage; and, besides, having reached a definite layer in the shaft, it may be easier to go through it to the next and lower beds rather than dig several holes on sloping surfaces, where there may be the greater uncertainty in regard to the top dirt. A careful study of the map and the general combined section is recommended for the better appreciation of these statements. Nos. 110, 111 and 112 on the latter represent these several openings.

W. C. PERRINE'S CLAY WEST OF SOUTH AMBOY, AND NEAR ROBERTS' BANKS.

Here some light, drab-colored and sandy clay has been dug. The pits are about 100 yards south of the old Burt's creek road and in ground whose elevation above tide is about 100 feet. The stoneware clay bed, if found so far to the northwest as this point, would be higher than this, and consequently the clay of these pits is either surface deposit or a lower bed. Neither does it look at all like the true stoneware clay. Like that of the pits near South Amboy and just described, it is not so white, but more of a drab color and not so compact or dense. But little has been dug at this locality, and of this less taken away. It is more as a trial or exploration than a working locality. Its place on the general section is No. 104.

CLAY PITS OF E. R. ROSE & SON.

These and the adjacent diggings of W. C. Perrine are at the side of the Camden and Amboy Railroad and near the old Bordentown turnpike, one and three-quarters miles southwest of South Amboy. The ground here, and for some distance to the north and west, is rather flat and 60 to 80 feet above tide level. The strata observed in these pits are in the following order and thickness, beginning at the surface:

(1) Sand, gravel and very sandy clay	6–10 feet
(2) Stoneware clay	6 feet
(3) Dark-colored sandy earth at the bottom	

Generally the top dirt is sand and gravel, but sometimes there is a little sandy clay also. The clay bed varies in thickness, having been found as much as 15 feet thick, but this included 8 feet of the top clay, which is sandy and stained a little by oxide of iron. And this top, inferior clay is sold for common yellow ware manufacture. The stoneware clay has a greyish color and is marked by dark spots of oxide of iron so characteristic of the clay of this bed and known as "fly-specked clay." It is very solid, and its specific gravity is 2.129—2.151. The composition of a representative specimen of the best clay of the pits is given in the following analysis:

Alumina	20.12	
Silicic acid	28.60	
Water (combined)	7.22	
		55.94
Sand (quartz)	37.10	
Titanic acid	1.10	
		38.20
Potash	1.50	
Soda	traces	
Lime	......	
Magnesia	0 29	
Sesqui-oxide of iron	1.38	
Water (moisture)	4.18	
		7.35
		101.49

This will be found to correspond closely with representative specimens of this bed as worked in Otto Ernst's clay mines and in Noah Furman's pits, for which see analysis under those heads.

The bed becomes more sandy towards the bottom and in the more northeastern pits it is underlaid by a dark-colored sandy clay which further west is replaced by a looser, sandy earth.

The top of the bed as opened in Rose's pits has a mean height of 70 feet above tide level. The position and height as here opened, is represented by No. 113 on the general section.

W. C. PERRINE'S CLAY PITS.

These are just southwest of Rose's and in the flat ground. The *bearing* on the clay is said to be thinner than in the pits of the latter, but the clay bed has the same average thickness. They were not worked when visited. It is said that there is no good stoneware clay southwest of this opening. In the Camden and Amboy Railroad cut, three-eighths of a mile southwest of these pits, the following strata are seen, viz.:

(1) Earth and gravel.. 6 feet.
(2) White sand.. 6 feet.
(3) Dark-colored, sandy clay, alternating with sand, which reaches down to the bottom of the cut..

The elevation of this latter layer is 87 feet. This cut is interesting only on account of its exposure of this clay and sand as strata overlying the stoneware clay bed in this part of the clay district.

West of the pits of W. C. Perrine, and near the Burt's creek and Jacksonville road, the stoneware clay has been found in borings made by Otto Ernst. These explorations were made in the low and flat ground at the head of Burt's creek, in search of the South Amboy fire clay bed. The layer penetrated was only one foot thick, and was one and a half feet beneath the surface, and under it there was white sand. Its elevation above tide level was about 67 feet, corresponding to its heights at the pits of Rose and Perrine. So thin a layer is of no practical importance. But it is a proof of the extension of the bed westward, and also of the uniformity of the dip. Two other borings near this one did not show any of this clay. The fire clay bed was not reached, as the borings did not get down far enough, in consequence of water stopping the work.

The deep valley of Crossway brook, south of South Amboy, running from the old Bordentown turnpike to Chesquake creek, across the *strike* of the stoneware clay bed, affords favorable localities for opening that bed. The bottom of the valley, or stream, descends from 65 feet where it crosses the above-named road, to high tide level near the old dam and mill pond, one mile to the southeast. As this descent is greater than that of the stoneware clay, this bed is found above the stream throughout the valley. E. R. Rose & Son, Morgan & Furman, W. C. Perrine and William Hayes have pits in this valley, and near the mouth of the brook Otto Ernst has a clay bank. Several of these localities have been quite recently opened. And no doubt others will be found. The map indicates the available area of clay territory and the general section, in its Nos. 116, 116¼, 116½, 116¾, 117 and 117½, exhibits these pits on the lines of strike, and at their proper elevation. And these show the dip towards the southeast. Beginning at the northwest, there are the

CLAY PITS OF E. R. ROSE & SON.

These pits are in two groups, or two openings, 150 feet apart, on the west side of the valley, and about a third of a mile southeast of the residence of Mr. Rose. The strata cut here are:

(1) Yellow, sandy gravel	10 feet
(2) Yellowish white sand	
(3) Dark drab-colored clay	1 foot
(4) Blue, stoneware clay	6–7 feet
(5) Yellow streaked earth at the bottom	

The stoneware clay is (bottom) 54 feet above tide level.

The above section was taken in a pit recently dug in the most northern opening. No work is doing at the other one. Both were opened about the same time, nearly two years ago.

MORGAN & FURMAN'S PITS AND MINES.

These are across the brook from the above described locality and near the head of a small tributary of the Crossway brook. They are not more than one mile southwest of South Amboy.

The southwest opening is on the south side of the brook. The following order of beds is reported by Mr. Furman, viz.:

(1) Yellow, sandy gravel	2–4 feet
(2) Yellow sand	10–11 feet
(3) Black clay (not in all the pits)	3–4 feet
(4) Blue, stoneware clay	10 feet
(5) Dark red clay	1–2 feet

At the bottom, there is, generally, a sandy black clay.

The top of the black clay (No. 3) was found to be 74 feet, according to which the bottom of the stoneware clay bed is about 60 feet above tide level.

The northeast pits are about 100 yards from the western opening and in higher ground. The surface has an elevation of 96 feet. In these pits the top dirt consists of:

(1) Yellow sand and gravel	6–8 feet
(2) Black clay	3–4 feet

The blue, stoneware clay bed is 10 feet thick and lies upon a black clay. From these figures and the elevation of the surface about the pits, the stoneware clay (bottom) is about 72 feet above tide level.

Much of the clay of these pits contains pyrite in small crystalline nodules and grains. And these damage it for finer uses. Otherwise these openings are favorable for working as there is not an excessive *bearing*, the drainage is natural and the bed is thick. Neither of these places are now being worked. The first work was done in 1876. On ground northeast from the last mentioned openings, and at an elevation of 110 feet, work is now going on in mining the clay. Square shafts are sunk through the overlying yellow sand and gravel (20 feet) and into the clay bed, which is said to be here 30 feet thick. From these shafts horizontal drifts about 10 feet high and 100 feet long, are cut in the clay, leaving a part of the bed as floor and roof. These are let to fall in after the clay has been removed and then others are driven by the side of the first and so on. The hoisting is done by a horse whim. Mr. Furman says that his explorations in the vicinity of these shafts indicate a *thinning out* of the clay bed towards the north and east. The thickness appears unusually great, above the average observed elsewhere in this bed and indicates a *swelling up* here, so that while the bottom of this clay is only 60 feet high, the *top* is 90 feet, higher than any stoneware clay outcrop or exposure in this clay district. No. 116 on the general section illustrates these statements.

WARD C. PERRINE'S PITS.

This opening is one of the oldest in this valley, and is situated about 60 rods southwest of Morgan & Furman's mines. It is at the head of a brook, which flows west into the Crossway creek.

The top dirt consists of yellow sand and gravel and a drab-colored, laminated sandy earth, and, in places, a black clay under the above. On the southern side of the excavation there is 25 feet, at least, of *bearing*. Eastward it is not so thick. The top of the black clay on the south side is 62 feet above high tide level. The stoneware clay was not seen. It was said by Mr. Perrine to be 3 feet thick. The heavy *bearing* and thin bed of clay caused the stoppage of work, and the bank has been idle for several months.

WILLIAM HAYES' CLAY PITS.

Hayes pits are down the valley, on its eastern side, and southeast of his residence near the top of the bluff. In these pits the following strata are seen :

(1) Yellow gravel	1–3 feet
(2) Yellow sand	12 feet
(3) Stoneware clay	5–6 feet
(4) Dark drab-colored clay	1–2 feet
(5) Yellowish earthy clay (yellow streaked) at the bottom	

The bottom of (3) the stoneware clay bed is 43 to 44 feet above mean high water. These pits were opened during the past summer. The clay is carted to South Amboy.

North of Hayes' pits deep gullies have cut deeply into the earth, gravel, &c., but have not shown any clay of value, although quite low enough to reach the *level* of the stoneware clay bed. These facts, with the results of borings made by Messrs. Perrine, Rose and Furman along this Crossway brook valley, show great inequalities and gaps where no clay is to be found. There must have been a great deal of erosion, which cut out the bed and left breaks that have been filled by the more recent beds of sand and gravel.

The map and sections indicate the probable existence of the stoneware clay down the valley, southeast of Hayes' pits to the Chesquake, although there are no outcrops or openings. The great length of the upland bluff bordering the tide meadows affords the best of facilities for exploration. Following the bends there is at least three miles of such banks in which searches can be made with some degree of success in discovering clay.

MORGAN'S CLAY BANK.

This old and well-known bank is one mile south of South Amboy, on the shore of Raritan bay. The upland here comes to the water front, the tide meadows disappearing, and in the bluff the stoneware clay bed and the overlying strata of sand, gravel and sandy clay crop out, from here southward to the mouth of the Chesquake creek. The side cut on the New York and Long Branch railroad goes down to tide water level, and shows the clay to that depth. To the northwest, in the old Clark bank, on the Conover tract, the yellow sand and gravel appears at the surface, resting upon the dark-colored, laminated sand, and sandy clay.*

The same surface gravel and sand bed is well exposed in the cut at the side of the railroad for a quarter of a mile northward from Morgan station. This bed is wanting in Morgan's bank and in its place the laminated sand and sandy clay rises to the top of the bluff, and attains a maximum thickness of 40 feet. It may average 25 feet. This bed consists of thin, horizontal layers of dark-colored, *very* sandy clay with much lignite and some pyrite, alternating with layers, or partings of white quartz sand, which are generally, somewhat thinner than the clay layers, the whole forming a quite sandy mass when it has fallen down in the bank and obscured the lamination. This laminated structure is very conspicuous in freshly cut vertical or highly inclined surfaces. The material is useless, excepting to fill pits. The sand might be used if it could be separated from the clay.

* The following layers were observed here when this bauk was worked by Clark & Furman, in 1855, viz.:—(1) Fire sand, 11 feet thick; (2) Black clay (not used), 5–7 feet; (3) Stoneware clay, 9 feet; (4) "Ashy stuff" and lignite, 1 foot; (5) Stoneware clay, 8 feet; (6) Dark-brown clay, full of pyrite, 2 feet; (7) Hard, yellow clay, 3 feet; (8) Sand and water at bottom. The top of (3) was 36 feet above tide.

The stoneware clay bed has a very uneven surface. It is about 25 feet high in the headland, or point east of the railroad and about the same height in Morgan's western pits near the Clark bank. In the other pits the top of the clay is not over 15 feet above high water level. The following is the order of the succession of strata and their thickness at this bank, beginning at the surface:

(1) Laminated sand and sandy clay	40 feet.
(2) Sandy clay (inferior)	8 feet.
(3) Blue, stoneware clay	3 feet.
(4) Red (including "peach-blossom") clay	6 feet.
(5) Stoneware clay (becoming sandy at bottom)	5 feet.
(6) Sand at the bottom	

These (layers, 2 to 5 inclusive) are not all distinct, but variously colored parts of one, the stoneware clay bed. And while this is the order in which they appear most frequently, it is not always the same. Nor do these figures apply to *all* pits. They were the measurements in one pit and are representative. The top, or *bearing* towards the old Clark bank includes a little gravel near the surface. This in some parts of the bank does not exceed 25 feet. From that it varies to 40 feet.

The sandy clay of the top of the bed is inferior in quality and much of it is thrown aside as refuse. The so-called "peach blossom" clay is properly a mottled, red and bluish white clay. It is quite sandy and contains a very little mica in fine scales. It is sold for making saggars, and some of it which is more spotted with patches of red and white, is used in the manufacture of door knobs. The clay under this is considered the best of the bank. Its appearance is very similar to that of the other stoneware clays of the clay district. It becomes sandy towards the bottom and finally grades into sand. This more sandy clay lacks the characteristic, dotted or "fly specked" appearance observed in the best clay found higher up. The *average* thickness of the whole clay bed is said to be 25 feet. It was found to be so in the cut made by the Long Branch Railroad, from which the clay was removed previous to the laying of the track.

The method of excavation here has been somewhat varied. More commonly the top dirt is removed, and then large pits are sunk in the clay, which are in turn, filled by the *bearing* of the succeeding pit and so on. But sometimes a pit is dug and then from it short drifts are cut in the clay bed, after which the top is allowed to fall down and thus fill the excavated space. From the pits the clay is carted at low tide to vessels lying off the shore and thence shipped as ordered. Most of it is sold for stoneware, but a large quantity of it goes to Norwalk, Conn., and elsewhere, to door-knob factories.

The location, right on the shore, but a dock's length from boat transportation, the great thickness of the bed and that nearly all above tide level, affording all the needed drainage and the varying character of the clay, suited to different uses are great natural advantages, which should be connected with systematic and comprehensive management. The unusual thickness of the bed in this bank would appear favorable to the introduction of underground working* or mining, such as is followed by Mr. Ernst in his clay mines on Chesquake creek.

This bank is one of the oldest in the State or country, potters' clay having been dug here before 1800, for the supply of potteries at Old Bridge.

From the elevation of the clay bed here as compared with its heights elsewhere it seems rather lower than would be expected, indicating a greater thickness in general and also some irregularity in it. (See No. 120 on the general section.) From the rate of dip or elevation going northwest, there are good reasons to suppose that this bed can be found further to the northwest beyond the Clark bank, and the steep, upland bluff there offers favorable points for explorations. The heights can be more easily fixed by a careful study of the map and general section.

OTTO ERNST'S CLAY AT SALT WORKS DOCK.

This locality is on the north bank of Chesquake creek a half a mile southwest of its mouth and the same distance from Morgan station. It was formerly worked by the Amboy Clay Company. It has been reopened and worked a little by its present owner, Mr. Ernst. There seem to be two distinct beds of clay here, an upper, which was worked in the bank or side-hill, being from 5 to 7 feet thick and 10 feet above high water level, and a lower

*The extraction by pits and horizontal drifts was practiced more than twenty years ago by Messrs. Clark and Furman in their bank north of the Morgan property, and now owned by Richard S. Conover.

one, which was found, in borings and trial pits, to be 17 feet thick and 12 to 29 feet below the same level. Mr. Ernst reports having prospected this property pretty thoroughly by numerous borings and says that he has found this lower clay confined to narrow limits, not exceeding a few rods square, and running out to nothing in one direction, towards the upland, and to 2 to 5 feet towards the water. This clay he considered very much like that from his mines, which is also partly below tide level.

The clay of this bank is included within the boundary lines of this stoneware clay bed as is shown by the general section No. 124. But the *lower* clay found here is altogether below the horizon of that bed, as also shown by the same section. Either there is here a greater thickness of the whole, as one bed, or there are two separate beds. Both of these explanations are in part correct, as they may be regarded as parts of one bed separated, locally, by deposits of sand, sandy clay, &c., which at other points are wanting and the two are seen together, making a greater thickness, as in Morgan's bank. Inequalities of surface are also evident from these discoveries of Mr. Ernst. These may apply to all the phenomena observed in the several pits along the bay shore and Chesquake creek.

THE AMBOY CLAY MINES—OTTO ERNST.

The banks and mines included under this head are in Madison township, near the head of Chesquake creek, and three miles south of South Amboy. The stoneware clay on this property was opened at first by digging and sinking pits in the upland, where it sloped to the tide meadows, south of Mr. Ernst's residence and southeast of the mines now worked. After following this mode of extraction for several years the proprietors, then holding it, began mining on a small scale, sinking shafts and then removing the clay by cutting short horizontal drifts in the clay bed. In 1868 Mr. Ernst came into possession of the property and continued this system of mining on an extended scale. New shafts were put down west and northwest of the old bank and old shafts, and nearer the head of the little semicircular depression or valley in which all of these clay workings are located. Three of these, put down in 1868, 1872 and 1876 are in line, east and west, and the vertical sections in these, as given by Mr. Ernst, are as follows:

Western Shaft (1872).

(1)	Yellow sand and gravel	7 feet
(2)	"Black stuff," (sandy earth, lignite and pyrite)	2 feet
(3)	Blue quicksand	5 feet
(4)	Good clay	4½ feet
(5)	Good clay (red streaks at top) (main drift)	8 feet
(6)	Good clay	4 feet

Bottom at high water level.

The stoneware clay bed includes (4), (5) and (6), or a thickness of 16½ feet. The place of the drift is represented by (5), while (4) is left as a roof and (6) as flooring to the mine.

The middle shaft, put down in 1868, is 100 feet east of the above and 240 feet west of that of 1876. In this the stratification was reported to be as follows:

(1)	Yellow sand and gravel	13½ feet
(2)	Sandy earth, containing lignite	2 feet
(3)	Blue quicksand	3 feet
(4)	Good clay	3 feet
(5)	Sandy clay	2 feet
(6)	Dark-colored clay	2 feet
(7)	Red clay	2 feet
(8)	Good clay (main drift)	9 feet
(9)	Good clay	5 feet
(10)	Clay (boring)	13 feet

The top of the drift (8) is 3 feet above high water level. Here the worked portion of the bed is represented by (8), but, as this section shows, there is good clay for 5 feet under it.

Shaft 1876.—(East.)

(1)	Yellow sand and gravel	17 feet
(2)	Quicksand	3½ feet
(3)	Blue gravel	2 feet
(4)	Good clay (lower 6 feet main drift)	10 feet
(5)	Sandy clay	5 feet
(6)	"Black stuff"	2 feet

The top of the good clay (4) is 4 feet above high water level. Most of (5) and (6) were determined by borings.

These sections show the stoneware clay bed in its relations to tide level and the inequalities in it. In the middle and eastern shafts the top of the bed is mostly below that level, whereas in the western it is above it. If the higher strata are carefully considered, these apparent differences are explained. Beginning at the west, the yellow sand and gravel goes down 7 feet, or 23 feet above high water level. This is the plane of division between the surface beds (drift) and the plastic clay series. In the middle shaft the dividing plane is 17 feet above tide level. In the eastern, it is only 4 feet. These figures show that there was a cutting out of the upper beds towards the east. The absence of the sandy layers in the east shaft indicates that there the erosion cut down to the good clay. These sections of Mr. Ernst are particularly instructive in this respect; and the slope of this ancient surface corresponded with that of the present surface in direction. It was steeper, being 1 foot in 18, or nearly 300 feet per mile. Looking at the bottom, the sections of the middle and east shafts agree; the other was not deep enough to prove anything as to the uniformity in the bottom of the bed.

In the deep ravine west of Mr. Ernst's residence, and northwest of the mines, there is a white sand and sandy clay in alternating layers, 40 feet thick. A thin layer of moulding sand is at the top of the bank, just under the soil. A dark-colored, sandy clay, containing lignite and pyrite in the form of broken sticks and small fragments, crops out in the bank west of the shafts. No leaf impressions have been found in it. Small pieces of amber are occasionally seen in it. This bed of black, sandy clay was found over the stoneware clay in the older workings near the meadows. The clay bed near the top is sandy and discolored by reddish streaks, as is shown by the above sections of the west and middle shafts. These variations are common, and in some places the mining has found large lenticular-shaped masses of such clay surrounded by good ware clay. One of these measured 75 feet in length and 1 by 3 feet in its other dimensions. The shafts and borings indicate a maximum thickness of 30 feet, but this is much above the average.*

* It is proper here to state, in deference to Mr. Ernst's extensive practical observations and experience in clay mining, that he considers the clay worked in his mines as a large pocket, or deposit, lying in this *recess* among the hills, and that it thins out towards the higher ground. The vertical sections given above may be so interpreted, but the survey of the other clay banks and outcrops in the vicinity of his mines and in the adjacent country do not favor such an hypothesis. And we think a careful study of the map and the general section with the local details of this report are altogether against it, and conclusive in regard to the generalizations respecting the *stoneware clay bed.*

Inasmuch as the mining is confined to the good ware clay stratum and care is taken to avoid cutting through it, the underlying bed of black, sandy clay has been found in borings only.

The mode of extraction by mining has been greatly improved by Mr. Ernst, and the extent to which he has carried it is shown by the map above referred to. The following description of this method of mining the clay, written in 1874, as a paper for the American Institute of Mining Engineers, and printed in their transactions, Vol. III, pages 211–215, is reproduced here in part as applicable to date.

The mining *operations* have been the sinking of vertical shafts, and then the removal of the clay by a system of horizontal drifts. The shafts stop in the clay stratum. On account of the very wet and porous beds of sand and sandy clay over it, the sinking of the shafts was attended with much difficulty. They had to be water tight. To do this the cribbing was doubled, and the intervening space was carefully filled with the best of clay, rammed down hard. This clay filling has been found efficient and, so far, enduring. From the shafts working tunnels have been cut, slightly rising, in order to allow easy drainage and to assist the loaded cars running to the bottom of the shafts. Some of these main tunnels have been cut in 500 feet. They are about eight feet wide and from eight to ten feet high. In driving these, as also in removing the clay from the side drifts, the boring auger is in constant use to ascertain how much clay is in front, as a thickness of five feet is always left below for flooring, and the same overhead for roof. This is rendered all the more necessary by the irregularities in the surface of this stoneware clay stratum, sometimes amounting to differences of 10 to 14 feet from a horizontal plane in a distance of as many rods. To support in part the roof, the ordinary mode of timbering horizontal drifts is employed, the uprights or props with their corresponding sleepers or collars being set from a foot to eighteen inches apart. In some places, for extra security, they are set closer, or they are doubled. Lagging on the sides keeps up the sand filling where the clay has been removed. From the main drifts *laterals* or side drifts are cut at right angles to the former and parallel to one another.

In these the timbering is not so substantial, its object being the temporary support of the roof while the cutting goes forward. Generally the timbering follows closely the extraction of the clay, rarely leaving more than five feet of roof in advance unsupported. As soon as one of these laterals has attained the proposed length, it is filled with sand brought from the surface, and a few yards only from the mouth of the shaft. A second side drift or tunnel is then cut, removing the clay quite to the first, and thus the work of extraction and filling goes on to the further end of the working or main tunnel. These side drifts are rarely more than 75 feet long. One main serves thus for the excavation of the clay from a width of 150 feet, or from an area of 500 by 150 feet, or nearly two acres. Owing to the earthy nature of both the roof and the floor and the weight of the *bearing*, sinking and *creeps* occur, ultimately shutting up the most carefully timbered tunnels. In practice these serve about a year, but this is generally sufficient for the removal of the clay from both sides of it. A second belt is then opened from a new shaft and tunnel. The sand filling has been found quite essential to economical mining, as it prevents the cracking and fissures through which, either in the roof or in the floor, water and quicksand would soon flow in and fill the mine. In a word, this sand filling completely replaces the clay, making the series of beds almost as solid as they originally were, and accidents from such breaks have but rarely happened. The greatest source of danger is in getting too near the adjacent sandy beds, and thus letting in the water. Hence the constant use of the auger to know what is ahead.

The clay is very solid and quite dry, and broad-edged picks, or grubbing hoes, are used to cut it down. The mass thus broken is shoveled into cars. These run on tracks which, in the lateral drifts, are temporary, being taken up and laid in the next drift, when one is finished. A more permanent track is laid in the main tunnel, and on this the loaded cars are pushed to the shaft. Here they are emptied into buckets, which are hoisted by horse-power to the surface.

The ventilation is effected through a board flue, built up one corner of the shaft, and running from the surface down to within three feet of the bottom. A current of air is created by the heat of two or three large kerosene lamps burning at the lower end of this flue. Without this the air would soon be so vitiated that work in the drifts would be impossible. * * * * Ventilation not only supplies good air, but also removes dangerous gases. Several explosions have resulted from these gases when ignited from the candle flames of workmen on entering the mine. Fortunately these have been slight, frightening rather than hurting. From the faint, blue, flickering flame, which can be seen by holding a lighted candle close to the roof, and near the sand filling, where it accumulates, it is supposed to be marsh gas (methyl hydride), mixed very likely with some carbonic acid gas (carbon dioxide) and nitrogen, but no chemical tests have been made, as the amount is so small, and it is not easily collected. The presence of this gas in a clay bed appears at first to be quite improbable, or, at least, anomalous. In this locality, however, the clay bed that is worked is covered by dark-colored sandy strata, which contain much lignite in the form of small stems, with leaves and fine woody matter distributed through it. And this lignite contains some volatile hydro-carbons, as is proved, on dry distillation. The decomposition of the lignite, with an insufficient supply of oxygen, would furnish these gases. Through very small cracks they might find escape into the chambers of the mine, and there manifest themselves in the phenomena observed. Marsh gas, or fire damp, has been noticed in some of the brown coal mines of Europe, and the conditions favoring its productions in the brown coal formations are not very unlike those which exist in the surroundings of this clay mine.

As the clay bed is impervious to water, and the shafts, which cut the overlying porous strata are water-tight, there is practically no water to be raised, at least only that which comes in by accidents, such as are sometimes unavoidable.

This mode of mining clay has been successfully employed by Mr. Ernst for several years. With further improvements in enlarged workings, in the modes of under ground transportation, and in hoisting, greater economy might be obtained. As it is, he gets a superior clay, since there is no mixing with overlying top dirt or inferior clays. Then there are no interruptions caused by slides, inclement weather, &c., common to open workings. In addition to those advantages, the mining goes on night and day, thus doubling the capacity of the same area in a given time.

One disadvantage will be evident at once. For every 8 feet of clay taken out, 10 feet (5 feet below and 5 feet above) is left. But as the area of clay land is yet large, this is not so serious nor objectionable.

The rapidly diminishing area of clays at depths easily accessible by open diggings, and the increasing value of superior clays to meet the large demands in making fire brick retorts, sewer and drain pipes, and the manifold forms of pottery, demand greater economy in mining them, and this mode, so successfully employed, ought to be more general, for it would extend vastly the workable areas of valuable clays and thus contribute to our mineral wealth.

The composition of the best average clay of these mines is as follows:

Alumina	20.20	
Silicic acid	28.80	
Water combined	5.80	
		54.80
Sand (quartz)	39.95	
Titanic acid	0.90	
		40.85
Potash	1.58	
Soda	......	
Lime	traces.	
Magnesia	0.50	
Sesqui-oxide of iron	1.45	
Water (moisture)	1.20	
		4.73
Total		100.38

The specific gravity of this clay is 1.971–2.138. It has the "fly specked" appearance, characteristic of this stoneware clay bed. The sand in it is very fine grained quartz. Mr. Ernst's practice is to keep his mining considerably ahead of the immediate demands, and in this way he keeps a large stock of clay on hand. And by the exposure of some months he thinks it is improved in quality.

The clay is carted a half a mile to his dock on Chesquake creek, whence it is shipped to all points on the Atlantic coast from Maine to Texas. It is known in the market as "mine clay" in distinction from pit clay.

NOAH FURMAN'S CLAY BANK.

A half a mile south southeast of Ernst's mines there is the old bank of Noah Furman, which was described in the Geological Survey report of 1855, page 72, as showing:

(1) Sand	3–10 feet
(2) Black clay	10–15 feet
(3) Stoneware clay	14 feet

This bank has not been worked much since that report was made. This top black clay includes in its mass a great deal of lignite and pyrite.

MORGAN ESTATE BANK.

This is southwest of the above described locality and at the border of the marsh. According to the same report, this bank cut the following materials:

(1) Sand	15–16 feet
(2) Black clay	7 feet
(3) Stoneware clay	10 feet

No work has been done here lately. At both this and the last mentioned banks the clay bed was found partly below the level of tide water.

NOAH FURMAN'S CLAY MINES.

These pits or mines are at the head of Chesquake creek, near the old Morgan bank, and about a mile northwest of Jacksonville. They were opened about eleven years ago. They are in the upland, near the marsh, and the surface is 20–30 feet above mean high tide level. In one of the shafts the top of the stoneware clay was found at an elevation of 20 feet; in a second shaft, 100 yards west of the first, it was at nearly the same height (19.5 feet) above the same datum plane, mean high tide level. The surface here is sand and gravel; then there is a black clay full of wood and pyrite, and containing some leaf impressions, 3–6 feet thick; then the stoneware clay 5–7 feet, and at the bottom a white sand. These heights correspond with the place of the bed as determined by its dip, and its elevations at other points. (See general section Nos. 121 and 123.) The extraction is here mostly by under ground tunneling, or mining, proper. A vertical shaft is sunk to the bottom of the clay bed, and this is well timbered. Drifts, generally 100 feet long, are cut from this shaft into the clay, which is in this manner taken out. By means of a succession of such drifts the bed is worked out, excepting a stratum left at the top as a roof, and another at the bottom, as floor. No particular care is taken to keep these drifts after excavation, and consequently they soon fall in, and thus become filled with the material from above.

This clay has the same characteristic physical qualities that belong to the stoneware clays in general. Its specific gravity is 2.012–2.022, and it is, on the average, a little more sandy than that of Ernst's mines, or that of Rose's pits. A selected specimen has the chemical composition seen in the following analysis:

Alumina	21.13	
Silicic acid	29.23	
Water (combined)	6.81	
		57.17
Sand (quartz)	37.85	
Titanic acid	1.00	
		38.85
Potash	1.81	
Soda	0.18	
Lime	......	
Magnesia	0.22	
Sesqui-oxide of iron	1.68	
Water (moisture)	0.69	
		4.58
		100.60

This clay is carted to the dock on the creek, about one mile distant. It goes to potteries for stoneware.

THEODORE SMITH'S CLAY PITS.

These pits are in Madison township, a half a mile east of the Camden and Amboy railroad, and 1½ miles northwest of Jacksonville. The ground here and towards the south is 30 to 40 feet high, rather flat, and drained by the headwaters of Prickett's brook, a tributary of the South river. The *bearing* on the clay is about 9 feet thick, of which the surface layer—2 feet thick—is a moulding sand; the remaining 7 feet is common yellow sand. The top of the clay bed has an average elevation above tide level of 40 feet. Its thickness is between 3 and 10 feet. The top spit is very sandy, and is thrown aside as waste. Towards the bottom also it grows sandy, and under it there is a laminated sand and sandy clay. There is some pyrite and lignite in the lower part of the bed. All of the clay is carefully sorted so as to avoid the pyrite, which occurs occasionally in all parts of the bed. The greater portion of what is dug in these pits is sold for stoneware. It is carted to a siding on the Camden and Amboy railroad half a mile west of the pits.

As can be seen on the section, No. 118, the height of the clay bed here coincides with the lines drawn, enclosing it at the proper dip, and these lines projected to the surface would indicate an area of available clay land south of these pits in the low, flat ground which extends southward to Tennent's brook and westward in a narrower belt to the railroad.

CHARLES B. REYNOLDS' CLAY.

