C. Kreischer photo.

Terra cotta vase, made at factory of B. Kreischer's Sons, Kreischerville S. I. Hight of vase, 5 feet.

University of the State of New York

BULLETIN

OF THE

New York State Museum

FREDERICK J. H. MERRILL *Director*

No. 35 Vol. 7

June 1900

CLAYS OF NEW YORK

THEIR PROPERTIES AND USES

BY

HEINRICH RIES PH. D.

ALBANY
UNIVERSITY OF THE STATE OF NEW YORK
1900

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CONTENTS

PAGE

Preface 493

Origin and nature of clay 496

Mineralogy of clays 503

Properties of clay 510

  Chemical properties 511

  Methods of analyzing 530

  The rational analysis 533

  Physical properties 538

  Mechanical analysis 561

Classification of clays 564

  Uses 564

  Coloring agents 565

Geologic distribution 572

  Occurrence in New York state 572

    Clays of Champlain valley 594

    Long Island clays 595

    Staten Island clays 607

  Occurrence in the United States 611

Clay-working 628

  Structure of clay deposits 628

  Prospecting and exploring 629

  Methods of working 631

  Purification of clay 633

Uses of clays 636

  Characters of brick clays 636

  Burning of brick clays 639

The brickmaking industry 643

  Crushing strength of bricks 647

  Building brick industry in New York state 650

  Methods of manufacturing 653

  Cost of production 685

  Detailed account of brick yards 686

  Paving brick 743

Terra cotta 758

  General properties 758

  Terra cotta clays 759

  Terra cotta manufacture 761

Roofing tile 765

Sewer pipe 767

  Clays used 767

  Manufacture of sewer pipe 768

  Drain tile 770

PAGE

Hollow brick, terra cotta lumber, fireproofing 773

Floor tile 774

Decorative tile 777

  Methods of tile decoration 777

Fire clays 781

  Refractory clay products 783

  Manufacture of fire brick 784

  Glass pot clays 786

  New York fire clays 788

Pottery 791

  Description of different grades 791

  Methods of manufacture 798

  Methods of decoration 814

  New York stoneware clays 817

  Pottery industry of New York 823

Shales of New York 825

  Distribution and properties 826

  Feldspar and quartz 841

Minor uses of clays 845

  Portland cement 845

  Mineral paint 848

  Clarifying oils and fulling earth 848

  Filling paper 852

  Food adulterants 852

  Ultramarine manufacture 852

  Polishing and abrasive materials 852

  Road materials 853

  Puddle 853

Testing of clay wares 854

  Porosity or permeability 854

  Breaking strength 855

  Hardness test 855

  Determination of deleterious impurities 856

  Determination of soluble salts 856

  Resistance to weathering 856

  Resistance to acids 857

  Abrasion test 857

Sections of clay deposits 858

Clay analyses 860

Bibliography of clay literature 908

Directory of clay workers in New York state 913

Index 927

The manner in which the New York state museum bulletin no. 12, entitled *Clay industries of New York*, was received by the public, indicated that the subject was of interest to a large number of persons and it therefore seemed important, as soon as the means were available, to thoroughly revise this bulletin and bring it up to date so as to cover the great progress made in this manufacturing industry. Dr Heinrich Ries has accordingly devoted himself to this work of revision and after much careful labor has produced the work now submitted to the public. The chapter on the physical properties of clay should be of particular value, since Dr Ries has made a special visit to Berlin for the purpose of investigating this subject in relation to the clays of Europe.

Frederick J. H. Merrill
Director.

New York state museum
Albany N. Y.
1899

CLAYS OF NEW YORK

THEIR PROPERTIES AND USES

PREFACE

The following report is an enlargement of one prepared by the writer in 1895, which was published as *Bulletin no.* 12 of the New York state museum, and is made necessary by the increased development of the New York clay-working industries, as well as by an increased knowledge of the properties and technology of the different varieties of clay.

While portions of the original report have been allowed to stand as first published, the greater part has been rewritten and many additional data have been incorporated.

New York is not the leading state in manufacture of clay products, but its output is by no means small, as can be seen from the following figures issued by the U. S. geological survey for the year 1898.

	Value of output
Common brick	$4 381 257
Pressed brick	260 135
Paving brick	302 680
Ornamental brick	8 665
Fire brick	386 624
Drain tile	74 072
Sewer pipe	89 224
Terra cotta	367 854
Fireproofing	87 152
Tile (not for drains)	83 910
Pottery	44 556
Miscellaneous	262 860
	$6 448 989

In order to show the development of the industry in this state during the four years previous to 1898 the following table is given from the 19th annual report of the U. S. geological survey, pt 6, p. 367.

Clay products of New York 1894-97

	1894	1895	1896	1897
Brick				
Common				
Quantity	821 286 000	955 442 000	931 565 000	828 868 000
Value	$3 945 022	$4 396 027	$4 141 973	$3 657 750
Average per M	$4.80	$4.60	$4.45	$4.41
Pressed				
Quantity	*a*	18 437 000	18 409 000	18 046 000
Value	....	$290 910	$298 515	$263 166
Average per M	....	$15.78	$16.22	$14.58
Vitrified				
Quantity	9 304 000	10 896 000	23 723 000	28 145 000
Value	$136 697	$121 892	$259 550	$309 564
Average per M	$14.69	$11.19	$10.94	$11
Fancy brick, value	$52 500	$1 025	$17 854	$2 680
Fire brick "	$298 578	$302 407	$345 485	$339 740
Drain tile "	$62 955	$56 740	$292 954	$25 385
Sewer pipe "	$10 000	$133 000	$85 289	$116 000
Ornamental terra cotta, value	$508 000	$336 000	$484 113	$420 601
Fireproofing, value	$828	....	$72 410	$56 410
Tile (not drain) "	$64 704	$143 465	$99 060	$150 360
Pottery				
Earthenware and stoneware, value	....	$44 033	$100 733	$179 265
C. C. and white granite ware, value	....	....	$15 000	....
Sanitary ware, value	....	....	$21 000	$1 000
Porcelain or china, value	....	....	$120 000	$3 000
Porcelain electrical supplies, value	....	....	$55 000	....
Miscellaneous	$84 738	$63 997	$5 270	$90 583
Total value	$5 164 022	$5 889 496	$6 414 206	$5 615 504
Number of firms reporting	302	280	262	231
Rank of state	4	4	3	4

It is highly gratifying to see the manner in which the shale deposits, specially those in the southern part of the state, are being developed, and yet it is not a matter for surprise, since they form an inexhaustible supply of plastic material which in most cases burns to a good red color at a very moderate temperature. The outcrops are so abundant that the prospective manufacturer can, by a little

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a Common and pressed brick not separately classified in 1894.

search, find the material most suited to his needs. In several plants already established the plastic clays have been given up for shale, this being true not only of works where ornamental wares are made, but also of those manufacturing common brick.

Next to the shale deposits it is probable that the clay beds of Long Island have the most promising future. It is true that they are at times pockety and the overburden is often considerable, but nevertheless there is an abundance of material of good quality.

Another noteworthy feature of the industry is the adoption of more modern methods of molding and burning. Dry press and stiff mud machines are frequently met with where they were not seen six years ago. There is also progress in the use of the most approved kilns, and those of the continuous type are gaining specially in favor. Six years ago there was not one in use in the state.

Many of the analyses given in the report are new, and a number of physical tests have been made, particularly on the shales, in order that they may be compared intelligently with some used in the manufacture of standard products at other localities.

Thanks are due to the many manufacturers who have kindly given aid and information in the preparation of this bulletin, and through their liberality it has been possible to give many of the illustrations which accompany the text.

Heinrich Ries

Ithaca N. Y., 10 *June* 1899

ORIGIN AND NATURE OF CLAY

The term "clay" is difficult to define, being often used in a rather loose manner. Recent investigations on the part of the writer and others lead to the conclusion that the term "clay" indicates a substance of peculiar physical characters, but having absolutely no constancy of either chemical or mineralogic composition. Two substances may appear to be entirely unlike from a chemical standpoint, and yet their physical characters may be such that both would be classed under the head of clay.

Probably the best mineralogic definition of clay is that given by Dr G. P. Merrill in his book, *Rocks, rock-weathering and soils,* in which he defines it "as an indefinite mixture of more or less hydrated aluminous silicates, free silica, iron oxid, carbonates of lime, and various silicate minerals which, in a more or less decomposed and fragmental condition, have survived the destructive agencies to which they have been subjected".

The only feature characteristic of all clays is that they are plastic when wet and when burned harden to a rock-like mass. This degree of plasticity has little probably to do with the chemical or mineralogic composition, for clays of either high or low plasticity may vary widely in their make-up. It seems to depend, and this point will be discussed in more detail later, wholly on texture and structure, that is on the shape and size of the particles. As Dr Merrill points out, pure quartz, chalcedony, flint, feldspar or other silicates, will when reduced to an impalpable powder possess a pastiness and even an odor similar to that of clay. Most of these simple mineral mixtures of extreme fineness do not seem to hold together like clay mixed by nature, probably because they lack the plastic particles which true clay contains. Clay may show all degrees of plasticity, and by the increase of one or another of its component minerals may pass into other rock types, as into limestone on the one hand by the increase of carbonate of lime, or into sandstone by the addition of sand.

To define clay from the physical standpoint, we may say that it is a fine-grained mixture of mineral fragments of variable composition, possessing when wet plasticity which permits it to be molded into any desired form and retaining that form when dry. That furthermore, when heated above a certain temperature it loses its chemically combined water and becomes converted into a rock-like mass, which if reground and mixed with water no longer shows plasticity.

All clays found in nature contain, so far as known, a variable amount of kaolinite, the hydrated silicate of alumina, which is commonly spoken of as the clay base or clay substance. (It should be stated that it is sometimes the custom, specially abroad in the case of many impure clays to call the finest particles of the clay irrespective of their composition the " clay-substance.")

A mass of kaolinite would be termed *kaolin*. These two terms are often used interchangeably, though the former is simply the mineralogic name while the latter is a rock term. *Pure* kaolin has not thus far been found in nature, though some very nearly pure is known. Properly speaking the term *kaolin* should be restricted to white burning residual clays, a usage which is widespread but has not become universal. " The name *kaolin* is a corruption of the Chinese *Kauling*, which means *high ridge*, and is the name of a hill near Jauchau Fu, where the mineral is obtained." (Dana, *System of min.*, p. 687)

Kaolinite is a secondary mineral formed by the decomposition of feldspar. This is commonly caused by percolating waters aided by disintegrating causes, the result being that the alkalies and alkaline earths of the feldspar are carried off in solution, while the alumina and silica, left behind, unite with water to form hydrated silicate of alumina. The feldspars are essentially anhydrous silicates of alumina, containing in addition varying amounts of lime, potash or soda, and depending partly on their chemical composition and partly on their physical characters. Nine varieties are usually recognized, which fall into two groups known as the orthoclase and plagioclase groups.

The orthoclase or potash feldspar has a composition of silica 64.7, alumina 18.4, potash 16.9, while in the plagioclase group the composition of the different members is given as follows.[1]

	Silica	Alumina	Potash	Soda	Lime
Albite	68	20	...	12	12
Oligoclase	62	24	...	9	5
Labradorite	53	30	...	4	13
Anorthite	43	37	...	...	20

In treating the decomposition or kaolinization of feldspar, most writers are apt to give the impression that it is the orthoclase which furnishes kaolinite by its decomposition, whereas both groups may produce it, and indeed the plagioclase varieties decompose much more readily than the orthoclase. This fact was noted by Leimberg. (*Z. d. d. G. G.* 35, 1883) The same fact was observed by the writer in the kaolin at Rönne, Denmark, which is produced by the decomposition of a granite containing both plagioclase and orthoclase. In partially weathered specimens the plagioclase was the more extensively affected. As a rule the orthoclase feldspar is much more common than the plagioclase.

Aside from the kaolinization of feldspar by the ordinary processes of weathering it seems possible and even probable that its decomposition may be brought about by the action of mineralizing vapors, that is, vapors whose presence seems to be necessary to the formation of certain minerals, as at Cornwall, Eng., where it was found that the feldspar of the granite on both sides of the tin veins had been altered to kaolin. This change is attributed to the action of fluoric vapors whose presence is pretty well proven. That such a process is possible is shown by J. H. Collins (*Min. mag.* 1887. 7:213, in the "Nature and origin of clays and the composition of kaolinite") who exposed feldspar to the action of hydrofluoric acid. The feldspar, according to Mr Collins, was converted into hydrated silicate of alumina, mixed with soluble fluorid of potassium, while pure silica was deposited on the sides of the tube.

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[1] G. P. Merrill. *Rocks, rock-weathering and soils*, p. 15.

With such treatment the orthoclase yielded more readily than either albite or oligoclase. The following analyses show the effect of 96 hours' treatment of orthoclase with hydrofluoric acid at 60° F.

	1	2	3
Silica	63.70	49.20	44.10
Alumina	19.76	35.12	40.25
Potash	13.61	.12	.25
Soda	2.26	tr	tr
Ferric oxid	.71	tr	tr
Water	tr	14.20	15.01
	100.04	98.64	99.61

From the analysis it will be seen that the composition of the outer layer simply approximates that of kaolinite.

No. 1 is the original feldspar.

No. 2 is inner layer of altered feldspar.

No. 3 is outer layer of altered feldspar.

The artificial clay thus produced, when examined under the microscope, resembled washed kaolin. It showed no hexagonal scales, but contained a number of minute colorless cubes which are supposed to be fluor spar.

The theory advanced by Mr Collins was first suggested by Von Buch and Daubrée, who believed that kaolinization is produced by fluids containing fluosilicates or fluoborates acting from below, generally, if not always, through fissures. (*Annales des mines* 20, 1841)

Von Buch early observed the constant occurrence of kaolin with minerals containing fluorin, and suggested that the kaolin of Halle, Germany, owed its origin to hydrofluoric acid. (*Min. Tasch,* 1824)[1]

Daubrée considered that the kaolin near St Austell in Cornwall must have had a similar origin. (*Annales des mines* 1841)

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[1] The writer can state from personal examination that the Halle kaolins were formed by ordinary weathering.

If Mr Collins's theory be correct, the kaolin deposits should extend to great depths, but if the kaolinization be due to weathering, then we should encounter undecomposed feldspar at the limit to which weathering has reached. In Cornwall the kaolin mines, which are probably the largest in the world, have reached a depth of over 200 feet without the kaolin giving out, while at Zettlitz in Bohemia a depth of over 400 feet has been reached with the same result. The latter locality is one of thermal activity. In these two instances the theory just mentioned seems to be very reasonable. There are many localities however where the kaolin decreases with the depth, passing into the undecomposed feldspar, as is the case for example in North Carolina, where the fresh feldspar is met at a depth of 60 to 120 feet. Still there are localities in the United States where the mineralizing vapors seem clearly to have aided in the formation of kaolinite. Thus in many of the mines at Cripplecreek in Colorado, kaolinite has been produced by the decomposition of the feldspar, and is considered by Penrose to have been formed by other agencies than those of weathering, for the reason that it shows no sign of decrease in quantity with the depth, occurring as abundantly in the bottom of the deepest mines as on the surface. The frequent association with it of the unaltered sulfid minerals suggests that superficial alteration had no part in the formation of the kaolinite, otherwise the sulfids would have been oxidized to sulfate[1]. It is possible that fluorin may have been the agent in the change, for it is abundant in many of the Cripplecreek ore deposits.

Whatever the species of feldspar, or the process of decomposition, the product is kaolinite, and, as previously observed, a mass of kaolinite would be termed kaolin, or pure clay. Such a thing as pure clay is however unknown, for one or more minerals are always associated with the feldspar and remain in the kaolin as impurities, but not necessarily injurious ones. Clay therefore is formed primarily by the decomposition of a feldspathic rock mass,

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[1] *U. S. geol. sur.* 16*th ann. rep't pt* 2, *p.* 131.

and, if the deposit is found in the locality where it was formed, it is known as a *residual clay.*

Clay may also be derived from the decomposition of aluminous limestones.

Deposits of kaolin are not very common, but residual clays are. Indeed in many of the southern states the surface soil over many square miles is nothing more than a residual clay. Such residual deposits often bear a close resemblance in chemical composition, to the rock from which they were formed.

Under the influence of weathering the residual surface materials are washed down into the rivers and carried to seas or lakes where they are spread out over the bottom as sediments. We thus have another class of clay deposits known as *sedimentary clay,* no longer resembling the parent rock, but composed of the residuum of several different areas.

These two types of clay deposits, the *residual* and the *sedimentary,* present certain distinguishable features, bearing on their origin.

Residual clays are composed of a mixture of angular grains representing in part undecomposed rock, and fine rock flour of clay, that is, particles sufficiently fine to float in water. There is generally a gradual transition from the fully formed clay at the surface to the unaltered parent rock below. The depth below the surface at which unaltered rock is reached varies from three or four feet to 150 or 200 feet. The structure of the parent rock is sometimes retained for a certain distance upward in the residual clay.

Sedimentary clays are stratified and occur in beds. They are as a rule more homogeneous than residual clays and contain a greater proportion of fine particles. They are also more plastic, and frequently have much disseminated organic matter, but they bear little or no relation to the rocks on which they rest.