Reynolds' pits are in Madison township, near the head of Jernee's mill pond, and about two miles west-southwest of Jacksonville. The surface of the country hereabouts is flat, and does not exceed 30 feet in height above tide water. The clay dug here is covered by a sandy loam and yellow sand to the depth of 3 feet. It is 5 feet thick. It is quite sandy, and near the surface is streaked with yellow earth. The best is drab-colored, sandy, and dries quite white. It wants the speckled appearance observed in the stoneware clay of the pits above described.

Only a few small pits have been dug. The clay from these has been carted to the pottery at Matawan, where it has been used, mixed with Furman's clay, in making stoneware.

The clay here, so near the top of the ground, appears to have been somewhat changed by surface agencies acting upon it. It looks more like a local deposit of recent age than it does like the regular stoneware clay bed of the plastic clay formation, yet its elevation and geographical position agree with the latter. Future exploration of the country between Tennent's brook on the south and as far northward as Smith's pits, will show either a more or less continuous bed of clay, or the isolated and entirely local character of this outcrop, and separate from all others. In the latter case it will most likely be found to be of a more recent formation, possibly of the drift. Its place in the general section, No. 125, and its location on the map illustrate these statements in part.

CHAPTER II.

EXTENSION OF THE MIDDLESEX CLAYS ACROSS THE STATE AND ALONG THE DELAWARE RIVER.

Southwest of the clay district of Middlesex county, as that district is represented by the map accompanying this report, white clays have been found in a few places, although not to an extent that has led to any developments other than the few trial pits put down to test these surface indications.

The following notes of these localities are here inserted as a record of facts accumulated. They indicate an extension of the plastic clay formation southwest, and are the connecting links between the Middlesex county district and the outcrops along the Delaware river. They are presented as the basis for further exploration, which, it is hoped, will demonstrate without doubt this extension, and still further enable the geologist to identify entirely across the state the several sub-divisions, as now recognized in the former district. Beginning at the northeast, a little light-colored, tough clay is cut in the road ditch on Rider's lane, ascending the hill south of Lawrence brook. This lies on the red-shale. It is of no practical importance as the layers are thin and uneven.

South of this and about 250 yards north of the old mill (Kraner's) there is an outcrop of this clay in the side of the road. Here its extent is not known.

Up the valley of Lawrence brook there are several outcrops. One of these is in the road, crossing the stream, about a quarter of a mile east of Milltown and a few rods south of the brook. Another is on the same side of the brook, in the road, a quarter of a mile east of Parson's snuff mills. Clay was once dug at the latter place and used in fulling cloth. The surface material here is spotted, blue and white, with yellowish stains of oxide of iron. It is quite sandy and micaceous and looks like a mixture of blue clay, white clay and some earthy material, derived from the wear of older clay beds. Near the brook, north of it, red-shale crops out, so that the clay must be close to this rock. Its height above tide level (about 30 feet) conforms to the elevation of the Raritan clay bed, assuming that to extend this far to the southwest and to have a uniform strike and dip.

One mile west of Parson's mills, and a short distance south of Lawrence brook, on the road to Dunham's Corners, clay was found in digging J. Hoy's well. It was near the bottom, and 20 feet deep. North of Hoy's place, and on the opposite side of the stream, there is an outcrop of yellowish-white and tough clay, but of limited extent. Its laminated structure and its position indicate the bottom of the Raritan bed. The red-shale is seen very near it, in the same little ravine a few rods east of the main road.

Another outcrop of clay is on the Cranbury road, on lands of Ross Drake, two miles southwest of New Brunswick. Here a white clay was cut in the ditch on the road, and also in the lot south of the road. At the latter place it was within two feet of the surface of the ground, and the layer was two feet thick. It was also encountered in digging a well at Drake's house. This clay was mixed with sand and a little earth. The red-shale crops out a few rods east of this. It appears to be a part of a thin sheet of clay which has here been left upon the shale, and the indications do not favor any workable amount.

There are probably other points on this border of the red-shale along Lawrence brook where white clay may be found cropping out in the road ditches, in the little tributary brooks of the main stream, and in its south bank. All of these are very close to the red-shale, and, so far as their appearances and characters indicate, are small areas of a once more or less continuous bed, and that the Raritan clay bed As the course of Lawrence brook is parallel to the general strike of the clay formation, and lies in the red-shale near its southeast border, the valley which it follows does not afford such opportunities for exploration as streams which cross the strata. As it is, only the lowest member of the plastic clay series is to be found along its valley.

Going further south, a yellowish-white clay crops out in the ditch just below the old dam at Pettey's distillery, a half a mile southeast of Woodsville, in South Brunswick township. The thickness of the layer has not been tested. That at the surface is very white and almost free from grit. Some of it is, however, more sandy and micaceous, and looks like *kaolin*. This outcrop, so far to the southeast of the red-shale border and near the middle of the clay belt, must belong higher in the series, possibly as high up as the South Amboy bed. But these are scarcely more than conjectures in our present want of facts. This locality is interesting and promising, as it can be so readily tested. A little boring or digging would determine the extent and thickness of the deposit.

So far as can be learned from residents and well diggers of this country, this is the only white clay known in that part of the clay belt south of Lawrence brook. The deep wells at Dayton and Rhode Hall, some of them over 50 feet, pass through sands and gravels, but no clays. In the lower lands bordering the Millstone river and the Cranbury brook the surface is partly alluvial in character and partly drift. These low lands are more easily bored or tested than the higher hills, nearly all of which are of drift and cover the regular strata thicker. At Cranbury a dark drab clay has been cut in a few wells, although some of the deepest were in sand and gravel only, indicating clays of local extent and probably a part of the general drift covering. Explorations could be easily made in the flat and lower ground along the Millstone river, near the Cranbury and Locust Corner road; on J. D. Grover's farm, one and a half miles south of Plainsboro, and at Swaenger's mills, in West Windsor township, Mercer county.

TEN MILE RUN CLAYS.

This locality is a half a mile south of Ten Mile Run, in Somerset county. The diggings and borings were made on the lands of Isaac Webster and W. E. Baker at the side of the Ten Mile Run and Kingston road. The clay crops out in the side ditches of this road and also gives character to the soil over quite a large area of land to the east of the road, towards the Sand Hills, in Middlesex county. In the pits of Mr. Webster there was a gravelly and sandy earth at the top, which was 5 to 6 feet thick; then the clay which was 11 feet, in the pit, and in a boring, 3 feet additional, making in all, a bed 14 feet thick. Several borings near the pits showed 7 to 14 feet of clay within an area of three or four acres. Red shaly materials brought up by the auger from the bottom indicated red-shale as the *bed rock.*

This clay is quite hard and dry, breaking up into shaly fragments. Portions of it are very white and fine. In places it is bluish white and mottled. Oxide of iron is seen in filmy coatings on some of the cracked surfaces. Its specific gravity is 1.607—1.612.

An analysis of the very white and best clay of the pits gave the following results:

Alumina	35.09	
Silicic acid	38.20	
Water (combined)	12.10	
		85.39
Silicic acid (sand)	8.60	
Titanic acid	1.30	
		9.90
Potash	2.44	
Soda	....	
Lime	....	
Magnesia	0.21	
Sesqui-oxide of iron	1.89	
Water (moisture)	....	
		4.54
Total		99.83

These figures show a rich clay, but contain too much oxide of iron and potash to be refractory or of much value in the manufacture of pottery. Very little has been dug, and that in these trial pits.

South of Webster's pits on the Gulick estate a white clay bed, 7 feet thick, was passed through in digging a well, about fifteen years ago. It was covered by sand and gravel and earth to the depth of 10 feet.

It is reported that clay was found in digging a well several years ago, at the upper Ten Mile Run school house, on the old Rocky Hill road.

Mr. Webster dug and bored on his farm near the Gulick house, but found gravel and "hard pan" only. On the west side of his farm he found a yellowish brick clay 2 to 3 feet thick resting upon "hard pan." Less than a quarter of a mile north of these several openings on the Webster farm, the red-shale crops out, forming the surface in the fields and appearing in the road to Ten Mile Run. Southward, towards Kingston, the trap rocks appear. The wet, tight bottom lands and the white oak timber east of the road, indicate an extension of the clay to the Sand Hills. The elevation of this clay above tide level, according to aneroid measurements, is 240 feet. From its position upon the shale this clay is the equivalent of the Raritan clay bed of Middlesex county. Prolonging the line of strike of the bottom of this clay bed at tide level southwest, this locality is three and a half miles northwest of it. From that line a rise of 60 feet per mile would place that bed 210 feet above tide water, which does not differ many feet from the actual height of this clay. This agreement in elevation together with its relation to the red-shale and its composition, all show that this deposit belongs to the Raritan bed. The trap rock and shale outcrops on the north, west and south, and the Sand Hills on the east, surround this clay holding it in a basin-like depression. The eastern and southern connections with the same bed, as seen elsewhere, have been removed, and in this manner this mass or pocket has been left isolated and closed in by these trap rock ridges and the great pile of drift of the Sand Hills.

Proceeding southwest the next outcrop of interest and importance is on the Pennsylvania Railroad, one mile south of Princeton Junction, where at the bottom of a low cut there is a sandy white clay mixed with coarse grains of glassy quartz and very small mica scales, a material resembling somewhat the *feldspar* of Middlesex county. It is, however, finer grained and more sandy than that. A similar mixture appears in another cutting on the same line of railroad, near the Clarksville road crossing. This is covered by a reddish, clayey quartz gravel, which is characteristic of the surface of the hills and knolls in this part of the belt.

J. H. Everett, at Lawrence Station, Mercer county, says that a white clay was cut in the railroad ditch about 200 yards northwest of his residence. Also, in digging for water at a small house near the station, clay was found from the surface down to a depth of 8 feet where the work stopped. None was found in digging a second well a few yards distant from the site of the first attempt.

Near Clarksville, whitish, sandy clays crop out north of the village, on the Port Mercer road, and also southwest of it on the straight Trenton road. But these look more like drift clays, and are not so promising localities for searches as those above mentioned, which are near the railroad.

Mr. Walker, of Van Hiseville, who has dug many wells in this belt between the Millstone and the Delaware rivers, says that he has not found any white clays, except in thin streaks, although some of these wells are between 25 and 40 feet deep. The surface in the triangle between Van Hiseville, Lawrence and Dutch Neck, is a stiff clay loam. Along the Assanpink creek there is the wet alluvial tract, known as Bear Swamp. In Hamilton township the surface is more sandy. These superficial beds conceal the older strata, and in the absence of explorations leave us in doubt as to the underlying rocks or beds. The clay of David Rulon, near Hamilton Square, and that of South's pits, along Pond Run indicate the existence of clay in places, if not in a continuous formation. The surface along Miry Run is also flat, and much of it of an alluvial character, but this does not appear very deep, and in Washington township, at James Hutchinson's mills and for a mile thence down the stream, the pits or borings would not have to go so deep to reach the strata in place, and thus determine the geological structure of this part of the country.

Clay is said to have been found on the farm of Edwin Chambers and on the T. Combs' estate near Miry Run, but nothing further of the extent or character of these reported discoveries could be learned. The higher ground at Hamilton Square and in Hamilton township is sandy and gravelly, and is probably drift to a greater depth.

DAVID RULON'S CLAY.

Rulon's pits are one mile west of Hamilton Square, and a quarter of a mile southwest of Mr. Rulon's house, in the flat ground drained by a branch of Pond run. The *bearing* on the clay is sand and gravel, and of varying thickness, but not generally exceeding 6 feet. The upper part of the clay bed is yellowish; the middle, red; and at the bottom, white or bluish white. The so-called red clay is, properly, fine, mottled and streaked red and white, and includes small, reddish masses that look like red-shale.

All of the clay of these pits is sandy, but the sand is fine-grained. That from the bottom is considered the best. White sand is found under the clay, in the bottom of the pits. This locality was first opened about four years ago. The clay is carted to Trenton, and used in making saggars. It sells at about $2.00 a ton. As the digging has been coupled with the work of the farm, it has been done at intervals of farm leisure, and the amount dug has not been large.

DANIEL SOUTH'S CLAY PITS.

South's pits are about three miles east of Trenton, and near Pond run, a tributary of the Assanpink creek. In the pits near the farm house the clay is white, and is deeply covered by sand and gravel. The first opening was in these. The later digging has been a quarter of a mile north northeast of the house, in the low ground bordering Miry run. At these pits both red and white clays are dug. They are quite sandy. None of the pits are more than 20 feet in depth, including a few feet of top dirt. Most of them get through the white clay and stop in the red clay. All of these clays are carted to Trenton and used principally in the potteries, in making saggars. Here, also, the clay digging is subordinated to the work of the farm proper, and the product of this place is comparatively small.

These clays of Rulon and South are placed, without much doubt, in the Plastic Clay Formation, although their exact place in it is not at all certain. They probably belong to beds which crop out in the bluff southeast of Trenton, along the Delaware river, although at present it is not possible to identify them there.

CLAY BANK OF AARON C. ANDERSON & COMPANY.

This bank is two miles northeast of Trenton, north of the Assanpink creek and about 100 yards north of the Delaware and Raritan Canal. The top dirt is gravelly and imbedded in it are many quite large boulders of white and jaspery quartz and blue flint. Immediately upon the clay bed there is a layer of these flinty boulders. Both the top and the bottom of the clay bed are uneven and consequently its thickness varies considerably, but does not exceed 23 feet. The bottom is about on a level with the water of the canal, or 50 feet above mean tide level. The upper part of the bed is a mixture of white clay with sand and fine white gravel. It hardens on exposure when laid on walks or roads and for such purposes is admirably adapted, making not only good but very pretty walks and roads. This clay gravel sells at 75 cents to $1.00 per ton. Under this gravelly part of the bed there is a mixture of white clay and fine white quartz grains and angular masses. It is not properly a clay, but more like a true *kaolin*. It is used in the Trenton Fire Brick and Terra Cotta Works of O. O. Bowman & Company, and sells at $2.50 per ton. At the bottom of the bank there is some reddish clay of inferior quality which is not used.

The crude clay has to be washed to get rid of the sand and quartz masses, for finer uses. The washed residue is white and fine clay. Its chemical composition is shown by the following analysis taken from the Geology of New Jersey, page 683:

ANALYSIS.

Alumina	37.10
Silica	45.30
Water	13.40
Potash	1.30
Lime	0.17
Magnesia	0.22
Per-oxide of iron	1.30
Zirconia*	1.40
Total	100.19

The flint boulders lying on the white clay are broken up and sent to the potteries in the city, bringing $5.00 a ton. They are from 1 to 2 feet in diameter. Some of them are remarkable for the purity of the quartz, hence their value in the manufacture of white ware. All of the beds exposed in this bank consist of unsorted materials, and show little, if any, evidences of travel. It is very probable that they are, in part, the result of decomposition and disintegration of strata belonging to the gneissic formation underlying this portion of the State.

* A re-examination of our New Jersey clays proves this constituent, which was then supposed to be zirconia, to be a compound of titanium. (See Part III, on the composition of clays.)

There is a sand pit in the adjoining field, east of Anderson's bank. The surface is lower, only a few feet above the canal level. But little of it has been dug lately.

Along the Delaware river, south of Trenton, dark-colored clays crop out near the foot of the upland bluff and the border of the tide meadow. This so-called "upland bluff" gradually rises going from Trenton, and near the residence of Dr. C. C. Abbott is 70 feet above the river flood plain. Thence on to the Crosswicks creek bridge it slowly descends. Throughout this whole distance it is very steep and precipitous, and is made up of a yellow sand and gravel, resting upon the clays. On Isaac De Cou's farm the bank has been cut into, and some clay has been taken out. Here the sand and gravel is between 20 and 30 feet thick, with some thin layers of sandy clay near the bottom. The sand is very sharp-grained. Some of it has been used in Trenton as core sand and for other purposes. Feldspathic nodules, with a hard, shell-like exterior, and soft interior mass of *kaolin*-like materials, are quite abundant in this gravel and sand bed. The top of the clay outcrop is 20 feet above the river, or tide water. The clay of the upper part of the bed is dark grey to black, with mottled and more sandy masses. Nodular aggregates of pyrite and lignite are common. Leaf impressions also appear to be quite abundant in this upper, darker-colored clay, but none of them have as yet been studied in their botanical relations.

This bank was first worked about ten years ago. The clay was taken out by tunneling in the side hill. Some of these horizontal drifts were 200 feet long. The roof was supported by timbers. After having been worked in this way for two or three years the bank was abandoned on account of the cost of timbering. The clay was carted to Trenton and worked up into saggars and terra-cotta ware.

On Dr. Abbott's farm a tough, yellowish-white clay crops out in the bed of a small brook, a few rods west of his residence. An unusually heavy rain, during the past summer, lowered the bed of the little brook from two to four feet, and exposed this clay for several rods along its course. From this wash the bed appears to be of considerable extent, and of workable thickness. An analysis of an average sample shows the following constituents:

Alumina and titanic acid	19.43
Silica (including sand)	70.05
Potash	1.60
Sesqui-oxide of iron	1.52
Water (combined and hygroscopic)	7.00
Total (determined)	99.60

In composition there is a close resemblance to the stoneware clays of Middlesex county, and, theoretically, it belongs to that class of clays. It is important that it be tried for some such use —for pottery, or for saggars, or pipe. The apparently workable extent of clay of this quality, point out the locality as a promising one.

No exploration or working has been done here. This clay outcrop is higher than that in DeCou's bank, and it is probably underlaid by the darker-colored bed, which is worked at the latter place. The lower part of the bluff is to be explored for this bed.

On the farm of E. Abbott's heirs, southeast of this, there is clay in the bluff.

ISRAEL LACEY'S CLAY PITS.

These are about half way between Trenton and Bordentown, near the Crosswicks creek draw bridge, and west of the road. They are in the low ground near the border of the tide meadow. Mr Lacey says that he found the clay 27 feet thick and under it a sand. This clay was dark-colored and sandy. East of this bridge and the road and also on the north side of the creek no outcrops of clay are seen, but yellow sand and gravel.

At the Albion mill, five miles southeast of Trenton, white clay and sand were observed by Prof. Henry D. Rogers in the First Geological Survey of New Jersey and mentioned in his Final Report, page 183. It was a rather sandy clay and supposed to be unfit for stoneware, but good for fire brick mixtures.

This river bluff or upland bank offers facilities for *mining* clay as a more practicable mode of extraction than digging pits as the thickness of the overlying sand and gravel is such as make the latter mode of working expensive, and only possible where there are thick beds of valuable clays. And thus far no such clays have been discovered here. Clay beds may yet be found nearer the surface, or as this bank is worked back those already known, may be found to rise and the top dirt, or *bearing*, to decrease in thickness. Inasmuch as this ground is not thoroughly understood, explorations are very desirable to determine its geological structure and the practical value of its strata. The Delaware river in its east southeast course from Trenton to Bordentown has cut across the plastic clays to the clay marls, thus making a good cross section of the former. At Bordentown the river bends towards the west and thence flows on the line of strike as far as Kinkora, where it is still more deflected towards the west and then west northwest, again cutting the strata of clay, but in this course, obliquely to the strike of the clay formation. This continues to Florence where it resumes its general southwest direction. This curving course of the river has twice cut across the clay formation and shown it in contact with the clay marls at several points. From Bordentown to Kinkora the bluff is steep and high and the beds of dark drab-colored clays are seen nearly the whole distance, although in many places the slides of the upper layers and surface washes have obscured the stratification and made the whole look like one bed, or uniform mass from the top down to the railroad and river line. The dark-colored clay which in this way appears to make up the whole bank is very sandy and is marked throughout by the presence of pyrite and lignite. The following strata were observed in a clean face of the bank, back of the Pennsylvania Railroad Company's freight car shop, about half a mile south of the Bordentown (lower) depot.

(1)	Yellow sand and gravel with some clay streaks	8–10 feet
(2)	Clay marl (green sand)	5 feet
(3)	Black, sandy clay, full of pyrite and lignite, alternating with layers of white quartz sand	35–40 feet
(4)	White quartz sand at level of railroad track	

This latter level is about 10 feet above mean tide.

The clay-marl at the top is a dark-colored and sandy bed, characterized by the green sand in it. The clay immediately under it contains much sand and many *crusts* of oxide of iron; sand and clay cemented together. Lower down, this bed shows much pyrite, which is commonly in irregularly rounded, or elongated masses. The sand layers are thin, generally, and are interbedded irregularly with the thicker clay beds. Towards the level of the railroad these alternations of sand and clay are particularly sharp and distinct; the former dark-colored and varying from half an inch to an inch in thickness; the latter, of clean, white sand, and often not thicker than a knife blade, appearing as mere films, or coatings, just enough to separate the clay into these thin sheets. There are, however, some thicker layers of this sand, especially towards the bottom of the bank. But this thin bedding or lamination is a character of the whole 30 feet, or more, of the bank under the clay marls. The white sand seen at the railroad line is said to extend down to the river, or tide mark, and even lower.

At White Hill the stratification of the bank, as it appears at the north end of Willard & MacPherson's forge building, is as follows:

(1) Yellow earth and gravel	8–10 feet
(2) Clay marl	6 feet
(3) White sand containing red oxide of iron crusts	12 feet
(4) Black sandy clay alternating with thin layers of sand	12 feet
(5) White sand from railroad track level to tide level	10 feet

Here also the alternations of clay and sand are very clearly marked, and very regularly bedded. Forty distinct layers were counted in a vertical section of 3 feet of the bank. This was near the level of the railroad track. Just over it there is a single bed of clay 3 feet thick. This is dark-colored, tough, and is found very serviceable in the forge.

About a quarter of a mile southwest of the forge building, the bluff section is very much like that described above, wanting, however, the clay marl at the top, and showing more white sand at the bottom. This sand is so clean and fine that it looks as if it might be put to some use. The upper clay layers contain a great deal of lignite in small pieces.

At the ice houses, and near the mouth of a large brook, the bottom of the clay marl is 28 feet above mean tide level. This is lower than the same bed appears at White Hill, due to the more southeasterly position of the former, in which direction the bed descends, or *dips*. The bank near the Kinkora depot, consists of clay marl, 6–8 feet thick; black, sandy earth, 8 feet; and white sand, 10 feet. Fifty yards south of this point the clay marl appears on top of a dark-colored, astringent clay. Under the latter there is a white, but very sandy, clay, of which a few tons have been dug and sent to Trenton.

CLAY BANK OF MULFORD & PINE, KINKORA.

Here the clay marl comes quite to the surface, and is 6 feet thick. It lies on the laminated clay and sand bed, under which, at the bottom of the pits, there is a white sand. The marl and clay are mixed together, and made into common, red brick. The same thin layers of clean white sand and thicker beds of clay are seen here also. A few feet under this sand, at the bottom of the pits, there is said to be a sandy, light-colored clay. Tide level is about 10 feet below the bottom of the pits. The adjoining cut on the Columbus and Springfield railroad, shows a section similar to that of the pits.

The composition of this clay is as follows:

ANALYSIS.

Alumina	17.70	
Silicic acid	25.50	
Water (combined)	11.80	
		55.00
Silicic acid (sand)	31.80	
Titanic acid	0.90	
		32.70
Potash	1.54	
Soda	......	
Lime	0.16	
Magnesia	0.65	
Sesqui-oxide of iron	6.40	
Water (moisture)	3.50	
		12.25
Total		99.95

This represents the constitution of the laminated sand and clay. The percentage of combined water shows a composition unlike that of the fire clays. The percentage of oxide of iron also is larger than it is in the latter.

In the brick clay bank south of the creek at Kinkora, there is a thick bed of tough, black clay, quite free from lignite and pyrite, but there is no clay marl upon it. This is lower than the pits of Mulford & Pine, and near tide level. Denudation has probably removed the clay marl from the immediate valley of Craft's creek, at this point.

These sections, here given, as well as others which could be added, between Bordentown and Kinkora, show very beautifully the contact of the clay marls and the plastic clays, and the upper members of the latter series.

West of Kinkora there are no bluffs for half a mile or more, but round knolls and a sandy surface, sloping gently northward to the river. Further west the ground rises, and there is a bluff fronting the river, from 30 to 75 feet high, and running northwest to the steamboat landing. At the foot of this bluff, clay is dug by Joshua Eayre and H. I. Tinsman.

JOSHUA EAYRE'S CLAY BANKS.

The openings are about a half a mile northwest of Florence station. At the extreme end of Eayre's eastern bank several pits have been dug in a very tough black clay which is free from lignite and pyrite and is 4 feet thick. A few rods west of this is the main stoneware clay bank. In this there is at the top yellow sand with some gravel, from 20 to 25 feet thick; then a bluish white clay bed which is 9 feet thick. This is thought to be the best clay of the bank. Under it, at tide level, there is a white sand. The clay is rather sandy, but the sand in it is fine grained. It dries white. The cost of extraction is increased by the labor of removing so much top dirt.

At the western opening, 500 feet west of that described above, the strata are in the following order, beginning at the top. The thicknesses are approximately:

(1) Yellow sand, in undulating, wavy lines	16 feet
(2) Gravel	2 feet
(3) Reddish and variegated clay	18 feet
(4) White clay	4 feet
(5) Clay and sandy earths	2 feet
(6) White sand (called *kaolin*)	6 feet
(7) Sand at mean tide level	

The best white clay of the bank has the following chemical composition:

ANALYSIS.

Alumina and titanic acid	21.06	
Silicic acid	26.57	
Water (combined)	5.80	
		53.43
Silicic acid (sand)	40.50	
		40.50
Potash	2.47	
Soda	0.21	
Lime	......	
Magnesia	0.60	
Sesqui-oxide of iron	1.98	
Water (moisture)	0.80	
		6.06
Total		99.99

Its specific gravity, 1.989—2.023.

By referring to the analyses on page 72 of the stoneware clays of Middlesex county, it will be seen that these figures correspond closely with those. This contains a little more potash, and also more iron oxide.

In places the clay is reddish and such is sold for saggers and to foundries. Its average price is $1.75 a ton. The bottom of the bed is more sandy than that represented by the analysis given above.

As these openings are in the river bank or bluff, there is no expensive handling beyond the wheeling from the bank to the boats, which can approach within a few rods of it. The most of the red clay and the more sandy white clays are sent to Trenton. Some of the best grades are sold in Philadelphia and in the Lehigh Valley, mostly for stoneware, bringing $3.00 per ton. A more recently cut bank shows:

(1) Sand and earth, with gravelly layers near the top of the bank	30 feet
(2) Black, sandy clay, full of lignite	6 feet
(3) White clay becoming sandy towards the bottom and at length grading into a *kaolin*	

Some of the sand in (1) can be used in tempering clay for red brick.

Some of the white clay is quite refractory and is used as a fire clay. A little of it has been made into retorts. The *kaolin* has very little mica in it, and it reaches down to the tide level in the river. The sales from Eayre's banks in 1874, amounted to 3,000 tons, including the *kaolin*.

West of this Mr. Eayre says there is much red clay, and that it is found all along this bank to the steamboat landing.

HENRY I. TINSMAN'S CLAY.

This opening is about 300 yards west northwest of Eayre's banks. The bluff here is about 30 feet high and shows the following layers:

(1) Sand	15 feet
(2) Black clay, with lignite	5–8 feet
(3) Bluish white clay, with some included masses of red clay in it	12 feet

The latter reaches down to tide water. Lignite is very abundant in certain layers, especially in the form of flattened branches, which lie with their longer diameters horizontally, as if they had been flattened by the pressure of the overlying beds. Leaf impressions are said to occur both here and in Eayre's banks, but none were obtained or seen at the time of our visits. This bank was opened three years ago.

Back of the Hygienic Institute the bluff is estimated to be 75 feet high, and the clay rises from the water's edge to a height of 35 feet or nearly half way to the top. Above this there is sand and sandy clay in thin layers for 20 feet. In this latter bed the layers of sand are from several inches to a foot thick, while those of the clay alternating with the sand do not exceed two inches. At the top there is the common, yellow sand and gravel of the country.

The laminated clay and sand bed seen in this bank, is considered the same as that which is cut in the clay pits at Kinkora, and which crops out under the clay marl, at White Hill and at Bordentown. Here it succeeds the stoneware clay, and affords us a clew to the order of the several beds observed along the Delaware river. The equivalency of these beds with some of those of the Raritan bay shore, between Morgan's bank and the Chesquake creek, has been discussed on page 225.

West of Florence Heights some clay has been dug near the foundry wharf, on McNeel's lands. Here, and also west of this, on the point, the ground is low and descends gently to the river.

At William Lanning's house, Florence village, the following were the beds cut through in digging a well:

(1) Sand	7 feet
(2) Moulding sand	4 feet
(3) Chocolate-colored clay, growing sandy towards the bottom	8 feet
(4) Quicksand at the bottom, 43 feet deep, which is about on a level with mean tide.	

A black, sandy clay is very commonly reported in well digging about Florence and Florence station, at depths of 15–25 feet beneath the surface. The sandy soil, and loose nature of the surface generally, at Florence and westward to the river, give no indications of the clay strata which underlie the whole district. From the point the course of the river is a few degrees west of south, but there are no clay outcrops, only the superficial beds of sand and gravel, and there is no bluff along the river.

BRIDGEBOROUGH CLAY.

A little clay has been dug near Bridgeborough, on the Rancocas creek, in Cinnaminson township, Burlington county.

Charles Hampshire's pits are a quarter of a mile east of the village, and near his residence. In the western pits, which are near the creek, there is only a thin covering of soil on the clay bed. The clay is 12 feet thick. It is red and mottled, some of it consisting of a mixture of red and yellowish-white masses. Although sandy it is a tough and strong clay. Under this there is a layer of white sand about a foot thick, and under that a sandy white clay, but the digging rarely gets deeper than the sand layer. The red clay is sold to terra cotta manufacturers and to iron works, at $1.50 to $3.00 a ton. The eastern pits are also in the low ground, but a few feet above tide level. At these a sandy white clay is dug. Over this there is a sandy clay, streaked with yellow dirt, and a layer a foot thick of black clay, making altogether 5 feet of top dirt. The clay bed rises slightly going back in the bank, towards the house, where the surface is not over 12 feet above tide level. These pits were first opened about four years ago.

Joseph Austin's pits are one mile east of those of Hampshire, and also close to the south bank of the creek. No digging has been done lately, and the locality has not been visited. The clay was described as light-colored, sandy and suitable for some kinds of pottery.

Current rumor says that there is clay on the Austin farm, west of Bridgeborough. None has been dug. The surface of the country on the south side of the stream, about Bridgeborough and west to the Delaware river, is very sandy. The highest points are not 20 feet above high water mark, and the slopes are all very gradual, so that there are no favorable outcrops or natural sections. These clays at Bridgeborough resemble those of Florence Heights, and they belong in the plastic clay formation. Their location, west of the outcrops of the clay marls and on the line of strike of the clays, shows their relation to the latter in general, although it is impossible to determine more precisely their true geological horizon in the clay series.

HYLTON'S BANKS.

These banks are on the south of the Pensauken creek, in Camden county, and one and a quarter miles south of Palmyra. The bluff here along this stream is about 80 feet high, and in this, from the Pennsylvania railroad bridge eastward to the wagon bridge, the strata are very finely exposed to view. The general northwest course of the creek is at right angles to the strike of these beds, or across the clay formation, so that following it up stream, the older, and then the newer and higher beds, are crossed. At the west end of Hylton's bank the clay bed is almost wholly above tide level. On the Morris property, east of that of Hylton, it is all below the same level. But there is much variation here, not only in the thickness of the several strata, but also in the order of arrangement of some of them. Hence no general vertical section is applicable at all points. The following is the order most commonly observed, and the thicknesses of the individual beds:

(1) Yellow sand (for moulding)	4–5 feet
(2) Yellow loam and gravel	0–12 feet

(3) Yellow fire sand	20 feet
(4) Fine white sand (*kaolin*)	12 feet
(5) Clay (white and red)	8–20 feet
(6) Fire sand, or *kaolin*	8 feet
(7) Clay and sand, in alternate layers, at the bottom	

This order is, as stated, not persistent throughout the bank. In some places there are gaps, and in others some of these are replaced by beds of a different character. The gravelly earth next under the sand, at the top of the bank, is very firm and solid, consisting of quartz pebbles mixed with a little yellowish red clay. When wet it is quite sticky, but dries like a stone. It is thrown down through chutes to the dock level, at the foot of the bank, where it is loaded on vessels, and shipped to foundries for moulding in large castings. It is also used in making walks and roads, for which it is an excellent material. Its price ranges from 75 cents to $1.00 a ton. The yellow sand, under the gravel (3), is nearly all quartz, mostly fine-grained. There is a little coarse-grained in some of the layers. It goes to the fire brick works as fire sand.