Sedimentary clays occur either at the surface, or may lie deep below it, interbedded with other rocks.

When sedimentary clays suffer consolidation under pressure they are known as *shale.* Shales simply represent the finest clay sediment, which has been deposited in those parts of the ocean which are very quiet and has become consolidated by the pressure of other sediments laid upon it. In some hard shales there is probably also some cementing material between the grains.

In the later discussion of the chemical and physical properties of clay whatever is said of clay will also apply to shale, unless it be otherwise stated.

Shales when ground up and mixed with water generally produce a plastic mass similar to common clays. If simply placed in water, however, they do not usually fall to pieces as an ordinary clay does, or, in other words, they do not slake. Shales may be either highly refractory or extremely fusible, and both forms of this material are of commercial value. Some of the most refractory material mined in the United States, as for instance the fire clays found at Denver Col., or those in Pennsylvania, are shales. The chief use of shales in the United States is in the manufacture of paving bricks. Those of New York state are treated in a separate chapter.

MINERALOGY OF CLAYS

The number of mineral species which may exist in clays is very great, and depends partly on the mineralogic composition of the parent rock, and the extent to which decomposition has proceeded in the clay mass.

The characters of the common minerals found in clays together with their more important features, are here given, arranged approximately in the order of their abundance. Any one of these may however at times become a predominating constituent.

Kaolinite. Formula: Al_2O_3, 2 SiO_2, 2 H_2O, or silica (SiO_2) 46.3%, alumina (Al_2O_3) 39.8%, water (H_2O) 13.9%

This is a white, pearly mineral, crystallizing in the monoclinic system, the crystals presenting the form of small hexagonal plates. Its specific gravity is 2.2–2.6; its hardness 2–2.5. It is naturally white in color and a mass of it is plastic when wet, but very slightly so. The occurrence of kaolinite in crystals has been noted from National belle mine, Red Mountain, Col. (H. Reusch, *Jahrb. f. mineralogie*, 1887, 2:70) and from Anglesey (A. Dick, *Min. mag.* 1876, 8:15). A microscopic examination shows the plates of kaolinite collected in little bunches. Their separation by grinding increases the plasticity.[1]

If kaolin be formed into briquets, of the same shape as those used in testing cement, its tensile strength, as determined by pulling these briquets apart in a testing machine, is usually 5–15 pounds the square inch — a very low degree compared with the tensile strength of more plastic clays.

Kaolinite is nearly infusible, but a slight addition of fusible impurities lowers its refractoriness.

Many kaolins contain very minute scales of white mica, which it would be difficult to distinguish under the microscope from kaolinite. Since white mica in a very finely divided condition is

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[1] *Clays of New Jersey*, N. J. geol. sur. 1878. G. H. Cook.

not unlike kaolinite in its behavior, as shown by the experiments of Vogt, its presence may be of no influence, unless there is an appreciable amount of it. The following quotation[1] exhibits those experiments.

> Mr Vogt considers that the plasticity which clays have is chiefly due to the hydrated silicate of alumina or kaolinite. Experiments which he made, show that the kaolinite is not the only substance which remains in suspension for a long period. For his trials he took quartz from Limousin, orthoclase from Norway, and a potash mica. All three were ground very fine, and then washed in a current of slightly ammoniacal water. The washed materials were then allowed to stand. After 24 hours each of the liquids was as opalescent as if it had washed clay in suspension. After nine days the turbidity still remained, but was less marked. At the end of this time the supernatant liquid was ladled off of each, and a few drops of hydrochloric acid added to it. The suspended materials coagulated and settled, and the precipitate was collected, dried, and weighed. The mica which had remained in suspension during the nine days was very fine; still the particles glittered in the light. The addition of hydrochloric acid caused the instant settling of the particles, which was also noted by the cessation of the glittering. The settlings of mica from 1 liter of water amounted to .15 gram. This fine-grained mica possessed a plasticity almost equal to that of the kaolin.
>
> From the decanted liquid of the feldspar the hydrochloric acid brought down .4 gram of this mineral per liter, while of the quartz only .1 gram of sediment was obtained.
>
> A very plastic clay from Dreux was treated in the same manner and after nine days a precipitate of .56 gram was brought down.
>
> From these experiments we see that in washing kaolin it is impossible to free it entirely from quartz, feldspar, and mica.

Associated with kaolinite we may find one or more other species of minerals, all hydrated silicates of alumina. Some of these have been found in crystals and are very probably good species, but others are known only in an amorphous condition. This may tend to suggest some doubt as to their validity. These associated species together with their characters are given by Dana as follows.

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[1] *Thonindustrie zeitung*, 1893. p. 140.

Halloysite. A massive, clay-like or earthy mineral, with a conchoidal fracture. It shows little or no plasticity. It has a hardness of 1–2. The specific gravity is 2.0–2.20. The luster is somewhat pearly to waxy or dull. The color is white, grayish, greenish, yellowish and reddish. It is translucent to opaque, sometimes becoming translucent or even transparent in water, with an increase of one fifth in weight. It is a silicate of alumina like kaolinite, but amorphous and containing more water; the amount is somewhat uncertain, but according to Le Chatelier the composition is probably $2H_2O$, Al_2O_3 $2SiO_2 +$ aq, or silica 43.5%, alumina 36.9%, water 19.6% = 100. It is not uncommon in the kaolin deposits around Valleyhead, Dekalb co. Ala., where it occurs as veins in the kaolin.

Rectorite. Monoclinic. In leaves or plates resembling mountain leather. Very soft, hardness less than that of talc. Feels soapy. Luster pearly. Color pure white, sometimes stained red with iron oxid. Composition: $H\ Al\ SiO_4$ or Al_2O_3, $2\ SiO_2$, H_2O= silica 50.0; alumina 42.5; water 7.5.

Newtonite. Rhombohedral. In soft, compact masses, resembling kaolinite. Color white. Composition: $H_8Al_2Si_2O_{11}$+water or Al_2O_3, $2\ SiO_2$, $5\ H_2O$=silica 38.5, alumina 32.7, water 28.8. Sp. gr.=2.37.

Allophane. Amorphous. As incrustations which are usually thin, with mammillary surface. Occasionally almost pulverulent. Fracture imperfectly conchoidal and shining, to earthy. Very brittle. Color variable. Translucent. A hydrous aluminum silicate, $Al_2SiO_5+5H_2O$=silica 23.8, alumina 40.5, water 35.7. Hardness 3. Sp. gr. 1.85—1.89.

Other species listed by Dana in the kaolinite group are cimolite, montmorillonite, pyrophyllite, collyrite and Schrötterite. *Indianaite,* a white residual clay found in Lawrence co. Ind., is placed under halloysite by Dana.

Clays may vary mineralogically within very wide limits. Pure clay, as before stated, would consist entirely of the mineral kaolinite, but in addition to this quartz, feldspar and mica are minerals most commonly present and we may also find calcite, gypsum, mica, siderite or carbonate of iron, pyrite, dolomite, iron oxid, etc.

Quartz. This mineral is present in sedimentary clays mostly in the form of fine grains, or sometimes in crystals, while in residual clays the particles are usually angular. It may be colorless, but the grains may be often superficially colored either red or yellow by iron oxid. It is a very hard mineral and scratches glass easily. Feldspar might be mistaken for it, but feldspar will not scratch glass.

Flint or amorphous silica is sometimes present in clays. It usually has a muddy color, and a conchoidal fracture. It might be found in either residual or sedimentary clays.

Quartz and flint are infusible except at very high temperatures; but the presence of other minerals in the clay acting as fluxes often causes them to soften at a much lower temperature. In addition quartz serves to diminish the shrinkage of a clay, and, if not naturally present in sufficient quantity, has to be added during the process of manufacture. The admixture of quartz also tends to decrease the plasticity, the more so, the coarser the grain. The size of the quartz grains affects the ease with which they can be fluxed; for, as fusion begins on the outside of a quartz grain, the larger the grain the longer it will take to reach the center. Therefore if the heat is not continued long enough, it may happen that the outside of the grain has been softened and the center is unaffected.

Feldspar. Since kaolinite is formed by the decomposition of feldspar, it seems but natural that we should find some undecomposed grains of the latter in almost every clay. The fragments would be scaly or rhombohedral in form. Feldspar is slightly softer than quartz, and while the latter scratches glass, the former will not. It is commonly pink, red, yellow or even white. Few fragments fail to show a white coating on the surface of the grains, or lining the cracks and cleavage planes of the mineral, indicating the presence of some kaolinite.

Calcite. This mineral may occur in clays in the form of little rhombohedral grains, soft enough to be scratched with a knife.

As calcite effervesces when moistened with muriatic acid, its presence in the clay may often be detected by the addition of this chemical to it. Calcite may be scattered through the clay in the form of small grains or be present as concretions (commonly called "clay dogs"). It not infrequently happens that some layers of the clay contain a much larger percentage of carbonate of lime than others, and indeed, with a very great increase in the amount of carbonate of lime, the clay might pass into a marl. Where a deposit of clay rests on a bed of limestone, the lower layers of the material may be more calcareous than the upper ones. The carbonate of lime found in clays is at times derived from particles of limestone if the clay is a sedimentary one, or in the case of either sedimentary or residual clays it may come from the decomposition of lime soda feldspars, or again it may be introduced by percolating waters.

Gypsum may be present in the clay as grains, needles, or well formed crystals, or lamellar masses. It is much softer than calcite, being scratched by the finger nail, often has a pearly luster, is transparent, and does not effervesce with acid. In hard burned bricks gypsum simply acts as a flux, but in lightly burned ones, it gives rise to soluble sulfates, which cause efflorescence. In the salina shales it often forms large transparent plates.

Mica. This can frequently be easily detected by the naked eye, even though it may be present in a very finely divided condition, for the small scales of it have a high luster. Mica is seldom absent in clays and is usually present to a greater or less extent in the best known kaolins. Owing to its nature it floats very easily, and is consequently very hard to eliminate by washing. As white mica is very refractory, and when finely ground possesses a certain amount of plasticity, its presence in small amounts is not very injurious.

The mica found in clays is generally derived from igneous or metamorphic rocks, such as granites, gneisses, or schists. Two kinds of mica are commonly found in clay, namely biotite and muscovite. The biotite mica is a silicate of iron, magnesia and alumina, occurring as six sided plates or irregular scales usually of a dark color. As it decomposes easily with the formation of iron oxid, it is not as commonly found in clays as muscovite. The latter is sometimes called potash mica, though it also contains a small amount of iron and magnesia. It is of a silvery white or light brown color.

As before mentioned, mica by itself is rather refractory, but in the presence of other minerals may serve as a flux at high temperature. Even in burned bricks the mica scales are often perceptible. This is frequently the case when the brick has been burned at a temperature of 2500° F.

Siderite. This is perhaps a more common constituent than is usually imagined. It generally occurs in the form of opaque, rounded masses, and effervesces on the addition of warm muriatic acid. In the burning of the clay siderite or iron carbonate is converted into iron oxid.

Pyrite. This is a combination of iron and sulfur. It has a metallic luster and yellow color, and is a very common constituent of many fire clays, occurring either in the form of small yellow metallic grains or concretionary masses of yellow crystals. In the burning of clay it may be changed to sulfate of iron and if the clay is heated to vitrification, it will serve as a flux. The brick makers' common name for pyrite nodules is "sulfur-balls".

Marl or limestone fragments. The action of these is the same as that of calcite. Their presence may be detected by treatment with muriatic acid.

Dolomite, the double carbonate of lime and magnesia, and magnesite, the carbonate of magnesia, may both occur in clay, either as earthy grains or as rhombohedral crystals. Either alone is highly refractory and in this condition is used as linings for furnaces, but when present in clay may serve as a flux, their action being similar to that of lime.

Iron oxid. This is perhaps the most common impurity of clay next to quartz. It may occur in the form of earthy grains, or metallic scales, or as a superficial coating on other mineral grains. It dissolves quietly in muriatic acid. Iron may also occur in clay as a constituent element of other minerals, and indeed the effect which it produces is dependent not so much on the actual amount of iron oxid present as on its condition, according as it is combined with silica, carbonic acid or some other acid.

Hornblende. This is not an uncommon constituent of clays, and when present is generally in the form of tiny scales or flakes of a dark green color, showing transparency under the microscope only when extremely thin. It is highly probable that the hornblende does not remain very long as such, for it decomposes quite easily, yielding hydrated ferric oxid or limonite.

Rutile is probably of widespread occurrence in clays, though never in large quantity. It occurs mostly in the form of bristle-like crystals. No systematic study of their occurrence in clay has ever been taken up. The writer has observed them in some of the Staten Island clays, and reference has been made to them from time to time by other writers. (*See* J. J. H. Teall. *Min. mag.* 7: 201; G. E. Ladd. *Amer. geol.* Ap. 1899)

Vanadiates, though not as common in clays, may cause discoloration. In Germany they have been found in clays associated with the lignites, and also in some fire clays, but in this country, so far as the writer is aware, they have never been investigated. Clays containing soluble vanadiates, if not burned at a sufficiently high temperature, will show on the surface of the ware a green discoloration, which, though it can be washed off with water, will continue to return as long as any of the salt is left in the brick. Vanadiates may be rendered insoluble by burning the clay to a point of vitrification. (Seger's *Ges. Schrift.* p. 301)

Other minerals may occur in clays, such as magnetite, titanite etc., but the quantity is small.

Organic remains. These consist of bituminous matter, roots, amber and other substances, which volatilize on ignition.

PROPERTIES OF CLAY

Pure clay would be composed entirely of the mineral kaolinite, the hydrated silicate of alumina. A mass of it would be called *kaolin.* The latter is the name of the rock, the former the name of the mineral composing it.

Pure kaolin has not been found thus far, though deposits containing as much as 70% of kaolinite are known, and these when washed yield in some instances a mass containing as much as 98.5% of kaolinite. Kaolin therefore contains a variable amount of foreign minerals, mixed with the kaolinite, or clay substance, as it is sometimes called. These impurities affect the properties of the kaolin materially, either as regards its shrinkage, fusibility, or color in burning. The last named effect is caused by the presence of ferruginous impurities. Their presence in an effective amount would necessitate classing the material with residual clay.

Kaolinite is supposed to form the base of all clays, or kaolinite together with other hydrated silicates of alumina. This clay substance forms a variable proportion of the clay mass, and stands in no direct relation to the plasticity, except that plasticity is lost with the expulsion of the combined water. The amount of clay substance ranges in known clays from 5% or 10% to 98.5%. The former might be a clay sand, the latter a nearly pure kaolin. In kaolins the chief impurities are quartz, feldspar and mica, but in other clays the number of mineral impurities may be very large. (*See* chapter on "Mineralogy of clays" p. 503)

The properties of clay fall generally under two heads, chemical and physical. The latter includes plasticity, fusibility, shrinkage, tensile strength, slaking, absorption, density. The former embraces the chemical composition, which exerts an influence on the physical behavior of the clay and should therefore be discussed first.

Chemical properties

The chemical composition, and indirectly therefore the mineralogic composition, may influence the fusibility of a clay, its color in burning, shrinkage, and perhaps plasticity.

The compounds which may be found in clay are silica, alumina, iron oxid, lime, magnesia, potash, soda, titanic acid, sulfuric acid, manganese oxid, phosphoric acid and organic matter. Compounds of chromium[1] and vanadium[2] may also be present in small amounts, and even lithium (N. W. Lord. *J. A. I. M. E.* 12: 505) and cerium, yttrium and beryllium oxids (*Jour. pr. chem.* 33: 132) have been recorded. Phosphoric acid is also known.[3] Not all of these are present in every clay, but most of them are. Pure clay would contain silica, alumina and combined water. The purest clays known contain traces of iron oxid, lime and alkalies.

All of the constituents of clay except alumina, organic matter, and water, may exert a fluxing action on the clay when burned, the intensity of this action depending on the amount of fluxing material and the temperature. Consequently the impurities of clay are often divided into fluxing and non-fluxing.

Fluxing impurities

Pure clay, theoretically composed altogether of the mineral kaolinite, is very refractory. This mineral contains two molecules of silica and one molecule of alumina. A higher percentage of silica tends, up to a certain point, to increase the fusibility provided it is in a finely divided condition. If the silica percentage however gets above a certain point, the refractoriness of the clay increases with the increase in silica up to the point at which the mass contains nothing but silica. This has been demonstrated by the experiments of Seger. (*Thonindustrie zeitung,* 1893. no. 17)

Other substances act as far more powerful fluxes than the silica, and these fluxes include not only elements but also definite chemical

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[1] Some Brazilian clays.

[2] See p. 509.

[3] Some pleistocene clays near Baltimore, Md., contain much vivianite.

compounds or mineral species, which either already exist in the clay or may be added to it artificially. The influence of fluxes increases not only with the amount present but also with the state of division, they being the more active the more finely they are divided. If the flux is present in the form of large grains, these grains will only exert a fluxing action on their surface, whereas the single grains alone will act more like quartz grains, that is, as diluents of the shrinkage. The minerals which may be present as fluxes or may sometimes be added are mica, feldspar, and similar silicates, slags, lime carbonate, magnesia carbonate, and various compounds of iron and manganese. In addition they may be present as soluble salts. It is usually the oxids of iron, manganese, and complex silicates containing these as well as lime, magnesium, potash, and soda that determine the degree of fusibility of the clay.