The next bed (4) is also nearly all quartz and sharp-grained. There is a little mica in it. An analysis shows its principal constituents to be represented by the following per centages :

Alumina	5.60
Quartz and combined silicic acid	91.80
Potash	0.20
Water	2.20
Total (determined)	99.80

It is said to stand fire well, and is used in fire brick, &c.

The bed of clay ranges between 8 and 20 feet in thickness. All of it is sandy, but this sand is *very* fine grained. It is hard and solid and breaks with an irregular fracture. Its specific gravity is 2.052—2.101. Most of it is white, sometimes with a pinkish tinge, but in places it is reddish, or variegated red and white. The red is more common at the west end of the bank and often runs out as the digging gets further in the hill, as if it had come from the surface. The composition of the clay, according to an analysis of an average specimen, typical of the bed, is:

ANALYSIS.

Alumina and titanic acid	18.11	
Silicic acid	17.50	
Water (combined)	5.50	
		41.11
Silicic acid (sand)	56.80	
		56.80
Potash	0.76	
Soda	0.20	
Lime	0.11	
Magnesia	....	
Sesqui-oxide of iron	1.09	
Water (moisture)	0.40	
		2.56
Total		100.47

The percentage of quartz sand is large. The oxide of iron, lime and potash, separately, exceed slightly the average amounts of these bases found in the best clays of Middlesex county, as can be seen by reference to the tabular statement of analyses in Part IV, on economic uses of clays, but they are not so large as in the other clays along the Delaware river, and not sufficient to prevent its employment in making fire brick. This clay is largely used at Trenton by O. O. Bowman & Co. in the manufacture of fire brick. Some of it is sent to Bethlehem, Pa., for retorts and condensers in zinc furnaces. Besides these it finds other customers and some additional uses, as in stove tile and flues, chimney tops, garden vases, &c. But none of it has been found to burn so as to hold the slip for terra cotta ware. The prices range from $2.50 to $3.00 a ton.

The *kaolin* under the clay bed is not often dug, as it is low and under the water. It is sold for fire bricks and to rolling mills. Under this at the west end of the bank there is a bed, consisting of thin, alternating layers of white sandy clay and sand. The vertical section of this bank, according to a letter recently received from the proprietors, included the following beds:

(1) Moulding sand	4–5 feet
(2) Moulding gravel (clayey)	4–20 feet
(3) Loose gravel	

(4) White sand, sharp sand and *kaolin*...	2–20 feet
(5) White and mottled clays..	7–23 feet
(6) Fire sands, *feldspar* and quartz...............................	

Sometimes there is a stony layer on the top of the *kaolin* (4). It is mixed in character and apparently a layer or thin bed of boulders.

Woody layers are occasionally seen in the *kaolin.* The quartz in this latter is very fine and uniform in size of grain, and angular. Fragments of sandy clay and a few mica scales occur in it. Some of it looks clean and of uniform size, fitting it for glass making.

The *lower* fire sand, found under the clay bed is coarser-grained containing pebbles and angular masses half an inch in diameter. Part of this layer is a mixture of quartz and yellowish white sandy clay. The quartz appears in sharp fragments and as pebbles and these are from $\frac{1}{8}$ to $\frac{1}{2}$ inch in diameter. It is called *feldspar.* But it is much finer grained and more sandy than the so-called *feldspar* of Middlesex county. It is used as a fire material in rolling mill furnaces.

No boring has been done to determine the strata below these, here described. In the *kaolin* or sand bed, over the clay, veins of very rich, fat clays are often met with, from the thinnest film to layers an inch thick. Rounded, ball-like masses of clay are also common. These abrupt changes in material are evidences of very sudden changes in the period of formation. And this bed may belong with the higher, gravelly and sandy beds, to a much later geological epoch, possibly to the later drift, or even post-glacial age, and not to the clay series. A curious phenomenon observed in this bank are vertical, cylindrical, or tubular masses of *kaolin* (pipes) several inches in diameter, or smaller, running through the clay bed, as if holes in the latter had been filled by the material of the succeeding and higher bed.

In working this bank, gunpowder is often employed to break off and throw down large masses of clay, &c., upon the level below. Thence it is easily wheeled on board of vessels at the docks. This bank very favorably situated, having a navigable, tide water front along the whole length of the working face and vessels of 200 tons burden can lie close to the shore. Then there is very little *pitting* or digging below the level and consequently no pumping expenses, or raising of water in any way. And all the materials *above* the clay bed are thrown down directly into the carts, or blasted off and so loaded. These facilities for easy handling and nearness to navigation and railroad enable the proprietor to utilize very much more of the upper gravel and sands than would be possible in many banks. The materials go into market as "Pensauken Creek clay and *kaolin*."

CHAS. MORRIS' CLAY.

East of Hylton's bank the same bluff or bank continues on the property of Charles Morris. The clay is deeper than on Hylton's lands. No openings have been made, but the clay outcrop can be traced up stream as far as the old distillery site.

These clays of Florence Heights, Bridgeborough and Pensauken creek are, it may be observed, along lines of denudation where the Delaware river and the Rancocas and Pensauken creeks have worn into and through the beds of drift, exposing the underlying strata of clays, sands, &c. And these openings are where nature has thus laid bare these valuable materials and made exploration almost unnecessary. It is not to be supposed that these streams have any connection with these beds, beyond such as accidentally occur in the drainage, and consequently there are good reasons to suppose that these beds are found in the intervals *between* them. In these intervals the drift sand and gravel has covered the clays and associated strata more or less deeply, and in the absence of exploration by boring or digging they have not been found. The slopes to the Delaware river and its tributary streams are generally very gradual, and hence there are no breaks in the drift mantle or covering. Borings and diggings for testing these apparently *barren* intervals could be made easily and cheaply; and a judicious choice of location where the drift is light and in the lower grounds, will most certainly add to our number of clay localities and our knowledge of the geology of this part of the State.

The above mentioned statements apply equally well to the low and flat country bordering the Delaware river in Camden and Gloucester counties. The slopes of the upland are very gentle, and there are wide meadows along most of the streams in the limits of the tide water district. Outcrops of clay have, however, been observed at a few points.

RED BANK CLAY.

On the United States government lands at this place and on the bank of the river, a tough, white and sandy clay is seen at low tide in the gently sloping bed of the stream. The locality is a few rods south of the battle monument. No digging or exploring work of any kind has been done here.

BILLINGSPORT CLAY.

Clay is dug on B. A. Lodge's lands one and a quarter miles south of Billingsport, Gloucester county. The opening for clay is in the upland bank or river bluff, which has an average height of 20 feet above high water mark. The strata exposed are:

(1) Sand and gravel	10–17 feet
(2) Yellow clay	2 feet
(3) Potters' clay	10–12 feet
(4) Yellow clay	1 foot
(5) Coarse white gravel at the bottom	

This clay is dark colored. Near the top of this bed there are some lumps of lignite. Towards the bottom a little pyrite is sometimes observed in it. The best of it is quite sandy. An analysis shows the composition to be as follows:

ANALYSIS.

Alumina and titanic acid	15.00	
Silicic acid	16.20	
Water (combined)	7.70	
		38.90
Silicic acid (sand)	56.00	
		56.00
Potash	1.68	
Soda	0.39	
Lime	......	
Magnesia	0.32	
Sesqui-oxide of iron	1.20	
Water (moisture)	1.10	
		4.69
Total		99.59

The sand makes up a little more than half the weight. The per centages of iron oxide and alkalies are quite large, and enough to render it fusible at a high temperature, and, therefore, unfit for some uses as a refractory material.

The clay is wheeled from the bank to vessels of light draught, or such as can lie near the shore, and sent to potteries as a potter's material. A short distance southwest of this, in the flats in the river, clay has been seen, probably of the same bed as that of Lodge's diggings. It is also reported as found in a well at a neighboring house, near Mr. Lodge's residence.

BRIDGEPORT CLAY.

This locality is near the Raccoon creek, one mile south of Bridgeport, in Gloucester county. It is on lands of James Kirby. This clay is yellowish-white and tough. None of it has been dug lately. There is said to be a large amount of it. This is the most southwesterly clay locality in the State.

Neither this nor Lodge's clays appear like those further to the northeast. And both may be more recent than the latter. With so limited outcrops, and so far apart, it is difficult to generalize with much certainty. More exploration and larger opening of these places are necessary to determine their geological relations, as well as their extent and practical value.

Beyond Bridgeport, southwest, the country along the river is low, and descends gradually to the tide water creeks and the river. Meadows border these, excepting a few points, as at Penn's Grove landing, Church's landing and Pennsville, in Salem county, where there are low banks of upland. It is not known that any valuable clay has ever been found in this belt of country along the river. The wells are shallow, and apparently not deep enough to get through the drift. The Delaware here flows in the clay, or between it and the gneissic rocks, which crop out on its western shore as far south as Wilmington. South of the latter place the clay formation appears on the west of the river, and its beds crop out at several points in Delaware. Christiania creek runs along its northwest border, and the southeastern follows near the line of the Delaware and Chesapeake canal. Both white and red clays crop out in the bank, and in the bed of the river about three miles south of New Castle. A considerable amount of clay was formerly dug here for pottery manufacture. Some of it was used in making glass pots in West Jersey. These clays resemble the best clays of the belt along the Delaware river in New Jersey, and in character, as well as in their relations to the adjoining greensand marl, on the southeast they appear to belong to the same formation and to be the southwestern extension of the clay belt of New Jersey, which has here been described in its outcrop across the State, and along the river from Trenton to Bridgeport, or to Red Bank.

CHAPTER III.

CLAYS OF SOUTHEASTERN NEW JERSEY.

As no geological classification or arrangement of these clay localities of the southeastern part of the State is possible, they are here described according to a geographical order, beginning at the northeast and proceeding south and southwest.

CLAY AT BENNETT'S MILLS.

Near Bennett's mills in Ocean county, there is an outcrop of white clay on lands of Charles H. Appleget, lying near a tributary of the Metedeconk creek and not far from the latter stream. Specimens selected by Mr. Appleget and sent to the office of the Geological Survey are tough and plastic, but quite sandy and a little streaked with reddish and yellowish earths. The locality has not been explored sufficiently to test the size of the bed uncovered so near the surface of the ground.

BRICKSBURG TRACT.

On this tract clay is dug near the old Seven Stars hotel and made into red brick. This is a very stiff, tough clay, and most of it of some shade of yellow or red, although some of it is said to be white. There is on it a *bearing* of earth, gravel, &c., 4 feet thick. It is possible that selected clay of these pits could be used for pipe or some kinds of pottery.

TOMS RIVER CLAY.

From Bricksburg to Toms River there is a belt of clay land quite in contrast with some of the more sandy surface east and west of it. Some gravel is mixed in the surface layers of this belt. A clay for red brick is dug one mile north of the village, at Dubuisson's brick yard. There is here an average thickness of 13 feet of clay covered by sand and gravel 4 feet thick. This clay is dark drab-colored and sandy, resembling somewhat the astringent earth called "rotten stone," which occurs on top of the upper marl bed in Monmouth and Ocean counties. It is said to burn light colored. But little of it has been used, and the bricks made of it are not very strong and do not command a ready market. By sorting, some clay could be got here which would make pipe.

East of Toms River a yellowish white bed of clay having a maximum thickness of three feet, appears in the bluff on the south side of Dillon's island. The bluff is 35–40 feet high and this clay is at a height of 25 feet. It is interstratified with sand. These strata dip gently towards the southeast.

STANTON TRACT.

On this tract three miles west of Toms River and near Sunken Branch some digging and boring 10 feet deep brought up yellowish white, sandy clays. These were found in two layers, each 18 inches thick and separated by sand. Clay, in thin layers, is said to occur on the same tract near the Bowman place. Borings 15–25 feet in depth, made by Ex-Sheriff Ivins, at many points on this tract did not discover any clay beds of value, although at one point a tough blue clay was found 10 feet thick. Sands and gravels were the prevailing strata encountered in these explorations.

It would be easy to increase this list of localities where such thin layers of clays, more or less sandy and earthy, could be found, or are already known. Their uncertain and limited extent and generally inferior, or worthless character, excepting as red brick material have rather prevented explorations which, properly conducted, might have led to discoveries of some beds, or deposits of more value. These clays already known, appear to belong with the sands, gravels and sandy earths to the drift which constitutes the surface material over so large an area in this part of the State, excepting the tidal meadows, the alluvial deposits of the swamps and the more recent sand dunes that follow the coast line.

LARRABEE'S BRICK CLAY.

This clay is on the line of the New Jersey Southern Railroad, one and a half miles northeast of Whiting's station, in Ocean county. It is yellowish red in color and covered by a thin bed of gravelly earth. The brick yard here uses it in making red brick.

CLAY AT MOUNT MISERY.

Near Mount Misery, one mile south of Hanover station of the New Jersey Southern Railroad, Burlington county, clay was formerly dug for making the brick used in the furnace at Hanover. The pits are near the old Brown's Mills road and about a half a mile northwest of Mount Misery. They are nearly filled up by the sand and earth of the suface and none of the clay can now be seen without digging. At the village a red brick clay was dug in the south bank of the stream. It is very sandy. An outcrop of red clay was seen near the old pits, west of this point. Exploration hereabouts might discover clays of some value, better than those once dug here.

TOWNSEND'S CLAY, WHEATLAND.

A pipe clay is dug by E. N. & J. L. Townsend one and a quarter miles southeast of Wheatland Station, Ocean county, near the boundary line of Burlington county. The strata seen in these pits are described as follows by Mr. Townsend:

(1) Gravelly sand and clayey sand	7–10 feet
(2) Black, sandy clay, full of lignite and pyrite	1–4 feet
(3) Blue pipe clay	3–8 feet
(4) Reddish-yellow, sandy clay	2–3 feet
(5) Sandy earth with some clay lumps (locally called a *kaolin*)	2–3 feet
(6) Sand with some gravel at the bottom	

In the top black clay, logs of wood (lignite) a foot in diameter have been found. Mr. Townsend has applied this clay as a fertilizer on sandy ground and observed good results from its use. It has been called a marl, but it is not properly such, but rather an amendment to the soil. It must be used sparingly, otherwise the sulphate of iron from the decomposition of its pyrite is injurious. The blue pipe clay is sandy, the sand being very fine grained. This layer is throughout very uniform in quality, The reddish clay at the bottom is sometimes very thin.

A little of the sand or *kaolin* from the bottom and the blue clay mixed together, have been made into fire brick. But most of the clay of these pits is used in the manufacture of pipe and chimney tops at the drain pipe works of the proprietors at Wheatland Station.

UNION CLAY WORKS.

This locality and these works are four miles south of Wheatland Station, Lacey township, Ocean county. In the south-eastern pits at this place there is a top inferior clay 8 feet thick; then a micaceous clay and sand 4 feet; then white clay 10 feet thick, and gravel at the bottom. In the pits north of the works there is at the top a gravel with yellow, loamy clay 4 to 9 feet thick, then a bed of white clay 10 feet thick, next a sand and gravel 4 feet thick, and at bottom white sand. These figures do not apply throughout, as there is some variation from pit to pit. In digging a well 62 feet deep at the works, the strata cut were reported to be:

(1) Loamy gravel and clay	
(2) Clay	8–10 feet
(3) Gravel (thin layer)	
(4) Good clay	2–3 feet
(5) White sand	22 feet
(6) Sandy gravel at the bottom	

Borings made near the works are said to show that this deposit, or bed of clay, is at working distances from the surface, under about seventy acres of the lands adjacent to the works. Some of the top clay is reddish in streaks. It has been put into red brick. The best of the clay was used in the works, in drain and water pipes, for which it is mixed with some of the micaceous sand which is found under the clay bed. The pipe manufacture here was started in 1866, previous to which date the clay was tried for making fire brick and common pottery. For the latter it answered very well, but for the former it was not sufficiently refractory. This use of it was abandoned. It appears to be better fitted to make stoneware than pipe. It has been tried in glass pots also, but alone did not answer. When mixed with German crucible clay it is said that it did well.

The first pits here were opened about eighteen years ago, but the locality has long been known for its clay, which the colliers were accustomed to use in chinking up their cabins and for other such purposes.

This deposit is on the high ground, or *divide*, between the head-waters of the streams flowing west to the Delaware river and those going east to the ocean. It is, at least, 150 feet above tide level. From its association with beds of gravel it appears more like a tertiary, or post tertiary, deposit, than of any older epoch.

In the southeastern portions of Ocean, Burlington and Atlantic counties sandy clays have been found at a few points, but hardly fit for any other use than the manufacture of red brick. There are two or three such near Tuckerton. At one of these, on the farm of Joseph Nugent, two miles west northwest of the village, a very fine white clay, containing but little gritty material is found within two feet of the surface, and as Mr. Nugent states, is at least 7 feet thick. The size of the deposit, or the value of this clay, are unknown. As it is in a low, sink-like basin, it must be more deeply covered in the adjacent higher ground. This clay looks as if it might do for stoneware. The locality should be further opened and the clay tried, as it might be used for stoneware, saggars or sewer pipe, and such manufactures at Tuckerton would have cheap fuel and labor, and be near good transportation by land or water.

A clay like the above is reported on Eayre Oliphant's farm, about three miles southwest of Tuckerton.

CONRAD'S CLAY PITS.

These pits are at Conrad, one mile south of Tansborough, Camden county. The Williamstown railroad runs a few rods west of them. The existence of clay here has long been known, and it has been used at times by the people of the neighborhood as a *whitewash* for outbuildings, fences, &c. About seven years ago the first pits were dug for clay, to make pipe, and about that time works were erected here for the manufacture of pipe, terra cotta and fire brick. The pits go through a *bearing* of 6 inches to 3 feet, and then the bed of clay, 5 to 16 feet thick. Under this latter there is white and yellow quartz sand. In some places there is a stony layer, from two to four inches thick, consisting of sand cemented together by iron oxide, between the clay and the sand. James Conrad, the former proprietor of the pits and works, says that this clay can be traced for a mile southeast of his pits; he has found it at several points in borings in that direction.

This clay varies considerably in its appearance. Generally the best of it is at the bottom, near the stony layer. All of it is sandy, and some of it is mixed with earth in streaks. Its colors are bluish-white, buff and chocolate shades.

The chemical composition is expressed by the following analysis of an average specimen :

ANALYSIS.

Alumina*	23.30	
Silicic acid	29.50	
Water (combined)	7.00	
	——	59.80
Sand	34.50	
	——	34.50
Potash	1.77	
Soda	0.16	
Lime	......	
Magnesia	......	
Sesqui-oxide of iron	1.50	
Water (moisture)	1.60	
	——	5.03
Total		99.33

These figures show that this clay cannot be refractory enough for the best fire brick. They indicate a composition like that of some of our best stoneware clays.

The specific gravity, washed clay, is 1.853—1.929; sifted clay, 1.866—1.946.

All of this clay answers for pipe. Some selected lots were used in fire brick, but nothing was learned of their character. For some of the finer and ornamental terra cotta ware the crude clay is washed, sifted and pressed. The ware made of it has a pleasing and soft shade. Some of the statuary looks very well. For the latter, the unwashed crude clay can be used. The products

* Including the titanic acid.

of the works are shipped over the Williamstown railroad, a side track running to the works. The thickness of the clay, the thin covering of soil, and the location so near the railroad, favor this place.

This deposit, like those near Wheatland, Ocean county, is on the water shed, between the drainage towards the Delaware river and the Atlantic slope. Its geological place is uncertain.

CHAPTER IV.

CLAYS OF NORTHERN NEW JERSEY.

In the northern part of the State clays fit for the manufacture of bricks and tiles are found very generally distributed throughout the several counties and these supply the local demands for the more common grades. There are no such large and extensive beds, or large manufacturing establishments as in the plastic clay belt of the central part of the State. And consequently these deposits are of local interest and value. They are all near the surface and belong to the drift and the alluvial formations. Their description is omitted in this report and referred to the chapters on the surface in the "Geology of New Jersey," and other reports specially devoted to such deposits.

Two localities of clay in this part of the State are here noticed, as they have furnished material for other and more valuable uses. These deposits or outcrops appear to belong in older rocks and to have resulted from changes produced in them by the long continued working of atmospheric and surface agents.

The first of these localities to be mentioned is in a narrow valley one and a half miles southwest of Bethlehem, Hunterdon county. The following description of this clay appeared in the annual report of the Geological Survey of 1874, viz.:

"The ridges on each side are gneiss rocks, and the bottom of the valley is also gneissic in character, but just here the rocks have been so decomposed by surface agencies, that this clay is all that is left of the original rock strata. The clay was discovered two years ago by the owner of the property, Mr. Willever. For a short time, the place was worked by a company from Easton. Last spring it was reopened by the present owner, S. L. Shimer, of Phillipsburg. The clay is covered by a very thin bed of drift earth. Its thickness has not been ascertained, although a shaft thirty-three feet deep has been sunk in it. Two trial pits, one lower down the valley, and the other several rods west of the mine, indicate an extensive bed. The mining operations consist of the single shaft, and a little digging at one side of it. The clay is properly a *kaolin*, being 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. A trial of it made by a Trenton pottery firm, shows that it will not make porcelain ware, on account of the dark color from burning. It would probably make good stoneware; and selected portions when washed, would answer well for paper facing. The company have erected a drying shed in which there is a washer, and at the side there are small vats for the reception of the clayey liquid. The sand in this clay is remarkably fine, and that sorted out by washing, appears pure enough for some uses in the arts. Only a few tons of the washed clay have been sold, and this more for its introduction into the market, than as a regular business."

Little work has been done since the above account was written. Such kaolin clays or *kaolins*, resulting from the decomposition of feldspars in gneissic, granitic and syenetic rocks are found in all parts of the world, and most of the fine and valuable porcelain clays of England, France, Germany and some of those in our own country belong to this class, thus formed *in situ* from the rock. The porcelain clay of the Hokessin valley, Delaware, is a notable example of this class of clays. From these statements it follows that wherever there is much decomposition of rocks containing feldspar, clays will be produced, varying greatly in character according as this change in the rock has proceeded to a greater or less extent, removing all the original potash and the excess of silica and making a fine clay, or partially carrying away these constituents and leaving an impure and inferior clay. The original constitution of the rock also determines in part the resulting product, rendering it more or less valuable as there may be more or less of foreign constituents in the rock mass. Throughout much of the highlands and gneissic rock district of the State, and particularly towards the southwest, in the western portion of Morris, in Warren, and in Hunterdon counties, the disintegration of the strata near the surface resulting in what is often termed "rotten rock," is a characteristic feature in the geology of these counties. The Bethlehem clay is one of these outcrops or localities of rock thus altered in appearance and composition. Other localities where a little of such clay can be dug are reported, but they have not been considered as sufficiently developed to be included in this report. That others of workable extent and of value may yet be discovered is highly probable, and careful searches, prudently carried forward, *within* the limits of the gneissic and associated rock outcrop of the *so-called* Azoic formation of the State are advised.

The other clay locality is about a mile north of Macopin pond, in West Milford township, Passaic county. The following description of this clay deposit, written for the annual report of the Geological Survey, in 1874, is here inserted, inasmuch as there has been nothing done there since that account was published:

"It was first worked about thirty-five years ago, by Moses Kinzey, afterwards by Mr. Wooley. But during the past twenty years nothing has been done. At present the pits are filled up by the surrounding earth, and the bank is so fallen down that there is no clay exposed to view. A little digging at the time of our visit in September last, cut through some thin layers of mottled (red and white) clay, which is apparently quite pure. A chemical examination of samples thus obtained, gave four per cent of alkalies, indicating the presence of some partially decomposed *feldspar* with the clay, and showing it to be unfit for the ordinary uses of fire clay until it is washed.

"The statements of residents in the neighborhood, and of one man who worked in the pits, are, that the clay occurred in layers, or beds, nearly horizontal and not exceeding two feet in thickness, and separated by thin strata of fine, white quartzose gravel. The banks, as now exposed, show that over this clay there was a quite thick covering of this quartz gravel, mixed with yellowish clay, and in places with a dark red sandy clay. The clay obtained from the pits was washed in works that stood near the pits, and then carted to Mead's Basin. It's use was not learned. This bed is very near the conglomerate outcrop of the Kanouse mountain range on the west. About four hundred feet west of it in the hillside a pinkish red bed of shaly rock was dug for red paint. On the east side of the valley the gneissic rocks crop out. About a quarter of a mile south, and near the farm house belonging to the clay mine lot, there is an old pit, in the sides of which a conglomerate, made up of quartz pebbles and a white clay, crops out. It is said that some clay was dug here. If so, it would appear to point to this feldspathic conglomerate rock as the origin of this clay."

No attempt can be made here to enumerate the localities in New Jersey where clay for red earthenware, for tiles, and for common brick can be found. A large number are known, and many more can undoubtedly be found by an inexpensive but judicious search.

Bricks of excellent quality are made at Newton, in Sussex county. They are made from clay found there, and may be taken as samples of what can be made from the clays of the Kittatinny valley. These clays have been formed by the disintegration and wear of the Hudson river slates. They are in quality like those on the Hudson river from Newburgh to Albany. And they may be looked for throughout Sussex and Warren counties wherever the slates are found.

A large business has been done in the manufacture of bricks and drain tile at Flemington, in Hunterdon county. The clay is found in the immediate vicinity. It is evidently produced by the disintegration of the red-shale which is the prevalent rock there. Clay of the same origin is used in the manufacture of bricks at Somerville, Somerset county.

A very large deposit of excellent brick clay is found near the Morris canal, at Singack, in Passaic county. A large quantity of excellent brick has been made at that place for Paterson and other towns on the canal. A large deposit of equally fine clay has been noticed about the flat country where the Whippany and Rockaway rivers join the Passaic in Morris county. And another at the south end of the Great Swamp in Passaic township, Morris county. The clay of these three localities is of comparatively recent origin, and is probably a sedimentary deposit from the sluggish streams which flow near them. The last two mentioned have not been worked.

Near Hackensack there are also considerable deposits of brick clay, which have been extensively worked. The clay is plainly of modern and sedimentary origin.

At Trenton there are extensive brick yards, and large numbers of common brick, and also of pressed brick of the best quality are made. The material used is the clay from the decomposed gneiss rock which underlies it. It is the same material that is used in making the fine Philadelphia and Baltimore pressed brick ; and it is specially liked on account of the fine color and accurate shape of the bricks made from it.

The localities of the brick clays cannot however be further detailed. They are numerous, and sufficient to meet the requirement of this most important though primitive art.

Part III.

COMPOSITION, PROPERTIES AND ORIGIN OF THE CLAYS, FELDSPARS AND KAOLINS.

CHEMICAL COMPOSITION.

The chemical composition of the clays, *feldspars* and *kaolins*, occurring in the State has been given in many analyses in Part II. In the first chapter of Part II the analyses of the clays and *feldspars* of the Middlesex county clay district are classified according to their geological position. Thus the Raritan bed clays are represented by tables on pages 43 and 46; the Woodbridge bed on page 51; the *feldspars* on page 62; the South Amboy bed on page 67, and the stoneware clay on page 72. These analyses are of specimens dried at 212° Fahrenheit. The local descriptions of the same district include these tables and many additional analyses of clays, *feldspars*, *kaolins* and fire sands. But these are of specimens well dried at summer temperatures (in summer air) and they all show the presence of a small amount of moisture, or hygroscopic water. Such analyses are of economic value since they give the composition of the raw materials, in their natural state, after extraction and drying and when ready for use. They are of special importance and significance to the clay miner or dealer and to the manufacturer. And in the considerations regarding the uses of these raw materials, for ware, fire brick, drain pipe, building brick, alum making, paper glazing, &c., &c., these analyses should be taken into account, since they show in some degree the value of these materials for special applications. They are important to the land owner and clay miner also, if they would know the value of their lands, or of the materials they would put in the market. No intelligent proprietor or manufacturer dealing extensively in clays can afford to be altogether ignorant of the facts which such analyses give. The tables referred to above, indicate the general character of the several geological beds. Hence their interest to the geologist. They may be studied advantangeously by the practical man who desires a basis for comparisons preliminary to more detailed examination and study of localities. For convenience in using these analyses scattered through this report the reader is referred to the list in the index (see under "Analyses") and to the table of contents.

The composition of the various clays, *feldspars* and *kaolins*, which make up the strata or beds of geological formations, and further studied as minerals, aggregations of which form rocks, is here presented. It follows naturally the descriptions of localities and of the materials as they occur. Here the analysis is studied with reference to the constituents and their chemical relations to one another. It is made to explain the constitution of the crude material and to exhibit both the essential and characteristic components and those which are foreign, or which are accidentally present. The crude clays are resolved according to these chemical determinations into their proximate and ultimate elements. By the former the mineral components are determined and by the latter the chemical constitution is ascertained. For example, a clay may be separated into water, sand, mica, lignite, titanate of iron, kaolinite, or clay proper. The last named is the essential constituent. Alone it is clay. The others may, one or all be wanting, that is they are accidents in the case. These several constituents, or minerals, can be further examined and resolved into elements, as silica, potash, titanic acid, alumina, &c. The complete chemical analysis gives these *elements*, but does not necessarily indicate their relations to one another, nor give the proximate constitution of the clay. To get this there must be physical examinations, special tests and microscopical work. The composition is, therefore, learned through the scientific study of the results of the chemical analysis, supplemented by these particular examinations which are made for the purpose of showing the mode of combination, &c., &c. For the better understanding of these discussions and for easy comparison the analyses are computed upon the basis of 100. That is, instead of taking the weights obtained in the laboratory and the totals of the determinations the sum is assumed to be 100 and the several constituents calculated according to the ratio between 100 and the sum obtained. By a simple proportion the percentages of the several constituents are thus obtained. Since the difference between the totals and 100 seldom exceeds one per cent the calculated percentages do not vary much from the weights got in the original analyses. Only a few of the more full analyses of typical specimens are used in this part of the report.

As has already been stated, the essential *part*, or constituent, of clay is the kaolin, or *kaolinite* of mineralogists. This is a hydrous silicate of alumina. According to analyses of pure specimens, its composition is as follows:

Silica	46.3
Alumina	39.8
Water	13.9
	100.0

This composition is expressed by the chemical formula $Al_2 O_3 2Si O_2 + 2H_2 O$. For comparison with this standard the following table of seven analyses of as many of the rich and purest clays from the Woodbridge and South Amboy fire clay beds is presented:

	1	2	3	4	5	6	7	Av'ge.	
Silica	42.94	44.22	44.64	42.55	43.17	44.39	43.45	43.62	
Alumina	40.20	38.08	38.75	38.05	39.67	39.48	38.84	39.01	
Water	13. 2	14.10	13.05	14.79	13.47	14.17	13.68	13.87	96.50
Potash	0.41	0.15	0.17	0.35	0.48	0.25	0.26	0.29	
Soda	0.08	....	....	0.37	0.22	....	0.18	0.21	
Lime	0.10	....	....	....	0.20	....	....	0.15	
Magnesia	....	0.11	0.11	....	....	....	....	0.11	
Ferric oxide	0.51	0.91	1.15	1.05	0.46	0.45	0.87	0.78	
Titanic acid	1.43	1.32	1.32	1.42	1.62	1.06	1.21	1.34	
Sand	0.51	1.11	0.81	1.42	0.71	0.20	1.51	0.90	
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00		

1. Loughridge & Powers' fire clay, Woodbridge.
2. H. Cutter & Sons' fire clay, Woodbridge.
3. H. Cutter & Sons' ware clay, Woodbridge.
4. W. H. P. Benton's fire clay, Woodbridge.

5. E. F. & J. M. Roberts' fire clay, near South Amboy.
6. E. F. & J. M. Roberts' selected paper clay, near South Amboy.
7. George Such's washed paper clay, near South Amboy.
Av. Average of analyses, 1–7.

The sum of the averages for the silica, alumina and water is 96.50. The calculation of the per centages of these constituents upon the basis of 100, gives:

Silica	45.20
Alumina	40.42
Water	14.38

Or, as compared with the percentages deduced from the above stated formula, there is a deficiency in the silica, and an excess of alumina and water. These differences might be explained by variations in analyses, which were made for technical uses, and not of specimens best adapted to yield data for formulas. Such variations might be expected under such circumstances. But an examination of each of these analyses shows like differences in all. No. 6 was the richest clay of the seven, containing, after throwing out the insoluble silica or quartz, oxide of iron, titanic acid, water and potash, 98.04 per cent. of soluble silica, alumina and water. These computed for 100 are as follows:

Silica	45.27
Alumina	40.28
Water	14.45
	100.00

These last per centage figures differ very slightly from those of the average. They all show the excess of alumina above that deduced from the formula of kaolinite. An examination of the several analyses of the fire and ware clays occurring in New Jersey, was made to ascertain the proportion of the alumina to the soluble silica and water (combined), and the following classification was deduced:

1. The constituents were in amounts approximately expressed by the average as above given. In this class nearly all of the fire clays were found; also, the porcelain, or ware clays.

2. The constituents were not in the amounts as above expressed,

the alumina being in considerable excess. The so-called *feldspars*, the potters clays of S. A. Meeker and B. A. Lodge, and probably others, and the fire clay of J. D. Hylton, Pensauken creek, belong in this class. Charles A. Campbell's white fire clay is also in this group.

3. The silica was found in excess. The clay of the island farm, and the stoneware clays of Middlesex county, belong here. Also Joshua Eayre's stoneware clay, Florence, and the fire clay at Conrad.

These classes are not sharply defined, since the analyses show gradations from one to another, which cannot be more accurately classified. Examples of the first class have already been given. For the second, the following are presented :

	1	2	3
Silica	19.46	16.65	17.52
Alumina	21.86	17.61	18.14
Water	5.89	6.35	5.41
Potash	2.25	0.12	0.76
Soda	....	0.21	0.20
Lime	0.28	....	....
Magnesia	0.24	....	....
Ferric oxide	1.57	0.54	1.09
Titanic acid	....	0.91	....
Sand	48.45	57.61	56.88
	100.00	100.00	100.00

1. S. A. Meeker's potters clay, Woodbridge.
2. Edgar Brothers' *feldspar*, near Woodbridge.
3. J. H. Hylton's fire clay, Pensauken creek.

In Nos. 1 and 3 the amounts of alumina are to be reduced, each about one per cent., for titanic acid. With these reductions, this constituent is relatively large in amount. Taking the average for the three constituents, they correspond to the formula $6Al_2 O_3 10Sio_2 + 11H_2 O$.

As examples of the third class we have the following analyses :

	1		3
Silica	46.11	29.67	29.29
Alumina	35.56	20.87	21.17
Water	14.89	8.61	6.72
Potash	0.12	1.55	1.81
Soda	....	....	0.18
Lime	....	....	....
Magnesia	....	0.30	0.22
Ferric oxide	1.38	1.45	1.68
Titanic acid	1 43	1.14	1.00
Sand	0.51	36.41	37.93
	100.00	100.00	100.00

1. White clay from Island farm, Middlesex county.
2. Stoneware clay, E. R. Rose's pits, Middlesex county.
3. Stoneware clay, N. Furman's pits, Middlesex county.

In No. 1 there is little foreign matter. The formula $5Al_2 O_3 11Si O_2 + 12H_2 O$, expresses very nearly the relative proportions of the alumina, silica and water. Nos. 2 and 3 may be expressed $4Al_2 O_3 10Si O_2 + 8H_2 O$.

The examples above stated prove conclusively that the clays are not altogether uniform in composition, even after throwing out all the accidental or foreign constituents. Either the essential *kaolinite* is not constant, or our clays consist of this mineral mixed in varying proportions with other hydrous silicates of alumina. Inasmuch as the greater number of the rich fire and ware clays of the State, and also others which have been here examined, do correspond very closely to the composition and formula assigned to this mineral, the latter explanation is the more plausible. What may be the constitution of these other silicates is not evident from the analyses. The specimens analyzed were not all of a character to furnish data for the construction of formulas, or to determine with certainty the composition of *kaolinite*, but many of them were of remarkable purity, and the generalizations here stated rest upon determinations which do not appear capable of any other explanations.

The excess of silica (soluble) may in part be due to the presence of free silica. The separation of the free or hydrated silica was attempted in many of the analyses, but the results, although quite constant (ranging from .4 to 1.5 per cent. in the fire clays), were not considered satisfactory, and were rejected. There is no doubt as to the existence of the silica in this condition, but present analytic methods fail to determine its amount with accuracy.

ACCIDENTAL OR FOREIGN CONSTITUENTS.

The foreign constituents or impurities in the clays and so-called *feldspars* of New Jersey, are quartz and *titanic acid* in nearly all, and feldspar, mica, pyrite, lignite, oxide of iron, amber, carbonates of copper, vivianite, red-shale, and various earthy matters more or less widely distributed.

Quartz has been found in all the specimens analyzed. It exists in all, even in the most fat and apparently gritless clays. The smallest amount determined was two-tenths of one per cent., in the paper clay of E. F. & J. M. Roberts' pits, near South Amboy. This is better expressed in a practical form by *four pounds in a ton of the crude clay.* The average amount in the best fire clays of the Woodbridge bed, Middlesex county, according to the table on page 51, is 5.07 per cent. But there is a wide range in the amount, as well as in the form, in which this constituent occurs. The stoneware clays of Middlesex county contain between thirty and fifty per cent. of fine white quartz sand. The average size of the grains in these clays is 1-250 of an inch in diameter, and they range from 1-70 to 1-1200 of an inch.

There are other clays, as that of Mrs. Clark's pits at South Amboy, Loughridge & Powers' extra sandy clay, and some of the clays along the Delaware river, in which the sand amounts to more than half of the mass In these latter, and generally in the fire clays, there is considerable variation in the fineness of the sand. In some the sand is coarse-grained, from 1-100 to 1-200 of an inch; in others it is very fine, less than 1-250 of an inch. The fineness does not necessarily go with richness of the clay, as in Roberts' clay there are grains 1-70 inch in diameter, although few in number. More commonly there is uniformity in the size of the grains in the same clay, so that in the coarser grained there is a preponderance of a larger size, while in the fine grained there is an absence of coarse grains, and also of the more minute quartz dust. In the *feldspars* the quartz occurs in a greater range of sizes, from dust to small pebbles half an inch in diameter; and these latter are somewhat rounded on the edges, as if worn by attrition. In the clays the sand, as examined under the microscope, appears little rounded and of exceedingly irregular shapes—fragments of translucent to transparent quartz. Occasionally there is some yellowish and, rarely, a grain of reddish quartz. The colorless, vitreous variety prevails. The sand is also evident in the greater specific gravity which its presence gives, as can be seen by reference to the table further on in this part of the Report. Scattering white pebbles of quartz have been observed in the bottom of the fire clay bed at Isaac Inslee's pits, near Woodbridge. This occurrence is exceptional. At the Neukumet bank, Sand Hills, the fire clay has some coarse sand grains here and there imbedded in it. As has been already mentioned (pages 52 and 67), there are no sharply defined planes of division between the rich, or *fat*, and the sandy clays, but gradations through which the former passes into the latter and *vice versa*. They are not distinct beds, but variations in the same continuous bed. Masses of sand and very sandy and inferior clays have been observed in the rich clays. Long lenticular sand masses, consisting of clean white quartz, have been found enclosed in the clay. These occurrences are much like some of the *horses* of rock which are found in the ore beds of older formations and like the association of the white crystalline limestone and gneissic rocks of the northern part of the State.

Titanic Acid—In the third annual report of the Geological Survey made in 1856, page 67, analyses of clays from Trenton and Burt's creek are given, containing each 1.4 per cent. of *zirconia*. These analyses made by Julius Koch were subsequently printed in the "Geology of New Jersey," 1868. In the year following the publication of the latter, a revision of these analyses was made by Mr. Bogardus, and what had been announced as zirconia was found to be titanic acid.* These revised analyses appeared in the annual report for 1872. Later chemical examinations have found titanium in nearly all the clays, both foreign and New Jersey, which have been tested.

*In the course of the re-examination it was found that in the ordinary method of analysis, by fusing the clay with bisulphate of potash, digesting in water, filtering and boiling the filtrate—no precipitate was obtained. This seemed to show the absence of titanium. The following method was then adopted: The clay was digested in hydrofluoric and sulphuric acids, the alumina, &c., was precipitated by ammonia, filtered, washed and heated in a solution of caustic potash; the insoluble portion consisting of iron and titanium was collected on a filter, burned and then fused in bisulphate of potash. The fused mass was digested in water; hydrosulphuric acid gas was passed through the liquid to reduce the iron and the liquid was boiled: the titanium was precipitated.

The combination in which the titanium exists is not certainly known. By careful washing the most pure clay, as that of Roberts' banks near South Amboy, (in which the quartz is 0.2 per cent. and titanic acid 1.05 per cent.) a mixture of quartz and brownish black grains was obtained. These were not magnetic. Most of them were of irregular shapes, and about of the same size as the fine (quartz) sand about 1-250 inch or .01 centimeters in diameter. This granular residue was digested in sulphuric acid and the filtrate analyzed. An average of two results gave the following percentage:

Insoluble in sulphuric acid	43.49
Alumina	4.04
Ferric oxide	11.31
Titanic acid	41.16
Total	100.00

The portion insoluble in sulphuric acid was further tested and found to contain a little soluble silica sufficient to combine with the alumina as clay, but no titanium.

A third sample of clay was more carefully washed to ensure as nearly as possible a complete removal of the clay. The washed mass was digested in hydrochloric acid. A large portion of the iron and an unweighable trace of titanium were dissolved. The insoluble mass was heated in sulphuric acid, the liquid filtered and analyzed. The results this time were:

Insoluble in sulphuric acid	77.97
Alumina	2.05
Ferric oxide	1.44
Titanic acid	18.54
Total	100.00

A reasonable explanation of these results is that these black grains are titanic iron (*menaccanite*) mixed with *nigrine*. Both of these minerals are found in granitic and gneissic rocks, and such rocks are supposed to have furnished the materials for the clay strata. Rammelsberg in his "Handbuch der Mineralchemie," S. 1008,* describes a compound containing of:

*From Gumbel's Geognostische Beschreibung des Ost Bayerischen Grenzgebirges, S. 229.

Titanic acid	89.49
Ferric oxide	11.03
Magnesia	0.45
Total	100.97

These proportions of titanic acid and oxide of iron are not very different from those given above. And its behaviour with chemical reagents is very similar to that of these black grains from the clay. According to Rammelsberg this compound of his analysis from Barnau, in Bavaria, is *nigrine*, a variety of rutile mixed with menaccanite.

The general occurrence of titanium in the clays of the plastic clay formation, and in nearly constant amounts is most remarkable. In twenty-one clays from as many different localities, it was found varying from 1.06 to 1.93 per cent., or excluding the maximum, the range in the remaining twenty was between 1.06 and 1.63 per cent., varying much less than the quartz sand. These titanium compounds have been found in the *feldspars* and fire sands of the same clay formation. They are evidently disseminated throughout all its beds.

Feldspar and Mica occur in the plastic clay formation, irregularly distributed through the several beds. The feldspar is seen in some of the coarser clays, and in the fire sands, and in the so-called *feldspar* bed, but in very small fragments. It appears much altered or *kaolinized*. This condition is very marked in the kaolin clay at Trenton, which is the decomposed gneissic rock. The clays on the eastern side of the State do not appear to have any of this mineral in them, or if there, it is in minute fragments. The alkalies in some of these, as well as a part of the silicic acid and also of alumina, may exist in such particles of undecomposed feldspars. No examinations have been made to determine the feldspathic species. This determination might be interesting and suggestive, as relating to the origin of the clays and *feldspar*. Mica is a more common constituent in the beds of this formation. It gives character to the *micaceous* sand, commonly termed *kaolin*, although in this material it does not amount in any case to ten per cent. of the mass. It occurs in small scales or flakes, rather unevenly mixed with the sand grains. The *top white clay* of the Middlesex county pits shows in washings the mica mixed with the quartz. And the potash in this clay may come from that source. As both of these minerals are fusible at high temperatures, their presence is undesirable in fire clays.

Pyrite is a common constituent in many of the clays in the State. It is most abundant in the darker-colored and more sandy clays, rendering them, in many cases, unfit for uses to which they might be applied, were it not for its presence. It is so abundant in the laminated clay and sand bed over the Woodbridge fire clay bed, and also in the black clay overlying the stoneware clay bed, as to give character to them. In these, as also in all the dark-colored clays, both in Middlesex county and in the beds along the Delaware river, it is generally associated with woody matter, or lignite. The latter is very rarely seen in any amount free from pyrite. Its presence in the lignite beds of the upper part of the clay formation, near Chesquake creek and the Raritan bay, has been one of the most serious obstacle in the utilization of that fuel. It is also common in the black clays along the Delaware river, between Trenton and Kinkora. The clay diggers frequently refer to the pyrite as "sulphur," or as "sulphur balls." It occurs in fire clays of some localities, and is removed by washing when in fine lumps distributed through the mass, or it is cut out by hand when present in larger ball-like aggregations of crystals. In these clays it is not associated with lignite. The round "sulphur balls," as commonly known, are from two to five inches in diameter, and often partially decomposed on the exterior, so that the outer portion or *shell* of oxide of iron encloses a centre of unaltered pyrite. Generally, such occurrences of spheroidal nodules are limited to certain horizons, or *levels*, sometimes at the top, at others at the bottom, and when they are found in this way their removal is an easy matter—by cutting them out of the *spits* as these are dug. Careful sorting and cutting, in this manner, obtains most valuable grades of fire, ware or paper clay, even from pyritiferous beds. (See pp. 192, 198 and 201.) When clays, rich in alumina, contain considerable pyrite scattered through them, so that it cannot be cut out or sorted, nor profitably washed, they can be used by alum makers, and much of this grade of clay is thus utilized. The oxidation of the pyrite has produced copperas or sulphate of iron, which is apparent in the inky or astringent taste frequently noticeable in some of the dark-colored clays, and occasionally observed in the white fire clays. The deep, brown color of water standing in and about clay pits, is owing to the presence of sulphates thus derived from the alteration of the pyrite. Since this mineral does not occur in sufficient amount to be workable as a source of sulphur, it cannot alone be utilized. And in the clay it is positively injurious. At moderately high temperatures it fuses, and acts therefore as a fluxing agent. It is one of the damaging constituents, and its presence is altogether undesirable. Its occurrence has been given in local descriptions of Part II, and for localities the reader may consult that portion of the report.

Lignite.—This term has been used to designate the various forms of fossil wood which occur in some of the beds of the clay formation, and to which reference has already been made in the notice of pyrite. It appears as trunks and branches of trees. These are of all sizes up to logs three feet in diameter and many feet in length. The wood structure is still apparent, and brown to jet black in shade. The smaller branches and stems are generally flattened, as if compressed by great weight. They lie horizontally, or nearly so, in the beds. Impressions or prints of leaves are often found accompanying the wood. This lignite burns with a blue blaze, giving off an empyreumatic odor. As above stated, pyrite is commonly associated with the fossil wood. Exposed to the atmospheric air it soon cracks badly and falls to pieces, so that lumps, solid when freshly taken out of the pits, are soon ruined as specimens in mass. Nearly all of the dark-colored clays, and particularly the more sandy of these, contain lignite, or *wood*, as it is commonly known among clay diggers, either in very small fragments very uniformly distributed through the mass, or in the form of sticks and larger pieces more irregularly imbedded in them. In the upper part of the clay formation, and near Chesquake creek, beds of lignite one to four feet thick occur among the black clays and sands. For a fuller description of these lignite beds the reader is referred to the "Geology of New Jersey," and also to pages 74 and 75 of this report It is needless to mention localities, as they are almost everywhere in the area of the clay formation and they are referred to in the local details of Part II. The composition according to an analysis made some years ago in the survey laboratory is,

Gases (volatile hydrocarbons)	50.2
Coke (carbon)	34.6
Ash	15.2
	100.0

Its use as a fuel is, of course, restricted to its occurrence in workable masses. Elsewhere it is valueless. It cannot be considered as injurious as it burns out and leaves the mass white and more open, or porous. The fire clays do not contain it, or very rarely. In the dark-colored to black clays it enters to the extent of seven per cent in some of them. These are generally used in pipe making.

Oxide of Iron (Ferric Oxide).—The hydrated oxide of iron occurs very generally in the clays and *feldspars* of the plastic clay formation. The analyses of the white and fine ware clays indicate from .4 to 1.2 per cent of ferric oxide. Nearly all of it is readily dissolved by digesting the clays in dilute hydrochloric acid, which shows that it, or the most of it, exists uncombined and mixed with the silicate of alumina, or clay proper. And it is regarded as an accidental constituent or impurity. In none of the analyses of fire clays, or of the *feldspars*, has there been over two per cent., and generally it is about one per cent of the whole. The common, red brick clays often contain much more, although in these a part of the iron is combined as silicate with other bases. This oxide is supposed to be the coloring agent, or matter, in the various shades of red clays. The "spotted," or mottled clays, owe their variegated appearance to the iron oxide present in the red portions. The strange mixed arrangement of the colored clays in some parts of the fire clay bed has been referred to on pages 52, 67, 85 and 134. Some of the red clays have been examined and found to contain as much as seven per cent of oxide of iron. It seems highly probable, from the behaviour of our clays in analysis that a portion of the iron exists as a protoxide (ferrous oxide) and is combined with silica and other bases as a double silicate. When present to the extent of about one-half of one per cent, as in the best fire clays of the State, it cannot be of much effect upon the refractoriness. And it does not show in any discoloration in burning. When it amounts to three or more per cent, as in the red clays it appears to be injurious, as these do not stand intense heating. The removal of the iron by treating with acid has been suggested, but the practicability of such a method has not been proved, at least not upon a large scale.

Amber (*Succinite*), has been found in small, nodular masses in the dark-colored clays at Isaac Inslee's pits, near Woodbridge, George Such's pits, Burt's creek, and at Ernst's mines, on Chesquake creek. The largest pieces which have been collected by the survey were not more than an inch in diameter. It was of dark yellow to reddish brown color. Its occurrence in the dark-colored, lignitic clays is an indication of vegetable origin.

Malachite, or Carbonate of Copper, and Vivianite are among the rarest of these foreign constituents of the clays. These minerals have been observed, each in a single locality. They appeared as incrustations, or filmy coatings, on the fractured surfaces.

Red-shale has been mentioned as one of the foreign constituents. Its occurrence is limited to the bottom of the lowest member of the plastic clay series—the Raritan bed and near the red-shale and sandstone rock of the triassic age. It appears in small fragments, and as shaly earth in the clay of two or three localities. Excepting these occurrences, no traces of these rocks have been discovered anywhere in the beds of the clay formation.

Sandy earths and loamy materials are found in places with the clays, not in one mass, mixed uniformly, but in streaks and irregular pockets and layers in the clay. They can hardly be considered as parts of the clays, but rather as associated impurities. In some cases these are superficial masses, or deposits of later age.

MICROSCOPICAL EXAMINATIONS.

A microscopical examination of some of the clays of the State as well as of some obtained elsewhere, was suggested by the paper of

Johnson & Blake, "on Kaolinite and Pholerite," in the American Journal of Science and Arts, II Vol., XLIII, pp. 351–361 (1867.) Their results, as therein presented, indicate the existence of a mineral of definite form and composition, and this was named by them *kaolinite* from the old and common word "*kaolin*."*

Under the microscope this mineral appears in the form of transparent or translucent, rhombic, rhomboidal, or hexagonal plates, or scales, which are generally aggregated in irregular, curved and sometimes in fan-shaped, prismatic bundles. The same paper further indicates an intimate relation between the plasticity of the clays and their fineness, or state of aggregation in which the plates or scales are found. In sedimentary clays these are more broken and fragmentary, and there are fewer bundles than in the *kaolin* proper, or clays which have resulted from the decomposition of *feldspar in place*. Trituration, as rubbing between the fingers, breaks up the bundles and the mass is rendered thereby more plastic than in its original state. The plates vary greatly, from .005 to .0001 of an inch in diameter.

The examinations made for this report were with powers ranging from 200 to 800 diameters. Many clays, *fieldspars* and *kaolins* were examined, more particularly with reference to the nature of the foreign constituents associated with the *kaolinite*. The specimens were exceedingly diverse in character and embraced both *kaolins* and sedimentary clays of different geological ages. The hexagonal scales or plates, were found in nearly all of these specimens. Generally they were much broken, and the mass appeared largely made up of their fragments. Curved and prismoidal aggregates, or bundles of these nummular plates were more abundant in the *kaolins* than in the sedimentary clays. In some of the latter no plates were recognized. The following specimens are selected as indicating the range of the examination and the results.

1. Washed, white clay from Bethlehem, Hunterdon county. This clay is simply the altered *feldspar, in situ*.

Plates very abundant and small, many fragments. No bundles. These may have been broken apart in the washing.

*This word *kaolin* has been used with much latitude, and its meaning greatly perverted in various ways. Originally from the Chinese *kaoling* or *kau-ling*, meaning high ridge, and applied to the pulverized rock employed in pottery—it has been transferred to the clays resulting from the decomposition of feldspathic rocks *in situ*, and then to those which have been removed from the original locality and deposited in beds, or sediments of later geological formations. In New Jersey and on Staten Island it has been still further used to designate a micaceous sand. Wherever so used in this report it appears italicized.

2. Clay from Trenton. Another clay which is on the site of its origin, or very near it.

Full of plates, mostly thin. Some rhomboidal but more irregular in outline.

3. *Kaolin* from Hokessin, Delaware. Decomposed *feldspar, in place.* Many very fine, thin plates; some masses of nummular plates, or shapes.

4. Paper clay, E. F. & J. M. Roberts, South Amboy. Very little quartz. Mass of fine particles largely made up of small discs or plates of irregular outline. A few of them were approximately hexagonal in shape.

5. Blue fire clay, same pits as No. 4. This appeared much coarser than No. 4. Very few plates were seen in it.

6. William H. Berry's retort clay, Woodbridge, extremely tough and plastic. Very small particles, No plates or bundles.

7. Charles M. Dally's clay (Raritan bed), south of Bonhamtown. No plates or bundles.

8. Clay from *feldspar*, Forbes' farm. Many plates, but very small. Prismatic bundles of nummular shaped plates also common.

9. Clay from *feldspar*, Knickerbocker Life Insurance Company's farm, Perth Amboy township. Much coarse gritty material. Many bundles of nummular shaped plates, but of less diameter than those of the clays.

10. N. Furman's stoneware clay, Chesquake creek. Much quartz in grains of irregular shapes. A few thin plates.

Among the foreign specimens examined were Chinese kaolin, which contained many small curved bundles, and kaolin from Aue, Saxony, in which fine plates and bundles were very abundant.

These examinations appear to show the very general presence of the crystallized *kaolinite*, and, further, the connection between the plasticity and the state of fineness of the clays. The absence of well defined hexagonal plates or scales, and the abundance of irregular shapes or fragmentary plates in most of our clays accords with their sedimentary character and their highly plastic nature. In this place it is proper to add that an examination of some of the altered *feldspar* from Trenton, discovered nummular like shapes and some irregular (broken) plates.

The subject has a practical application, and it is highly probable that the microscope can be used to ascertain the degree of plasticity as depending upon the abundance, nature and state of aggregation of these crystalline forms, (*kaolinite*) in the raw materials.

Microscopic examinations are also of value in the determination of the foreign, or accidental, constituents of clay, that is, the minerals associated with the *kaolinite*. The field is very interesting both scientifically and practically. Want of time prevented the continuation of this work further.

PROPERTIES.

All the clays occurring in New Jersey are earthy, differing essentially from the hard and rock-like fire clays which are found in the coal formations both in this country and in Europe. Consequently they are mined or dug from their beds by the use of spades and grubbing hoes, and rarely are so hard as to require the use of a pick. They break with a dull fracture, often conchoidal or irregular in outline. When breathed upon they exhale a peculiar *argillaceous* odor. Moistened with water they form a pasty mass, more or less tough, according to a variety of conditions all of which are not certainly known. This affinity for water is strong, and the combined water is entirely removed only by intense heat.

The density, or specific gravity, varies considerably in specimens from different localities, and in those from the same place according to their physical constitution. The following table of specific gravities of clays occurring in New Jersey exhibits the range of variation in this respect. It may be stated here as a convenience in using this table, that water is assumed as the standard of comparison, and is represented as unity, or 1.000. If, therefore, a clay has a specific gravity of 2.000 its weight, bulk for bulk, is just twice as great as that of water. It may be added, as convenient in the practical application of these figures, that the weight of a cubic foot of water is 62.5 pounds. Consequently 30.4 cubic feet will equal one ton (2,000 pounds); or 15.2 cubic feet of a clay, whose specific gravity is 2.0, will weigh 2,000 pounds; or, in another form, 1 cubic yard (27 cubic feet), will weigh 3,550 pounds. With a specific gravity of 1,750, the average for the rich fire clays of Middlesex county, 1 cubic yard weighs about

3,100 pounds—or 1½ tons. In practice it is found that a cubic yard of a clay a little sandy weighs about 3,300 pounds.

The method of taking the specific gravity was as follows: A prism about an inch in length was cut out of the solid mass. This was covered by a film of paraffine and weighed, first in air, then in water.

A few were taken in this way; afterwards the prisms were placed in water, in a glass vial very little larger than the clay, and then weighed. No water was absorbed by the clay in this modification of the method.

By this method the *openness*, or porous condition, which affects the density, was taken into account. The ordinary method neglects this condition and the specific gravity as obtained, is that of the clay, sand, &c., or solid mass, without any reference to the space or interstices between the particles of solid matter.

TABLE OF SPECIFIC GRAVITY.

The arrangement of the table is geographical. The percentage of sand (quartz) appears in a second column, in the clays which have been analyzed and that constituent determined.

	Specific gravity.	Percentage of sand (quartz.)
Clays North of the Raritan River.		
William B. Dixon's best fire clay	1.994—2.047	28.81
Loughridge & Powers' ware clay	1.731—1.809	0.50
Loughridge & Powers' alum clay	1.869	....
Loughridge & Powers' sandy clay (bottom of bed)	1.813—1.897	....
William H. Berry's fire clay (for retorts)	1.743—1.789	6.51
Salamander Works pipe clay	1.853—1.941	....
J. R. Watson's fine sandy clay	1.777	....
S. A. Meeker's potters (stoneware) clay	2.047—2.077	48.40
H. Cutter & Sons' fire clay	1.764—1.769	1.10
H. Cutter & Sons' ware clay	1.766—1.893	0.80
H. Cutter & Sons' black clay	1.569—1.614	....
Charles Anness & Sons' fire clay	1.861—1.864	20.60
Philip Neukumet's fire clay	1.798—1.814	....
Crossman Clay and Manufacturing Company's blue pipe clay	1.689—1.699	....
W. N. Weidener's white clay (Martin's dock)	1.528—1.542	0.71
David Flood's mottled or "spotted" clay	1.790	....
David Flood's mottled or "spotted" clay (white portion)	1.778	....
David Flood's mottled or "spotted" clay (red portion)	2.170	....

TABLE OF SPECIFIC GRAVITY.—(Continued).

	Specific gravity.	Percentage of sand (quartz.)
Clays South of the Raritan River.		
Island Farm white clay	1.578—1.610	0.50
James Bissett's red brick clay	1.778—1.812	....
Sayre & Fisher's fire clay	1.657—1.705	3.10
Sayre & Fisher's (clay for front brick)	1.705—1.732	27.80
Sayre & Fisher's common brick clay	1.860—1.882	....
Whitehead Brothers' blue fire clay	1.837—1.883	....
Whitehead Brothers' red clay	1.745—1.771	....
J. K. Brick estate, No. 1 fire clay	1.760—1.773	....
J. K. Brick estate, No. 2 fire clay	1.852—1.901	....
George Such's (unwashed) fire clay	1.716—1.751	....
George Such's buff (washed) clay	1.530—1.571	....
George Such's alum clay	1.539	....
George Such's top (inferior) clay	1.660	....
E. F. & J. M. Roberts' fire clay	1.738	0.70
E. F. & J. M. Roberts' paper clay	1.723—1.742	0.20
E. F. & J. M. Roberts' common white clay	1.702—1.746	....
Feldspars.		
Forbes Farm, W. N. Weidner's pits	2.321	58.40
Edgar Brothers	2.283	57.10
Stoneware Clays, Middlesex County.		
E. R. Rose & Son's stoneware clay	2.129—2.151	37.10
Otto Ernst's stoneware clay	1.971—2.138	39.95
Noah Furman's stoneware clay (Chesquake creek)	2.012—2.022	37.85
Theodore Smith's stoneware clay	1.946—2.062	....
Clays Along the Delaware River.		
Daniel South's saggar clay	1.864—1.873	....
Joshua Eayre's clay, Florence Heights	1.981—2.023	40.50
J. D. Hylton's fire clay, Palmyra	2.052—2.101	56.80
B. A. Lodge's clay, Billingsport	1.898—1.917	....
Clays Unclassified.		
Isaac Webster's, Ten Mile Run, Somerset county	1.607—1.612	8.60
James Conrad's washed clay, Conrad, Gloucester county	1.803—1.961	....
Joseph Nugent's clay, Tuckerton, Burlington county	1.827—1.864	....
R. L. Shimer's (washed clay,) Bethlehem, Hunterdon county	1.523—1.579	....
Hokessin, *Delaware* (washed clay)	1.604—1.622	....

It will be observed that the variation in the density, corresponds in some degree with the percentage of sand, but this is not altogether the case, as there are differences aside from the admixture of sand. The specific gravity of quartz is 2.5—2.8, consequently the greater the proportion of sand, the clay being the same, the greater the density. Some of the dark-colored pipe and red brick clays are exceptions to this, although they are generally quite sandy. It will also be evident upon consideration, that clays which contain sand of various degrees of fineness, or exceedingly fine sand are more dense than coarser grained mixtures. In the former case the intervening spaces are smaller. In some of the clays the sand is almost *dust fine;* while in others the average size of the grains may not be less than .01 inch in diameter. The clay itself, in some specimens, appears more compact and dense, as, for example, the ware clay of H. Cutter & Son's, compared with the fire clay of the same pits. The older beds appear to be more dense; thus, if there be any difference between the Woodbridge and the South Amboy fire clay beds, it is in the greater density of the clay in the former. The washed clays are all lighter than the raw, or crude clays, of the same grade. The table shows this in the clays of George Such and that of Bethlehem, as also the Hokessin, Delaware clay.

For many purposes the density of a clay is an important element of consideration. When strong fire brick are needed, or glass house pots, a dense, solid clay is desirable. One of the superior qualities of the celebrated Stourbridge clay of England, and that from Coblentz, Germany, as also the Missouri clays, is their comparatively great density. That of the first named is 2.435—2.553; that of the Coblentz, 2.229—2.266; that of the Cheltenham clay, Missouri, 1.708—1.715; that of the Evans Mine, Missouri, 1.759—1.789. The nearest approach to these figures in our New Jersey clays, is that of Dixon's pits, Woodbridge.