The amount of fluxes which a clay contains has an important bearing on its applicability. For some purposes it is desirable as well as necessary that the percentage of fluxes should be low (producing refractory wares), not only with a view to refractoriness, but also, as in porcelain or white earthenware manufacture, to prevent discoloration of the ware. Again, the combination of fluxes in large amount may be desirable for the production of a vitrified body, such as is required for paving brick or sewer pipe.

In kaolins the amount of fluxes may be as high as 7% provided they do not exert a coloring action. Some of the best kaolins known contain about 35% of feldspar, which means about 5.5% of potash. In fire clay 4–5% is the permissible limit, depending on the physical properties of the clay, while in a paving brick clay the total of fluxes may run as high as 16%.

Alkalis

These are never present in a clay in the form in which they are determined in the ordinary quantitative analysis, but generally as a constituent element of one or more minerals. Clay may contain two classes of alkalis, fixed and volatile. The former are soda, potash and lithia, the latter ammonia.

Ammonia. Clays possess a strong absorptive capacity for gases and in consequence of this frequently contain an appreciable amount of ammonia, to which is largely attributable the characteristic odor of clay.[1]

While the presence of this compound may exert some action on the plasticity and absorptive power of the clay, still it need not be considered in burning, for it passes off as a vapor at a temperature considerably below dull redness, or may even volatilize with the moisture of the clay during the early stages of burning.

Fixed alkalis. These include potash, soda and lithia, but the latter is such a rare constituent that it need not be considered. Potash and soda are present in nearly every clay, in amounts varying from a mere trace to 10%, but the usual average is 1%–3%. The chief sources of potash and soda are the different species of feldspar; white mica or muscovite may furnish potash. The variation in amount might be accounted for by the presence of undecomposed feldspar in the clay, the common feldspar orthoclase containing 17% of potash alone.

When either feldspar or mica decomposes, the alkalis are converted wholly or in part into soluble compounds, and thus we get both soluble and insoluble alkaline compounds.

Soluble alkaline compounds. These may be present in any clay, but they seldom occur in large quantities. They may influence the plasticity of the clay, by causing a flocculation of the particles; but their chief importance, or disadvantage, is in giving rise to the formation of efflorescence on the surface of the ware, where they become concentrated by the evaporation of the moisture in the clay, unless previously rendered insoluble by the addition of proper chemicals. This crust may interfere with the formation of salt glaze, or the adhesion of a glaze applied to the ware before burning.

Soluble alkaline sulfates are powerful fluxes. They cause blistering of the ware if the clay is heated sufficiently high to decompose the sulfate and permit the escape of sulfuric acid gas.

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[1] F. Senft. *Die Thonsubstanzen* p. 29.

In some clays containing sulfate of iron the latter may be decomposed by chemical reactions taking place in the clay and sulfuric acid being set free. This acid is apt to attack the alumina of the clay substance, and if potash, soda or ammonia be present they give rise to potash, soda or ammonia alum, which can frequently be detected by tasting the clay.

Insoluble alkaline compounds. All the sources of these in clay are minerals, silicates of complex composition. Feldspar and mica are the most abundant sources, but some may be derived from garnet, hornblende and pyroxene, fragments of which may be present in nearly all impure, and specially ferruginous clays.

The feldspars are complex silicates of alumina and potash, or alumina, lime and soda. Orthoclase, the most common of the feldspars, contains about 17% of potash, while the lime-soda feldspars have from 4% to 12% of soda, according to the species. Feldspars are the most important source of alkalis in clay, and, as the species vary somewhat in their fusibility, they may exercise a varying influence on the fusing point of the clay. Thus the lime-soda feldspars are more fusible than the potash ones.[1]

The micas are complex silicates of alumina, with iron, magnesia and potash. Muscovite, the commonest species of the group, contains nearly 12% of potash and may contain a little soda. While feldspars fuse completely at about 2300° F., mica alone is very refractory, being unaffected by a temperature of 2550° F. While it probably serves as a flux, it is not known positively at just what temperature it begins to act as such.

Alkalis, specially in the form of silicates, are frequently a desirable constituent of clay, on account of their fluxing properties, as in burning they serve to bind the particles together in a dense, hard body and permit the ware being burned at a lower temperature.

In the manufacture of porcelain, white earthenware, encaustic tiles and other wares made from kaolins, and having a body which

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[1] Seger. *Ges. Schrift.* p. 413.

is impervious or nearly so, the alkalis are added for fluxing to the body in the form of feldspar. Much feldspar is mined both in the United States and Europe for potters' use, but in nearly every case it is the potash feldspar.

Alkalis exert little or no coloring influence on the burned ware in most instances, but if an excess of feldspar be added to a white burning clay, it will produce a creamy tint when burned. Potash seems to have a tendency to deepen the color of a ferruginous clay in burning.

The amount of alkalis contained in clay varies. It may sink to a mere trace or rise to 7% or 8%. The limits for a number of clays are given below the figures being taken from tables at end of report.

	Range	Aver.
Kaolins	.10–6.21	1.01
Fire clays	.048–5.27	1.46
Pottery clays	.52–7.11	2.06
Brick clays	.17–15.32	2.768

Iron oxid

Iron oxid is the great coloring agent of both burned and unburned clay, and in addition serves as a flux. Furthermore in the form of hydrated oxid it may increase the absorptive power of clay.[1]

It is not only one of the most widespread and common of clay ingredients, but is also derived from the greatest number of minerals. The compounds which may serve as sources of iron oxid in clays are

Oxids — limonite, hematite, magnetite, ilmenite
Silicates — mica, hornblende, garnet, etc.
Sulfids — pyrite, marcasite
Sulfates — melanterite
Carbonates — siderite

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[1] E. A. Smith. *Ala. geol. sur., rep't on agricult.* p. 45.

The iron oxids, limonite and hematite, are present in nearly all clays. They may be introduced by percolating waters, or result from the decomposition of any of the iron-bearing silicates, such as hornblende, mica or garnet. They are not infrequently distributed through the clay in a very finely divided condition, or may form a thin film around the other mineral grains. Limonite tends to color the unburned clay brown or yellow, while hematite imparts a red color. Ferric carbonate may give gray tints. Mica is found in most clays. Hornblende and garnet are probably wanting in a few. Pyrite is present in many clays, specially stoneware and fire clays, its yellow, glittering metallic particles being easily recognizable. These particles may be either fine grains, or large lumps, the former of which have to be separated by washing, the latter by handpicking. Pyrite alters under the influence of weathering or burning to sulfate of iron, which is soluble in water and may indirectly or directly act as a discoloring agent on clay wares, provided the clay is not burned to vitrification. If burned to this point however the pyrite acts as a flux (and according to Wipplinger[1] a very strong one) forming little specks, or larger ones, according to size of pyrite grains, of fused ferrous alumina silicate. In all iron-bearing minerals found in clays, the iron exists in one of two conditions, viz., as ferrous or ferric, and the fusibility of any given clay depends somewhat on this fact, for the reason that ferrous compounds lower the fusing point of a clay. In burning any clay the ferrous salt will be changed to the ferric condition, provided the fire is oxidizing in its action, but if the action is reducing, the iron will remain in the ferrous form. The action of weathering agents in nature is often sufficient to oxidize the iron in the clay, so that in most clays more ferric than ferrous iron will be found. Evidence of this change in the condition of the iron can often be detected by the red or yellow color of the upper or more porous layers of the clay, the lower layers being colored gray. A gray color may at times be produced also by the presence of organic

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[1] *Keramik*, p. 26.

matter, and this material, if present in a dense wet clay, to which the air can not gain access, may keep the iron in a ferrous condition.

Whenever the iron exists in the clay in combination with silica, it is present probably as a complex silicate, for pure ferric silicate is very rare in nature.

The presence of ferric hydrate in clay increases its absorptive power for both gases and water, but both it and the carbonate are converted in burning to the oxid.

While it may be said that the burning of clay in an oxidizing fire converts the iron to the condition of ferric oxid, still this statement only holds true up to a certain temperature, depending on the fusibility of the clay, for in every clay the iron seems to return to the ferrous condition as the point of vitrification is approached. The change would of course be accompanied by a liberation of oxygen, which would increase with the amount of iron in the clay, and may account for the greater blistering of ferruginous clays as the point of vitrification is passed, and that of viscosity approached.

While this fact is not unknown, very little attention seems to have been paid to it.

Remole[1] considers that the greenish color of hard burned clays is due to this cause. Seger[2] also notes the ferrous condition of iron at high temperatures, and states that in this form it is a powerful flux.

The tendency of iron oxid is to unite with the silica and alumina and also with the lime of the clay the moment that fusion begins, thereby forming a complex silicate, whose fusibility is lower than the simpler ones from whose union it was formed.

The experiments of Berthier (Percy's *Metallurgy, refractory materials and fuel,* p. 60–75) on mixtures of iron, alumina and silica point out these facts very clearly. These consisted in making up the mixtures given below and subjecting them to a high temperature, that of molten steel, with the results also stated below.

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[1] Wagner. *Manual of chemical technology.* 1897. p. 634.

[2] Seger. *Ges. Schrift.* p. 391.

Action of heat on mixture of silica and bases

Aluminum silicate	$4Al_2O_3,3SiO_2$	Agglomerated
	$2Al_2O_3,3SiO_2$	Agglomerated
	$Al_2O_3,3SiO_2$	Strongly agglomerated, compact; fracture stony, dull
	$2Al_2O_3,9SiO_2$	Compact, stony fracture, slightly shining
Ferric silicate	$2Fe_2O_3 3SiO_2$	The mixtures did not decrease in volume; there was no combination, the buttons were tenacious of a deep gray color and magnetic. It is now known that silicate of protoxid of iron is formed with the evolution of oxygen.
	$Fe_2O_3,3SiO_2$	
Ferrous silicates	$4FeO,SiO_2$	Bubbly, finely granular in one part, crystalline in another
	$2FeO,SiO_2$	Very easily melted. Deep olive green
	FeO,SiO_2	Melted into compact mass
	$2FeO,3SiO_2$	Melted into compact, homogeneous mass
Double or multiple silicates	$Fe_2O_3,Al_2O_3,3SiO_2$	Apparently was only in pasty state
	$Fe_2O_3,Al_2O_3,6SiO_2$	Completely melted into brilliant black glass
	$3FeO,Al_2O_3,3SiO_2$	Melted into compact mass free from bubbles

From these results Berthier drew the following conclusions:

No silicate of alumina is completely fusible at the highest temperatures attainable in the furnace (that is such as were in use when Berthier wrote).

Protoxid of iron produces a remarkably fusible silicate.

The fusibility of multiple silicates is greater than that of the mean of the component silicates.

If the action of the fire is oxidizing, the presence of ferrous salts need not be considered, provided the heat is raised high enough to oxidize them.

The rapidity with which the temperature is raised is important, for if the heat is raised too quickly the outer portion of the clay may shrink and become dense before the air has had time to permeate the clay and oxidize the iron in the center of the body. This is the cause of the black cores sometimes seen in bricks whose surface is red.

The same variety of colors seen in the raw clay may be similarly produced in the burned clay, the result being conditioned on the relative amounts of ferrous and ferric compounds. Ferrous oxid alone produces a green color when burned, while ferric oxid alone may give a purple or red, and mixtures of the two may produce yellow, cherry red, violet, blue and black.[1] The more intense the heat, the deeper the color produced by the iron. At very high temperatures it is difficult or impossible to obtain an oxidizing action in the kiln or furnace.

Seger[2] found that combinations of ferric oxid with silica produced a yellow or red color in the burned clay, while similar compounds of the ferrous salt showed blue and green.

The black coloration produced by iron oxid in hard firing is often to be seen on breaking open the arch bricks of a kiln. The surface of such bricks may frequently get black, this being duc in part to the slagging action of the ashes from the fire which stick to them.

The coloration of clays by iron in burning will be farther discussed under that head.

The amount of ferric oxid permissible or desirable in a clay depends on the use to which it is to be put. Kaolins or plastic clays to be used in the manufacture of white bodies should contain less than 1% if possible. A greater amount might be present, provided

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[1] *Keramik*. p. 256.

[2] *Notizblatt*. 1874. p. 16.

there were three times as much lime to destroy the red color, but even then the resulting tint would be yellowish. Even a very small amount, below 1%, may produce a grayish tint at high temperatures.

Brick clays should contain sufficient iron to give a good red color, provided that is desired in the product.

For fire clays a small iron percentage is desirable, in fact the total of fluxes should be low, and in every case the permissible quantity of iron, so far as its fluxing effect is concerned, depends on the relative amounts of the other fluxes contained in the clay.

The following is the range of ferric oxid contained in a number of clays.

Kind of clay	Max.	Min.	Aver.
Brick clays	32.12	.126	5.311
Fire clays	.01	7.24	1.506
Kaolins	tr	6.87	1.29

Lime

Lime is a very common impurity of many clays, specially of low grade ones.

A large number of minerals may serve as its source, but in all of these it is present in one of three conditions.

1 As a silicate in certain feldspars, hornblende, garnet

2 As a carbonate, limestone or calcite, dolomite

3 As a sulfate in gypsum

The first two classes include primary mineral constituents of clays, but the third, gypsum, is most commonly of secondary origin, having resulted from chemical action within the clay.

In many clays, lime probably occurs as a constituent of some silicate mineral, a lime soda feldspar, hornblende or garnet. This would be the case if the clay was derived from an igneous or metamorphic rock. There are other silicates containing lime, but their presence in clay is probably not very frequent. Lime when present in a silicate acts as a flux, but is seldom liable to exert a decolorizing action on the clay, by the formation of a double silicate of iron, lime and alumina, except at higher temperatures.

Carbonate of lime is very abundant in clays, either sedimentary or residual, which have been derived from areas underlain by calcareous rocks. It may result from the decomposition of lime-bearing feldspars. Its presence as carbonate can be frequently determined by treating the clay with muriatic acid, which produces effervescence if more than 4% or 5% of lime carbonate is present.

The effect of carbonate of lime in a clay depends on its physical condition. If present in the form of lumps or pebbles, it is very injurious, and is commonly removed by screening or washing, or at times the clay is simply washed to break up the lumps. If present in a finely divided condition, it may not only be harmless but even desirable, provided there is not an excess of it. Clays with 20%–25% of carbonate of lime can be used for common or even pressed bricks, also for earthenware. Calcareous clays find an additional use in the manufacture of glazes.

The effects of carbonate of lime may be briefly stated as follows. In burning the lime carbonate is broken up into carbon dioxid and caustic lime. If the clay is not raised to the temperature of vitrification in order to make the lime unite by fusion with other ingredients, the lime will absorb moisture from the air and slake. The swelling which accompanies this may, if the lime is in lumps, cause a bursting or flaking of the brick.

Lime also tends to destroy the red color produced by iron in burning, giving a buff, or greenish product, depending on the intensity of the firing. To destroy the iron coloration, it is necessary for the clay to contain three times as much lime as iron. Buff colors are not always due to this cause, for a small percentage of iron in a clay may yield the same hue.

In high grade clays large amounts of lime do not need to be considered, for such materials can not be used; but in the manufacture of building brick, pressed brick, or terra cotta, it is sometimes necessary to use clays with a large amount of lime, either from necessity, or to obtain a cream colored ware. For the latter purpose semi-fire clays yield the best results, but are not always obtainable; hence calcareous clays must be used. It is therefore desirable to know the amount of lime carbonate which is allowable. A good, but not at the same time vitrified, brick can be made from a clay containing 20%–25% of lime carbonate, provided it is evenly and finely distributed through the clay.

The objection to highly calcareous clays is that the points of incipient fusion and vitrification lie so close together that it is not safe to burn them hard, because of the risk of fusing them. It has been found possible to separate these points however by the addition of quartz and feldspar to the clay, or by adding sand containing a large proportion of them.[1]

Aside from lowering the fusibility of a clay, and affecting its color when burned, lime also exerts a powerful effect on the shrinkage.

Seger[2] found that calcareous or marly clays required usually only 20%–24% of water to convert them from a dry condition into a workable paste, whereas other clays needed 28%–35% of water to accomplish the same change.

In burning, such clays lose not only their combined water but also carbon dioxid, and consequently they are more porous than other clays up to the point of sintering, and this porosity, attended by diminution of shrinkage, increases with the amount of lime carbonate contained in the clay. The shrinkage may indeed become zero, or the brick even swell.

The small difference between the points of incipient fusion and viscosity have already been mentioned.

Gypsum, the hydrated sulfate of lime, is not uncommon in some clays, specially those which originally contained carbonate of lime and pyrite. The oxidation and decomposition of the latter produce sulfuric acid, which attacks the lime carbonate, producing lime

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[1] See "Glazed brick", p. 652.

[2] Seger. *Ges. Schrift,* p. 265.

sulfate. This takes up water in chemical combination and forms gypsum.

In many instances the presence of gypsum can be instantly detected by the large transparent crystals scattered through the clay; at other times it is found in the form of parallel fibres filling cracks or cavities in the clay. So far as the writer is aware, only the former type has been found in the New York clays. Gypsum may serve as a flux, but at the same time it may do considerable damage in the burning by the liberation of sulfuric acid, which in its efforts to escape may cause blisters on the surface of the ware. Lime may be introduced into a clay by absorption, where a clay deposit rests on a limestone or marl formation, the clay absorbing waters from below that contain lime in solution, which the clay tends to separate.