Plasticity is another of the essential and important properties. By it is understood the capacity which a clay has of absorbing water and forming a tough, pasty mass. On drying, it hardens, and when burned it becomes stone-like. The plastic property has been variously explained. Some opinions ascribe it to the impurities in the clays. But this cannot be, since clays equally pure are not at all alike plastic. A large percentage of sand, which is non-plastic, may affect this property, and render a clay more loose and friable, but in moderately aluminous, or rich, fat clays, the greater or less admixture of sand does not appear to make any differences in this direction. The alumina has been regarded as the basis of the plasticity, and highly aluminous clays have been said to be more plastic than others containing less of that element. Neither is this a satisfactory explanation, as some of those which are richest in alumina, are deficient in this property. The amount of combined water is another constituent in which the plasticity has been supposed to reside. Like the above, this also is not adequate to every case. There are marked exceptions to any of the above hypotheses. And it would be easy to cite numerous examples against any one of them. Chemical composition does not appear to be competent to furnish a theory which meets all cases and explains the facts. The physical constitution must afford us the clew. And in this direction it has been stated that the fineness of the material, that is, of the *kaolinite*, or essential part, of the clay was so related to the plasticity that the one might be assigned as the cause of the other. To the unaided eye the *clay* portion presents no differences in structure. The accidental, or foreign constituents, as sand, oxide of iron, &c., manifest themselves plainly either in their structure or in color, but the kaolinite is all apparently of the same *texture*—a homogenous mass. Microscopical examination is here necessary. And it discovers marked differences. Some clays appear to consist of well defined crystalline forms; others show a few of these in a mass of fragmentary shapes; others still seem to be wholly made up of irregular forms and exceedingly fine particles of matter. A satisfactory explanation of these different conditions is that the more finely divided clays are those which have had their crystalline forms broken up, either wholly or in part by the several agents that have moved them from the place of their origin to their present location, while those in which these forms still abound have not suffered the same constitutional derangement. Now, it has been observed that the former class of clays are more plastic than the latter. And a further observation is that by breaking up these crystalline forms and rendering them finer the plasticity was promoted. We know that in some of the metals a tendency to crystallization reduces their tensile strength; most notably in the case of iron; and it may be that the crystalline structure of clay is somewhat analogous to the metals. Thus far there seems to be a close correspondence between this state, or condition and the property of plasticity, and it appears to be a reasonable explanation consistent with most, if not all, the facts. The microscopical examination of a few of the clays of the State, with reference to the investigations of Profs. Johnson and Blake, of New Haven, given on pages 280–283. illustrate briefly some of the above statements. As corroborating this view, is the mechanical preparation of clays by variously kneading, grinding, or otherwise working up the mass, which appears to render them more plastic and better fitted for manufacture. The weathering of clays, by the action of rains, frosts, &c., is said to improve their texture and make them more easy to mould into desired shapes. This action of atmospheric agents may break up not only the lumps or spits as they come from the pits or mines, but to some extent the crystalline structure of the *kaolinite* as well, and thereby increase their degree of fineness and render them more highly plastic.

One peculiar property of the clays of all grades and varieties is that when heated to redness, or until the combined water is expelled, they lose entirely the plastic property. Burned clay, as for example, brick earth may again be wet up or become moist, but cannot recover the lost water of combination. In consequence of this the plasticity has been supposed to be due to the combined water, and the absence of this constituent is said to account for the want of it in burned clay. That the water is essential cannot be denied. It does not, however, make clear the very marked differences which exist in different clays in their degrees of plasticity. In these statements relating to New Jersey clays it must be understood that our clays are nearly all of a sedimentary origin, and are not properly kaolins, or porcelain clays in the sense in which those terms are used. The only clays of the latter class are those found in the northern part of the State. They are in, or very near the localities of their origin, and the parent rock from the decomposition of which they have resulted. The distinctions employed in the designations of the clays of Middlesex county, and of those along the Delaware river, as ware, fire, potters, stoneware and pipe clays, are to some extent interchangeable, that is some of the best clays may be applied in part to all these uses and receive names according to their several applications. The names refer to uses, and these are quite as often determined by the demand as by their adaptation to the various uses to which they may be given. In Europe these terms generally imply special characters that mark them strongly as varieties. Here the clays of the same geological bed are often variously used. There are, however, marked characteristics in the materials of the same bed, or even pits sometimes, and these do to a great extent limit their uses, but the lines are not as sharply drawn between them as elsewhere. The clay of the stoneware clay bed is perhaps as definite as any. All are plastic, but not in the same degree; and all discussion of plasticity is relative to grades, not to absolute distinctions of plastic and non-plastic.

Fusibility and Refractoriness. Inasmuch as clays are prepared for their most extensive and most varied uses by the action of heat, or *fire*, their behavior when subjected to the action of intense heat is the most important and decisive test which can be applied to them. According to the results of such tests they are very generally classified according to the several uses to which they are adapted. All clays which can be moulded into shapes can be baked and thereby made hard and solid approximating to stone. At moderately low temperatures, as incipient redness, nearly all are infusible and to this extent their action in the fire is somewhat alike. But here the resemblance or uniformity ceases. Beyond the facts of *baking* and not *melting* or fusing in a moderate heat, there is nothing common or characteristic of all. This degree of heat produces various effects, depending in some degree upon the combinations in the clay. The first and great change in all is the removal of the moisture or hygroscopic water, and after that the expulsion of the remaining water, which is combined with the alumina and silica as a *hydrous* silicate of alumina. As has already been said the removal of the latter changes essentially the nature of the clay, permanently destroying its plasticity. It further affects the mass by causing a shrinkage from the original shape. This varies greatly in different clays, dependent in part upon the quantity of water in the original clay, and also upon its constitution. Thus some clays which are almost exclusively silicate of alumina, that is, contain little, if any, foreign matter when baked, contract as much as one-quarter in linear dimensions. And in general the *fat*, or aluminous, clays shrink much more than the *lean*, or sandy and impure, clays. The change is essentially in the silicate of alumina and the percentage of this, or of the clay proper, is in part the measure or index of the shrinkage of the whole mass. The various foreign constituents, which are not destroyed by the *baking heat*, or remain unaffected thereby, as quartz sand, oxide of iron, &c., have no tendency to shrink and in the clayey masses counteract that of the silicate of alumina or clay proper. And their effect is proportioned to the amounts in which they may enter into the original composition. Consequently, when in quantity or in excess of the clay itself there is little shrinkage, and sometimes it may be entirely counteracted by the expansion of these foreign constituents. Sandy clays therefore shrink but little, if at all; in some cases they expand, and on cooling return to their original dimensions. Shrinkage manifests itself variously. It may be by a diminution in all directions and the baked mass may be as solid and free from fractures as it was when fresh from the mould. The change may be simply in bulk. The baked clay is not as long nor as broad nor as thick as originally. But a more common form or development of the shrinkage is in more or less fractures, cracks or checks, as these are sometimes termed. The very rich and pure clays, when baked, generally exhibit the shrinkage throughout in many little cracks and fractures. Hence the need and use of a non-shrinking material, as quartz, to prevent too great contraction and fractures, in other words to *temper* the mixture. The brick maker and potter have constant recourse to some such counteracting admixture in their arts.

The *baking* process produces other changes in addition to the expulsion of water and the consequent shrinkage; and one of these is the combustion of the carbon and hydro-carbon compounds of the raw clay. These exist in many clays, but in varied forms. Lignite, a hydro-carbon, is one of the most common in our clays of New Jersey. This is consumed in the fire, and its place left open in the burned mass. A result of such change is seen in the more open and porous condition of materials which, in their unburned state, contain some of these combustible constituents. The value of such fuel in the raw clay cannot be accurately estimated. At low temperature it cannot be much, as then the volatile gases might be expelled without combustion, and their removal would consequently take up, rather than yield, any additional heat. If volatilized, and then consumed in the kiln or furnace, they must contribute to the degree of heat, and in such cases be of value in practice. As some of our black and dark-colored clays contain from two to seven per cent. of such materials, they are not less valuable on this account. The economy of fuel in such form and shape is also evident from the common usage of brickmakers in mixing coal dust with their clay and sand for the brick mixture. When present in the form of sticks, and large, irregular lumps in the clay, woody matter, or lignite, may be a disadvantage, causing vacancies and gaps in the products. Careful mixture, as grinding, &c., may obviate this evil. Another constituent affected by a moderate degree of heat is the pyrite (sulphide of iron.) This constituent, not uncommon in sedimentary clays, is decomposed, its sulphur driven off, and its iron oxidized to ferric oxide, or to a mixture of ferrous and ferric oxides. The escaping gases may produce other changes, both physical and chemical, which may be prejudicial. These changes are not altogether desirable, although the resulting compounds are not so injurious as the sulphide of the crude clay. But they are unsightly, and mar the beauty of the baked products. Hence their removal before baking, when possible, so as to avoid these after results. From these statements it will appear that clays of diverse composition must behave variously, even at moderately low temperatures, as that in ordinary brick making, or that of baking, as in the case of earthen ware. Differences in the original clay manifest themselves in the burning.

More intense heat produces greater and more marked effects, and some clays reach their fusing point and are melted. This temperature of fusion is not uniform for all, but varies somewhat according to many circumstances. Some clays remain unmelted at the highest temperature of metallurgical operations. They are practically infusible. This fire resisting or refractory property of clays, is the most remarkable and valuable one which they possess. All of these terms relating to fusion are not absolute, since all clays can be fused before the oxyhydrogen blow pipe, and at a given temperature clays may be infusible, whereas when subjected to a greater heat they would melt. They are limited to the degree of heat employed. This refractory property of clays is intimately connected with their physical nature or structure and their chemical constitution. Or in other words, it is dependent upon these, and the varying phases of the latter explain the differences in their behavior under like conditions.

The physical constitution of clays has an effect upon the fusibility in several ways. The density and fineness of grain are important elements in the consideration. The finer grained the clays, the more fusible they are, other things being equal. Greater density arising from a more compact arrangement of constituents increases the refractory property. In this consideration the size of the grains of sand which enter into the composition of most fire clays is important. Comparisons based upon these physical differences are not easily made as they are so apt to be associated with slight differences in chemical constitution, making the proper estimate of these several factors extremely difficult. Consequently the more prominent distinctions rest upon the

Chemical constitution. As a starting point, it may be assumed that the basis of clays, hydrous silicate of alumina, is practically infusible. Before the oxyhydrogen blow pipe both this silicate and alumina can be melted. Quartz also is readily melted in the same way. But in the highest furnace heats of metallurgical operations, alumina and its silicate, the basis of clay, are infusible. The clays whose composition correspond to this silicate are refractory. The variations from the normal composition as a standard are many according to the varying amounts of foreign matters which are mixed with the *kaolinite* base. And they all have their effect, separately and collectively, upon the whole. Each one may be said to have a particular tendency, which may vary according to its percentage of the mass. This statement shows how difficult it is to fairly estimate, or even in some cases to judge of the nature of the effect produced by these constituents in making any given clay more or less refractory. One may neutralize in part another, or the presence of one may increase the tendency of another to injure the fire-resisting property. In consequence of the difficulty there is much difference of opinion regarding the nature of the effects and their extent. Authorities both theoretical and practical are not altogether agreed upon many points. And so, too, theoretical considerations are not in all cases confirmed by practical tests and the results of work.

The variation from the *kaolinite* composition (46.3 silica, 39.8 alumina, and 13.9 water), may be by an increase of the alumina or a larger percentage of silica, due to the existence of other silicates. That such do exist is certainly the case, if the above composition for the base (kaolinite) be accepted, chemical analysis shows that the relative proportions of the silica and alumina are not always expresed by the above figures. Hence the presence of other silicates of alumina is inferred to explain the facts of analysis. It has been stated that the most aluminous clays were the most refractory. That is, the refractory property varies directly as the alumina to the silica, other things being equal*. Whether this is equally true in the case of two or more silicates, and in a more basic silicate assuming a different composition from that above, is not known. As has been stated on page 270, our clays are highly aluminous, and the alumina is in excess of the silica, to form *kaolinite*. An excess of silica is said, at long continued and very high temperatures, to favor the formation of a fusible silicate†. An examination of the analyses of this report appears to be in accordance with this proposition. The stoneware clays of Middlesex county, and those along the Delaware river, contain an excess of silica (see pages 271 and 300), and these are fusible clays. The percentage of potash and other bases may, however, explain their fusibility.

The accidental or foreign constituents found in fire clays, and which affect their refractory property, are sand (quartz) and titanic acid, and the bases potash, soda, lime, magnesia and oxide of iron. In the analyses in Part II these are arranged in two groups, the quartz and titanic acid in one, and the bases here mentioned in the other. The latter are viewed as fluxing agents, while the former may be considered as neutral.

Silica in the form of sand is infusible, excepting at very high temperatures. Practically it stands the fire in all ordinary furnace work. But it is not so refractory as pure clay or silicate of alumina. When associated with the alkalies, to the extent of one

* C. Bischof, Dingler's Journal No. 194, et seqr.

† Kerl's Muspratt's Chemie, 5. 361.

or two per cent. each, it is sometimes made fusible, by the formation of a slag containing these bases, combined as a double silicate. The tendency of sand to *slag*, when brought in contact with bases, is well known to furnace men, and it is avoided in constructions exposed to such agents. It is valuable for tempering the rich clays and for special uses, but simply as refractory material, can not rank with the clay basis. Titanic acid is found in most fire clays, but rarely in amount above 1.5 per cent. In New Jersey clays it exists in the form of rutile, or a variety of this mineral with some titanate of iron. It is supposed, from its relation to silica, to act like sand or quartz, and not to be specially detrimental to a fire clay. As it is always in such small amounts, its effects cannot be great either way.

Oxide of iron may be in the clay uncombined, or in combination with other bases and silica, or it may result from a decomposition of sulphide or sulphate of iron, through the action of the fire. As to the degree of its influence upon the refractory property of a clay, there is some difference of opinion. Bischof in experiments with silicates of known composition and tests of various mixtures containing oxide of iron, lime, magnesia and potash, obtained the following results.* At the melting point of wrought iron the lime and the potash mixtures melted; the magnesia partly melted; the oxide of iron was unaffected. At most intense white heat the oxide of iron prism was rounded to a ball, and the one containing potash fused to a porcelain-like mass. In point of fusing tendency the potash was most active and the iron least so. An increased percentage of bases gave similar results. It has been observed in the case of Stourbridge clays that none of them contain over two per cent. And when alkalies are absent, the iron oxide may be present to the extent of three per cent.† This experience agrees with the observations made on New Jersey clays. Those which contain three or more per cent. of this oxide, as some of the dark-colored, common brick clays, and all the red and spotted clays, are less refractory than the rich blue fire clays. All of them can be fused. It is, however, difficult to be positive upon this point, as these contain other bases also, and notably potash.

Lime and magnesia also exert a fluxing influence. And ac-

* Dingler's Journal, No. 196, p. 438, et seqr,
† Journal of the Iron and Steel Institute, 1875, pp. 514–520.

cording to Richters, they are more active than potash or oxide of iron.* As the silicates of these bases are easily fusible, the tendency to the formation of such a compound would have its fluxing effect upon the clays containing them. The clays of New Jersey contain low percentages of these constituents. They have not in all cases been estimated, but in none of the complete analyses do they amount together to one-half of one per cent. In the best foreign fire clays they rarely amount to one per cent.

Potash.—It is generally admitted that potash possesses the most active tendency as a fluxing agent. And this, as stated above, may be helped by the presence of other bases, as iron oxide, favoring the production of a silicate with two or more bases. Opinions differ as to the amount of potash which may be positively damaging in a fire clay. Snelus says that about one per cent. confers so much fusibility as to render them unsuitable at high temperatures.† Bischof found that four per cent. of potash, in a silicate of alumina, without any other bases, could be fused at the melting point of wrought iron. The difficulty of accurate determinations of alkalies, has no doubt led to some confusion of opinions, as compared with the results of practice. Clays containing from two to three per cent. of potash, are said to stand well at high temperatures. The most carefully made analyses of the more noted and best fire clays of this country and Europe, do not generally show more than two per cent. of potash, and the greater number do not contain one per cent. of alkalies. So far as the clays of this State have been tried, those which are found to have one and a half to two per cent. and upwards of potash, have not proved to be good fire clays, and none containing over two per cent. are in use as fire clays. And yet they are otherwise rich and tolerably pure clays. The potash alone appears to explain their low refractory property.

These statements indicate the effects based upon the chemical constitution, and from them it follows that chemical analysis does, to some extent, show the refractory property, or the degree of fusibility, of a fire clay. And from carefully made analyses, it is possible to draw some general conclusions regarding the fire-

* Dingler's Journal, 191, 59.
† Journal of the Iron and Steel Institute, 1875, p. 513.

resisting power of any given clay. Bischof has attempted this, and has constructed the following formula by which to test fire clays. It is based upon the general principle that a clay is more refractory the greater the quantity of alumina it contains in proportion to the silica and to the fluxing constituents. And an expression is obtained by dividing the quotient of the fluxes into the alumina, by that of the alumina into the silica.* This is a very simple formula to use, and it rests upon generalizations that are founded on practical observations and results. Knowing the composition of a clay, its fire-resisting power, or refractory value, can be readily ascertained.

The following table of analyses, made in the laboratory of the Survey, is here presented as a convenient arrangement of facts for reference, and also as an illustration of the statements given above. In it the constituents are arranged somewhat as in Part II. In the first column the silica, which is in combination, is given; in the second, the alumina; in the third, the water of combination; in the fourth, the sum of these three constituents, or the essential elements of a clay; in the fifth and sixth, the titanic acid and quartz sand appear; in the seventh, the sum of these two; in the eighth, nine, tenth, eleventh and twelfth, are given the potash, soda, lime, magnesia and sesqui-oxide of iron; the thirteenth gives the sum of these; the fourteenth has the hygroscopic water (moisture), fluxing agents. In the last column the total of the constituents determined, is placed. By this arrangement it is easy to use the formula of Bischof or others, and apply them to these analyses. In the appendix, additional analyses of foreign clays, by other chemists, are placed, for comparison with those of this report.

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* $\frac{Al_2O_3}{RO} \div \frac{SiO_2}{Al_2O_3}$

RO includes the bases, potash, soda, lime, magnesia and oxide of iron. Dingler's Journal, 200; 110.

TABLE OF ANALYSES OF FIRE CLAYS AND ASSOCIATED REFRACTORY MATERIALS.

MADE IN THE LABORATORY OF THE GEOLOGICAL SURVEY OF NEW JERSEY.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
		Silica (combined.) ($Si O_2$.)	Alumina ($Al_2 O_3$)	Water (comb'ed.) ($H_2 O$)		Titanic acid. ($Ti O_2$)	Silica (quartz sand.) ($Si O_2$)		Potash. ($K_2 O$)	Soda. ($Na_2 O$)	Lime. ($Ca O$)	Magnesia. ($Mg O$)	Sesqui-oxide of iron. ($Fe_2 O_3$) (1)		Water, (hygroscopic.) ($H_2 O$.)	Total.	For description, see page here mentioned.
	Raritan Fire Clay Bed.																
1	William B. Dixon, Woodbridge	31.12	26.95	9.63	67.70	1.90	28.81	30.71	traces	traces	....	0.07	1.24	1.31	0.57	100.29	78-80
2	David Flood, Southeast of Bonhamtown	....	....	9.60	....	....	....	....	0 42	....	....	....	....	....	....	....	(5) 158-159
3	B. Ellison, South-southwest of Bonhamtown	17.90	15.50	4.90	38.30	1.60	57.35	58.95	0.17	....	....	....	1.20	1.37	1.30	99.92	165-166
	Woodbridge Fire Clay Bed.																
4	William H. Berry, Woodbridge	40.50	35.90	12.80	89.20	1.30	6.40	7.70	0.28	0.16	....	....	1.10	1.54	1.50	99.94	Used for maki'g retorts.(6). 82-84
5	Loughridge & Powers, Woodbridge	42.23	39.53	13.59	95.35	1.40 with	0.50	1.90	0.41	0.08	0.10	....	0.50	1.09	1.21	99.55	90-92
6	Loughridge & Powers, Woodbridge. Extra sandy	20.00	(2) 18.92	6.70	45.62	AL2 O3	51.80	51.80	0.48	....	....	....	0.88	1.36	0.50	99.28	Under the ab've fire clay. 93
7	A. Hall & Son, Woodbridge	42.05	35.83	12.20	90.08	1.10	5.70	6.80	0.44	....	....	0.11	0.77	1.32	1.50	99.70	94-96
8	H. Cutter & Sons, Woodbridge	43.90	38.24	14.10	96.24	1.30	1.10	2.40	0 15	0.00	traces	0.11	0.96	1.22	0.70	100.56	105-109
9	W. H. P. Benton, Woodbridge	42.00	37.56	11.60	94.16	1.40 with	1.40	2.80	0.35	0.37	....	....	1.01	1.76	0.80	99.52	114-115
10	Charles Anness & Son, Woodbridge	34.30	(2) 31.66	10.50	76.46	AL2 O3	20.60	20.60	1.53	....	....	....	0.74	2.27	0.60	99.93	115-116
11	Crossman Clay and Mfg. Company, Raritan river	37.85	35.75	12.30	85.90	1.60	10.50	12.10	0.37	....	....	traces	0.95	1.32	1.00	100.32	No. 1 fire clay 144-146

(1) In some of the clays a part of the iron exists as Fe O.
(2) Alumina and titanic acid.

(5) Analysis on page 166 should be as in this table.
(6) Analysis on page 83 should be as in this table.

TABLE OF ANALYSES.—(CONTINUED.)

Woodbridge Fire Clay Bed.—(Continued.)

No.		1 Silica (combined.) (SiO_2)	2 Alumina. (Al_2O_3)	3 Water (combin'd) (H_2O)	4	5 Titanic acid. (TiO_2)	6 Silica (quartz sand) (SiO_2)	7	8 Potash. (K_2O)	9 Soda. (Na_2O)	10 Lime. (CaO)	11 Magnesia. (MgO)	12 Sesqui-oxide of iron. (Fe_2O_3) (5)	13	14 Water, (hygroscopic.) (H_2O)	15 Total.	For description, see page here mentioned.
12	Crossman Clay and Mfg. Company, No. 2 fire clay	....	....	7.00	....	....	40.00?	....	0.21	....	....	....	0.78	....	....	....	146
13	R. N. & H. Valentine, Sand Hills	39.80	(2) 36.31	12.90	89.01	with Al2 O3	8.10	8.10	0.15	....	....	0.01	1.01	1.20	1.20	99.51	153-5
14	Charles A. Campbell & Co., Sand Hills. White fire clay	36.20	35.94	12.10	84.21	1.50	12.20	13.70	0.08	....	....	....	0.96	1.01	1.10	100.08	150-2
15	Freeman & Vanderhoven, Near Bonhamtown	(1) 47.10	36.33	(3) 13.60	....	1.60	....	....	0.20	....	....	....	1.07	1.27	....	99.90	163-4
	South Amboy Fire Clay Bed.																
16	E. F. Roberts, Pits near Eagleswood	40.40	(2) 38.40	12.50	91.30	with Al2 O3	5.20	5.20	0.59	....	0.22	0.25	1.20	2.26	1.30	100.06	135-6
17	E. F. & J. M. Roberts, Near South Amboy	42.71	39.21	13.32	95.27	1.60	0.70	2.30	0.47	0.12	0.20	....	0.46	1.55	1.58	100.70	200-202
18	E. F. & J. M. Roberts, (Selected)	44.20	39.14	14.05	97.39	1.05	0.20	1.25	0.25	....	....	....	0.45	0.70	0.90	100.24	Also used for paper. 203
19	George Such, Burt's Creek, Washed clay	42.90	38.31	13.50	94.74	1.20	1.50	2.70	0.26	0.18	....	....	0.86	1.30	1.10	99.81	197-199
20	Sayre & Fisher, Sayreville	41.10	38.66	13.55	93.31	1.20	3.10	4.30	0.28	0.18	....	....	0.74	1.20	1.00	99.81	188-9
	Feldspars.																
21	W. N. Weidner, Forbes farm, Perth Amboy twp	16.85	(2) 18.80	4.90	40.55	with Al2 O3	58.40	58.40	0.15	0.21	....	....	0.49	0.85	0.80	100.60	119-122
22	Edgar Brothers, Woodbridge township	16.50	17.46	6.30	40.26	0.90	57.10	58.00	0.12	0.21	....	....	0.54	0.87	0.50	99.63	137-138
23	Knickerbocker Life Ins. Co. Farm, Perth Amboy township	(1) 77.40	(2) 16.07	(3) 4.30	....	....	....	....	0.15	....	....	0.25	0.53	0.93	....	98.70	125-126

Kaolins.

24	Merritt's, Perth Amboy township	...	(4) 17.10	(3) 4.50	...	...	(1) 77.10	...	1.30	...	...	...	...	...	...	100.00		129-130
25	Charles A. Campbell & Co., Staten Island	...	(4) 5.70	(3) 0.70	...	...	(1) 92.70	...	0.35	...	...	...	...	...	...	99.45		131
26	Whitehead Estate, Washington	...	(4) 7.80	(3) 2.60	...	...	(1) 89.40	...	...	...	...	...	...	...	...	99.80		178

Fire Sands.

27	A. Hall & Sons, Fire sand	...	3.15	...	...	...	(1) 96.30	...	...	...	...	...	0.55	...	...	...	White and coarse grained	
28	A. Hall & Sons, Fire sand	...	6.65	...	...	...	(1) 92.50	...	...	...	...	...	0.85	...	...	...	White and fine grained	
29	M. Compton's, Southeast of Bonhamtown	...	(4) 1.45	...	...	0.25	(1) 98.00	...	0.20	traces	traces	...	...	...	...	99.90	Coarse grained	159-160
30	M. Compton's, Fine grained	...	(4) 2.10	...	...	...	(1) 96.40	...	...	...	...	...	...	...	...	...		159-160

Clays Unclassified.

31	W. N. Weidner's white clay, Martin's dock	45.10	(2) 38.60	10.90	91.60	with Al_2O_3	0.70	...	2.24	0.25	...	...	1.00	3.49	1.00	99.79	(7)	170-172
32	Island Farm,	45.20	31.85	13.60	93.65	1.40	0.50	1.90	0.12	traces	0.25	traces	1.35	1.72	2.80	100.07		174-175
33	Isaac Webster's, Ten-Mile run, Somerset county	38.20	35.09	11.80	85.09	1.30	8.60	9.90	2.44	0.21	...	0.21	1.89	4.75	0.30	100.04		231-234
34	A. J. Disbrow, White clay, Old Bridge	24.55	19.85	5.70	50.10	1.00	44.80	45.80	1.90	0.32	...	...	1.00	3.22	0.90	100.02		180-181
35	Mrs. Clark, South Amboy	19.50	(2) 17.58	4.50	(41.58)	with Al_2O_3	53.20	...	2.21	...	traces	0.43	1.42	4.09	1.20	100.07		205-206
36	S. A. Meeker, Sandy clay, Woodbridge	19.44	(2) 21.83	5.90	47.17	with Al_2O_3	48.40	...	2.24	...	0.28	0.24	1.57	4.33	0.80	100.70	Used for stoneware.	99
37	William H. Berry, Sewer pipe clay, Woodbridge	(1) 67.70	19.91	(3) 5.50	...	1.00	...	...	2.56	...	...	0.72	1.69	4.97	1.00	100.08	(7) For sewer pipe.	82
38	H. Cutter & Sons, Black clay, Woodbridge	(1) 56.00	20.75	10.67	...	0.95	...	...	0.91	...	0.22	0.18	1.60	2.91	2.40	100.41	Lignite, 6.73	107
39	Isaac Inslee, Top (pipe) clay, S. of Woodbridge	(1) 54.80	28.80	7.80	...	1.00	...	...	2.97	...	0.20	0.64	2.20	6.01	1.50	99.91		127-128
40	W. H. P. Benton, Pipe clay, Woodbridge	33.00	23.80	6.70	63.50	1.70	20.10	30.80	2.01	(8) 0.76	traces	0.57	1.60	4.91	1.00	100.24		113-114
41	Crossman Clay and Mfg. Company, Top white clay, Raritan river	(1) 61.00	(2) 29.08	(3) 6.80	...	...	...	...	2.61	...	...	...	1.12	3.76	...	...		145
42	Sayre & Fisher, Front brick clay, Sayreville	28.30	27.12	6.60	62.32	1.00	27.80	28.80	2.71	...	...	0.18	2.68	5.57	(9) 2.90	99.59		185-186

(1) Combined silica and quartz sand together.
(2) Alumina and titanic acid.
(3) Water (combined) and moisture.
(4) Alumina and sesqui-oxide of iron.
(5) Weighed as Fe_2O_3: part of iron exists as FeO.
(7) On page 172 analysis is of specimen dried at 212° Fah.
(8) Possibly too large.
(9) Including some organic matter (lignite).

TABLE OF ANALYSES.—(CONTINUED.)

Clays from Trenton and Southern New Jersey.

	1 Silica (combined) ($Si\ O_2$)	2 Alumina. ($Al_2\ O_3$)	3 Water (comb'ed.) ($H_2\ O$)	4	5 Titanic acid. ($Ti\ O_2$)	6 Silica (quartz sand.) ($Si\ O_2$)	7	8 Potash. ($K_2\ O$)	9 Soda. ($Na\ O$)	10 Lime. ($Ca\ O$)	11 Magnesia. ($Mg\ O$)	12 Sesqui-oxide of iron. ($Fe_2\ O_3$) (7)	13	14 Water, hygroscopic ($H_2\ O$)	15 Total.	For description see page here mentioned.
43 Washed Clay, Trenton	45.30	37.10	(3) 13.40	95.80	(4) 1.40	....	....	1.30	....	0.17	0.22	1.30	2.97	....	100.19	236
44 Dr. C. C. Abbott's clay, Trenton	(1) 70.05	(2) 19.43	(3) 7.00	....	....	....	....	1.60	....	....	....	1.52	3.12	....	99.60	237–8
45 Joshua Eayre's best white clay, Florence Heights	26.57	(2) 21.06	5.80	53.43	with $Al_2\ O_3$	40.50	40.50	2.47	0.21	....	0.60	1.98	5.26	0.80	99.99	242–3
46 J. D. Hylton's fire clay, Pensauken Creek	17.50	(2) 18.11	5.50	41.11	with $Al_2\ O_3$	56.80	56.80	0.76	0.20	0.11	....	1.09	2.16	0.40	100 47	246–8
47 B. A. Lodge's clay, Billingsport	16.20	(2) 15.00	7.70	38.90	with $Al_2\ O_3$	56.09	56.00	1.68	0.39	....	0.32	1.20	3.59	1.10	99.59	251
48 James Conrad's clay, Conrad, Gloucester county	29.50	(2) 23.30	7.00	59.80	with $Al_2\ O_3$	34.50	....	1.77	0.16	....	....	1.50	3.43	1.60	99.33	258–260

Clays from Delaware, Maryland and Pennsylvania.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	For description see page here mentioned.
49 Trucks & Parker, washed clay, Hokessin, Delaware	40.72	34.10	12.35	87.15	0.00	6.50	6.50	1.64	0.27	....	0.39	2.49	4.79	1.35	99.81	Appendix A
50 Woodland fire clay, Woodland, Clearfield, Co., Pa.	42.15	31.43	9.40	82.98	1.60	10.25	11.85	2.01	....	....	0.32	1.57	3.90	1.20	99.93	Penn. Steel Co., B'ldwin St'n, Pa
51 Flint clay, Solomon's Run, near Johnstown, Pa.	42.95	37.02	12.60	92.57	1.70	3.85	5.55	0.20	....	....	....	0.88	1.08	0.80	100.00	Cambria Ir'n Co Johnstown, Pa.
52 Mineral Point fire clay, near Johnstown, Pa	41.95	38.81	12.50	96.29	1.55	0.30	1.85	0.35	....	....	....	0.91	1.26	0.70	100.10	Cambria Ir'n Co Johnstown, Pa.
53 Mount Savage fire clay, Mount Savage Maryland	39.90	30.08	7.60	77.58	1.15	16.90	18.05	2.30	....	....	....	1.67	3.97	0.90	100.50	Jas. S. Mackie, New York

Clays from Indiana, Illinois and Missouri.

No.	Clay																Analyst
54	China clay from Huron, Lawrence Co., Indiana.....	40.10	36.35	(5) 22.60	99.05	0.00	0.40	0.40	0.14	....	....	0.13	0.15	0.42	....	99.87	John Moses, Trenton.
55	Potters' clay from Pope Co., Illinois..........	34.70	31.34	12.00	78.01	(6)	12.20	12.20	0.79	0.16	....	0.10	0.16	1.21	8.00	99.45	John Moses, Trenton.
56	Utica clay, Utica, La Salle Co., Illinois..........	38.25	26.45	9.80	74.50	1.15	18.40	19.55	1.10	....	....	0.30	2.10	3.50	2.10	99.65	North Chicago Rolling Mill Co.
57	Fire clay, Winchester, Illinois..........	23.15	17.08	6.30	46.53	0.90	46.70	47.60	1.10	....	....	0.28	3.47	4.85	1.20	100.18	C. Frost & Co., Winchester, Ill.
58	Fire clay, Cheltenham, Missouri..........	38.10	31.53	11.30	80.93	1.50	12.70	14.20	0.40	....	....	traces	1.92	2.32	2.50	99.95	Evens & Howard, St. Louis.
59	Fire clay, Evens' mines, Montgomery Co., Missouri..........	43.93	(2) 40.09	13.80	97.82	with Al_2O_3	0.60	....	0.20	....	....	....	0.88	1.08	0.50	100.00	Evens & Howard, St. Louis.

British Fire Clays.

No.	Clay																Analyst
60	Garnkirk fire clay, No. 1, Garnkirk, Scotland..........	44.35	35.30	13.70	93.35	0.95	1.30	2.25	0.75	....	....	....	1.60	2.35	2.70	100.65	Brown, Bayley & Dixon, Sheffield, England...
61	Glenboig Star fire clay..........	30.40	24.68	9.00	64.08	1.10	31.05	32.15	0.20	....	....	0.10	1.67	1.97	1.90	100.10	Jas. Dunnochie, Glasgow, Scot.
62	Glass pot clay (strong), Stourbridge, Worcester co., Eng...	30 50	22.52	8.30	61.32	1.00	33.65	34.65	0.50	....	....	....	1.43	1.93	2.10	100.00	Mobberley & Bayley, Stourbridge.
63	Glass pot clay, Stourbridge, England..........	30.29	27.68	9.36	67.33	1.05	26.80	27.85	0.43	....	....	0.36	1.88	2.67	1.44	100.29	A. K. Hay's Glass Works, Winslow, N. J.
64	"Derby clay," John Knowles & Co., Barton-on-Trent, Derbyshire, En.	46.10	35.24	10.30	91.64	(6)	1.70	1.70	1.96	....	....	....	2.26	4.22	3.00	100.56	Brown, Bayley & Dixon, Sheffield, England.
65	Crucible fire clay, Halifax, Yorkshire, England..........	39.45	32 19	11.80	83.44	(6)	11.80	11.80	0.51	....	....	....	2.65	3.16	1.60	100.00	Brown, Bayley & Dixon, Sheffield, England.
66	China clay, Redruth, Cornwall, England..........	28.40	24.11	7.20	59.71	0.20	37.80	38.00	0.96	....	....	....	0.79	1.75	0.70	100.16	Brown, Bayley & Dixon, Sheffield, England.
67	Fire clay, Blaydon Burn colliery, near Newcastle-on-Tyne..........	43.00	30.92	9.60	83.52	(6)	10.50	10.50	1.96	....	....	....	1.98	3.94	1.70	99.66	Joseph Cowan & Co,

Clays from Belgium and Germany.

No.	Clay																Analyst
68	Fine clay, Soree, Belgium..........	41.70	33.50	10.65	85.85	(6)	8.20	8.20	1.40	....	....	....	2.05	3.45	2.50	100.00	M. Greiner, Seraing, Belgium.
69	Fire clay, Frankenthal-on-Rhine, Germany	41.90	31.69	9.45	83.04	0.90	8.10	9.00	2.22	....	....	....	2.54	4.76	3.20	100.00	M. Greiner, Seraing, Belgium.
70	Glass pot clay, From Coblentz, Germany..........	18.35	15.66	6.84	40.85	1.20	53.03	54.23	0.63	traces	....	0.28	1.19	2.10	2.86	100.01	A. K. Hay, Winslow, N. J.

(1) Combined silica and quartz.
(2) Alumina and titanic acid.
(3) Water (combined and hygroscopic.)
(4) In the analysis as previously printed this appears as zirconia. (See page 236.)
(5) Combined and hygroscopic.
(6) Undetermined.
(7) Includes some Fe O.

TABLE OF ANALYSES.—(CONTINUED.)

Fire Clays from France.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
		Silica (combined) ($Si\,O_2$)	Alumina. ($Al_2\,O_3$)	Water (comb'ed.) ($H_2\,O$)		Titanic acid. ($Ti\,O_2$)	Silica (quartz sand.) ($Si\,O_2$)		Potash. ($K_2\,O$)	Soda. ($Na\,O$)	Lime. ($Ca\,O$)	Magnesia. ($Mg\,O$)	Sesqui-oxide of iron. ($Fe_2\,O_3$)		Water, hygroscopic ($H_2\,O$)	Total.	For description see page here mentioned.
71	Fire clay, Bollene, Department de Vaucluse	38.20	28.19	10.50	76.89	1.15	14.95	16.10	0.40	....	....	....	2.76	3.16	3.60	99.75	From the Terre Noire Co., Lavoulte et Besseges, France.
72	Fire clay, Macon, Dept. de Saone et Loire....	17.80	13.10	4.30	35.20	(6)	62.90	62.90	0.15	....	....	....	0.60	0.75	1.20	100.05	From Schneider & Co., Creusot, France

(6) Undetermined.

This table of analyses is valuable as a basis for comparisons and for further examinations and practical tests. The analyses were all made by the same chemist and under like conditions. Some additional analyses of foreign clays will be found in the appendix. At present it does not appear to be possible to estimate accurately or even approximately, from the results of chemical analyses, the fire-resisting power of all clays before they have been tested in the fire. This is evident from the table. From some of these analyses we should anticipate fusion of those clays, yet they are noted fire clays. Analyses need to be supplemented by fire tests, and these should be of the specimens examined. A couple of preliminary fire tests have been made with the specimens represented in the above table and some others. They were incomplete, and in the case of many specimens, indecisive. Want of time since the reception of many of these, and since the analyses were finished, has prevented the completion of this most interesting and promising series of investigations. The first trials were made in a crucible steel furnace, at the Newark Steel Works. The clays were cut in the form of tetrahedrons, seven-eighths of an inch on a side. The clays as they came from the pits and mines, well dried at summer temperatures, were used in all cases where they could be cut easily and with regularity. The hard clays, as those from coal formations, were pulverized and moulded into the desired shape. All were put in a graphite crucible, and set in a steel furnace, and exposed for *one heat* (about four hours), at least up to the melting point of hammered steel. Among the specimens thus tested there were several pipe, saggar, stone ware, yellow ware, and alum clays. These were all more or less fused. Some of them melted down to flattened buttons; others were rounded considerably. Some fire clays were partially fused, others were sharp and true, as at the outset. So far as it is possible to generalize, the clays containing much oxide of iron and potash together, were fused. The iron, when it exceeds 2.5 per cent., appears to be more detrimental than the potash. Nearly all of the more sandy clays were slightly fused. The rich fire clays of Woodbridge, the Raritan river banks and South Amboy, remained unaffected—not even glazed. The Missouri and the more noted British, French and Belgian clays, also stood well. Further trials are needed to complete these examinations, and to enable one to be specific, and give details as to the behaviour of each clay tested. These with analyses of the *same* specimen are essential to reliable and valuable results. And from the facts already gathered it is plain that there are very marked differences even among fire clays of good character—and it is believed that such a series of fire tests will agree with the results of practice, and be explained finally by differences of physical and chemical constitution.

THE GEOLOGICAL ORIGIN OF THE CLAYS.

The source from whence these clays was derived is not plainly apparent as yet. They join on their northwestern edge, the red sandstone and shale formation, from Woodbridge almost to Trenton. They are of more recent age than the red sandstone for they overlap and lie directly upon it, as is seen in many places. At several clay pits about Woodbridge, they have dug through the white clay, and come down at the bottom to solid red-shale. The conclusion cannot be avoided that the latter rock is much the oldest of the two, and yet there are no fragments of red-shale to be found in the clay, anywhere except at its very bottom. If the material had come from the north it must have passed over the red-shale, and, in so doing, it could not have failed to bring with it some of that peculiar and strongly marked material; for the red sandstone formation is about 20 miles wide; and its color is everywhere a purple red, while the color of all the red materials found in the clays, is a yellowish or salmon red. The most careless observer can perceive the difference, as they are seen near to each other in very many places. The material found in one cannot have been derived from the other.

That the clay is derived from decomposed feldspar of granitic or gneissic rocks is altogether probable, for we find feldspar in the gneissic rocks at Trenton, Philadelphia, and near Wilmington in Delaware, in this peculiar and decomposed form, and these localities are all of them near to the northwest border of the New Jersey clay deposits.

In New Jersey there are no gneissic or other crystalline rocks on the southeast side of the plastic clays. But this seems to be an exceptional case on the eastern border of the United States, as the gneiss rocks appear on the island of New York, and widen out to a great breadth in their extension northeast to New England; and towards the southwest the same rocks appear again at Trenton, in a narrow point, and widen out in Pennsylvania, Delaware, Maryland and Virginia, into a broad belt a hundred miles or more in width. If this belt were continuous from New England across New Jersey to the States further south, it would occupy all of the ground now covered by the clay, greensand and later formations, quite out to the coast and into the ocean. An inspection of the coast survey charts shows that the ocean over this sunken interval is very shallow, and an upheaval to a very small amount would bring it again above water.

The hypothesis that the plastic clays, the green sand, the dark clays and the glass sands of New Jersey have been formed from the decomposed rocks of the southeastern belt of the azoic formation has many facts to support it:

1. The mineral constituents of these are unlike those of the older formations found to the northwest of them.

2. Their beds overlap the older rocks on the northwest, in a layer which is very thin on the outcropping or northwestern edge, and becomes gradually thicker towards the southeast.

3. The fossil wood, leaves, roots, and fruit found so commonly in the plastic clays and the scarcity of shells, indicate that the deposit was a very quiet one, and probably in muddy fresh water. This could only have been the case if the sea water was kept out by the high ground southeast of these deposits.

4. The lower beds of clay have a southeastern dip of 60 feet or more per mile. The higher beds have a dip of only 30 feet per mile. The green sand which is next higher has an average dip of 30 feet. The glass sand bed which is the highest of the series has a dip of not more than 10 feet to a mile towards the southeast, which is the same dip that the ocean bottom has from the New Jersey shore out to the border of the gulf stream.

This regular diminution in the amount of dip in the beds higher in the series is consistent with the gradual subsidence of this southeastern high ground.

The green sand formation was evidently all deposited in salt water. It contains immense numbers of marine shells, wood is exceedingly scarce in it, and what there is, is bored full of holes by a marine worm. The lowering of the high ground would allow of this irruption of salt water, and of the change from a fresh water to a marine formation.

The dark clays overlying the green sand are also evidently marine in their origin, as shells, sharks' teeth, &c., are found in them.

The glass sand bed which is the highest in this series has not yet yielded any fossils except an occasional piece of charcoal. It appears to have been formed beneath the level of the sea, as there are patches of miocene containing fossils, found in places very near to it.

PART IV.

THE ECONOMICAL USES OF CLAY.

The economical uses of clay are numerous, indispensable for the common arts of life, and of the highest importance for their artistic applications.

Clay when moistened with water is plastic and sufficiently firm to be fashioned into any form desired. It can be shaped by the hands alone; by the hands applied to the clay as it turns with the potter's wheel, or it can be shaped by moulds, presses or tools. When shaped and dried, and then burned in an oven or kiln, it becomes firm and solid, like stone; water will not soften it, it has entirely lost its plastic property, and is permanently fixed in its new forms, and for its designed uses. These singular and interesting properties are possessed by clay alone, and it is to these it owes its chief uses. It is used

1. For making pottery.
2. For making refractory materials.
3. For making building materials.
4. For miscellaneous purposes.

1. Pottery. Pure clay worked into shapes and burned, constitutes *earthenware.* The ware of itself is porous, and will allow water and soluble substances to soak through it. To make it hold liquids, the shaped clay before burning is covered with some substance that in the burning of the ware will melt and form a glass coating or *glazing* which will protect the ware in its after uses from absorbing liquids, and give it a clean smooth surface. The color of the ware depends on the purity of the clay. Clays containing oxide of iron burn red, the depth of color depending on the amount of the oxide, even a small fraction of one per cent being sufficient to give the clay a buff color.

Clay containing oxide of iron in sufficient quantity to make it partially fusible in the heat required to burn it, when made into forms and burned, is called *stoneware clay*. The heat is carried far enough to fuse the particles together so that the ware is solid and will not allow water to soak through it; and the fusion has not been carried so far as to alter the shapes of the articles burned. The oxide of iron by the fusion has been combined with the clay, and instead of its characteristic red, has given to the ware a bluish or grayish color. Stoneware may be glazed like earthenware, or by putting salt in the kiln, when its vapor comes in contact with the heated ware and makes with it a sufficient glaze.

Clay which is pure white in color and entirely free from oxide of iron, may be intimately mixed with ground feldspar or other minerals which contain potash enough to make them fusible, and the mixture still be plastic so as to be worked into forms for ware. When burned, such a composition retains its pure white color, while it undergoes fusion sufficient to make a body that will not absorb water. And its surface can be made smooth and clean by a suitable plain or ornamented glaze. Ware of this kind is *porcelain* or *china*.

The large portion of plain white and decorated wares now sold as C. C. and white granite wares are intermediate between the old earthenware in which the body was of clay unmixed, and the porcelain in which the body is of mixed earths that undergo incipient fusion when burned at a high temperature. The fine earthen wares of both kinds mentioned above are being improved in quality and appearance every year, and approaching nearer in real excellence to porcelain. It is the aim of the potter to give them the accuracy of form that characterizes earthenware, to give them the body which shall be least porous after burning, and to glaze them with a material that incorporates itself most perfectly with the body of the ware and does not crack or *craze* with any changes of temperature to which it is exposed.

It is the art of the potter to make these different wares in such forms and of such qualities as may suit the demands of the market and the tastes of those who must use them. The clay is here in unlimited quantities, and in quality sufficient for its best uses. It has been our own fault that they have not been sooner used. In the catalogue of British pottery in the Museum of Practical Geology, in London, it is said that "The great advance of the porcelain manufacture in England is due to the discovery of the kaolin of Cornwall by William Cookworthy, of Plymouth, about 1755. He apparently had his attention directed to the subject by an American who showed him samples of China-stone and kaolin from Virginia, in 1745." This suggestion from our country was productive of most fruitful results. The manufacture of fine wares thus begun in England has grown to an immense extent, while in the country of its origin it lay dormant for a hundred years or more.

Stoneware from the Amboy clays was made at Chesquake and at South River soon after the revolution, and the good quality of that clay, and its convenience to water transportation, has caused its use to extend very widely. At the present time it is taken from there to be used in potteries in most of the towns along the coast from Maine to Georgia. Its good qualities are known and appreciated, and the *stoneware* made from it is highly esteemed.

The clays for making common earthenware are very widely distributed, and they are used in making such qualities as are in demand for the common purposes of daily life.

Those clays which are pure enough to be used for making the finer varieties of earthen ware, are by no means common. And it is in these that the clay district, which is described in this report, is singularly rich. They are white and plastic, excelling in the latter property the fine white china clays brought from South Carolina, or those from Indiana or Illinois. They are not quite so white as those last mentioned, containing a little more oxide of iron. But a reference to the tables of analyses will show that this impurity is very small in either of them. It is so small that the expense of removing it by acids and washing would not greatly increase its first cost. And some experiments made in the State laboratory show that it can be done satisfactorily. Whenever this process is carried out, the New Jersey clays will take precedence of all others; their superior plastic properties making it possible to prepare stronger and better shaped ware than from any other.

The manufacture of the finer kinds of pottery was established very late in our country, but it has advanced with extraordinary rapidity. The precise statistics of its growth cannot be ascertained now. A note in the Geology of New Jersey, 1868, furnished by a manufacturer of pottery at Trenton, says that, "In the coming year our products will doubtless be at least one-eighth of the whole quantity consumed by the home market of white ware, for which Trenton is by far the most important point. The manufacture of yellow and Rockingham ware is more generally diffused throughout the States, and the quantity now imported is comparatively small." The value of the various kinds of pottery imported into the United States during the fiscal year ending June 30, 1876, was

Brown, earthen and stoneware	\$36,744 00
China, porcelain and parian ware, plain white	409,538 00
China, porcelain and parian ware, gilded or ornamented	718,155 00
All other earthen, stone or crockery ware (white granite and C. C.)	2,948,516 00
Total value	\$4,112,953 00

The United States Potters' Association report that the value of the goods sold from the factories of its members, in 1875, was \$2,993,000, and most of this was of the kind enumerated in the above list of importations, under the fourth head; so that the relative values of the home-made and the foreign, instead of being one to eight as in 1868, is now one to one and a half.

The following statistical statement from the United States Potters' Association, shows very nearly the condition of this branch of industry in the United States in 1876:

Number of firms in the Association	40
Number of kilns belonging to the members	140
Value of goods sold in 1875	\$2,993,000
Capital invested	4,089,000
Yearly wages paid	1,110,000
Horse power employed	1,000
Capacity of works, if used the year round	4,895,000
Tons of coal used in 1875	50,000
Other raw materials, in tons	50,000

About three-fourths of the above is represented in the works at Trenton. The location is peculiarly favorable for getting the requisite supplies of raw materials and fuel, and for sending off manufactured goods by railroad, canal or river. The climate is favorable, and supplies for living abundant and cheap.

Should the present growth of the business continue, the need for foreign importations will cease in a very few years.

2. *Refractory Materials.* The largest use for the white clays of New Jersey is in making fire bricks, and retorts for gas works and for zinc works. Modern improvements in metallurgy, and in furnaces for all purposes, are dependent to a great degree on having materials for construction which will stand intense heat without fusing, cracking, or yielding in any way. The two materials to which resort is had in almost all cases, are pure clay, and quartz in the form of sand or rock. They are both infusible at the highest furnace heats. The clay, however, is liable to have in it small quantities of impurities which are fusible, and it shrinks very much when heated to a high temperature. Quartz rocks are very liable to crack to pieces if heated too rapidly, and both the rocks and sand are rapidly melted when in contact with alkalies, earths or metallic oxides, at a high temperature. They do not shrink in heating. Sandstone, or quartz rock, is not as much used as a refractory material as it was formerly. Bricks to resist intense heat are made of clay, of sand, and of a mixture of clay and sand. The different kinds are specially adapted to different uses.

Fire bricks made of clay, or clay and sand, are the ones which have been generally made in the United States. To make these, the clay which stands an intense heat the best, is selected as the plastic material of the brick. This is tempered so that it may not shrink too much or unevenly in burning, by adding to the raw clay a portion of clay which has been burned till it has ceased to shrink and then ground, or a portion of coarse sand, or a quantity of so-called *feldspar*. These materials are added in the proportions which the experience of the manufacturer has found best. The formula for the mixture is the special property of each manufacturer, and is not made public. The materials, being mixed together and properly wet, are moulded in the same way as common bricks are, and after they have dried a little, they are put into a metallic mould and subjected to powerful pressure. They are then taken out, dried, and burned in a kiln at an intense heat.

It does not appear which is the best for tempering, burned and ground clay, or coarse sand, or *feldspar*. Respectable manufacturers are found who use each of these materials, and make brick that stand fire well. It is of the utmost importance to select the materials carefully, and to allow no impurity to get in while handling the clay or working the components together.

The manufacture of fire brick is carried on very extensively at Woodbridge, Perth Amboy and Sayreville. There were made at those places in 1873, when business was brisk, eight million brick.

Fire bricks intended, in addition to their refractory qualities, to retain their size and form under intense heat without shrinkage, have been made to some extent. The English Dinas bricks are of this kind, and the German and French "silica bricks." The Dinas bricks are of quartz sand or crushed rock, and contain very little alumina and about one per cent. of lime. They stand fire remarkably well, the lime being just enough to make the grains of sand stick together when the bricks are intensely heated. In the other "silica bricks," fire clay to the amount of 5 or 10 per cent. is mixed with the sand, and this plastic material makes the particles of the sand cohere sufficiently to allow of handling the bricks before burning. They have met the expectation of those who made them, and are extensively used. A few trial bricks, like the silica brick, have been made by Mr. A. Hall, of Perth Amboy, and they have been tested and found to stand fire very well, but the demand for such brick has not been large.

Fire clay, fire sand and *feldspar* are also sent away in great quantities, to be made into fire bricks at other places, near where they are to be used. At the glass houses much fire clay is worked up into large blocks, which are shaped in moulds so as to suit the different, and perhaps irregular, parts of the furnaces. The quantity of clay and refractory materials sent off for these purposes in 1873, amounted to 260,000 tons.

The quality of these fire brick is superior. They have satisfied the demands of the manufacturers who use them, so well, that very few fire bricks of foreign manufacture are now brought into the country. Fire bricks are made from the fire clays or shales of the coal formation in Pennsylvania, Maryland, Ohio and other States where they are needed, but for some uses the New Jersey fire bricks or fire clays receive the preference over all others. And the chemical composition given in the table of analyses, as well as the fire tests of the clays made here, justify this preference. More refractory bricks than these are not yet found.

Retorts for gas makers' use have been made of clay for several years past, and they are replacing the iron retorts formerly used. They are made of material prepared in the same way that it is for fire brick. But on account of their great size and weight, peculiar management is requisite in handling and burning them. A large quantity of clay is consumed in their manufacture.

Retorts for making zinc are also made from these clays. They are simple in form, and are made in part, at least, by machinery. This clay stands well in them.

Pots for glass makers' use are made from fire clay. The clay is always tempered with burnt clay, and great care is taken in mixing and working over the materials, for weeks or months before using, and the pots are very carefully made by hand. Up to this time nearly all the clay used in making these pots in this country has been brought from Europe, and most of it from Germany. So much depends on the perfection of the pots in glass making, that the manufacturers are very careful to follow the practice which experience has proved to be successful, and avoid all experiments where much chance for damage is involved. On this account the German clay continues to be used, and our own has not been thoroughly tried for glass pots. It is chemically much purer, and is more refractory. It is not generally as dense as the German clay, and it may be more liable to check in heating to intensity. But it does not cost more than one-third as much. Intelligent and well directed experiments in preparing and handling our clays, must surely succeed in making them fit for glass pots. Some experiments already made with clay from the Raritan fire clay bed, have been very encouraging; the clay standing fire well and burning to a hard, dense body, without cracks.

Refractory clay is also used for making sewer pipes, chimney tops and terra cotta wares. It must stand fire so well that the articles will be burned hard without softening under the heat, or in any way losing the regularity of their forms or the accuracy of their outlines. If not sufficiently infusible, pipes will become crooked and flattened in the kiln; and objects of more elaborate workmanship will lose their artistic character and their value.

The poorer qualities of the fire clays are sent off in enormous quantities to the manufacturers of sewer and drain pipes, and to terra cotta works, in all the principal cities of the Atlantic States.

3. Uses of Clay for making Building Materials.—Clay of the common kind can be tempered, worked into the form of bricks, roofing tiles, drain tiles, &c., and then burned into most durable building material. The clay costs but little; much of the labor, in working it, is unskilled, and a large amount of the work can be done by machinery. If works can be located on navigable waters, so as to bring fuel and carry the products to market at the least expense, these indispensable articles can be furnished to the purchasers at very low prices—far below what any other articles designed for the same purposes can be supplied. In these respects the district which has been described has singular advantages. The beds of clay suitable for such purposes are very thick, 10 to 40 feet in some exposures, and they come out in bold bluffs in many places near the water. In the district of 68 square miles, there are 30 miles of navigation and 25 miles of available water front. The distance from Perth Amboy to New York city is only 22 miles by water, and by railroads it is 23–25 miles.

Much of the navigation is never stopped by ice, and in the narrower passages it is seldom closed more than six or eight weeks in a winter. And fuel is delivered along the water as cheap as it is in the cities.

The value of bricks as building material, especially where strength and solidity are required, can be best judged by tests of their capability to resist the crushing force of heavy weights. To ascertain something in regard to this quality in bricks made from New Jersey clays, specimens of hard brick were obtained from several places, which were judged to be representatives of those made from the principal kinds of brick clay in the State. They were tested at the establishment of Messrs. Riehlé Brothers, Philadelphia, in their machine for measuring the force required to crush building materials. The following are the samples tested, and the weight per square inch required to crush them:

Manufacturers.	Pounds.
Sayre & Fisher, Sayreville, Middlesex county	4,057 4,750
H. F. Worthington, Washington, South River, Middlesex county	5,535 5,217
A. Ridgway, Newton, Sussex county	5,337 4,500

Manufacturers	Pounds.
Trenton, Mercer county	2795.
	2200.
	3340.
	2497.

The following table of the "Resistance to crushing of bricks and natural stone," is copied from Gen. Q. A. Gilmore's "Treatise on Coignet-Beton," &c., p. 42.

Materials.	Crushing weight per square inch, in pounds.
Brick, weak red	550 to 800
Brick, strong red	1,100
Brick, first quality, hard	2,000 to 4,368
Brick, fire	1,700
Chalk	330
Granite, Patapsco	5,340
Granite, Quincy	15,300
Marble, Montgomery county, Pennsylvania	8,950
Limestone, granular	4,000 to 4,500
Limestone, marble	5,500
Sandstone, strong	5,500
Sandstone, ordinary	3,300 to 4,400
Sandstone, Connecticut	3,319
Caen stone	1,088

Brick is one of the most common and cheap of building materials. It is also one of the most strong and durable. It resists fire better than any other building material whatever. Bricks are in such shape that they can be laid with little labor, and in walls that are no thicker than is necessary for the needed strength. A comparison of materials in the two tables above will give information in regard to the real values of various well-known building stones and bricks. To make the comparisons easily, in weight as well as size, it may be mentioned that the specific gravity of building stones varies from 2.25 to 2.75, and that of hard bricks from 1.75 to 2.10—common bricks weighing about four pounds each.

There are eight brick yards on the Raritan river and the bay shore, at which 54,000,000 bricks are made annually from the common clays of this district. It is estimated that there are also 18,000,000 made yearly at Keyport and Matawan, and 10,000,000 at Trenton and Kinkora, on the Delaware.

A small number of very handsome white brick for building purposes have been made by Messrs. Sayre & Fisher, at Sayreville, and by Messrs. A. Hall & Son, at Perth Amboy.

Hollow bricks have been introduced for house building in many of the countries of Europe. They are light, strong enough to hold up all the weight that can be loaded upon them, and they make a drier wall. Dry bricks are not good conductors of heat, and the air enclosed in the hollows increases this non-conducting property, so that houses built of such brick keep out the summer's heat and the winter's cold better than those built of solid brick. They 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 trial of this promising improvement in building materials.

Roofing tiles have long been in use. They are made of brick clay, and form a tight and durable roof. Their weight is objectionable; but they find an important use in ornamental architecture, and their strong colors and manageable forms make them an effective addition to the resources of the architect. The New Jersey Building on the Centennial grounds at Philadelphia in 1876 was covered with tiles made by Henry Maurer.

Draining tile are made from the same kinds of clay that are used for common brick, and they are made in great quantity from the brick clays of this district, at Woodbridge and on the Raritan.

The material of which common brick is made is not all clay. It contains a good deal of sand and oxide of iron, lime, or potash enough to make the mass easily fusible at a high temperature. Hard brick are obtained when the heat is great enough to produce the beginning of fusion; and the economy of brick-making is effected when the temperature necessary to produce well shaped hard brick is obtained with the smallest amount of fuel. The following analyses show the composition of two common brick clays.

1 is from the brick yard at Chesquake creek, Middlesex county.
2 is from the brick yard at Kinkora, Burlington county.

	1	2
Silicic acid	28.30	25.50
Alumina	21.50	17.70
Combined water	8.04	11.80
Quartz sand	28.70	31.80
Potash	1.90	1.54
Lime	....	0.16
Magnesia	0.82	0.65
Ferric oxide	4.31	6.40
Moisture	1.70	3.50
Sulphur	1.00	0.48
Carbon	3.80	....
Titanic acid	....	.90
Totals	100.07	100.43

4. MISCELLANEOUS USES OF CLAY.

Paper Clay. Clay which is pure white, and that also which is discolored and has been washed to bring it to a uniform shade of color, is used by the manufacturers of paper hangings, to give the smooth satin surface to the finished paper. It is used by mixing it up with a thin size, applying it to the surface of the pieces of paper, and then polishing by means of brushes driven by machinery. The finest and most uniformly colored clays only are applicable to this use, and they are selected with great care. Clay is also used to some extent by paper manufacturers, to give body and weight to paper.

Alum Clay. A large quantity of clay is sold every year to the manufacturers of chemicals, for making alum. A rich clay is needed for this purpose, but those containing lignite or pyrite which renders them inapplicable for refractory materials, do not spoil them for this use. Alum is made by digesting the clay in sulphuric acid, which forms sulphate of alumina, then dissolving out the latter salt from the silica and other impurities, and forming it into alum by the addition of the necessary salt of potash, soda, or ammonia, and crystallizing out the alum.

Portland Cement. Hydraulic limes and hydraulic cements are coming into large use both with engineers and builders. The magnesian limestones, when burned at a low heat, furnished a lime which possessed hydraulic properties. The improvement in limekilns, and the use of coal instead of wood for fuel, has led to the burning of lime at higher temperatures than formerly and but little lime with hydraulic properties is produced. Limestones containing a considerable amount of clay are found in many places; when these are burned at a moderate heat and then ground in a mill they furnish hydraulic cement. Immense quantities of such cement are made near Rondout, New York, at Louisville, Kentucky, and at other places. The composition, however, is liable to variation, and engineers have sought a more uniform and reliable article, by mixing pure clay and carbonate of lime in proper proportions, burning them together at a moderate heat, and then grinding them for the cement. The proportions are nearly four of carbonate of lime to one of clay. These artificial cements are made successfully and in large quantities in England, France, Germany, and other European countries. The English Portland cement, which is artificial, is brought into this country and finds a moderate demand at high prices. The attempt to make such cements in this country has been made several times, but up to the present without success. It must, however, eventually succeed. The shores of the Raritan, Staten Island sound, and Woodbridge creek, all of which waters are navigable, offer most advantageous sites for such manufactories. The rich clays spotted or otherwise discolored by oxide of iron, can be had here at little cost, and the rich shell marls of Sussex and Warren counties will supply, at a cheap rate, an abundance of carbonate of lime which needs no grinding, but is in its natural condition fine and ready to be mixed with the clay at once. This is a promising field for a new industry. Cement is indispensable in mortar which has to be exposed to water, and its use in all mortars for stone and brick work is increasing rapidly. There were, in 1860, 14 establishments, with a capital of $759,000, employing 740 hands, and having an annual product of $767,000. In 1870, there were 45 establishments, with a capital of $1,521,000, employing 1,190 hands and producing $2,033,000 worth of cement.

PART V.

EXPLORING, DIGGING, MINING AND MARKETING CLAYS.

SEARCHING FOR CLAYS.

The examination of ground for clays includes, first: a careful survey of its surface features, natural outcrops and artificial cuttings and a consideration of all the facts relating to previous diggings, borings, &c.; and second: testing the ground by boring and digging trial pits, or shafts.