All clays do not contain lime, and indeed it sometimes happens that the clays over very large areas are singularly free from it, while in other regions the opposite may be true. The clays in many parts of Alabama are remarkably low in lime. Those underlying the region around Chicago, and again around Buffalo have an appreciable amount of it. This material has been one of the chief causes in restricting the utilization of the Hudson valley clays, which for combining extent, location and accessibility are not surpassed by any other deposit.

The range of lime in different clays is given below.

Kind of clay	Min.	Max.	Aver.
Brick clay	.024	23.20	2.017
Pottery clay	.011	9.90	1.098
Fire clay	.03	15.27	.655
Kaolin	tr	2.58	.47

Magnesia

Magnesia rarely occurs in clays in the same quantity as lime, and in fact seldom exceeds 2%. The same classes of compounds may furnish it as furnish lime, viz, silicates, carbonates and sulfates. The silicates are probably the most important form of its occurrence in clay, and are represented by the minerals, mica, hornblende, chlorite and pyroxene. These are scaly minerals containing from 15%–25% of magnesia. Mica is a very common constituent of many clays, and its shining scales easily render it recognizable. Chlorite scales may be present in many clays, and if in abundance color the clay green. Hornblende also is not an uncommon constituent, and specially present in clays derived from rocks of very basic composition, that is, those with a low silica percentage. Indeed the decomposition of hornblende may give rise to a hydrous aluminum silicate, which is highly colored by iron, the product therefore being a ferruginous clay. (G. P. Merrill's *Rocks, rock-weathering and soils,* p. 21)

Dolomite, the double carbonate of lime and magnesia, may be a source of magnesia as well as of lime in clay.

Magnesium sulfate, or Epsom salts, occurs sparingly in clays, but when present may give rise to the formation of a white coating on the surface of the ware. It is commonly found in those clays where sulfuric acid, set free by the decomposition of pyrite, has attacked magnesium carbonates. The presence of this salt can frequently be detected by the bitter taste which it imparts to the clay.

The chemical effects of magnesia in clays are probably similar to those produced by lime. This is not to be taken as absolutely certain, for magnesia is present in most clays in such small amounts as to make its exact action uncertain.

The range of the percentage of magnesia in the different clays, deduced from the analyses given at the end of this report, is as follows:

Quality	Min.	Max.	Aver.
Brick clays	.02	11.03	2.66
Pottery clays	.05	4.80	.85
Fire clays	.02	6.25	.513
Kaolins	tr	2.42	.223

Silica

Three types of silica may be recognized in clay: 1) quartz; 2) that which is combined with alumina and water in kaolinite; 3) that which is combined with one or more bases in silicate minerals. In chemical analysis the first and third are sometimes grouped together under the head of "sand," or at times erroneously spoken of as "free" silica. The silica included under the term sand is practically insoluble in sulfuric acid and caustic soda. This fact is utilized in the rational analysis of clay to extract the kaolinite or clay substance, which is soluble in sulfuric acid and caustic soda.

Quartz is present in every clay so far as analysis shows, but in variable amounts. Cook[1] found a minimum of .2%, and gives 5% as the average in the Woodbridge fire clays. Wheeler[2] gives the minimum as .5% in the flint clays, and the sand percentage as 20%–43% in the St Louis fire clays and 20%–50% in the Loess clays. 27 samples of Alabama clays analyzed by the writer contained from 5% to 50% of insoluble residue mostly quartz.[3]

In 70 North Carolina[4] clays there were from 15.05% to 70.43% insoluble residue; while in three samples, of which a rational analysis was made, the percentage of sand was from 24.55% to 56.58%. The quartz varied from 16.58% to 49.06%, with the feldspathic residue from 7.52% to 16.05%.

In European clays similar variations in the amount of sand and quartz are observable. Thus a clay from Hainstadt, Germany contains 67.03% of quartz (*Ziegler Kalender*. Berlin 1896), while one from Ruppersdorf showed .26%. (Seger's *Ges. Schrift.* p. 891)

The following table gives the variation in the total silica in four types of clay:

Quality	Min.	Max.	Aver.
Brick clays	34.35	90.877	59.27
Pottery clays	45.06	86.98	45.83
Fire clays	34.40	96.79	54.304
Kaolins	32.44	81.18	55.44

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[1] N. J. geol. sur. 1878. *Clays of New Jersey*, p. 213.

[2] Mo. geol. sur. 1896. 11: 54.

[3] Ala. geol. sur. 1900. *Bulletin no.* 6.

[4] N. C. geol. sur. 1898. *Bulletin no.* 13, p. 24.

The effects of free silica proper, or quartz, and sand on the behavior of the clay are to be considered separately.

Quartz serves as a flux only at high temperatures, viz, 2800° F.; but at lower temperatures it tends to increase the refractoriness of the clay, and this property is governed somewhat by the size of the quartz grains and amount of fluxing material present, which will fuse at lower temperatures.

In connection with the fluxing action of silica at high temperatures, the following experiments of Bischof's[1] may be quoted. Mixtures of alumina and silica were made in varying proportions, and their fusibility determined. The fusion point of alumina alone lies above cone 36, while the fusion point of silica alone is at cone 35. Bischof found that a mixture of one equivalent of alumina and two of silica showed the greatest refractoriness. If the percentage of silica increases, the fusibility is gradually lowered, till the mixture of one alumina to 17 silica is reached, the fusibility of which is the same as cone 30. With an increase of the silica, the refractoriness of the mixture again increases up to the fusion point of silica alone.

Titanium

Titanium is probably of more widespread occurrence in clay than is commonly imagined. The apparent freedom of the clay from this impurity has resulted from the fact that in the usual quantitative analysis it is ordinarily overlooked. Its source is either the mineral rutile (oxid of titanium) or ilmenite (the titanium-bearing magnetic oxid of iron), or possibly titanite. Much more importance has at times been attached to its presence than is really warranted, and some chemists, on finding traces of it, delight in dwelling on the important influence which it may exert on the properties of a clay. While it is present in many clays, the percentage seldom exceeds 1.5% to 2%. The analyses of 21 New Jersey clays showed it to range from 1.06% to 1.93%. (*Report on clays of N. J.* 1878. p. 277) In

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[1] Seger. *Ges. Schrift.* p. 434.

the Pennsylvania clays the variation was found to be from .87% to 4.62%. It probably reaches a far higher amount in bauxites than it does in clays, for analyses show a range commonly from 3% to 5%.

In order to determine definitely what the effect of titanium was, Seger and Cramer[1] mixed two parts of sample of Zettlitz kaolin (which has 98.5% of clay substance) with respectively 5% and 10% of quartz, and two other samples of the kaolin with respectively 6.65% and 13% of titanium. These samples were molded into pyramids which were heated to a temperature above the fusing point of iron, with the following results.

1 Pure Zettlitz kaolin burned to a white, sharp-edged dense body.
2 100 pts kaolin and 10% silica burned white.
3 “ 5% “
4 “ 6.5% titanium oxid softened on heating and showed a blue fracture.
5 100 pts kaolin and 13.3% titanic oxid fused to a deep blue enamel.

It is therefore seen that titanium acts as a flux at lower temperatures than silica, and it is suggested that the blue color given to some stoneware clays by hard firing may not always be due to iron oxid.

Organic matter

Organic matter affects not only the color of clay, but also its plasticity, absorptive power and tensile strength.

It generally consists of finely divided pieces of plant tissue, or larger pieces of stems and leaves which settled in the clay during its deposition. All surface clays contain plant roots in their upper layers, but these do not directly influence the color of the clay. Clays colored by organic matter and containing no iron burn white, as the plant tissue passes off at bright redness; if such a clay however be heated too quickly, before all the organic matter has had an opportunity to escape from the interior, the surface becomes dense, and it remains dark colored.

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[1] Seger. *Ges. Schrift,* p. 411.

Organic matter may also mask the presence of iron, so that the clay, instead of burning white, would burn red at a temperature above that at which the organic matter passes off. Below that temperature, though, the vegetable matter would tend to keep the iron reduced, and the color would be gray instead of red.

In most chemical analyses the organic matter is seldom determined separately, but the amount of it can sometimes be judged from the ratio between the loss on ignition and amount of alumina in the clay.

Organic matter may increase the plasticity of a clay provided too much sand is not present, in which case a highly carbonaceous clay might be very lean. (*see* "Plasticity of clays", p. 539)

Water in clay

All clays contain two kinds of water:

1 Hygroscopic water, or moisture

2 Chemically combined water

Moisture. Clays contain two kinds of moisture:

1 That which is held in the pores of the clay by capillary attraction.

2 That which adheres to the surface of each clay grain as a thin film.

The latter is of little importance practically.

The former is of importance in connection with the shrinkage and plasticity of clays. The amount of total moisture contained in clays varies within wide limits. In some air-dried clays it may be as low as .5%, while in those freshly taken from the bank it may reach 30% or 40%. Capillary moisture is absorbed by clays only when they are brought into actual contact with water, but that which forms a film on the surface of the clay particles is readily absorbed by the clay from the atmosphere, and to a certain extent given off again as readily, so that some days a brick if left exposed to the air would weigh more than on others. The amount of either kind of moisture present in a clay depends on the number and size of the spaces between the clay grains, the size of the clay particles, and the amount of organic matter present.

Air drying usually causes the evaporation of most of the water in a clay, accompanied by a shrinkage of the mass, which ceases however before all the moisture has passed off. The reason for this is that the shrinkage of the clay ceases when the particles come in contact, which may happen and still leave interstices. These of course still contain moisture, and consequently the brick will keep on losing weight till not only this interstitial water, but also the surface moisture of the particles, is driven off. In practice, it is this that evaporates during the first period of the burning known as "water-smoking." The shrinkage of the clay attendant on drying varies, with the nature of the material, from 2% or 3% to 10% or even 15%. It is governed largely by the causes influencing the absorption of the clay.

Sandy clays usually show the least shrinkage, and of this kind the coarser grained diminish in size the least. Highly plastic clays generally show the highest shrinkage.

The amount of water which a dry clay needs in order to develop its maximum plasticity is a variable quantity. Plastic clays absorb large quantities of water, but a lean clay if fine-grained may do the same. As a very general rule it may be stated that lean clays absorb from 12%–20%, while fat clays require anywhere from 25%–50%; and the more water a clay absorbs, the more it has to part with in drying and the greater will be its shrinkage.

Highly aluminous clays do not always absorb the most water, nor are they the most plastic. Some clays low in alumina and high in organic matter are not only highly plastic but also absorb a high amount of water.

Owing to the high shrinkage of most clays with high absorptive power, there is frequently danger of their cracking, if rapidly dried, on account of the active disengagement of water vapor.

Moisture may play another important and injurious role in the working of a clay, in that it tends to dissolve soluble salts in the clay, and bring them to the surface in drying, giving rise to the formation of efflorescence. It may also permit acids contained in the fire gases of the kiln to act on the mineral ingredients of the clay and thus form soluble compounds, specially sulfates and chlorids.

By the addition of water to an air-dried clay, it gradually passes from a powdery or lumpy condition to a pasty mass, the tenaciousness of which increases till the point of maximum plasticity for the given clay is reached. If the addition of water be continued, the clay gradually passes into a soft mud. In some clays this change takes place slowly, in others (specially many residual clays) very rapidly.

Combined water is present in every clay. In pure kaolin there is nearly 14%, and amounts are found in different clays intermediate between this and 3% or 4%.

The sources of combined water in clays are either kaolinite, limonite, or hydrated silicates; the quantity in different clays can be seen from the table of analyses given at the end of the report.

It is driven off at a low red heat; and when this occurs an additional shrinkage takes place, the extent depending on the quantity of water present. The shrinkage varies commonly from 2%–10% or even 14%.

While the amount of combined water does not seem to stand in direct relation to the plasticity of the clay, nevertheless, when it is once driven off, the clay can no longer be rendered plastic.

Methods of analyzing clay

By H. T. Vultê Ph.D.

One grain of the dried and finely pulverized clay is fused in a platinum crucible with five to 10 times its weight of a mixture of 11 parts of dry sodium carbonate and 14 parts of dry potassium carbonate, the amount of fusion mixture necessary depending on the more or less refractory character of the clay. The fusion is transferred to a porcelain casserole, dissolved in water, and the solution acidified with hydrochloric acid; the solution is then evaporated to dryness, and the casserole with its contents placed in a drying oven at 105° to 110° C., and allowed to remain till all the hydrochloric acid is expelled. The silica present is thus rendered insoluble. Hydrochloric acid and water are now added; the casserole is warmed for a few minutes on the water bath and the solution filtered, the silica being washed with hot water till the washings are free from chlorin. The silica is then ignited and weighed, and, as it is likely to retain small quantities of alumina, it is treated with hydrofluoric and sulfuric acids and heated, the silica being thus volatilized as silicon tetra-fluorid. The residue from this treatment is weighed, and its weight added to that of the alumina subsequently found.

If the original fusion of the clay showed little or no green color, the filtrate from the silica is treated with a slight excess of ammonia, and the solution boiled for a short time to expel the excess. The solution is then filtered, the precipitate dissolved in dilute hydrochloric acid, and reprecipitated in the same way; filtered out, washed and then ignited and weighed, giving the amount of alumina and iron (as $Fe_2 O_3$) present. The combined filtrates from the iron and alumina, which should be concentrated to about 200 cc, are heated to boiling and about 25cc of sat sol. of ammonium oxalate added, and the boiling continued for two or three minutes longer, when the heat is removed and sufficient ammonia added to render the solution strongly alkaline. The precipitate is allowed to settle, and the supernatant liquid decanted off as closely as possible through a filter; hydrochloric acid is then added to the precipitate to dissolve it, and then sufficient ammonia to reprecipitate it. It is then washed on to the filter; washed; ignited with sulfuric acid, and weighed as calcium sulfate. The filtrate receives a farther addition of ammonia and of hydrodisodic phosphate, is well stirred, allowed to stand for some hours in the cold, when the magnesium precipitate is filtered out, washed with ammonia, ignited and weighed.

In case manganese is present, the filtrate from the silica is neutralized as closely as possible, sodium acetate solution added, the solution diluted largely, and boiled for about a minute and filtered as rapidly as possible, the precipitate washed with boiling water, redissolved in dilute hydrochloric acid and reprecipitated in the same way, washed, ignited and weighed as Fe_2O_3 and Al_2O_3. The combined filtrates from the iron and alumina are evaporated to about 300 cc, bromin water added and the solution boiled, when the manganese is precipitated as MnO . This is filtered out, dissolved in a little dilute hydrochloric acid, a solution of microcosmic salt added, the solution heated to boiling and then ammonia added to exact neutrality, any excess of ammonia being removed by heating on the water bath. The precipitate of manganese ammonium phosphate is filtered out, ignited and weighed as $Mn_2P_2O_7$. The filtrate from the manganese precipitation is acidified with hydrochloric acid, boiled for a short time, and then treated in the same way as when manganese was absent, for the determination of lime and magnesia.

For the determination of alkalis one grain of clay is mixed by grinding in an agate mortar with one grain of granular ammonium chlorid and eight grains of pure calcium carbonate, the mixture transferred to a platinum crucible with a well fitting lid and slowly heated to decompose the ammonium chlorid, then heated to redness and the bottom of the crucible kept at a bright red for about an hour. The contents of the crucible are transferred to a porcelain casserole with about 80cc of water and heated to boiling; this is then filtered and to the filtrate, after evaporation to small bulk, about one and one half grams of pure ammonium carbonate is added and the solution heated nearly to boiling and filtered into a platinum dish, evaporated nearly to dryness, a little more ammonium carbonate added and the evaporation finished on the water bath. If the last addition of ammonium carbonate produced a precipitate, the residue in the dish is dissolved in a little water and filtered into another platinum dish, where it is evaporated into dryness and ammonia salts driven out by heat. The residue is dissolved in water, filtered into a weighed platinum dish, evaporated, dried and weighed as Na Cl + K Cl. If the last addition of ammonium carbonate failed to produce a precipitate, the transfer to another dish may be dispensed with and the ammonia salts driven off at once.

Rational analysis

It is a common custom of the manufacturers of porcelain, white earthenware, fire brick, and other refractory goods — in fact of all products made from high grades of clay — to use the rational analysis as a guide in making up their mixtures and keeping them constant. The advantage of this analytical method is that it resolves the clay into its mineral components, and enables us thereby to get an insight into the physical character of the material used, which is frequently a matter of far greater importance than its chemical composition.

The ordinary quantitative or ultimate chemical analysis regards the clay as a mixture of oxids of the elements, though they may be present in entirely different combinations, such as silicates, carbonates or hydrates, sulfates, etc. This condition of combination is of importance, for it may make a vast difference whether a material is present as a silicate or a carbonate. Silica if present as quartz will decrease the shrinkage and up to certain temperatures increase the refractoriness, but if present in the clay as a component of feldspar it serves the purpose of a flux and somewhat increases the plasticity.