The first point of examination is the study of the best geological maps of the country or locality to be examined to ascertain its geological structure and to get a correct basis for the further study of the surface and the strata which explorations may discover. This may at the outset indicate the improbability of discoveries of any value, and prevent useless work and disappointments. Again, attention to the geology will enable the explorer to understand the relations of the surface features to the strata beneath, and thereby to interpret more clearly the indications which they may present to him. Thus, for example, the geological map and survey may represent the locality in question as in a region of glacial drift, and consequently one whose surface would be characterized by irregularly shaped elevations and depressions, all marked by abrupt changes of slope and irregularities without any apparent order of arrangement. Knowing this, the explorer finds the configuration of the surface to be such as was indicated by the glacial drift of his map, and at once appreciates the difficulties in his way in exploring it. He knows that his selection of points for his bore holes and test pits must be made so that they can reach the regular strata hidden under this boulder drift and not be compelled to stop in it, since every boring pit which fails to penetrate this drift covering is not only useless as indicating nothing more than the surface showed him, but also a waste of time and capital and a discouragement that may tend to retard or wholly stop further exploration.

The personal inspection of the surface, as above stated, takes into account the nature of the slopes as especially important in locating pits or borings. The top of a hill or ridge is to be avoided if it is a true boulder drift, or a bank of sand or gravel. For a like reason the hillside may not be suitable for exploration. Flat lands, such as tide marshes or swampy ground may also be unfavorable, from the thickness of the alluvial or recent beds of earth and mud. Generally the hillsides, near the foot of the hills offer the least thickness of diluvial covering, or top earth, and are the best locations for exploring.

Natural outcrops exposed in washes in the sides of hills and in the banks of streams ought always to be looked at, as some of the strata are often seen in these places, and by an examination of them it is possible to learn the depth to which shafts must reach in order to test such localities for any given bed of clay or other valuable material. These outcrops from their relations to the beds searched for, may also indicate too great a depth for successful exploration or for practical working.

Artificial cuttings on railroad lines, street or road grading, wells and other excavations, are also to be considered as furnishing some indications as to the nature and extent of the strata, and by the facts they afford, aiding the explorer in his preliminary survey. All the facts from such excavations are, however, to be considered in their relation to the surface, since in certain localities these, unless very deep, may cut drift or alluvial beds only, and consequently afford no positive information of the lower strata or beds in place. The study of the surface requires much care in considering the various facts of topography, outcrops and exposures, in order to arrive at just and valuable conclusions, and yet this preliminary work is so easily and cheaply done, that it is economy to take time enough for it, as subsequent mistakes and failures are manyfold more costly and vexatious.

Boring is a common and quick mode of testing ground, preparatory to sinking shafts or pits. It is available through all strata or beds, and, if a chisel-pointed bar replace the auger, can be got through thin layers of ordinary brown sandstone, which is the only hard or rocky layer ever found in the clay belt of the State Boulders of large size cannot be penetrated, and layers of gravel are often difficult to get through. Wet sand, such as quicksand, is also troublesome, but these obstacles are of limited extent, and by repeated trials can nearly everywhere be avoided. The use of the auger is practicable through almost the whole clay territory of the State. Beds of clay are readily and easily penetrated, and the borings brought to the surface are tolerably fair specimens, giving information as to the character, as well as to the thickness, of the bed. As the boulder earth, or gravelly strata which so generally cover the clay formation, is difficult to penetrate, it is easier and more expeditious to dig well-like pits through these to the clay, and then begin to use the auger, than to attempt to bore from the surface. Where there is no quicksand, and the earth stands up, trial pits $2\frac{1}{2}$ to 3 feet in diameter can be dug to a depth of 40 feet, at a cost of 25 cents per vertical foot, and at a lower rate where the pits are not so deep. Owing to the treacherous nature of some of the sandy clays and sands which occur in the clay formation, larger shafts are necessary, and much care to prevent accidents by caving or sliding. The depth to such pits is rarely greater than 20 feet, as sites for boring are seldom on thick masses of drift. For boring, various patterns of augers are in use, the most common and most serviceable is the ordinary carpenter's screw auger, having a straight cutting bit, and from an inch to two and a half inches in diameter. A pod auger, with a vertical or spiral slit up its side, and sometimes provided with a valve inside, which, opening upward, prevents the materials cut from falling back into the hole, is another form. Sometimes the bit is made convex or spade-shaped, instead of straight, and sometimes double edged.

For loosening the earth or clay, a tapering screw auger, with a narrow bit, is useful. Some of the so-called well excavators—pod augers of larger size—are applicable to boring in these earthy strata. Whatever the form, those which most easily penetrate the strata and bring up specimens as they are cut in succession, are the best. The auger, or borer, is the essential part of the mechanism. The shank, or rod, may also be of various styles. The more common form is a square iron bar, $\frac{3}{4}$-inch on a side and 8 to 14 feet long, upon which the auger is welded. This is made so that it can be spliced on to a second bar (the ends being fastened together by a ring shoved over them), and that to a third, and so on to any desired length. Rods and pipes are also used. These are generally screwed together, the threads being reversed that the turning of the handle may not unscrew the sections. Gas pipes or tubes are of a convenient size, easily obtained and much used. These are lighter, stiffer and cheaper than the solid rods or bars, and preferable to them.

The sizes are proportioned to the diameter of the bit. It is always advisable to have the size uniform throughout. In the deep boring of the Crossman Clay and Manufacturing Company, on the line of the Easton and Amboy railroad, the auger was $1\frac{3}{4}$ inches in diameter, and was put down through a gas pipe 2 inches in diameter, which was driven down in sections that screwed into one another. The first length, that holding the auger, is usually 10 to 15 feet long. Others are not so long, generally about 8 feet. Upon this bar, rod, or pipe, as the case may be, a handle is fitted, so constructed that it can be readily adjusted at any point, and also be firm enough to turn the auger.

The boring implement thus put together is worked by means of the handle, requiring two men to turn it. Longer bores, of course, require more power. When the thread is filled the auger is drawn up and the material examined, so that every portion of the strata penetrated can be examined at the surface. Augers are rarely used at greater depth than forty feet, and in nearly all cases this is sufficient to test ground. At such depth, and even at twenty feet, the raising of the auger is a difficult matter, and then a windlass, or, better, a derrick with block and pulley, may be employed. Such a length of rod also requires guides to keep it erect, and for this purpose shear poles set up at the mouth of the boring are necessary. These may be of the same length as the rods or a little shorter.

In the case of wet and running material, or quicksands, it is frequently impossible to make any progress, the sand filling the hole as fast as the auger removes it. Then tubing becomes necessary. For this purpose gas pipes a little larger than the auger are employed, usually $1\frac{1}{2}$ to 2 inches in diameter. These are driven down in sections, one screwed to another at the top. The interior is then bored out, and if the tubing be driven deep enough to shut off all loose sand, the boring is continued beyond to the desired depth. If gravel or cobble stones, or other stony and hard material, is encountered, a chisel-pointed bar is driven down to break them or drive them to the sides of the hole and open the way for the auger. Equipped with these tools, two men can put down several 30 feet holes in a day, or with a third man, one or two 40 feet deep, but the time is dependent on many circumstances, and differs with the localities. For removing the water, and in case of quicksand, sand pumps have been suggested, but with how much success is not known.

In Germany boring is an almost universal mode of searching for brown coal. The strata covering this are earthy and such as are readily penetrated by the auger, but the thickness of this covering often exceeds 100 feet. At this, and even greater depths, the auger is employed with success. In Saxony, borings having an average depth of 120 feet cost twenty-seven cents per vertical foot. The diameter of the bit is sometimes as much as six inches, and then the rods are correspondingly large, and the working of them requires long levers at the surface and increased power. In New Jersey depths of 40 feet are in nearly all cases sufficient, as at greater depths the amount of top earth is too much to be moved, and subterranean mining would be too expensive. For this depth an auger two or two and half inches in diameter, with five-eighths inch rods, is sufficiently large.

One of the drawbacks to boring is that the specimens are not always unmixed and representative of the variations encountered in the hole. In the stiff clay there is no difficulty, as the threads or pod of the auger hold it firmly, and each auger full represents the last cut made. Thus, if the auger thread be six inches long, the auger full represents the last six inches that was cut. But if the materials are quite loose they slip off in raising, especially if there be any water in the hole. Again, the borings are apt to get mixed with material on the sides of the hole while the auger is brought to the surface. Consequently, borings are not generally quite as good as specimens from diggings, and are never to be regarded as altogether decisive, but as indications of strong probability, which urge the final step in the exploring work—that of sinking pits.

The digging of trial pits may be merely to test the ground or to do work in the extraction of the materials sought. The location of pits must be determined by the borings, by the nature of the surface and the best sites for opening and working. The discoveries of the auger alone are not sufficient to determine the sites, as often the opening of a bank is best where the bed is thinner or of inferior quality, near the foot of the hills, or other advantages of location for steady working. The size of the pits is a matter of business rather than of exploration. To test ground, a shaft or pit 8 by 10 feet is quite large enough for convenient working; if the strata be firm the pits may be little more than a well, or they can be as much larger as the explorer wishes.

In boring, failure at one point should not discourage or stop further work; the hole may have been just where the clay or other bed sought for was once, but subsequently was partly or completely worn away and its place occupied by depositions of recent material; or it may have chanced to strike a point where the thickness of the bed was much above its average dimensions. Here there should be several borings, depending somewhat on the disclosures they make. If the depth and thickness of the strata appear to be uniform, fewer borings will answer. Generally the inequalities in these particulars require more to furnish much valuable information.

What has been said of borings is to a less extent true of pits. The latter do more in showing the exact value of the materials dug; the former give *approximately* correct ideas as to their character but tolerably *accurate* opinions as to their extent.

The employment of the auger and the digging of trial pits ought to be far more general in the clay districts of the State. If more generally adopted, discoveries might show beds and deposits of superior character and great extent in localities much more favorably situated than some of those now worked. It is possible that we are expending uselessly some of our activities that could be better employed at other points; so that this subject of exploration is important not only to the capitalist and prospector in search of new localities, but to the clay miners and proprietors.

The map of the clay district of Middlesex county, which accompanies this report, is a guide to explorers in that part of the State. It shows, by special designations, the location and extent of the pits of clay, *feldspar*, *kaolin* and fire sand, as they are now opened. It further shows the configuration of the surface, or *make of the country*, by contour lines of elevation above mean high tide level. The figures on these are the heights above that level. By a series of colors it indicates the territory, or country, in which each of these beds may be found of workable thickness, and at depths below the surface of the ground, which are practicable for economical digging by open pits. A thickness of 15 feet is assumed as needed for practical working. Whenever the height of the ground and the dip of the bed indicate less than this, the location is considered unavailable for working, and it is left uncolored. It is proper, in this place, to state that the absence of color does not imply barren ground, or no clays or *feldspar*, but that the bed there cannot be more than 15 feet thick, and that it has not yet been found. Great inequalities may show exceptions, but these are quite as likely to make it less than 15 feet. A thickness of 25 feet of top dirt is assumed as a limit to practical working, beyond this, generally, the removal of the *bearing* is unprofitable. In places where the bed is unusually thick, and particularly if this be due to a *swelling up* at the top, above the general *level* or plane of the top of the bed, the top dirt may not be so thick, and such ground may be profitably worked for that bed. Variation in the opposite direction may make the top of the bed lower than the mean elevation, and thereby increase the thickness of the covering to more than 25 feet.

Figure 4 is here presented as an illustration of these statements, and of the facts which have served as the basis for coloring the map. It represents one valuable bed of clay in its relations to the overlying strata and the surface; the map shows the relations of the Raritan clay bed, the Woodbridge fire clay bed, the *Feldspar* and *Kaolin* bed, the South Amboy fire clay bed and the stoneware clay bed, to the surface, and, according to these relations, the areas in which these several beds are available for economic mining. The figure is, therefore, an illustration of each of the valuable beds here enumerated. In it there is at the bottom a sandy clay stratum, which is not considered to be of any value. Upon this rests the bed of clay, which is sought. It may represent any one of those mentioned above, according to location in the clay district. Both of these beds are supposed to belong to the plastic clay series, and they dip towards the southeast. Another and valuable bed may be supposed as underlying the sandy clay, but it is unimportant, as such would be too deep to be reached, except by sinking shafts and then cutting horizontal drifts, that is, by underground working. The clay bed is represented as 20 feet thick. At (*e*) the bottom of this bed is near the surface and slight digging may uncover it, but from this outcrop, or point to (*A*) denudation has so worn it off that it is not thick enough for profitable mining. West of (*e*) the surface is lower than the horizon of the clay bed. The ground west of (*A*) is, therefore not available for working. From (*A*) to (*D*) there is a hill, the top of which is boulder drift and between (*B*) and (*C*) this drift is from 25 to 40 feet thick. Such a thickness of useless materials is regarded as too great for profitable working and the interval (*B*)—(*C*) is marked as *unavailable*. Going down the steep southeast slope of this hill the drift mass becomes thinner until at (*C*) it is only 25 feet thick. Thence to (*a*) it rapidly diminishes and from that point to (*b*) there is but a thin sheet of it, lying uncomformably upon the clay bed. Here is more available clay territory and between the points (*C*) and (*D*) exploration and mining are eminently practicable. East of the latter point the clay bed again becomes too thin for working and at (*b*) is altogether wanting. The surface at this point is below the *level* or horizon of the bed. The underlying sandy clay crops out in the, depression, on each side of the water, that lies in a hollow excavated in it. Ascending the slope on the east side of the little valley, the out-

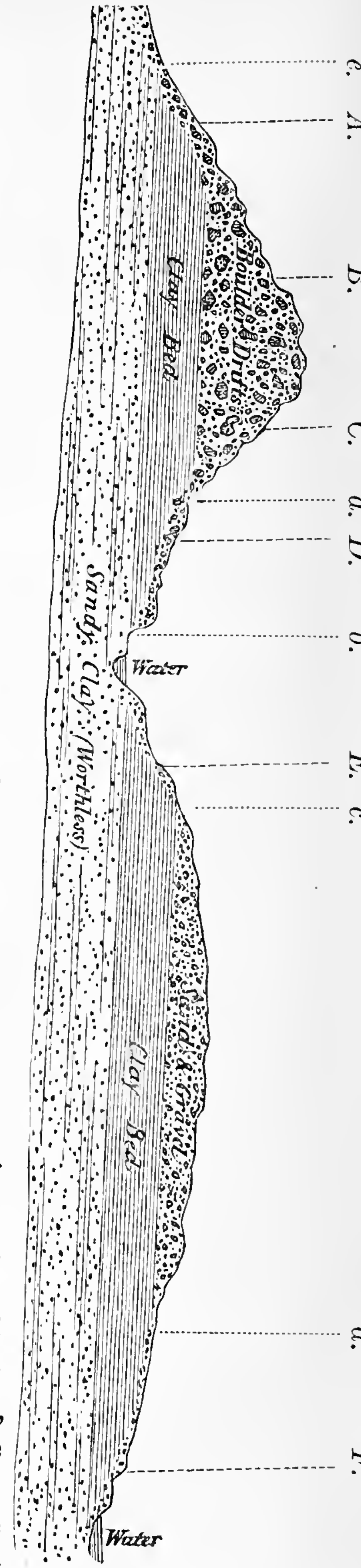

FIG. 4. IDEAL SECTION ILLUSTRATING AVAILABLE CLAY LANDS.

crop of the clay bed may be discovered, at or near (*E*) but on account of denudation it is too thin to be profitably worked. From (*D*) to (*E*) there is a breadth of *unavailable* territory, or clay land. It will be observed that this valley is one of erosion and the wear has removed the whole of the boulder drift and the clay bed, and cut down into the underlying sandy clay. This is an illustration of many valleys of the clay district, which have been described in the local details. East of (*E*) a lower hill, or ridge, is represented. The superficial bed in this ridge consists of stratified materials, of sand and gravel. And it is not so thick as the boulder drift of the other hill. As its maximum thickness nowhere exceeds 25 feet, the hill is all workable clay lands. The space (*E*)—(*F*) is, therefore, available territory. Between (*d*) and (*F*) the clay bed is covered by a thin sheet of the sand and gravel drift. Beyond (*F*) eastward it thins out and is wanting at the water on the extreme east. To resume, there are

1. *Unavailable areas* on account of great thickness of top dirt *B—C.*

2. *Unavailable areas* owing to denudation of bed, *e—A ; D—E* and *d—F.*

3. *Available areas, A—B ; C—D ; E—F.* The map by its several colors exhibits the areas, or territory in which each of the beds above mentioned are of workable thickness and at accessible depths from the surface. The key to the colors appears at the side of the map. Where two beds occur close together one above the other as the *feldspar* and *kaolin* bed and the South Amboy fire clay bed both are represented by their colors.

DIGGING AND MINING CLAYS.

The extraction of the clays, *feldspars, kaolins,* fire sands and other materials occurring in the plastic clay belt of the State, is mostly by digging pits in the beds worked, the overlying strata having been previously removed. The removal of the superficial beds, or *bearing,* as it is frequently termed, and the digging vary somewhat in the details according to the nature of the circumstances of location, relation to water, cost of labor, prices of materials, transportation and business management.

The first work on opening a clay bank, after satisfactory exploration, is to remove the top dirt, or *bearing.* This is done in wagons in case it has to be carried to some distance, or else by cars on a moveable track. Wheelbarrows are occasionally used. At older banks, where a large amount of clay is dug, a car track, or tramway, generally runs from the bank to the point of delivery —main lines of railroad, or to docks on navigable water—and in these the track is generally laid quite to the heading or face of the bank, or alongside of it, so that the cars can be easily loaded. This material is taken outside to the dumping ground. Teams are in common use as the motive power, being cheaper than steam, and quite as effective in short distances. If any of the materials of this *bearing* are of probable value they are sorted and put by themselves preparatory to future use, or are at once shipped as desired. Whenever, in working banks, pits or excavations, areas have to be filled, the top dirt is used for that purpose.

According to the general practice, the digging advances by a succession of contiguous pits, and the dirt of the pit which is being uncovered is thrown at once into that which has just been dug. In some cases this is sufficient to use the dirt from the top of the new pit, and the necessity of removal to dump or waste heaps is avoided. But this is exceptional, as in most localities the amount of top dirt is in excess of that needed for filling, and the surplus must be removed.

The cost of removing the top dirt depends on so many and such constantly varying conditions that it is not possible to give prices. The nature of the strata, the distance of removal, the price of labor, and other items, enter into the cost. Excavation by machinery, or by steam diggers, has not been attempted. This is due, apparently, to the generally limited extent of most of these works.

Since the top dirt nearly everywhere is earthy, the employment of steam excavators or similar machinery is certainly practicable. The introduction of larger capital and more comprehensive management in the mining of these clays, &c., will be accompanied by more machinery to replace much of the slow and primitive methods now in use.

An important question is the location of the heaps of top dirt or dumpings. This is especially important at a new locality, and care is always necessary to avoid sites which are to be worked. By boring or digging small trial pits, it is easy to select areas which are not profitable for mining. Wherever the area worked over is large, they becomes the proper place for storing them, if the distance is not too great.

The mining of clay is generally by digging small pits; these are of different sizes according to circumstances of place and men to be employed. A common size is a rod square, or an oblong pit of about the same area. These are dug through the beds of value, or as deep as practicable. Generally they are made of sufficient depth to extract all of a given bed of clay, *feldspar*, *kaolin*, or other material, which may be worked, and the digging or pitting stops at the bottom of that bed. Thus in the fire clay banks, they are dug through that stratum, although in some places, where there are valuable beds underneath this, the digging is continued into these lower beds. The work is often stopped on account of the water in some pits; the danger of caving in, water flooding and other such circumstances determine the depths of the workings.

It is customary to have on the ground at the side of the pit a platform of a few boards, on which the clay or other material is thrown, and, if needed, is sorted into different grades. This sorting is done piece by piece as the spits are dug. A gouge spade is used in digging clay. This differs from the common spade in having its blade cylindrical, and the upper edge is broader than that of the common spade, a tread to receive the weight of the pitman, necessary to cut down into the solid clay bed. The lump of clay, or *spit*, as it is called, thus loosened is taken by another workman, who cuts out any nodules of pyrite that may be in it, or any other foreign matter which can be removed by a knife, and thrown on the platform. This workman sorts the clays for ware, fire brick, paper, alum, pipe or other grades. The pitman confines his operations to cutting down the clay, continuing this over the pit area, and then begins a new *spit* level, and so proceeds till the bottom of the bed is reached.

In some of the clay banks the working floor or base is lower than the top of the clay bed, or on a level with the bottom of it. The digging at these banks is not properly by pits, although it goes forward by a succession of pit-like excavations. The platform for the clay is below, the carts are driven to the side of the bank and loaded at once by the workmen; or the clay is carted to heaps near by and there stored, each grade or variety by itself, or it is taken to boats or cars for transportation to market.

Wherever the sides or the walls of the pits or banks are weak or liable to fall in, these have to be strengthened and the workmen protected by planking and bracing. In pits of ordinary size three heavy planks, on a side, are sufficient with bracing timbers placed across between the opposite sides. Excavation into the bank and above a working level is not often attended by such dangers. The lateral thrust in pits appears to be the more common cause of slides or caving. In sinking pits it is necessary and customary to leave walls of clay 1 to 2 feet thick on the sides which have been worked. These act to hold up the ground and keep out the water. Most of the danger from slides comes from these walls and the pressure of wet drip behind them. After the pit is dug and before it is filled up, a part of the clay walls is taken out so that as little as possible is left in the ground.

Occasionally picks are used instead of the gouging spade, when the clay is very hard and compact. At a very few localities blasting by powder is employed to break up extra hard clay or strong layers associated with it. Undermining and splitting off large masses of earth, clay, &c., by wedges or powder is practiced at banks where the materials are of a coarser or less valuable character. This is common at the red brick clay banks. It consists in digging under at the foot of the bank as far as can be done with safety, and then either allowing the undermined mass to tumble of itself, or to force it off by using powder or wedges at the top of the bank. In this manner hundreds and thousands of tons are tumbled down at once and broken, making the handling much easier than the removal of an equal weight by spading and shoveling down from the bank.

As the beds of clay are nearly always impervious to the flow of water there is no water to be removed, except the very little rainwater which falls or the leakage from the surface drain about the top of the pits. This is usually allowed to accumulate in a deeper corner of the pit and is bailed out from time to time with a bucket. As the time for sinking a pit of the ordinary size does not often exceed two or three days there is little water from these sources. The greatest amount of water comes from the sand or other layers that are sometimes interstratified with the clay and which allow the water to percolate quite freely through them. Sometimes the clay bed is found to be quite sandy in the middle and to allow water to leak through.

At most of the clay banks the bed of clay is underlaid by sand, kaolin, or sandy clay and these strata are generally full of water so that the bottom of the pits are wet and the pits soon fill with water if it is not pumped out or if they are not filled at once with earth. In banks where all of the clay bed is above the working floor, open ditches or partially covered drains are constructed so that the water can run off without further inconvenience or cost.

In pits the water has to be hoisted to the level of the working floor, and thence carried off by drains. Various modes of raising water are in use; the most common is by a pump worked by hand at intervals, as is necessary to keep the pit clear and in working condition.

Hoisting by buckets and a windlass has been used in a few localities. Steam power has also been employed in a few places, where the depth of the pits and the surrounding wet ground, as in tide meadows, furnished a large amount of water to be raised. The judicious arrangement of the location and appliances so as to avoid heavy expenses in keeping water from the pits, have much to do with the profits of clay digging. Comprehensive plans and skillful management are as important in this as in any other department of industry. The profits of clay digging have in some instances been very large, but for lack of judicious plans they have not been long continued.

At a few places in the State the extraction of the clay has been by underground work or mining. This consists, on side hills, in cutting short drifts, or tunnels, in the clay bed, timbering them so as to hold up, temporarily, the superincumbent earth, and, when the work is done, allowing it to fall in. By a series of drifts side by side most of the bed is in this way worked out. There is some loss of material in the clay which has to be left at the bottom as a floor and at the top as a roof to hold up the overlying sand or other loose material, and to keep out the water. These drifts are inclined a little, if the bed allows any inclination, to let any water which may get in them by accident run out. They are narrow, being only wide enough for the passage of men with their barrows or carts. The timbering consists of upright posts set at the sides, at varying distances apart, sometimes close together, and at others a foot and a half or two feet apart. Upon these, cross beams or sleepers are laid to support the roof. These drifts are seldom more than 100 feet long. At Furman's mines, on Chesquake creek, shafts are sunk through the overlying top dirt to the clay bed, and then drifts are cut in this. Here the clay has to be hoisted to the surface in buckets by a windlass and horse power. At Morgan's bank, on Raritan bay shore, drifts were cut in from pits dug outside of the bank. At Isaac De Cou's bank, on the Delaware river, south of Trenton, the drifts were cut in from the face of the bank. This was here possible, as the mouth of the drifts opened several feet above water level. An excellent example of mining clay is to be seen at Otto Ernst's mines, on Chesquake creek. For the description of this, reference can be made to pages 221—224 of this report, where it is described.

This mode of mining clays could be adopted at several places in the clay belt of this State. Wherever the beds of clay are uniformly thick, the bearing heavy, and the clays of superior quality and value, it may be practicable and more economical than the ordinary mode of stripping off the top and pitting the clay. It is costly and attended with risks; and these objections must be considered in its application to any locality. It is believed that the scarcity of clay at easily accessible depths for open working will in the future compel the attention of clay miners to it as practicable, and the only way in which some of our clay territory can ever be made available and productive.

The digging of fire sand, *kaolin* and *feldspar* is carried on very much like that of the clays. As the strata are not impervious to water, the pits are generally smaller, so that the length of time in sinking one is seldom more than a day. The quantity of water to be raised is commonly much greater, and in some cases it is so large that it is scarcely possible or practicable to get to the bottom. In working the strata of these materials there is more loss than in digging clay. More of the bed is left in the ground. In digging these the gouge spade is rarely used, but ordinary shovels and spades, aided occasionally by picks where the material may be more firm or too hard for spading. The loading is generally direct from the pit or the side platform into carts or cars, and there are fewer grades, rarely more than number one and number two.

Nearly all of the clays, and all of the *feldspar*, *kaolin* and fire sand, are sent into market in a crude state. They are shipped in bulk, either in boats or in cars. With some varieties, as the paper and ware clays, more care is taken in keeping them clean and free from admixture with inferior grades. Formerly the paper clays were shipped in barrels, but at the present time they are generally transported in bulk.

The improvement of clays by washing is practised at a single locality only, by George Such, at Burt's creek, near South Amboy. The work is done on a large scale. The following account of the principles and practice followed in doing the work, is perhaps sufficiently full.

Clay stirred up in water will remain in suspension a long time, while sand, gravel, and nodules and grains of iron pyrites settle quickly. And the finer the clay is, the longer it will remain suspended in water. Advantage is taken of this property in washing the clays and freeing them from impurities. Washing has the further advantage, too, of bringing the clay to a uniform tint or color. As taken from the bank or pit it may be streaked with brown, or yellow, or red colors, or with all of these, but after passing through the washing process these colors are all blended into one uniform tint. And by a proper selection of the white and stained clays, a great variety of colors are produced.

Mr. Such's works are located on a stream, from which an abundance of water can be drawn for all the purposes of the washing apparatus. The machinery for washing the clay is driven by a powerful steam engine.

The apparatus for washing consists of large troughs or bins, in which the clay from the banks is dumped, covered with water, and allowed to stand for twenty-four hours. Other large troughs, in which long horizontal shafts, armed with knives, revolve, receive the clay. The knives are set at right angles to the shafts, and are fastened in a spiral line, so that at every revolution of the shaft the clay in the whole length of the trough is thoroughly stirred up and mixed with the water, which is constantly streaming into it. Large vats are used, in which to receive the clay and water. These vats are made of puddled clay at the bottom, which is then covered with boards; the sides are made of a double casing of boards, filled in with puddled clay between the boards and backed up with earth. They are nearly five feet deep. And they cover about an acre and a half of surface. There are a number of vats entirely separate from each other, which are intended for white clays, and different shades of colored clays. Each vat also has partitions or guiding boards in it, which are so arranged as to cause the water, with suspended clay in it, to circulate between them and cross the vat repeatedly before it reaches the farthest part, and so that the clay may have time to settle and let the water run off clear at last. Some of the vats are low enough to be filled through troughs, which run from the washers directly to them; while others, on higher ground, have to be filled by pumping up the clay and water together, from the washing machine, and running it off through elevated troughs to the proper vats.

When the washing machine is in operation, a constant stream of water is run into it and is thoroughly mixed up with the clay, which is thus divided into its finest particles and separated from its heavy impurities, and only that which is fine and completely suspended in the water can run off into the settling vats. The process of washing any desired quality of clay is carried on from day to day, till the deposit in the vat is thick enough to handle conveniently and to furnish a supply adequate to the demand.

The operation is a very complete and satisfactory one. It improves the quality of the white clays, and indeed of all the clays washed. It makes saleable those which would otherwise be worthless. And it brings those which in their natural state are unsightly, to soft, pleasing, and even beautiful shades of color.

The work is a success. The process is slow, and the investment of capital in machinery, vats, sheds, &c., seems large.

The extension of this method of improving clays will soon become a necessity—and the subject should receive the attention of all who are interested in the profits of clay digging.

The removal of sand, pyrite, or other mineral masses from clay, by washing is easy and effectual. The removal of oxide of iron which discolors the clay is attended with more difficulty, as washing does not take it out. The treatment of such clays with hydrochloric acid has been tried in Europe, and found effective in removing both oxide of iron and lime from them. A practical way of using this method to obtain good fire clay from inferior and common clays is given as follows in the Oesterreiche Zeitung, No. 32, by Kerpely. "Clays containing lime and iron are stirred with boiling water, the latter being poured on till it is eight or ten inches deep above the clayey mass. To this is added hydrochloric acid to the extent of two per cent. of the clay. After further agitation it is allowed to stand for some hours and then the acidulated water is conducted to a second vessel to which more acid is added. The clay mass is well washed with hot water, and is thrown upon a linen filter stretched over the waste ditch. In four washing troughs it is possible to clean 100 centners (5 tons) of clay for which the cost amounts to 5–5.80 florins ($4.30)."

The washing of clay is common in all kaolin districts where clays for ware or paper are obtained, and also at potteries as a further preparation for their use in the body of the finest white ware. These modes involve various styles of machinery whereby the clay or kaolin is agitated with water, and then the clayey liquid is conveyed to a series of settling vats. The simplest form of a washer or agitator consists of an inclined trough in which a cylinder, set with spiral rows of knives or cutters, revolves, and by the movement of its knives pushes the mass from the feeding end up the incline and out at the opposite end. There may be many modifications in the mechanical arrangement of these appliances for stirring the clay, as well as differences in the sizes and forms of vats. The washed clay is allowed to dry in the vats on long exposure, or the water is pressed out of it by subjecting it to great pressure in bags. The latter method obviates the length of time requisite for drying in the open air, and does not need such large vats.

APPENDICES.

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Appendix A.

METHOD OF ANALYSIS.

The method of chemical analysis adopted and pursued in the examinations of the clays, *feldspars*, kaolins and fire sands, which are given in this report with analyses, was as follows: One gramme of the air dried pulverized material was digested in sulphuric and hydrofluoric acids until the silica was completely dissipated; the residue was dissolved in hydrochloric acid (a few drops of nitric acid being added to oxidize the iron), and the alumina, sesqui-oxide of iron and titanic acid were precipitated by ammonia (in some cases by acetate of ammonia). In the filtrate the lime was precipitated by oxalate of ammonia, and weighed as carbonate. The filtrate from the lime was divided into two equal portions. In one of these the magnesia was determined, by precipitation by phosphate of ammonia. The second portion was evaporated to dryness and heated to drive off the ammoniacal salts. The residue was dissolved and chloride of barium was added to remove the sulphuric acid and then caustic lime to remove the magnesia. The liquid was boiled and then filtered. To the the filtrate ammonia and carbonate of ammonia were added to remove the chloride of barium and lime; the liquid was filtered, evaporated to dryness and the ammonia salts driven off by ignition. The potash was precipitated by bi-chloride of platinum and weighed as potassio-bi-chloride of platinum. The alcoholic filtrate was evaporated to dryness, the platinum compound decomposed by heating to redness with oxalic acid; treated with water; filtered; a few drops of hydrochloric acid added; evaporated to dryness and weighed as chloride of sodium.

A second sample (one gramme) was treated with hydrofluoric and sulphuric acids, as before, and then ammonia added to precipitate the titanic acid, alumina and oxide of iron. This precipitate was reserved for the determination of the titanic acid. The filtrate was treated as before for the determination of the potash and soda, as duplicates.

A third sample was fused with carbonates of potash and soda; the fused mass treated with water; hydrochloric acid added in excess; evaporated to dryness to render the silicic acid insoluble; treated with dilute hydrochloric acid; heated, and then filtered for the total silicic acid. This weighed determination was checked by the difference in the analysis by hyrofluoric acid. The alumina, oxide of iron and titanium were precipitated by ammonia as in the first sample. Lime and magnesia were also determined as before (duplicate determinations).

The precipitate in the second sample, reserved for the titanium determination, was treated with a solution of caustic potash and heated, to remove the alumina. The insoluble portion, consisting of oxide of iron and titanic acid, was collected on a filter, burned, fused with bi-sulphate of potash, dissolved in water, and saturated with hydrosulphuric acid gas, to reduce the iron oxide. The liquid was filtered and boiled; the titanic acid was precipitated and collected on a filter, then burned and weighed.

For the determination of the quartz the clays were digested in sulphuric acid, and the liquid filtered. The insoluble matter on the filter was burned and weighed as a duplicate of the total silica. This insoluble matter was then boiled in a solution of potash, and the undissolved residue weighed as quartz. These determinations were duplicated by the same method.

The moisture or hygroscopic water, was determined by heating over a water bath, and the loss at 212° (100 C.) taken as its amount. The samples were then heated to redness, ignited, and the loss noted as combined water. In most of the dark-colored clays there was some organic matter. In a few analyses this was estimated; in others the combined water includes very small amounts of organic matter.

The iron was determined by volumetric analysis, using the method by proto-chloride of tin.

Appendix B.

LIST OF FIRE CLAYS EXAMINED BY THE SURVEY, FOR COMPARISON WITH THOSE OF NEW JERSEY.

AMERICAN CLAYS.

1. Trucks & Parker, Hokessin, Delaware.

White and buff colored clays resulting from the decomposition of feldspar in granitic rocks. Used for paper glazing and pottery.

Specific gravity of washed clay, 1.604—1.622.

For analysis of the white clay (washed) see No. 49, page. 300. Collected by Geological Survey.

2. Mount Savage Fire Clay, from the Union Mining Company, Mount Savage, Alleghany county, Maryland.

A grey, shale clay from the Cumberland coal field. See analysis No. 53, page 300. Specimen from Jas. S. Mackie, President, 71 Broadway, New York.

A second sample, received from the mines after printing the analysis above referred to, was examined, and found to contain, of sesqui-oxide of iron, 1.12 per cent., and of potash, 0.80.

The following specimens were received from the Pennsylvania Steel Company. L. S. Bent, Superintendent. Steel Works post office, Dauphin county, Pa.

3. Fire clay from M. D. Valentine & Brother, Woodbridge, N. J.

4. Pensauken Creek clay, J. D. Hylton, Palmyra, N. J.

5. Huntingdon County clay, from Sam'l Hatfield, Alexandria, Huntingdon county, Pa

A light buff colored, very sandy, clay, containing 2.00 per cent of water. Some streaks stained by oxide of iron.

" A semi-plastic refractory clay, containing a good deal of free sand and is used for linings, joints and other places where it is readily held in place."

6. Lebanon Valley clay, from Horace Keefer, Harrisburg, mined at Sheridan, Pa.

Faint buff colored, fine grained, not quite as sandy as (5), contains 5.9 per cent of water.

" A clay similar to above " (5).

7. Sandy Ridge clay, from W. R. Miller, Center county, Pa.

A mixed earthy and rock fragment mass, grey, contains 9.9 per cent of water.

"A rock clay, poorly plastic, but is non-shrinking, refractory and resists chemical action, hence is an excellent setting for fire brick after it has been screened and boiled."

8. Woodland clay, from Woodland Fire Brick Company, Woodland, Clearfield county, Pa.

Drab colored, shaly clay. For analysis see No. 50 of table page 300.

"A clay similar in every respect to the above, possibly a shade more refractory."

The Cambria Iron Company, Johnstown, Pa., sent the following seven specimens of fire clays :

9 Clay from near Mapleton, Huntingdon county, Pa.

A white, fine-grained, very sandy, clay. Has 2.1 per cent. of water. Of this 0.5 per cent. is moisture.

"Good for lining converters, mixed with gannister."

10. Flint clay, from Solomon's Run, near Johnstown, Pa. Lower coal measures.

Very light drab colored, exceedingly hard and compact; sub-conchoidal fracture; 12.6 combined water and .8 hygroscopic water. Analysis No. 51 of table, page 300.

"Fine quality of flint clay from lands of Jacoby and others, adjoining lands of A. J. Hawes. Same can be had on lands of Cambria Iron Company."

11. Springfield Kaolin, from mines of Cambria Iron Company. Found associated with hematite ores in lower beds of II.

White, fine-grained, very sandy mass, resembling some loose sand rocks. Contains 5.0 per cent of combined water and .4 per cent of moisture.

"Good for lining converters. Mixed with flint clay makes a cement."

12. Flint clay from barren measures on lands of A. J. Hawes, at Johnstown, Pa.

Light drab-colored rock clay, not quite as hard as No. 10; irregular fracture; contains 7.2 per cent. of combined water, and .9 per cent. of moisture.

"Good for common or second quality of fire brick."

13. Dark fire clay from lands of A. J. Hawes, 50 feet above coal bed C, at Johnstown; also on lands of the Cambria Iron Company.

Dark grey rock clay; hard; irregular fracture; water of combination, 8.6 per cent.; moisture .2 per cent.

"Converter bottoms; best that can be found for this purpose."

14 Mineral Point fire clay, near Johnstown. In lower coal measures.

Light drab-colored rock clay; hard; irregular fracture; combined water, 12.50 per cent.; moisture, 0.7. Analysis No. 52, page 300.

"For rolling mill and blast furnace brick. Best for steel works purposes cemented with Springfield *kaolin*."

15. Fire clay from floor of coal bed B, Miller seam. In Blast Furnace mine of Cambria Iron Company, at Johnstown.

Grey hard shale clay; irregular fracture; combined water, 4.5 per cent.; hygroscopic water, 1.0 per cent.

"Good for a cementing clay to lay fire brick in, &c., &c."

The following two specimens were obtained from John Moses, Trenton, New Jersey:

16. Porcelain clay (Indianaite) from Huron, Lawrence county, Indiana.

Very white, tolerably hard and compact.

Specific gravity 1.878—1.972 and 2.040. Varying in hardness and density. Fracture conchoidal and smooth, opal-like. For composition see analysis No. 54 of table, page 301.

This clay is used in pottery manufacture at Trenton. It is not very plastic.

17. Clay from Pope county, Illinois.

An earthy clay of mixed characters.

Analysis No. 55, page 301. Used at Trenton.

Charles Frost & Co., Winchester, Illinois, sent one specimen of

18. Fire clay from a vein 12 to 17 feet thick, 100 feet under the surface and under coal shaft.

Hard, grey, rock clay of irregular fracture. For its chemical composition see No. 57 of table, page 301.

Has not been used in practice.

The North Chicago Rolling Mill Company, O. W. Potter, President, sent three clays:

19. Utica clay, La Salle county, Illinois.

An uneven mixture of yellowish and greyish clay masses. Earthy and crumbling. Its composition is given in analysis No. 56, page 301.

"Very plastic, tolerably refractory. Mixed with quartz is used at these works for linings and bottoms of Bessemer converters. Capital clay for such uses."

20. Blue clay, Wilmington, Will county, Illinois.

Greenish grey, crumbling shale clay. Has 11.9 per cent. of water.

"Becomes very strong and plastic by wetting and kneading. Not specially refractory. Used at these works for tap holes and repairs about the hearth of blast furnaces and for tap holes of cupolas in Bessemer works. Very good clay for such uses."

21. Anna clay, Anna, Union county, Illinois.

Yellowish white, earthy clay, with reddish and yellow streaks of oxide of iron. Water (combined) 13.2 per cent.

"Very plastic and tolerably refractory. Used at the works when mixed with quartz for linings and bottoms of Bessemer converters and as a mortar for laying fire brick, for which it is excellent."

Evens & Howard, St. Louis, Missouri, sent five samples of clays, as follows:

22. Glass-pot clay (crude) from Cheltenham, Missouri.

Grey and greenish grey, irregular fracture, hard and compact. Specific gravity 1.708—1.715. For composition see analysis No. 58 in table, on page 301.

"Very refractory; used in glass pots and crucibles."

23. Cheltenham clay, calcined and floated (washed).

"Not so refractory but valuable for crucibles, allowing them to expand and contract more, with less liability to fracture than crude clay."

24. Cheltenham clay (washed).

25. Fire clay from the Evens mines, Montgomery county, Missouri.

Light cream-colored, conchoidal and smooth fracture, hard and compact; specific gravity 1.759—1.789. For its composition see analysis No. 59 in table, page 301.

"For special purposes and mixed with Cheltenham clay."

26. Calcined clay from Evens mines.

Used with Cheltenham clay.

BRITISH CLAYS.

The following samples were received through Bell Brothers, Middlesborough, England.

27, 28, 29. Stourbridge clay Nos 1, 2 and 3, (ground), from Harper & Moore, Stourbridge, Worcestershire, England.

No. 1 has 7.9 of water; 2 has 8.7, and 3 has 11.7.

30. Stourbridge clay, No. 1, (strong).

Hard, solid, greyish color; 7.8 per cent. of water.

31. Stourbridge clay, No. 2, (mild.)*

Darker colored, finer grained and softer than No. 1. It has 11.3 per cent. of water. These two specimens from King Brothers, Stourbridge.

32. Pease's West (Durham) clay.

Black-shale clay; 11.5 per cent. of water.

33. Fresh-wrought fire clay from the Low Main Seam, South Benwell colliery, Newcastle-on-Tyne, from Wm. Cochran Carr, Newcastle.

Black-shale clay.

34. Fire clay from J. Walker & Co., Kingswinford, North Dudley.

Grey-shale clay (ground.) Contains 8.6 per cent. of water.

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*The mild Stourbridge clay is perhaps fairly represented by analysis No. 63 of the table, on page 301 from specimens sent by A. K. Hay, of Winslow, N. J.

35. Fire clay from South Brancepath colliery, Durham; Bell Brothers.

Hard, dark grey-shale clay; 10.2 per cent. of water.

36. Fire clay from Wm. Ingham & Sons, Wortley, near Leeds.

Hard, compact, grey, rock clay. Water 11.8 per cent.

37. Fire clay from Joseph Cliff & Sons, Wortley near Leeds.

Grey-shale clay; 9.5 per cent. of water.

38. Fire clay from W. Stephenson & Sons, Throckley colliery, Newcastle.

Sample ground. Has 7.1 per cent. of water.

Dr. C. W. Siemens, London, sent samples of Glenboig and Stourbridge clay and gannister, as follows:

39. Glenboig star fire clay, Glenboig, Scotland, from James Dunnochie, Glasgow.

Light, drab-colored, close grained, rock clay. Analysis No. 61 in table, page 301, gives its composition.

40. Glenboig gannister, from James Dunnochie.

A close grained light greyish sandstone.

41. Stourbridge pot clay (strong) from Mobberley & Bayley, Lye, near Stourbridge.

Grey, solid rock clay. Analysis No. 62 in table, page 301. 10.4 per cent of water.

42. Stourbridge pot clay (mild), from above firm.

Light greyish, compact, rock clay. It has 9.9 per cent of water.

43, 44. Stourbridge clay (burned and unburned samples), from George King Harrison, Stourbridge

Brown, Bayley & Dixon, limited, Sheffield Iron and Steel Works, Sheffield, England, sent the following samples:

45. Crucible fire clay, D. Sharrott, Halifax, Yorkshire.

A grey shaly clay. Analysis No. 65, page 301, gives its composition.
"High class fire brick, cupola linings and Bessemer steel makers requirements. The bricks are excellent."

46. Crucible fire clay, E. I. & J. Pearson, Stourbridge

Grey, hard and solid.
"Steel melters, crucibles, glass pots and retorts. Very good where liable to sudden changes from high to low temperatures."

47. Brick fire clay, Thomas Wragg, Sheffield.

Dark-colored, stony clay, uneven grained, not homogenous in structure.
"From this clay Sheffield fire brick are made. Not of very good quality."

48. Crucible fire clay, Thomas Wragg, Sheffield.

Dark drab-colored shale clay.

"From this tuyeres and stoppers are made for Bessemer process. The tuyeres are very good."

49. Crucible fire clay, John Knowles & Co., Woodville, Burton-on-Trent, Derbyshire, from 25 yards deep.

Grey, rock clay.

"This is the well known Derby clay—for steel makers' crucibles probably the best in England. The clay seam varies from 4 to 7 feet in thickness; is got in same way as coal. It commands a high price."

50. Same locality as above, 50 yards deep.

Dark drab-colored, shale clay. Has 13.0 per cent. of water. Analysis No. 64 on page 301.

51. Crucible fire clay, Farnley Iron Company. Limited. Farnley, Leeds.

Dark-colored, coarse grained rock clay.

"From this clay the well known productions of the owners are made."

52 Crucible fire clay, Andrew Peak, Horwichtown, Lancashire.

A grey, fine grained, shale clay.

"Used chiefly for tuyeres, stoppers, &c., for the Bessemer process."

53. Crucible fire clay, Garnkirk Fire Brick Company. Limited. Glasgow and Lanark, Scotland.

No. 1. Black, shaly clay. Analysis No. 60, page 301. Water and organic matter 16.4 per cent.

54. Same locality, No. 2.

Drab colored and not so shaly as No. 1. Water 13.7 per cent.

55. China clay, from Redruth, Cornwall, from George Smith, F. G. S., Coalville, Leicester.

A kaolin clay, very white, consisting of clay and quartz in angular grains. Water (combined) 7.2 per cent. Analysis No. 66, page 301.

"This is porcelain, or china clay. Is used with other clays to give toughness to vessels liable to sudden changes of temperature. Will bear frequent heating and cooling—high priced."

56. Joseph Cowan & Co., of Blaydon Burn, near Newcastle-on-Tyne, sent a specimen of grey, shaly clay.

Thomas Belt, F. G. S., of London, sent two specimens of china clays as follows:

57. China clay (kaolin) from Cornwall, England.

Very white and gritless. Contains 11.9 per cent of water (combined).

58. China stone, Cornwall, ground and used in Staffordshire.

FRENCH CLAYS.

From Petin, Gaudet & Co., St. Chamond, Department Loire, ten samples were received :

59. St. Egreve clay, Department Isere, sold by Fumet.

White, sandy clay, containing 5.2 per cent of water. Used in converters.

60. Orange colored clay, same place.

Sandy. 1.4 per cent of water.

61. White sand, from Voiron, Department Isere. Rosset fils et cie.

Used in converters.
White, has 3.6 per cent of water.

62. Fire clay, same place and same use.

White and sandy; 3.2 per cent of water.

63. Macon clay, Department Saone et Loire. No. 1 sold by M. Taupenot.

Sandy clay; 6.0 per cent of water. Used in fire brick.

64. Lean clay, from same place.

Salmon colored, sandy clay; 4.6 per cent of water. Used in coke foundry furnaces.

65. Bollene clay. Department Vaucluse, sold by Carron Jeune.

White clay, containing a little sand. Water 10.9 per cent. For fire bricks.

66. Courpiere clay, Department Puy de Dome, No. 2, sold by Fraisse freres.

White, some quartz sand in it. Water 10.5 per cent. Used for crucible covers.

67. Courpiere clay, No. 1, same place and dealer.

Pearl grey, fine, very little quartz. Water 11.8 per cent. Used in crucibles.

68. Mussidan clays, Department Dordogne, sold by Baignot freres. Used in making crucibles.

White, fine grained and compact. Water 13.1 per cent.

Schneider & Co., Creusot, Department Saone et Loire, sent six samples of fire clays, used in their works. They are as follows:

69. Bollene clay, near Avignon, Department Vaucluse.

Faintly variegated, shades of red and green in white mass, dense, contains 12.9 per cent of water.
"Blast furnaces where the heat is most intense."

70. Clay from Decize, Department de la Marne.

White, with streaks of yellow. Water 10.2 per cent.
"Blast furnaces where the heat is low."

71. Clay from Lezanne, Department de la Marne.

Drab colored compact clay. Water and organic matter 15.2 per cent.
"Converter tuyeres and special shapes for steel works."

72. Clay from Macon, Department Saone et Loire.

Salmon colored clay. Grains of quartz quite coarse. Water 6.7 per cent. Analysis No. 72, page 302.
"Is used with Lezanne clay for converter tuyeres."

73. Clay from Gravoine, Department Saone et Loire.

Coarse granular mixture of quartz and white clay. 4.5 per cent of water.
"Puddling and preheating furnaces, Siemens' regenerators; Cowper stoves; coke ovens."

74. Quartz from Dorat, Department Haute Vienne.

"Silica bricks for melting furnaces."

From the Compagnie des Fonderies et Forges, Terre Noire, La Voulte et Besseges, five samples of fire clays used in their works, were received. They are:

75. Macon clay, raw or crude.

White, sandy, coarse grained. Water 1.9 per cent.

76. Macon clay (prepared).

The preparation consists in drying on heated plates, then grinding it. Used for Bessemer converter bottoms. Sometimes bear over 40 successive heats. Water in it 2.0 per cent.

77. Bollene clay.

Fine white clay. For its composition see analysis No. 72 in table, on page 302.
"This is the most noted and most sought after of French clays, for the manufacture of refractory materials. Used one-third crude and one-third burned, with one-third quartz sand for tuyeres of Bessemer converters and steel furnace hearths."

78. Voreppe clay.

Brown earthy and coarse sand in it. Water 3.2 per cent.
"It serves for the linings of converters. Mixed with one-third quartz sand it is used for repairs in the Siemens-Martin steel furnace."

79. Varielle clay.

Snuff-colored, coarse grains of sand. Water 3.9 per cent.
"Used without preparation or mixture for steel pots. It is moderately refractory and shrinks in the fire. Its use is very limited."

The Bollene clay shrinks considerably in the fire. Voreppe clay being mostly quartz, shrinks little. Macon clay also contracts but little, and becomes very hard in the fire.

BELGIAN AND GERMAN CLAYS.

M. A. Greiner, Manager of the Steel Works, at Seraing, Belgium, sent ten samples of clays:

80. Soree Francesse clay.

White, sandy, dense clay; 7.8 per cent of water.
Lean clay, rarely used, except previously calcined for cement.

81. Natoye clay.

White, solid, sandy clay, containing 7.4 per cent. of water.
Used as above for cement only.

82 Vandaigle clay.

Greyish white, little sandy; contains 9.2 per cent. water. Used as above.

83. Strud (pale) clay.

Dark greyish, solid, and contains 11.5 per cent. of water.
A strong clay, used mixed with others; and sought after in the manufacture of glass and steel.

84. Strud (slate) clay.

Very dark-colored and dense. Water 13.6 per cent. Used as strud (pale.)

85. Nanines, No. 2, clay.

White, solid, little gritty; water 9.3 per cent. Used as strud clays.

86. Nanines, No. 1, clay.

Black, hard and dense; 14.8 per cent. of water.

87. Soree (fine) clay.

White, solid and fine clay. 13.1 water. For its composition see analysis No. 68 in table, page 301.
A very rich clay used in the manufacture of artificial stone, beginning to vitrify at a red heat without losing shape.

88. Soree, No. 3, clay.

Drab-colored, fine grained, little sandy, solid; has 7.8 per cent. of water.

89. Frankenthal clay from Frankenthal-on-the-Rhine, Germany.

White, very little grit; water 12.6 per cent. Analysis No. 69 in table, page 301.
Very refractory.

From A. K. Hay, of Winslow, N. J., the following sample was received:

90. Glass pot clay from Coblentz, Germany. From A. K. Hay's glass works, Winslow, N J.

White, dense, specific gravity 2.229—2.266; fine grained sand in it. Analysis No. 70, page 301. Imported for glass pots.

Appendix C.

ANALYSES OF SOME AMERICAN FIRE CLAYS. (*Copied*).

	1	2	3	4	5	6	7	8
Silica	50.46	44.95	50.15	45.42	46.90	60.97	61.02	59.60
Alumina	35.90	37.75	35.60	36.80	39.60	26.38	25.64	26.41
Water	12.74	13.05	13.61	12.65	13.80	8.93	9.68	10.48
Potash	traces	0.98	0.07	....	....	0.82	0.48	0.29
Soda	....			....	0.17		0 25	0.16
Lime	0.13	0.30	0.11	0.87	....	0.85	0.70	1.00
Magnesia	0.02	0.21	0.16	0.45	....	0.23	0.08	0.07
Oxide of iron	1.50	2.70	0.83	3.33	....	1.46	1.70	1.61
Oxide of manganese	traces	....	....	0.48	....	....	....	....
Sulphuric acid	....	0.07	0.14	....	....	....	....	....
Bisulphide of iron	....	....	0.03	....	....	....	....	....
Sulphur	....	....	....	....	....	....	0.45	0.38
Total	100.75	100.01	100.70	100.00	100.47	99.64	100.00	100.00

1. Mount Savage fire clay, by Prof. J. M. Ordway, Massachusetts Institute of Technology.

2. Fire clay, Sandy Ridge, Centre county, Pennsylvania, Andrew S. McCreath, Second Geological Survey of Pennsylvania (1874, M. 80).

3. Fire clay, mine at Clearfield, Clearfield county, Pennsylvania. Same report (M. 81).

4. Fire clay, Johnstown, Pennsylvania. Analysis by T. T. Morrell, Second Geological Survey of Pennsylvania (R. P. H. H., p. 147).

5. Kaolinite scales, Tamaqua, Pennsylvania, (mean of two analyses purified by chlorhydric acid). Preliminary report on the Mineralogy of Pennsylvania, by F. A Genth, Second Geological Survey of Pennsylvania, B. 119.

6. Fire clay of Charles Frost & Co., Winchester, Illinois. Analysis of Chauvenet & Blair, St. Louis, Missouri, (communicated by C. F. & Co.)

7. Fire clay, Cheltenham, Missouri, (crude). Analysis by Prof. A. Litton, (circular of Evens & Howard).

8. Fire clay, Cheltenham, Missouri, (washed). Analysis by Prof. A. Litton, (circular of Evens & Howard).

BRITISH FIRE CLAYS.

Copied from Percy's Metallurgy. Fuel. Pages, 98–100.

	1	2	3	4	5	6	7	8	9
Silica	65.10	48.04	45.73	48.08	67.12	53.05	55.50	46.32	46.29
Alumina	22.22	34.47	34.14	36.89	21.18	28.13	27.75	39.74	40.09
Potash	0.18	1.94	0.45	1.88	2.02	4.19	2.19	....	....
Soda	....	....	....	....	....	....	with Cl & SO_3 0.44	....	....
Lime	0.14	0.66	0.79	0.55	0.32	0.17	0.67	0.36	0.50
Magnesia	0.18	0.45	0.74	trace	0.84	1.20	0.75	0.44	....
Protoxide of iron	1.92	....	1.76	....	....	....	....	0.27	0.27
Sesqui-oxide of iron	....	3.05	....	2.26	1.85	2.48	2.01	....	....
Oxide of manganese	....	....	trace	....	....	....	....	....	....
Water (combined)	7.10	11.15	10.17	10.87	4.82	5.82	10.53	12.67	12.67
Water (hygroscopic)	2.18	....	4.45	....	1.39	2.20	....	....	....
Organic matter	0.58	....	0.70	....	and CO_2 0.90	2.82	trace	....	....
Titanic acid	....	....	trace	....	....	....	....	....	....
Total	99.60	99.76	98.93	100.53	100.54	100.06	99.84	99.80	99.82

1. Stourbridge clay. Best clay used for glass pots. Silica is partly free, gritty sand

2. Clay from Stannington, near Sheffield. Weighed for analysis after desiccation at 100° C. (212° Fahrenheit). Used for cast steel pots.

3. Edgemount, near Sheffield. Analysis of sample dried at 212°. Used in maklng crucibles for melting cast steel in, and said to be excellent for that purpose.

4. Edensor, near Derby. Analysis of sample dried at 212°. Used for cast steel pots.

5. Dowlais, South Wales. Considered the best fire clay at Dowlais.

6. Dowlais, South Wales. This clay melted down on the bridge of a *balling furnace.*

7. Newcastle-on-Tyne. The soda contains some chlorine and sulphuric acid. From Blaydon Brown colliery in Tyneside. Used in fire brick.

8. China clay from Cornwall. Analysis of specimen dried at 100° C.

9. China clay from Cornwall. Analysis of specimen dried at 100° C.

These are said to be the finest china clay in Cornwall. The two analyses are of the same clay by different men.

DINAS "CLAY."

Copied from Percy's Metallurgy. Fuel. Page 147.

	1	2
Silica	98.31	96.73
Alumina	0.72	1.39
Protoxide of iron	0.18	0.48
Lime	0.22	0.19
Potash and soda	0.14	0.20
Water combined	0.35	0.50
	99.92	99.49

These analyses give the composition of the sand rock which is used in making the celebrated Dinas brick. One per cent of lime is put in the mixture. These bricks are remarkable for their endurance at high heats and for their property of swelling and making a tight roof for furnaces.

FIRE STONES AND FIRE CLAYS.

ANALYSES BY RILEY.

Copied from the Journal of the Iron and Steel Institute No. 2, 1875, page 522.

	1	2	3	4	5	6
Silica	56.42	65.41	55.61	62.35	59.33	98.94
Alumina	26.35	30.55	27.50	18.47	22.01	0.57
Combined water	10.95	....	6.96	5.22	8.18	0.42
Potash	0.48	0.55	0.81	2.47	2.42	....
Lime	0.60	0.69	0.32	trace	0.36	0.62
Magnesia	0.55	0.64	0.79	1.36	1.47	0.21
Sesqui-oxide of iron	1.33	1.70	1.91	4.77	4.80 †	0 67
Titanic acid	1.15	1.33	0.33	1.10	....	....
Moisture	2 80	....	2.12	4.15	1.38	....
	100.63	100.87	96.35 *	99.89	99.95	101.43

* Organic matter, 3.34. † Protoxide of iron.

1. Glenboig clay, Star Works.
2. Glenboig clay, calcined.
3. Etherley clay.
4. Derbyshire clay.
5. Mine shale, Dowlais.
6. Sheffield gannister, hard.

ANALYSES OF SOME BELGIAN AND GERMAN CLAYS.

	1	2	3	4	5	6	7	8	9
Silica (combined)......	36.69	38.21	32.18	35.35	39.32	38.94	19.99	40.53	*46.59
Alumina................	34.78	33.47	37.95	35.36	35.05	36.30	17 31	38.54	36.54
Water..................	10.73	11.81	10.02	11.72	7.43	14.52	5.70	13.00	9.69
Potash.................	0.41	1.18	3.00	1.24	3.18	0.42	0.46	0.66	1.32
Soda...................	....	....	....	....	....	....	....	....	....
Lime...................	0.68	0.93	0.04	0.16	0.16	0.19	....	0.08	3.02
Magnesia...............	0.41	0.67	0.11	0 07	1.11	0.19	....	0.38	1.28
Sesqui-oxide of iron...	1.80	4.60	0.95	2.69	2.30	0.46	0.56	0.90	0.69
Sand...................	9.95	9.43	14.79	12.41	8.01	4.90	55.89	5.15	....
Moisture...............	1.27	....	....	....	3.08	3.26	....	....	....
Total..................	96.72	100.30	99.04	99.00	99 64	99.18	99.91	99.24	99.13

* Including sand.

1. Andennes, Belgium. Best Belgian clay, according to Bischof. (Dingl. Polyt. Journ., 200, 110 and 289).

2. Vallendar, near Coblentz on the Rhine, Germany.

According to Richter's tests glazed at melting point of steel. (Kerl's Muspratt's Chemis., 5 S. 623).

3. Ebernhahn, near Vallendar. According to Bischof's tests very refractory. Very much sought after for glass works use. (Kerl's Muspratt's Chemis., 5 S. 623-4).

Muhlheim on the Rhine, between Coblentz and Andernach. Moderately refractory, very plastic; with cement very refractory. Kerl's Muspratt's Chemis., 5 S. 623-4.

5. Grunstadt, Bavarian Palatinate, used for glass pots and steel crucibles. Fire-resisting power 30, as compared with Saarau (No. 6), which is put at 100, and standard of comparison. (Bischof, Dingl. Polyt. J., 185; 39 and 200; 110 and 289).

6. Saarau, Silesia, (washed clay). (Bischof in Dingl. Jour. l. c.)

7. Saarau clay (crude). According to Bischof, (Dingl. J., l. c.), fire-resisting power of this clay, as compared with No. 6, is only 50.

8. Zettlitz, Bohemia, washed kaolin. (Bischof in Dingler's Journ.). Fire resisting power 60-70.

9. Passau, Bavaria, kaolin or porcelain clay. (Knaffl., 1860, in Gumbel's Geognostische Beschreibungdes Ost Baierischen Grenzgebirges S. 359.)

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ERRATA.

Page 12, twenty-sixth and twenty-seventh lines, read Isaac Inslee, Sr., instead of Knickerbocker Life Insurance Company.
" 29, fourth line, read sequoia instead of sequvia.
" 43, in analysis (3) of table, insert for titanic acid 1.30; and for total 100.04 instead of 98.74.
" 51, in analysis (8) of table, 36.78 for alumina includes titanic acid.
" 62, third line of foot note, read alumina instead of silicic acid.
" 66, fourteenth line, read 39 instead of 54.
" 82, fourth and fifth lines, read (3) in place of (2), and (2) instead of (1).
" 83, analysis should be as in table, page 297 (No. 4).
" 99, for total of alumina, silicic acid and combined water read 47.17 instead of 46.17, and total of analysis 100.70.
" 108, sixth line, read (4) in place of (3).
" 124, eighth line, read west instead of east.
" 166, analysis should be as No. 3 in table, on page 297.
" 200, fifth line read east northeast instead of east southeast.
" 245, second line read 75 in place of 225.
" 269, in first column of table of analyses for water read 13.82.
" 281, in fourteenth, fifteenth, twenty-ninth and thirty-fourth lines read feldspar in place of *feldspar*, and kaolin in place of *kaolin*.
" 282, fifth line from top and third line from bottom same correction as page 281.
" 283, sixth line from bottom read 32 instead of 30.4.
and fifth line from bottom read 16 instead of 15.02.
and third line read 3,375 in place of 3,550.
" 284, second line read 3,000 instead of 3,100.
" 293, ninth line read *period* after accepted.
" 319, second line from bottom insert *or* between boring and pit.
" 329, second line for *they* read *that*.
" 330, fourteenth line read dirt for drip.
" 345, tenth and fifteenth lines read ganister instead of gannister.
" 348, In paragraph seventy-seven, Bollene clay, read No. 71 instead of 72.
" 352, fifth line from the bottom read Blaydon Burn in place of Blaydon Brown.
" 354, In paragraphs two and three read chemie for chemis; insert 4 before Muhlheim and in same paragraph read chemie for chemis.