It is not intended, though, that the rational analysis should entirely supplant the ultimate, for this is not possible, as each serves its own purpose. The ultimate analysis may be used to supply information on the following points:

1 The purity of the clay, showing the proportions of silica, alumina, combined water, and fluxing impurities.

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

3 The color to which the clay burns. This may also be judged approximately, for the greater the amount of iron present the deeper red will the clay burn, provided the iron is evenly and finely distributed and an excess of lime is not contained in the clay. If the proportion of iron to lime is as 1 to 3, then a buff product results, provided the clay is heated to incipient fusion or vitrification. The above conditions will be affected by a reducing atmosphere in burning or the presence of sulfur in the fire gases.

4 The quantity of combined water. Clays with a large amount of combined water sometimes exhibit a tendency to crack in burning. This combined water would be shown in the chemical analysis.

5 Excess of silica. A large excess of silica would indicate a sandy clay.

These are practically all the points which the ultimate analysis explains, and they are mostly of a chemical nature. As regards the rational analysis, it may be carried out in a simple way or an elaborate one.

Most kaolins and other high grade clays consist only of kaolinite, quartz and feldspar, the kaolinite forming the finest particles of the mass, while the balance is quartz, feldspar, and perhaps some mica. The finest particles are known as the clay substance, which may be looked on as having the properties of kaolinite, for the latter is present in it in such a large excess. Now as each of these three components of the kaolin — clay substance, quartz and feldspar — have characteristic properties, the kaolin will vary in its behavior according as one or the other of these constituents predominates or tends to increase.

As to the characters of these three. Quartz is nearly infusible, nonplastic, has very little shrinkage, and is of low tensile strength; feldspar is easily fusible and of low plasticity by itself; kaolinite is plastic and quite refractory, but shrinks considerably in burning.

In Europe, specially Germany, the custom has been to disregard mica and figure it in as clay substance, partly because there was so little of it, and partly because it was thought to be like kaolinite in its behavior. Where the mica percentage is very low, say 1% or 2% and is in a very finely divided condition, it can be neglected, but where it reaches 5% or more it does not seem proper to class it as clay substance, for the reason that mica tends to decrease the plasticity, which effect is greater the coarser the mica. It does resemble kaolinite in refractoriness. In many of our washed kaolins now on the market there is very little mica, but some contain 8%–10%, which does not always yield to sulfuric acid treatment.

If now a kaolin containing clay substance, quartz and feldspar be treated first with sulfuric acid, the kaolinite is decomposed into sulfate of alumina and hydrous silica. The former is soluble in water, the latter is removed by subsequent treatment with caustic soda, and we have the insoluble residue consisting of quartz and feldspar. In this residue the alumina is determined, and from this the amount of feldspar is calculated, viz:

$$\underset{\substack{\text{molec. wt}\\ \text{alumina}}}{102} : \underset{\substack{\text{molec. wt}\\ \text{orthoclase}}}{556} :: \underset{\substack{\text{weight of}\\ \text{alumina}}}{a} : x$$

This is subtracted from the insoluble residue, and the difference is the quartz.

There is still another way of conducting a rational analysis, which is chiefly applicable when the clay contains other minerals beside the kaolinite, feldspar and quartz, such as carbonate of lime and magnesia, and appreciable amounts of ferric oxid and such mica as is attacked by sulfuric acid. This second method is Seger's method as elaborated by Langenbeck, and may be illustrated by the following example, a fire clay from Ohio.

Analysis of fire clay from Ohio

	1 Total analysis	Insoluble in H_2SO
	Per cent	*Per cent*
SiO_2	73.21	55.38
Al_2O_3	14.56	2.35
Fe_2O_3	4.79	.39
CaO	.51	.15
MgO	1.07	.05
K_2O	1.75	1.71
Na_2O	1.16	....
Ignition	3.70	....
Total	100.75	60.03

The insoluble residue consists of quartz, feldspar, and perhaps traces of silicate minerals approaching feldspar in composition. In orthoclase (the common feldspar) the amount of silica is about 3.51 times that of alumina. Therefore, the alumina of the insoluble portion multiplied by 3.51 gives the silica of the feldspar, which, subtracted from the total silica of residue, leaves the silica present as quartz. Thus, in the column 2, above, we have:

	Silica *Per cent*
2.35 × 3.51 =	8.25
Alumina	2.35
Fluxes	2.20
Per cent feldspar	12.80

Subtracting this from the total insoluble residue gives the amount of quartz.

As the clay substance, mica and ferric oxid are the soluble portion of the clay, their total composition is obtained by subtracting the insoluble residue (r) from the total analysis, thus obtaining:

	Per cent
SiO_2	17.83
Al_2O_3	12.21
Fe_2O_3	4.40
CaO	.36
MgO	1.02
K_2O Na_2O	1.20
Ignition	3.70

If we take the average composition of mica (including muscovite and biotite) as: SiO_2, 50%; Al_2O_3, 32%; alkalis, 10%; and other fluxes, 8%, then we have:

	Per cent
1.2×3.20=	3.84 Al_2O_3
1.2×5=	6.00 SiO_2
1.2×1=	1.20 alkalis
1.2×0.8=	.50 magnesia .46 iron

Substracting column 4 from 3 gives us clay substance and ferric oxid:

	Per cent
SiO_2	11.83
Al_2O_3	8.37
Fe_2O_3	3.94
CaO	.36
MgO	.52
Ignition	3.70
Total	28.72

By this operation the clay has been resolved into:

	Per cent
Quartz	47.23
Feldspar	12.80
Mica	11.84
Ferric oxide	3.94
Clay substance	24.78

Whether it will be of practical advantage to carry out a rational analysis to this extent still remains to be seen. In its simpler form, however, when applied to high grade clays, the rational analysis has been found to possess great practical value, owing to the fact that if two clays have the same rational composition they will, other things being equal, behave much alike when burned. This fact is made use of by the potter, for example, in the preparation of his porcelain or white earthenware mixture, also by manufacturers of encaustic tiles, fire brick, etc.

To illustrate this point we may take the manufacture of porcelain. Porcelain is made from a mixture of kaolin, quartz and feldspar. Suppose that we are using for the manufacture of porcelain or fire brick a kaolin which has 67.82% of clay substance, 30.93 of quartz, and 1.25 of feldspar, and that to 100 parts of this are added 50 parts of feldspar. This would give us a mixture of 45.21% of clay substance, 20.62 of quartz, and 34.17 of feldspar.

If now for the clay we had been using we substituted one with 66.33% of clay substance, 15.61 of quartz, and 18.91 of feldspar, and made no other changes, the mixture would then contain 44.22% of clay substance, 10.41 of quartz, and 45.98 of feldspar.

This last mixture shows such an increase in feldspar that it must give much greater shrinkage and fusibility; but, knowing the rational analysis of the new clay, it would be easy, by making a simple calculation, to ascertain how much quartz or feldspar should be added to bring the mixture back to its normal composition.

Physical properties

These properties are fully as important as the chemical, if not more, plasticity for instance being one of the two characters in clay which make it of such inestimable value to man. Similarity in chemical composition counts for little in the comparison of two clays, if they do not agree in physical characters.

The physical properties of the most importance from a practical standpoint are plasticity, fusibility, shrinkage, tensile strength, slaking, absorption and density.

Plasticity

This property permits the clay to be molded into any desired form when wet, which shape it retains when dry.

Just what the cause of plasticity is, remains to be proven with certainty. We find this property best developed in the pasty clay, but even here it is exceedingly variable, and it is possible to collect a series of samples showing all grades of transition from a very plastic clay to a mass of sand, which would not ordinarily be looked on as plastic, and yet does possess a slight amount of pastiness resembling plasticity, if ground very fine. We can not say, therefore, that plasticity is confined to clay, but simply that the physical conditions existing within a mass of clay are such as tend to produce the maximum degree of tenacity, the highest grade of plasticity.

Many theories have been advanced to explain this remarkable property. For a long time plasticity was supposed to be directly connected with the hydrated silicate of alumina, or kaolinite; clays high in kaolinite were said to be very plastic. This is plainly not true, as any series of clays tested will demonstrate. Pure or nearly pure kaolins are very lean, while clays low in kaolinite may be highly plastic.

Prof. G. H. Cook[1] considered plasticity to be due to a plate structure present in the clay, the plates sliding over each other and thus permitting mobility in the mass without cracking. He farther found that in the kaolins the plates of kaolinite were frequently collected in little bunches, and that, after these clays were rubbed in a mortar, in order to tear apart the plates, they showed increased plasticity.

There seems to be much to commend this theory as far as it goes. Compare for example the white washed kaolin from Dillsboro, N. C., with the washed, white plastic clay from Edgar, Fla., the one a residual clay, found just where it was formed, the other

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[1] **N. J. Geol. sur. 1878.** *Clays of New Jersey.*

a transported or sedimentary clay which has been washed down to its present resting-place. In transit, the particles have been ground apart naturally, either by rubbing against one another or between the white quartz pebbles scattered so plentifully through the clay.

These two clays are practically identical in their composition, as can be seen from the two following analyses.

	Edgar, Fla.	Dillsboro, N. C.
SiO_2	45.39	43.90
Al_2O_3	39.13	40.66
Fe_2O_3	.45	.14
CaO	.5	
MgO	.29	tr
Alk	.83	.46
H_2O	14.01	14.84
	100.61	100.00

Physically, there is a marked difference, the Edgar clay being decidedly plastic, the Dillsboro clay being very lean. This plate theory would suggest therefore that plasticity was due to capillarity, the force of surface tension tending to hold the plates together, but not interfering with their gliding motion.

The one objection to explaining plasticity entirely by the foregoing theory rests on the fact that not all minerals occurring in clay are scaly, and that neither scaly kaolinite nor even scaly mica predominates in all clays.

Clays may be said to have two classes of particles, viz, plastic and nonplastic, the latter being the sandy grains.

Olchewsky[1] was probably the first to suggest that the plasticity and cohesion of a clay are dependent on the interlocking of the clay particles and kaolinite plates, and in this connection used the briquet method of testing the plasticity, or rather obtaining a

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[1] *Töpf. u. Zieg. Zeit.* 1882. no. 29.

numeric expression of it by testing the tensile strength of the air-dried clay.

The same opinion was held by two Russian investigators, W. Aleksiejew and P. A. Cremiatschenski,[1] who hold that plasticity is not only due to the interlocking of the clay particles, but varies also with the fineness of the grains, the extreme coarse and extreme fine ones having inferior plasticity.

In this country Wheeler's work on the Missouri clays has substantiated these views.[2] Experiments by the writer on the clays of North Carolina, Alabama, New York and other states incline him toward the idea that there may be much in this theory. It seems very probable that the true explanation will be obtained by combining Cook's and Olchewsky's theory.

Interlocking of the grains no doubt has much to do with the tenacity exhibited by highly plastic clays, but the gliding of the particles is probably explained by the circumstance that such movement offers the least resistance to surface tension.

Tensile strength, however, seems to be more affected by size of grain than plasticity is. Fine-grained clays seldom show high tensile strength, whereas some fine-grained clays show high plasticity. That a certain relation appears to exist between plasticity and tensile strength, and that the former does not necessarily increase with the amount of kaolinite (or indirectly alumina) present are shown by the following tests of some North Carolina clays.

	Per cent of alumina	Tensile strength in pounds per sq. in.	
		Average	Maximum
Roanoke Rapids plastic clay	16.09	206	218
Washed kaolin	40.61	20	22
Spoutsprings fine-grained clay	32.51	24	29

While this relation between tensile strength and plasticity seems to hold good in a large majority of clays, still it can not be said

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[1] *Zap. imp. russk. techn. obschtsch.* 1896. 30, pt 6–7.

[2] *Missouri geol. sur.* 1897. 11: 102.

that it is the rule, and that high tensile strength always denotes high plasticity. There are clays running low in their tensile strength that exhibit marked plasticity, as for example some of the New Jersey clays, or some English ball-clays, but on the other hand it can be said that probably no clay of low plasticity has high tensile strength.

A means of measuring the plasticity of a clay and expressing it numerically for purposes of comparison has been the one aim of clay technologists. Several methods have been suggested, none meeting with universal, and few with even partial adoption. One of the more important is testing with Vicat's needle.

The clay is reduced with water to a mass of the proper consistency for ordinary working. It is then forced into a metal ring, and the resistance which it offers to a steel wire of given size under known pressure is noted. This method is followed in cement testing, and the apparatus is known as Vicat's needle. It gives the most satisfaction for comparative testing, that is for determining the relative plasticities of several clays examined at the same time.

A second method is to mold the plastic clay in a briquet mold similar to that used in testing cement, care being taken that the clay briquet is homogeneous throughout and contains no flaws. It is then allowed to dry thoroughly, and subsequently pulled apart in a cement testing machine, the tensile strength being expressed in pounds per square inch. As the clay shrinks in drying, it is necessary to measure the cross-section of the briquet before breaking it, and to calculate from this the strength of a briquet whose cross-section is one square inch.

Another method is to form the plastic clay into a cylinder, which is placed horizontally in a semicircular channel of the same diameter, and so arranged that a wire can be laid across it at right angles. A weight is attached to the wire, and the time which is required for the wire to cut through the clay observed.[1]

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[1] C. F. Binns. *Ceramic technology*, p. 35.

A fourth plan is to press the mixed clay into a form of given thickness, and then bring a metal cylinder to bear on the upper surface. This cylinder can be weighed, and the weight be noted which has to be added in order to force the cylinder through the clay in a given time; or the determination may be made by measuring the amount of water mixed with the clay in order to produce the proper consistency to permit the passage of the cylinder through the clay in a certain time under given pressure.

Olchewsky[1] states that the amount required for lean clays is as low as 17%, while for very plastic clays it is not uncommonly 50%.

Bischof has suggested forcing the wet clay from a circular opening in the lower end of a vertical cylinder, and observing the length of the clay which would issue before the mass broke. This is not, however, an accurate method.

The difference in plasticity between residual and sedimentary clays is dwelt on by Seger, who says:

> In clays which show a mixture of plastic and nonplastic particles the degree of plasticity depends on the relations existing between the two. We also know that the true clay substance [meaning kaolinite], even when of constant composition, may show considerable variation in plasticity. One clay substance may be lean and permit of very little admixture of nonplastic particles, while another may be very fat and permit considerable material being mixed in, and still be not only plastic but dry to a hard mass. The former case is generally to be found in residual clays, the latter in sedimentary.

Seger considered it unsettled whether this is due to a finer state of division, or the introduction of plastic particles not derived from the feldspar.

The degree of hardness which clays assume on drying also stands in direct relation to the plasticity. Slightly plastic kaolins when dry give only a loosely knit mass. This point as well was commented on by Seger in comparing two clays of nearly the same com-

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[1] Post. *Chem. tech. analyse.* 1890. v. 2, pt 1, p. 43.

position but different plasticity; viz, washed Zettlitz kaolin and plastic refractory clay from Mühlheim, near Coblenz. Both have only a small admixture of quartz sand, viz, about 1½%, the balance being nearly pure clay substance, while in the percentage of ferric oxid they differ by only 1%.

Briquets (air-dried) of the Zettlitz kaolin were loose, and rubbed easily, while their porosity was 42%. Those of the Mülheim clay were hard, and showed only 28% porosity. If both are heated, the latter gets thoroughly dense at 1100°—1150° C., while the kaolin retains its porosity up to a high temperature. The exhibition of density by kaolin is not to be regarded as even the beginning of fusion, for the clay, after assuming it, retains it unaltered up to a high temperature. Many plastic and hard drying clays act in this respect like the Mühlheim material; they sinter however at a much lower temperature.

For the manufacture of glass pots, this is of high importance; for it is not the most refractory clays that are the best, but those which burn dense at a low temperature, and are consequently less attacked by the molten glass.

The same is true of brick used in coke ovens holding coal with soluble salts.

Plasticity, whatever its cause, is an important property from a commercial standpoint, and interesting from a scientific one.

The amount of water required to develop the maximum plasticity varies. If too little is added, the clay cracks in molding and is stiff and hard to work. If too much water is used, the paste becomes soft and retains its shape with difficulty. Lean clays usually require less water to produce a workable mass than fat ones.

Tensile strength

The tensile strength or binding power of a clay often stands in relation to its plasticity, but not always. It is, however, an important property, and exerts an important effect in connection with the cracking in drying. One way of testing the tensile strength is the briquet method mentioned under "Plasticity," p. 539.

Another method requires that the clay be formed into a bar of known cross-section. When dried, the bar is held in a horizontal position by supports under the two ends, and the weight noted which is needed to cross-break it when the pressure is applied to the central portion of the bar.

An objection to this method is that very plastic clays are apt to develop structural peculiarities, which cause their tensile strength to appear much lower than it really is. In such cases, it has been suggested that the clay be pulverized and mixed with an equal quantity of fine sand. If when made into briquets this mixture shows a higher tensile strength than the clay alone, it is an indication that the low tenacity of the original clay was due to flaws.

The tensile strength of air-dried clays is highly variable. The following figures may be taken as representing the average for different clays, in pounds per square inch.

	Pounds
Kaolins	5- 15
Brick clays	60- 75 or even 100
Pottery clays	150-175
Some very plastic clays	200-300

Shrinkage

All clays shrink in drying, and again in burning. The first is known as air, the second as fire shrinkage. Some clays shrink more in drying, others in burning, consequently the amount is variable.

Air shrinkage depends partly on the amount of water absorbed, and partly on the grain or texture of the clay.

Air shrinkage. As soon as evaporation of water takes place from a clay, it begins to shrink, and within certain limits, the greater the amount of water absorbed, the greater the air shrinkage. Plastic clays show this property in a marked degree. The shrinkage continues till all the clay particles are in contact with one another, but this does not mean that all the mechanically combined water has passed off, for there may remain spaces which hold some. Consequently a clay will continue to lose weight after the air shrinkage has ceased. This fact is shown by the following tests made on samples of clay of New York state.

A sample of soft, moderately plastic shale was mixed with water and molded into briquets and then allowed to dry.

When molded	Air shrinkage	Weight in grams
When molded	....	41.220
End of 12 hrs.	1¼%	38.030
End of 1 day	2%	37.616
End of 3 "	2%	37.500
End of 4 "	2%	37.496

Coarse-grained clays commonly shrink less than the fine-grained; they may at the same time absorb as much water. Having larger pores, they will permit the water to escape more rapidly, and hence can often be dried more quickly than fine-grained clays, from which the water, on account of the smallness of the pores, can not escape so quickly. Again, if fine-grained clays are dried rapidly, the surface shrinks more quickly than the interior, and cracking may ensue, more specially if the clay has a low tensile strength, or if it is highly plastic.

Air shrinkage begins as soon as the clay is molded and set out to dry, at first taking place very rapidly, but with decreasing speed. It is in nearly all cases completed before the brick or wares are placed in the kiln. The final traces of moisture are not driven off, however, till the first stages of burning.

Fire shrinkage. This generally commences when the combined water begins to pass off, or at about 1200° F. It varies in different clays and may reach any point between 2% and 15%.

The shrinkage in burning may be just as variable as that in drying; it does not depend on the same causes but is influenced by the temperature to which the clay is exposed, percentage of combined water and organic matter.

It sometimes happens that the clay, instead of shrinking during the burning, appears to expand, and this is specially the case in very quartzose clays, for the quartz has the property of expanding at high temperatures. If the clay contains a large amount of quartz, the expansion of the latter will not only tend to decrease the shrinkage but may even counteract it and cause the clay to expand. This may sometimes account for the presence of cracks in the burned ware.

As the addition of quartz to diminish shrinkage also tends to decrease the tensile strength of the clay, there will be a certain limit in each case beyond which the addition of quartz must not proceed, otherwise the clay will not hold together in molding or drying.

Organic matter and combined water tend to increase the shrinkage in burning, but lime has the opposite tendency, some calcareous clays even appearing to swell.

Clays containing a large amount of feldspar will, instead of showing a steady shrinkage up to the temperature of complete vitrification or sintering, often exhibit a temporary increase of volume when the fusing point of the feldspar (about 2300° F. for orthoclase) is reached.

The shrinkage of most clays in burning does not proceed regularly and steadily to the temperature of vitrification, for some reach their maximum density at a comparatively low temperature, far below that at which they vitrify.

Between the points at which the moisture has ceased coming off and that at which the combined water begins to escape, the clay shrinks little or none at all; consequently the heat can be raised rapidly in this interval, but above and below these two points it must proceed slowly to prevent cracking or warping of the ware.

Method of counteracting shrinkage

As many clays shrink to such an extent in drying that they crack, it is often found necessary to add materials that will prevent this. Such substances go under the collective name of grogs, and may include sand, ground bricks, coke, graphite, etc.

Grogs serve to prevent cracking in both burning and drying. They also tend to prevent the blistering of easily fusible, ferruginous clays when fired hard. They furthermore add to the porosity of the ware and thus facilitate the escape of the moisture in drying and in the early stages of burning, and also enable the product to withstand sudden changes of temperature. Grogs may however act as fluxes at high temperatures; the finer the grog, the more intense will be this action.

If the grog is to decrease the shrinkage in drying and burning, it must not be added in the form of powder, but as grains, and even in this case, the grains must not exceed a certain size, otherwise they will only serve to increase the tearing of the wares in drying and burning. The cause of this lies in the fact that the grog itself does not as a rule shrink, and if in any one place the clay substance shrinks to such an extent that it can no longer surround the particle of grog, the latter will act as a wedge, tearing the grains apart, and a crack will be started. If this action shows itself in the raw material, it can be eliminated by the addition of powdered grog. When this is not possible, the coarse particles must either be removed or reduced by crushing.

Sand. This is the form of grog commonly found in nature and most frequently used artificially. Sand as it occurs in nature is commonly composed of mineral grains, representing a variety of species. Pure quartz is of course the most desirable, but quartz sands generally contain impurities, which at times may be sufficient to prevent their use for certain purposes. Clay impurities might be washed out, but, as others like feldspar, calcite, etc., could not be removed by washing, the best way to obtain clean quartz sand is to crush up vein quartz, or quartzite. An advantage connected with this type of sand is that the grains have an angular structure, whereas grains of natural sand, being usually of sedimentary origin, have a rounded form, and will not interlock as well. In addition to quartz sand, both artificial and natural flint, which is the amorphous form of quartz, often furnishes a grog of splendid purity. Quartz when exposed to high temperature gradually passes from a crystalline to an amorphous condition and in so doing expands.

The more nearly round the grains of sand, the greater will be the interstitial space. In the case of quartz sand this amounts to 35% or 40%. In fine mica sand (glazing sand, for instance) it may reach 50%; and the more mica that is mixed with quartz sand the greater is the amount of interstitial space, and the lighter the weight.

Dümmler gives the following figures for one liter of sand, the material in each case being compacted by shaking and jarring.

One liter common moist sand, 1.61 kilograms.

One liter fine quartz sand, 1.57 kg.; porosity, 35% to 40%.

One liter fine chamotte flour from hard burned material, 1.43 kg.; porosity, 45%.

One liter mica sand (glazing sand), 1.30 kg.; porosity, about 50%.

One liter of the finest ground quartz or feldspar flour, 1.16 kg.; porosity, about 56%.

Chamotte. This is the term applied to burned clay. It possesses all the advantages of quartz as a diluent of the shrinkage, but has the advantage over it that it does not affect the fusibility of the clay, or swell with an increase of temperature. Hence, it does not tend to loosen the structure of the finished product. The clay used for this purpose must be burned to such an extent that it will not shrink on being farther subjected to heat. The degree to which this burned clay is ground depends on the use to which it is put; for, to produce a porous body, it is not ground as fine as it would be if a dense one were to be made. The burned clay used for this purpose can either be ground up bits of broken ware, or can be clay specially burned for this use. Through the hard burning of clay, or the repeated burning of some wares, as in the case of retorts, the

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[1] *Deutscher ziegler-kalender,* 1898, p. 81.

shrinkage of the clay is not only arrested, but the alkalis are also volatilized, whereby the hard burned clay becomes more refractory. This is the case in Belgium, where the clay used as chamotte is burned twice. (Bischof. 2d ed. p. 265)

In the case that cast off wares are used, it is necessary to see that the pieces have not become impure by any slagging action that may have taken place in the kiln. Powdered fire bricks are sometimes used as chamotte.

Graphite and coke. These are materials that are often added to clay to increase the refractoriness, but they also serve the purpose of imparting to the ware a greater heat conductivity and making it more resistant to changes of temperature. It is this last property that makes a mixture of clay and graphite specially adapted to the manufacture of crucibles. The graphite should contain 90% or more of carbon. It should also be intimately mixed with the clay.

Coke is sometimes used instead of graphite, but is less refractory, and works best in materials which in use are not in contact with the air.

Sawdust. This also acts as a diluent but, unlike the others, burns when subjected to a high temperature, and leaves a cavity behind. It is therefore necessary that the particles should not only be small, but of even size. Sawdust and similar substances leave more or less ash behind, whose mineral constituents may act as fluxes. As, owing to the formation of these pores, the clay may be somewhat weakened or loosened, it is necessary that only very plastic clays or those of high tensile strength should be used.

Fusibility

Change on heating. In the heating of a clay, or subjecting it to a gradually rising temperature, it not only shrinks but begins to harden. If raised only to a temperature sufficient to drive off all moisture, the clay will still be soft enough to permit its being scratched with the finger nail. If the temperature is raised still farther, the combined water begins to pass off at a dull red heat, and the clay shrinks to an additional extent, becoming not only harder but denser, till it reaches a condition approaching imperviousness, and a hardness of about 6. (*See* scale of hardness, p. 855) This condition of hardness commonly indicates the beginning of fusion, not of the whole clay mass, but of the more fusible constituents, which soften slightly and bind the whole together. It is called the stage of incipient fusion. In clays that have been burned to this condition, the clay particles are commonly still recognizable.

With an increase of the temperature ranging from 50° to 200° F., or sometimes even more, an additional amount of shrinkage occurs, and most or all of the particles have become sufficiently soft to allow their adjustment to the most compact condition, leaving no interspaces, or, in other words, making the burned clay impervious. This is spoken of as vitrification, and brick or other clay products burned to this stage are vitrified or completely sintered. The particles are no longer recognizable, and the maximum shrinkage has been reached. With a farther rise in temperature the clay becomes viscous or flows.

We can therefore recognize three stages in the burning of a clay:

Incipient fusion [1]
Vitrification
Viscosity

The three stages are not by any means sharply marked, they do not show the same difference in temperature, nor does incipient fusion begin at the same temperature in all clays.

In general we can say, that other things being equal, the greater the percentage of total fluxes, the lower the temperature of incipient fusion, vitrification and viscosity.

The difference in temperature between incipient fusion and viscosity varies with the composition of the clay. In calcareous

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[1] These three terms have been suggested by H. A. Wheeler. *Vitrified paving brick*, p. 12. 1895.

clays they may not be over 50° F. apart, while in refractory clays they are separated sometimes by an interval of 700° or 800° F. The glass pot clays approach the latter condition. The majority of clays show a difference of 200°–400° between the points of incipient fusion and viscosity.

The practical bearing of this will be easily seen, when one remembers that in the manufacture of many kinds of clay products, the body has to be vitrified. Consequently the greater the difference between the temperature of vitrification and that of viscosity, the easier will it be to bring a kiln of ware up to the one without overstepping it and reaching the other, for kilns can not be regulated within a range of a few degrees of temperature.

In many clays the point of vitrification is midway between incipient fusion and viscosity, but in others it is not.

Temperature of fusion. The fusibility of a clay depends on:

1 The amount of fluxes

2 The size of the grain of the refractory and nonrefractory constituents

3 The condition of the fire, whether oxidizing or reducing

All the fluxing impurities do not act with the same intensity. Fine-grained clays fuse at lower temperatures than coarse-grained ones, other things being equal.

In order to express the relative fusibility of clays numerically, Bischof[1], on the assumption that the refractoriness of a clay is directly as the square of the alumina and inversely as the silica and fluxes, deduced the following formula, in which F. Q. stands for the "refractory quotient".

$$F.\ Q = \frac{(Al_2O_3)^2}{SiO_2 \times RO}$$

This has been found incorrect when there is a variation in the fineness and density of the clay, and in order to recognize the effect of these two features, Wheeler[2] has suggested the formula: $F.\ F. = \frac{N^3}{D + D^1 + C}$, in which F. F. is called the fusibility factor.

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[1] *Die feuerfesten thone*, p. 71. 1876.

[2] *Eng. and min. jour.* 10 Mar. 1894.

[3]N = sum of nondetrimentals, or silica, alumina, titanic acid, water, moisture, and carbonic acid

D = sum of detrimental impurities, or the iron, lime, magnesia, alkalis, sulfuric acid, sulfur, etc.

D^1= sum of alkalies which Wheeler supposes to have twice the fluxing value

C = 1, when clay is coarse-grained and specific gravity exceeds 2.25

C = 2, when clay is coarse-grained and specific gravity from 2–2.25

C = 3, when specific gravity ranges from 1.75–2

C = 2, when clay is fine-grained and specific gravity above 2–25

C = 3, when clay is fine-grained and specific gravity from 2–2.25

C = 4, when clay is fine-grained and specific gravity from 1.75–2

This formula gives better, but still not regular results. The insertion of a term to account for fineness of grain is perfectly rational, but the specific gravity is dependent on the mineral composition of the clay and therefore indirectly connected with the chemical constitution.

Determination of fusibility. The temperature at which a clay fuses is determined either by means of test pieces of known composition, or by some form of apparatus or mechanical pyrometer whose principle depends on the expansion of gases or solids, thermo-electricity, spectro-photometry, etc.

When test pieces are used, there are two methods for determining the fusibility of a clay, the direct and the indirect.

The direct method is that of Seger, who devised the test pieces known as " Seger cones ".

These consist of a series of mixtures of clay with fluxes, so graded that they represent a series of fusion points, each being but a few degrees higher than the one next to it. The materials used in making them are such as would have a constant composition, and consist of washed Zettlitz kaolin, Rörstrand feldspar, Norwegian quartz, Carrara marble, and pure ferric oxid.

Cone no. 1 melts at the same temperature as an alloy composed of one part of platinum and nine parts of gold, or at 1100° C. Cone no. 20 melts at the highest temperature obtained in a porcelain furnace, or at 1530° C. The difference between any two successive numbers is 20° C. The upper member of a series is cone 36, which is composed of a very refractory clay slate, while cone 35 is composed of Zettlitz kaolin.

A lower series of numbers was produced by Cramer, who mixed with boracic acid the materials already mentioned. Hecht obtained still more fusible ones by adding both boracic acid and lead to the cones. The result is that we have now a series of 58 numbers, the fusion of the lowest being 710° C., and that of the highest 1850° C.

As the cone reaches its fusion point, it begins to bend over, and it is considered that the kiln has reached the fusion temperature when the tip bends over so as to touch the base.

For practical purposes these cones are very successful, though their use has been perhaps somewhat unreasonably discouraged by some. The full series can be obtained from Messrs Seger and Cramer, of Berlin, for 1 cent each (or about 2½ cents each, including duty and expressage), or nos. .010–10 can be obtained for 1 cent each from Prof. E. Orton jr, of Columbus university, Columbus, O. Recently this series of cones has been restandardized by Seger and Cramer. The new table is given herewith.

Composition and fusing points of Seger cones

No. of cone	Composition			Fusing point	
				°*F*	° *C*
.022	0.5 Na_2O 0.5 PbO	....	2.0 SiO_2 1.0 B_2O_3	1 094	590
.021	0.5 Na_2O 0.5 PbO	0.1 Al_2O_3	2.2 SiO_2 1.0 B_2O_3	1 148	620
.020	0.5 Na_2O 0.5 PbO	0.2 Al_2O_3	2.4 SiO_2 1.0 B_2O_3	1 202	650
.019	0.5 Na_2O 0.5 PbO	0.3 Al_2O_3	2.6 SiO_2 1.0 B_2O_3	1 256	680
.018	0.5 Na_2O 0.5 PbO	0.4 Al_2O_3	2.8 SiO_2 1.0 B_2O_3	1 310	710
.017	0.5 Na_2O 0.5 PbO	0.5 Al_2O_3	3.0 SiO_2 1.0 B_2O_3	1 364	740
.016	0.5 Na_2O 0.5 PbO	0.55 Al_2O_3	3.1 SiO_2 1.0 B_2O_3	1 418	770
.015	0.5 Na_2O 0.5 PbO	0.6 Al_2O_3	3.2 SiO_2 1.0 B_2O_3	1 472	800
.014	0.5 Na_2O 0.5 PbO	0.65 Al_2O_3	3.3 SiO_2 1.0 B_2O_3	1 526	830
.013	0.5 Na_2O 0.5 PbO	0.7 Al_2O_3	3.4 SiO_2 1.0 B_2O_3	1 580	860
.012	0.5 Na_2O 0.5 PbO	0.75 Al_2O_3	3.5 SiO_2 1.0 B_2O_3	1 634	890
.011	0.5 Na_2O 0.5 PbO	0.8 Al_2O_3	3.6 SiO_2 1.0 B_2O_3	1 688	920
.010	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.50 SiO_2 0.50 B_2O_3	1 742	950
.09	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.55 SiO_2 0.45 B_2O_3	1 778	970
.08	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.60 SiO_2 0.40 B_2O_3	1 814	990
.07	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.65 SiO_2 0.35 B_2O_3	1 850	1 010
.06	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.70 SiO_2 0.30 B_2O_3	1 886	1 030
.05	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.75 SiO_2 0.25 B_2O_3	1 922	1 050
.04	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.80 SiO_2 0.20 B_2O_3	1 958	1 070
.03	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.85 SiO_2 0.15 B_2O_3	1 994	1 090
.02	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.90 SiO_2 0.10 B_2O_3	2 030	1 110
.01	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.95 SiO_2 0.05 B_2O_3	2 066	1 130

Composition and fusing points of Seger cones (*continued*)

No. of cone	Composition	Fusing point	
		°*F*	°*C*
1	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}\left\{\begin{matrix}0.2\ Fe_2O_3\\0.3\ Al_2O_3\end{matrix}\right\}4\ SiO_2$	2 102	1 150
2	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}\left\{\begin{matrix}0.1\ Fe_2O_3\\0.4\ Al_2O_3\end{matrix}\right\}4\ SiO_2$	2 138	1 170
3	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}\left\{\begin{matrix}0.05\ Fe_2O_3\\0.45\ Al_2O_3\end{matrix}\right\}4\ SiO_2$	2 174	1 190
4	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}0.5\ Al_2O_3\ 4\ SiO_2$	2 210	1 210
5	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}0.5\ Al_2O_3\ 5\ SiO_2$	2 216	1 230
6	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}0.6\ Al_2O_3\ 6\ SiO_2$	2 282	1 250
7	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}0.7\ Al_2O_3\ 7\ SiO_2$	2 318	1 270
8	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}0.8\ Al_2O_3\ 8\ SiO_2$	2 354	1 290
9	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}0.9\ Al_2O_3\ 9\ SiO_2$	2 390	1 310
10	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}1.0\ Al_2O_3\ 10\ SiO_2$	2 426	1 330
11	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}1.2\ Al_2O_3\ 12\ SiO_2$	2 462	1 350
12	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}1.4\ Al_2O_3\ 14\ SiO_2$	2 498	1 370
13	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}1.6\ Al_2O_3\ 16\ SiO_2$	2 534	1 390
14	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}1.8\ Al_2O_3\ 18\ SiO_2$	2 570	1 410
15	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}2.1\ Al_2O_3\ 21\ SiO_2$	2 606	1 430
16	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}2.4\ Al_2O_3\ 24\ SiO_2$	2 642	1 450
17	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}2.7\ Al_2O_3\ 27\ SiO_2$	2 678	1 470
18	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}3.1\ Al_2O_3\ 31\ SiO_2$	2 714	1 490
19	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}3.5\ Al_2O_3\ 35\ SiO_2$	2 750	1 510
20	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}3.9\ Al_2O_3\ 39\ SiO_2$	2 786	1 530
21	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}4.4\ Al_2O_3\ 44\ SiO_2$	2 822	1 550
22	$\left\{\begin{matrix}0.3\ K_2O\\0.7\ CaO\end{matrix}\right\}4.9\ Al_2O_3\ 49\ SiO_2$	2 858	1 570

Composition and fusing points of Seger cones (*continued*)

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

The theory of these pyramids is that the cone bends over as the temperature approaches its fusing point. If the heat is raised too rapidly the cones which contain much iron swell and blister and do not bend over, so the best results are obtained by the slow softening of the cone under a gradually rising temperature. For practical purposes these cones are considered sufficiently accurate.

In actual use they are placed in the kiln at a point where they can be watched through a peep hole but at the same time will not receive the direct touch of the flame from the fuel. It is always well to put two or more cones in the kiln, so that warning can be had not only of the approach of the desired temperature, but also of the rapidity with which the temperature is rising.

In order to determine the temperature of a kiln several cones of separated numbers are put in, as for example: .07, 1, and 5. Suppose .07 and 1 are bent over in burning but 5 is not affected, the temperature of the kiln is between 1 and 5. The next time nos. 2, 3 and 4 are put in, 2 and 3 may be fused but 4 remains unaffected, indicating that the temperature reached the fusing point of 3.

These pyramids have been much used by foreign manufacturers of clay products and are coming into use in the United States.

There are several indirect methods of determining temperatures, but that of Bischof (Dingler's *Polyt. jour.* 196: 438, 525; 198: 396) is perhaps the best known. This consists in increasing the refractoriness of weighed samples by adding to them increasing quantities of an intimate mixture of equal parts of chemically pure silica and alumina, and heating them with a prism of Saarau fire clay (whose fusing point is Seger cone 36) to above the melting point of wrought iron. While involving more labor than the direct method, it has the advantage of requiring only one standard.

This method was tried by Hofman and Demond ("Further experiments for determining the fusibility of fire clays", *Trans. Amer. inst. min. eng.* Mar. 1895) who mixed various samples of fire clays with varying proportions of calcium carbonate, and calcium carbonate and silica, to render them fusible at temperatures below the melting point of platinum, while common brick clays were mixed with alumina and silica to decrease their fusibility, the object of this being to arrive at a standard temperature at which both refractory and fusible clays could be tested. The results obtained at first were very satisfactory, but subsequent ones did not result as was desired and the method had to be abandoned. More recently however this method has been tried by J. L. Newell and G. A. Rockwell with much better results (*Trans. Amer. inst. min. eng.* Oct. 1898, "A modification of Bischof's method for determining the fusibility of clays, as applied to nonrefractory ones, and the resistance of fire clays to fluxes", H. O. Hofman)

In the last experiments the Seger cone 26 was used as a standard, as it forms the line between refractory and nonrefractory clays, the nonrefractory ones being toned up till they show the same behavior in the fire as cone 26. The amount of toner added then gave an idea how far the clay stood below the lower limit of refractoriness.

The silica used in the experiments was quartz, ground to pass a 100 mesh sieve and purified by boiling in nitro-hydrochloric acid. It had 99.88% silica. The alumina contained 98.48 Al O_3.

The method followed was to weigh out samples of 1 gram of the clay to be tested and mix them severally with .1, .2, .3, etc., grams of the silica-alumina mixture. The samples were then tested in the Deville furnace.

The following table gives the results of the experiments just described, the clays being arranged in the order of their refractoriness, and in each case the amount of flux being given that was required to raise the fusing point to that of cone 26 of Seger.

Analyses and results of tests.

Sample no.	26[a]	25[a]	3[a]	22[a]	24[a]	23[a]	1982[b]
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
SiO_2	64.10	55.60	57.10	57.45	57.15	49.30	43.94
Al_2O_3	21.79	24.34	21.29	21.06	20.26	24.00	11.17
H_2O comb	6.05	6.75	6.00	5.90	5.50	9.40	3.90
Total	91.94	86.69	84.39	84.41	82.91	82.70	59.01
F_2O_3	2.51	6.11	7.31	7.54	7.54	8.40	3.81
CaO	0.10	0.43	0.29	0.29	0.90	0.56	11.64
MgO	0.58	0.77	1.53	1.22	1.62	1.60	4.17
K_2O	2.62	3.00	3.44	3.27	3.05	3.91	2.90
Na_2O	0.03	0.09	0.61	0.39	0.58	0. 7	0.7
Total	5.84	10.40	13.18	12.71	13.69	14.63	23.23
Moisture	1.10	2.65	1.30	1.90	2.70	1.20	15.66[c]
Grand total	98.88	99.74	98.87	99.02	99.30	98.54	98.00[d]
Stiffening ingredient, p.c.	20	40	60	80	80	100	180

[a] Analyzed by N. W. Lord.

[b] Analyzed by E. Orton jr.

[c] Includes CO_2.

[d] Includes P^2O^5, 0.10%.

Thermoelectric pyrometer. Le Chatelier's thermoelectric pyrometer depends on the measurement of a current generated by the heating of a thermopile. The latter consists of two wires, one of platinum and the other an alloy 90% platinum and 10% rhodium, twisted together at their free ends for a distance of about an inch, while the next foot or two of their length is inclosed in a fire clay tube, so that when the couple is inserted in the furnace only the end which is held near the body whose temperature is to be measured will receive the full force of the heat. The two wires connect with a galvanometer, the deflection of whose needle measures the temperature at the point where the free end of the wire couple is applied. As at present put on the market, the thermoelectric pyrometer costs about $180, and the price, together with the delicacy of the galvanometer, has tended to restrict its use. There is no reason however why one should not be made and put on the market for a much lower price. It is not necessary that the recording instrument shall be in the immediate vicinity of the kiln; it may be kept in another room where it is safe from dust and rough handling, and the wires can extend from there to the kiln. This pyrometer is considered to be accurate to within 10° F.

Seger cones are very useful for determining the completion of firing, but the thermoelectric pyrometer serves as a guide during the burning operation, indicating whether the temperature is rising slowly or quickly, and whether steadily or unevenly.

If careful records are kept of these facts during the firing of a kiln, and the results obtained compared, we are enabled to collect valuable data concerning the conditions necessary.

A crude means of judging temperature is to observe the color of the fire as shown by the following table, which gives the color of a body when heated to different degrees, thus:

Just glowing in the dark	977° F.
Dark red	1252° F.
Cherry red	1666° F.
Bright cherry red	1832° F.

Orange	2102° F.
White	2372° F.
Dazzling white	2732° F.

Mechanical analysis of clays

The mechanical analysis of a clay determines the percentage of particles of different sizes which it contains.

The method employed for this determination is partly a dry and partly a wet one. Clays which are used for the finer grades of ware have to be sufficiently fine to pass through a 150 mesh sieve. The relative quantity of coarser particles which a clay contains can be found out by sieving.

If the clay grains are smaller than $\frac{1}{150}$ of an inch, the common method of sorting them is by means of a rising current of water. This operation is known as "slumming" and consists in brief of placing a known weight of clay in a vertical tube through which a current of water passes. The velocity of the current can be regulated. Careful experiment has determined the size of particles that are carried off by a given velocity of the current. The water as it passes off at the top of the tube is conducted into jars, where the suspended particles are allowed to settle, and can afterwards be collected and weighed.

The diameters of the grains commonly separated are:

Clay substance	Up to .01 mm
Silt	.01 —.025 mm
Finest sand	.025—.04 mm
Fine sand	.04 —.2 mm

An excess of the finest particles tends to increase the shrinkage of the clay, while the coarser particles have the reverse effect. For thorough comparative work on the physical properties of clay, it is well to make a mechanical analysis. This has been done with a number of the New York samples.

Chemical effects of heating. On heating a clay to redness, it undergoes certain changes, which exert an influence on the physical character of the clay, though the primary changes are of a chemical nature. In kaolins this change simply amounts to the loss by the kaolinite or clay substance of its combined water. In impure clays many other changes may occur, viz:

The burning off of organic matter.

Limonite losing its water and becoming hematite.

Pyrite (FeS^2) becoming oxidized to ferric sulfates, which in turn are broken up by the expulsion of their sulfur, leaving hematite or ferric oxid. Both lime and magnesium carbonates if present will part with their carbon dioxid.

The general effect of these changes is first to make the clay more porous, but subsequently to increase its shrinkage. The color of the clay is also changed. A chemical interaction between the component minerals of the clay has not taken place up to this point.

It is held by Seger[1] that the more plastic a clay is when wet, the harder it will be after light burning. Such lightly burned wares will not, however, withstand weathering or pressure, and are very porous; resistance to weathering is attained only when certain portions of the clay fuse, and unite the whole into a stony mass.

The shrinkage and decrease in porosity will be the greater, the larger the number of particles taking part in the fusion of the mass.

The process of fusion involves two separate processes, one physical, causing change in volume, and one chemical, giving rise to the formation of new compounds in the mass. These have a lower fusing point than the substances through whose interaction they were formed. In some cases however it is probable that solution takes place.

From the foregoing it would appear that the fusion of a clay is influenced not only by the melting point of the most easily fusible component of the clay, but also by the relative amount of infusible ingredients, and the relative size of the fluxing and nonfluxing particles. In the earlier stages of fusion we must therefore look

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[1] Seger. *Ges Schrift.* p. 380.

on the clay as a mixture of fused particles, with a skeleton of unfused ones. If the proportion of the former to the latter is very small, there will be a strong hardening of the clay with little shrinkage, and the burned clay will still be porous. With an increase of temperature, and the fusion of more particles, the pores fill up more and more, and the shrinkage goes on till at the point of vitrification the spaces are completely filled. Above this point there is no longer a sufficiently strong skeleton to hold the mass together, and the clay begins to flow.

The conditions which influence the difference in temperature between vitrification and viscosity still remain to be satisfactorily explained, but it probably depends on the relative amounts of fluxes and nonfluxes, and the size of grain of the latter.

The preservation of form in burning is primarily dependent on the refractoriness of the mineralogic components which are present in the greatest quantity, because these build a framework or skeleton. In kaolins and some refractory clays this component is the clay substance.

A feldspar percentage aids the fusion above a certain temperature. At high temperatures the quartz tends to increase the fluidity of the fused clay, but at lower temperatures the quartz is to be classed with those components which aid in preserving the form, and in low grade clays the quartz has an important office in this connection.

The recent experiments of Hofman lead him to believe that size of grain does not influence the refractory qualities of a clay (*Trans. Amer. inst. min. eng.* Oct. 1898), and in the case of fire clays tested by him this seems to be true.

CLASSIFICATION

As clays show all gradations from the purest kaolins to the most impure brick clays, it is hard to draw any sharp lines of division between the different kinds. These great divisions can however be made, residual and sedimentary, and to these might be added a third, chemical precipitates.

Each of these three may include varieties having similar properties and similar uses.

Seger makes the following divisions:

1 *Yellow burning*, containing lime and iron

2 *Red burning,* nonaluminous, ferruginous clays which are free from lime

3 *White and yellow burning*, clays low in both iron and lime

4 *White burning*, low in iron and high in alumina

To give a classification based on the uses of the clay is also unsatisfactory, for some clays may be used for as much as five or six different purposes, either alone or mixed with other clays.

A rough classification based on their use would be perhaps somewhat as follows:

Brick clays
Potter's clays
China clays
Fire clays

A good idea of the varied uses of clays may be obtained from the following table compiled by R. T. Hill[1] and added to by the writer.

Uses

1 **Domestic.** Utensils, porcelain ware; china ware; granite or iron-stone ware; yellow ware; rockingham ware; earthenware; majolica; stoves; polishing brick.

2 **Structural.** Brick, common, front, pressed, ornamental, hollow, glazed; adobe; terra cotta; roofing tile; glazed and encaustic

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[1] U. S. Geol. surv., *Min. res. of U. S.* 1891. p. 475.

tile; drain tile; chimney flues; chimney pots; door knobs; puddling; portland cement; fireproofing; terra cotta lumber; paving brick copings

3 **Agricultural.** Drain tile, barn flooring

4 **Hydraulic structures.** Water conduits; sewer pipe; sewer brick; turbine wheels

5 **Sanitary engineering.** Granite ware; urinals and closet bowls; wash tubs; bath tubs; sewer pipe; ventilating flues; foundation blocks; vitrified brick

6 **Industrial uses.** Crucibles and other assaying apparatus, acid vats and jars; acid bricks, gas retorts; fire bricks; glass pots; saggers; stove and furnace linings; wall and writing paper fillings; porcelain chemical apparatus; grinding mills; insulators; pumps; filters; mineral paint; packing horses hoofs; fulling cloth; ultramarine manufacture

7 **Ornamental and esthetic uses.** All forms of ornamental pottery; terra cotta and various forms of tiles either glazed or unglazed

8 **Imitative uses.** Food adulterants and paint adulterants

Coloring agents

This includes those substances which impart a definite color to the clay in burning. Pure clay would burn to a snow white color, but in nature it is frequently tinged with more or less impurity. The most common coloring agent is oxid of iron or iron compounds which, in burning, change to the oxid. The depth of color produced in burning depends on the amount of iron present. It may vary from the lightest yellow to red and dark brown or bluish black. The presence of other compounds may however have a marked influence on the iron coloration. Some of the purest clays known, though containing a mere fraction of a per cent of iron oxid, will, nevertheless, when burned at a very high temperature, develop a very slightly yellow tint. If such clays have a considerable amount of feldspar added to them, they keep this yellow color; on the other hand the addition of quartz tends to minimize it. Magnesia and lime may exert a much stronger effect on the color of clay and specially influence the coloring action of iron. Calcareous clays in burning develop a yellow, instead of a red color, and at the temperature of vitrification this passes into a yellowish green. Seger has shown that the color of a hard burned clay depends on the relation of iron oxid to alumina, and in calcareous clays on the ratio of iron oxid to lime.

Dümmler in his table of analyses[1] shows the ratio of iron and manganese oxid to the sum of nonvolatile constituents, and the ratio of lime and magnesia oxid to iron and manganese oxids. From this it follows that in all clays in which the combined iron and manganese oxids are more than $\frac{1}{20}$ of the amount of the total nonvolatiles, a distinct red color is produced, if at the same time the sum of the two is more than two and a half times greater than the combined magnesia oxids.

Of course the grade of firing has an influence on the color, and in addition the composition of the kiln gases might exert a marked influence. Thus, for instance, clays high in iron burned slate blue in a reducing fire, while yellow burning noncalcareous clay takes on a distinct red color, if subjected to alternating reducing and oxidizing action. (Dümmler. *Die ziegel fabrikation,* p. 42)

The shades which ferric oxid takes in burning vary partly with the nature of its formation. According to Seger that which is made from ferric nitrate burns brown red, that from iron sulfate by ignition is reddish orange.

Heating deepens the color of the ferric oxid with increase of the temperature; and this holds true for all ferruginous clays, so that in general the color of clay products containing iron will be darker the higher the temperature to which they are burned.

A small percentage of iron in a clay produces a buff color when burned to, say 2000° F., but might give a red if burned to 2500° F.

If a clay contains enough iron to color it red when burned to incipient fusion, it may become deep red or brownish at the temperature of vitrification, and black at the temperature of viscosity.

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[1] *Die ziegel fabrikation.*

The physical condition of the iron in the clay may also exert a marked influence. If the iron be distributed evenly through the clay in a finely divided condition or as a film around the clay grains, the coloration produced will be more even than if it were scattered through the clay as isolated grains. The percentage of iron oxid shown by analysis might in either case be the same, but the effect produced in burning would be an even color in the former case, and a speckled appearance in the latter.

Ferrous oxid may form in burning, under several conditions; it may be due to the presence of organic matter, or to reducing action of the fire, or it may have existed in the unburned clay. It is not as strong a coloring agent as the ferric oxid. Alone it produces a green color in burning, but variable mixtures of ferrous and ferric oxids are capable of producing a variety of shades. (*See* "Division on iron")

Manganese oxid in general produces darker colors than iron.

Other coloring substances might be present in clays in small amounts. Cobalt oxid might produce a blue color, and chromium a green color.

Both cobalt and chromium are sometimes added to white or light burning clays to color them artificially, 5% of the former producing a bright blue, and ½%–1% of the latter giving a green. A black color can be produced by adding a mixture of 6% iron oxid, and 6% manganese superoxid.

Seger[1] classifies clays according to the color assumed in burning as follows:

1 Aluminous clays, poor in iron, which burn white or very slightly yellowish

2 Aluminous, moderately ferruginous clays, whose color when burned is pale yellow to light brown

3 Aluminous, ferruginous clays, such as brick clays, whose color when burned is brick red

4 Nonaluminous clays, rich in iron and lime, whose color when burned is yellow

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[1] Seger. *Ges. Schrift*. p. 85.

Without giving the composition of the clays which Seger experimented on, in this connection it may be interesting to give some of his conclusions.

The first group includes the porcelain clays, and in these the ferric oxid may at times exceed 1% without influencing the color. In this connection it is considered that the presence of a large amount of alumina has the same effect as lime, in destroying the red color of the iron. Evidence of this fact is afforded by Seger's experiments on clays included in the second group.

In the second group are included clays which burn white at low temperatures, with an occasional pink tint, but at higher temperatures show more or less yellowish or brownish color, but never a red, assuming a greenish color at the highest temperatures due to the reduction of the iron to a ferrous condition. The alumina in clays of this group is generally 20%–30% and even more, while the percentage of ferric oxid may in some cases approach that of the brick clays, but it generally ranges between 1% and 5%. It is an interesting fact that a mixture of red burning clays of the third group and kaolin does not give a pale red product on burning, but instead a yellow one, which Seger believes is due to the excess of alumina.

This group includes many fire clays, semi-fire clays, stoneware clays. Five examples are given by Seger to illustrate this effect of the alumina in destroying the red color of the ferric oxid. Their color when burned, as well as the ratio of ferric oxid to alumina, is given below.

Color when burned	White to yel. white	Light yellow	Yellow to light brown	Yellow brown	Yellow
Ratio of ferric oxid to alumina	1:13.2	1:7	1:5.4	1:7.2	1:6.3

The exact temperature at which these were burned is not stated but it was the same in each case.

This group somewhat resembles the fourth group in respect to the colors produced, but differs from it in fusibility, becoming porcelain-like at high temperatures, and not green, but brown or gray in color. The percentage of alumina, it will be seen, far exceeds the iron. The color seems to be lighter the greater this excess.

In the third group, which includes the brick clays, the alumina percentage is small as compared with the ferric oxid. They are all easily fused, and the percentage of lime, magnesia and alkalis is low in those which burn to a bright color. The usual color of such clays when burned is red, which becomes deeper with an increase in the temperature and greater density, changes to violet red and finally becomes black.

The percentage of ferric oxid is generally one third to one half the alumina percentage, as indicated by the following figures from five examples given by Seger.

Color when burned	Dark red	Dark red to violet red	Dark cherry red	Dark red	Dark red
Ratio of Al_2O_3: Fe_2O_3	1:2.8	1:1.19	1:1.9	1:1.29	1:1.29

A comparison of the second and third groups shows that those in which the alumina is not more than three times as great as the ferric oxid show a decided red color; those where it is five and one half times as great show a brown to yellow color.

Probably other physical properties exert an influence, but these are not clearly understood.

The fourth group includes calcareous clays, and in this the succession of colors produced in burning is reversed. The ferric oxid exerts its coloring action at low temperatures, but at higher ones the influence of the lime is seen on the silicates of the clay, and the red passes into yellow or yellowish white, which at higher temperatures grades into green, and at viscosity becomes dark green or black.

The relations between iron and alumina, and iron and lime, and the color when burned are shown below.

Color	With light burning red to flesh red; hard burning yellow white to sulphur yellow; at vitrification yellow green to green					
Fe_2O_3: Al_2O_3....	1:2.3	1:1.16	1:3.1	1:2.5	1:2.5	1:2.4
Fe_2O_3: CaO.....	1:2.9	1:3.2	1:2.2	1:3.0	1:3.5	1:2.2

The iron in this group runs about as high as in group 3, the lighter color being due to lime, the percentage of which ranges from 11%–19%.

The relation of Fe_2O_3 to CaO it will be seen is as 1 : 2, or 1 : 3, but the lime could probably be lower still, and yet be effective. To prove this Seger took the red burning clay from Rathenow, whose composition is

Silica	61.30
Alumina	18.87
Ferric oxid	6.66
Lime	.85
Magnesia	1.20
Alkalis	3.20
Water	8.28

To this clay he added increased amounts of lime, which gave the proportions of ferric oxid to lime carbonate in the different mixtures, as follows:

1:.13, 1:.48, 1:.83, 1:1.18, 1:1.53, 1:1.88, 1:2.23, 1:2.58, 1:2.93.

These nine samples were first burned at a red heat in a small gas furnace, and on cooling the color of all of them was found to be red.

They were next heated to bright redness and after this it was found that the color of the first four was bright red, but still slightly off color, the more so the greater the proportion of lime which they contained. The fourth had a yellowish brown shell, one millimeter thick with a red interior. The fifth and sixth showed the yellow color to a greater depth, while the seventh and eighth were yellow throughout with a slight tinge of gray.

From this Seger infers that the yellow color first appears when the proportion of ferric oxid to lime is as 1 to 1

As regards the action of ferrous oxid, Seger came to the conclusion that in porous bricks the percentage of this can run quite high without producing much effect, but in dense bricks the reverse is true.

Brick clays often have more or less organic matter which may sometimes reduce the iron. Thus the clay from Rathenow, when ignited in a closed crucible, showed 2.20% of ferrous oxid. In the presence of air, however, it was converted to ferric oxid, for after being ignited for one hour, exposed to the air, the same clay showed only .76% of ferrous oxid.

The black color of bricks is due to the reduction of iron in the last stages of burning.

One interesting result of Seger's experiments is that oxidation of the iron can take place within a clay which has been burned to vitrification. This was explained by an experiment in which he took a prism 2 cm thick, and burned it to vitrification. After burning, the surface of the prism was cherry red, but in passing from the middle to the surface the colors encountered were cherry red, gray red, gray green, black violet, gray green, gray red, and cherry red. An analysis of these different colored portions showed the following:

	Cherry red	Gray green	Black violet
Ferric oxid....................	5.35	3.43	2.14
Ferrous oxid....................	.12	1.85	3.01

The above is explained by supposing that the flame of the fire caused a reducing action of the iron, which did not extend the entire distance to the core; later, on cooling the outer portion of the brick was reoxidized.

GEOLOGIC DISTRIBUTION

Clays or shales occur in every geologic formation even in the archean. It can be said in general that all those which are older than the Cretaceous are shale, while those of Cretaceous and Tertiary age are sometimes soft plastic clays, as those of New Jersey and Long Island, or at times shales, as exampled by the fire clays of Colorado.

The Quaternary deposits of clay are all unconsolidated, so far as known, no shales occurring in this formation.

The geologic age of a clay or shale is no indication of its commercial value, except at most for the comparison of two deposits in closely adjoining areas, but even here it is not safe to rely on such a guide.

Those deposits which are of marine origin are commonly much more extensive than those formed in inland waters.

Occurrence of clay in New York state

Deposits of clay or shale are to be found in nearly every county of the state. They are divisible into the following classes.

1 Residual clays	Soft plastic clays
2 Sedimentary clays	Shales or consolidated clays

1 **Residual clays.** Deposits of this type are rare in glaciated regions; still several small kaolin veins have been found to the east and southeast of Sharon Station on the New York & Harlem railroad, but it is doubtful if they will ever become of commercial importance. They are also found in the adjoining portion of Connecticut, one being worked 4 miles east of Sharon. Residual clays also occur in association with the limonite deposits at Amenia, and in the vicinity of New York city the dolomitic limestones have by their decomposition sometimes given rise to clays of a residual nature.

Old lake bottom, Spencer N. Y. Underlain by clay.

The mellowed outcrops of many of the shale formations occurring within the state should also, perhaps, be classed under the head of residual clays. In the latter case however the clay is a product of disintegration; in the former, of decomposition.

2 **Sedimentary clays.** The soft plastic clays belong to three geologic formations, Quaternary, Tertiary and Cretaceous.

The first class is by far the most common. The second class is somewhat indefinite in extent, but a large number of the Long Island deposits probably belong to it.[1] Of the third class there are undoubted representatives on Long Island and Staten Island, as well as some additional ones on Long Island, which are questionable. The clays of the mainland are all Quaternary so far as known. This does not include the shales which are treated in a separate chapter.

Many of the deposits are local and basin-shaped, lying in the bottoms of valleys which are often broad and fertile. They vary in depth from 4 to 20 or even 50 feet and as a rule they are underlain by modified drift or by bed rock. The clay is generally of a blue color, the uppermost portion for a few feet being weathered red or yellow. Stratification is sometimes present, and streaks of marl are common. In some of the beds small pebbles, usually of limestone, are found, and these have to be separated by special machinery in the process of manufacture; at other localities the clay is covered by a foot or more of peat.

The basin-shaped deposits are no doubt the sites of former ponds or lakes, formed commonly by the damming up of the valleys, and filled later with the sediment of the streams from the retreating ice sheet. The valleys in which these deposits lie are usually broad and shallow, that in which the Genesee river flows from Mt Morris to Rochester being a good example. The waters of the river were backed up by the ice for a time, during which the valley was converted into a shallow lake in which a large amount of aluminous mud was deposited. This material has been employed for common brick.

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[1] F. J. H. Merrill. "Geology of Long Island," *Ann. N. Y. acad. sci.* Nov. 1884.

An idea of the depth of clay and alluvium in the Genesee valley may be had from the following table. The figures have been taken from the records of salt wells.

York[1]	York salt co.	Clay	52 ft
Piffard[1]	Genesee salt co.	Clay and gravel	64 ft
"	Livingston salt co.	"Soil"[2]	158 ft
Cuylerville[1]	....	"Soil"	184 ft
Mt Morris[3]	Royal salt co.	"Soil"	191 ft

For other localities the following depths are given.

Aurora[1]	....	Blue clay	15 ft
Wyoming[1]	Pioneer well............	Soil and clay	40 ft
Warsaw[1]	Standard salt co.	Surface, soil and clay	26 ft
"	Gouinlock and Humphrey	clay	17 ft

There are a number of these deposits which are of sufficient interest, geologically as well as commercially, to be mentioned in some detail.

At Dunkirk there is a bed of clay having a depth of over 20 feet. The upper 6 feet are yellow and of a sandy nature, while the lower two thirds are blue and of much better quality. It is mentioned by Prof. Hall[4] in his report, and is an instructive example of the manner in which the clay changes in color, downward as far as the water can percolate and oxidize the iron.

Around Buffalo is an extensive series of flats underlain by a red clay. A thin layer of sand suitable for tempering overlies the clay in spots, and limestone pebbles are scattered through it. Similar deposits occur at several localities to the north of the ridge road and around Niagara Falls, also at Tonawanda and La Salle, to the north of Buffalo, as well as south of it along the shore of Lake Erie. Much of this clay was deposited during the former extension of the great lakes.

Prof. Hall mentions deposits of clay at the following localities: at Linden one mile south of Yates Center;[5] along the shore of Lake

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[1] I. P. Bishop. *5th ann. rep't N. Y. state geologist.* 1885.

[2] The term soil is probably meant to indicate sand and clay.

[3] *Ann. rep't Onondaga salt springs.* 1888. p. 19.

[4] *Geol. New York,* 4th district. 1843. p. 362.

[5] " p. 437.

Ontario east of Lewiston; on Cashaqua creek[1] deposits of tenacious clay due to the crumbling of the argillaceous green shales. In Niagara co.[2] beds of clay are said to occur in every town, but they often contain a considerable amount of lime.

A bed of blue and red clay is being worked at Brighton near Rochester. This deposit lies near the head of Irondequoit bay and was deposited by some stream flowing into it. To the southeast of Rochester is a large eskar which extends in a northeast direction to near Brighton. Mr Upham, who has described this eskar, considers that it was formed by a river which flowed between walls of ice and deposited the bed of clay above mentioned.[3]

Clays are also found at several points in the valley of the Oswego river from Syracuse to Oswego, an important one being at Three River point.

An extensive bed of red and gray clay, 20 acres in extent and horizontally stratified, occurs at Watertown. The deposit is 20 feet thick and rests on Trenton limestone.

Another deposit of considerable size is being worked at Ogdensburg. The clay is blue and has a depth of 60 feet.

At Madrid, in St Lawrence co., is a small deposit, probably the remnant of a formerly extensive one. The section is:

Yellow stratified sand	3	feet
Blue clay with shells	1	"
Blue clay	20	"
Total thickness	24	"

The shells are probably Macoma fusca *Adams*

Turning our attention to the southern portion of the state we find clays in abundance, in all the valleys and lowlands, the exten-

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[1] *Geol. New York,* 4th district. 1843. p. 227.
[2] " p. 444.
[3] *Roch. acad. sci. proc.,* 2: 181.

sive marshes near Randolph and Conewango for example being underlain by clay throughout their entire extent.[1]

At Levant, 4 miles east of Jamestown, Chautauqua co., is an interesting bed of blue clay underlying an area of several acres. It is probably of postglacial age, and the section as determined by an artesian well-boring is:

Yellow sand	4 feet
Quicksand	4 inches
Yellow clay	5 feet
Blue clay	70 "
Hardpan	..
Total thickness	83 "

The owner of the clay bed informed me that leaves were often found between the layers of the clay at a depth of 15 or 20 feet.

At Breesport near Elmira there was a bank of blue clay rising from the valley to a hight of 50 feet, but it represents the lens-shaped type of clay deposit included in the moraine at many points, and has been worked out. A similar deposit is found at Newfield 6 miles south of Ithaca, where a moraine crosses the valley, the clay forming a large portion of one of the morainal hills, but surrounded by till. Deposits of clay suitable for brick and tile occur extensively in the lowlands bordering the Mohawk river from Rome to Schenectady. The beds vary in thickness from 6 to 15 feet and are mostly of a red, blue, or gray color.

Among the most extensive and important clay formations occurring in New York are those of the Hudson valley.[2] Here are deposits of two types: 1) estuary deposits of fine stratified sand, yellow and blue clay, and 2) cross-bedded delta deposits, the materials of which are much coarser. The estuary deposits indicate a period of depression, and deposition in quiet water.

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[1] *Geol. New York,* 4th district. 1843.

[2] H. Ries, *Rep't of N. Y. state geologist,* 1890.

Plate 3

H. Ries photo.

Aldridge Bros. clay bank, Dutchess Junction. This represents the stratified clay of the Hudson valley.

The clay is chiefly blue, but where the overlying sand is wanting or is of slight thickness, it is weathered to yellow, this weathering often extending to a depth of 15 feet below the surface, and to a still greater depth along the line of fissures through which the water can percolate. The depth of oxidation is of course influenced by the nature of the clay, the upper portion weathering easily on account of its more sandy nature and hence looser texture. Horizontal stratification is marked and the layers of clay are separated by extremely thin laminae of sand. At some localities the layers of the clay are very thin and alternate with equally thin layers of sandy clay. This condition is found at Haverstraw, Croton, Dutchess Junction, Stonypoint, Fishkill, Cornwall, New Windsor, Catskill and Port Ewen. At all of the above mentioned localities except the last two, the clay is overlain by the delta deposits of rivers tributary to the Hudson, and the alternation of layers may be due to variations in the flow of the rivers emptying at those points, the sandy layers being deposited during period of floods. The delta of Catskill creek has been found at Leeds, some 2 miles west of the Hudson river.[1] The delta of Rondout creek, which flows into the Hudson at Port Ewen, will no doubt be found by following the creek back to the ancient shore line of the Hudson estuary. Isolated ice-scratched boulders are not uncommonly found in the clay.

There is often a sharp line of division between the yellow weathered portion and the blue or unweathered part of the clay. The line of separation between the clay and overlying sand is also quite distinct in most cases. Of the blue and the yellow clay the former is the more plastic, but both effervesce readily with acid due to the presence of 3%–6% of carbonate of lime, and are therefore, properly speaking, marly clays. The clay is underlain by a bed of gravel, sand, hardpan, boulder, till or bed rock. From Albany to Catskill the underlying material is a dark gray or black sand

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[1] W. M. Davis. *Proc. Bost. soc. nat. hist.* Nov. 1892.

with pebbles of shale and quartz. The sand grains are chiefly ground-up shale, the rest being silicious and calcareous, with a few grains of feldspar and garnet. This sand can often be used for tempering, but at Catskill contains too much lime for this purpose.

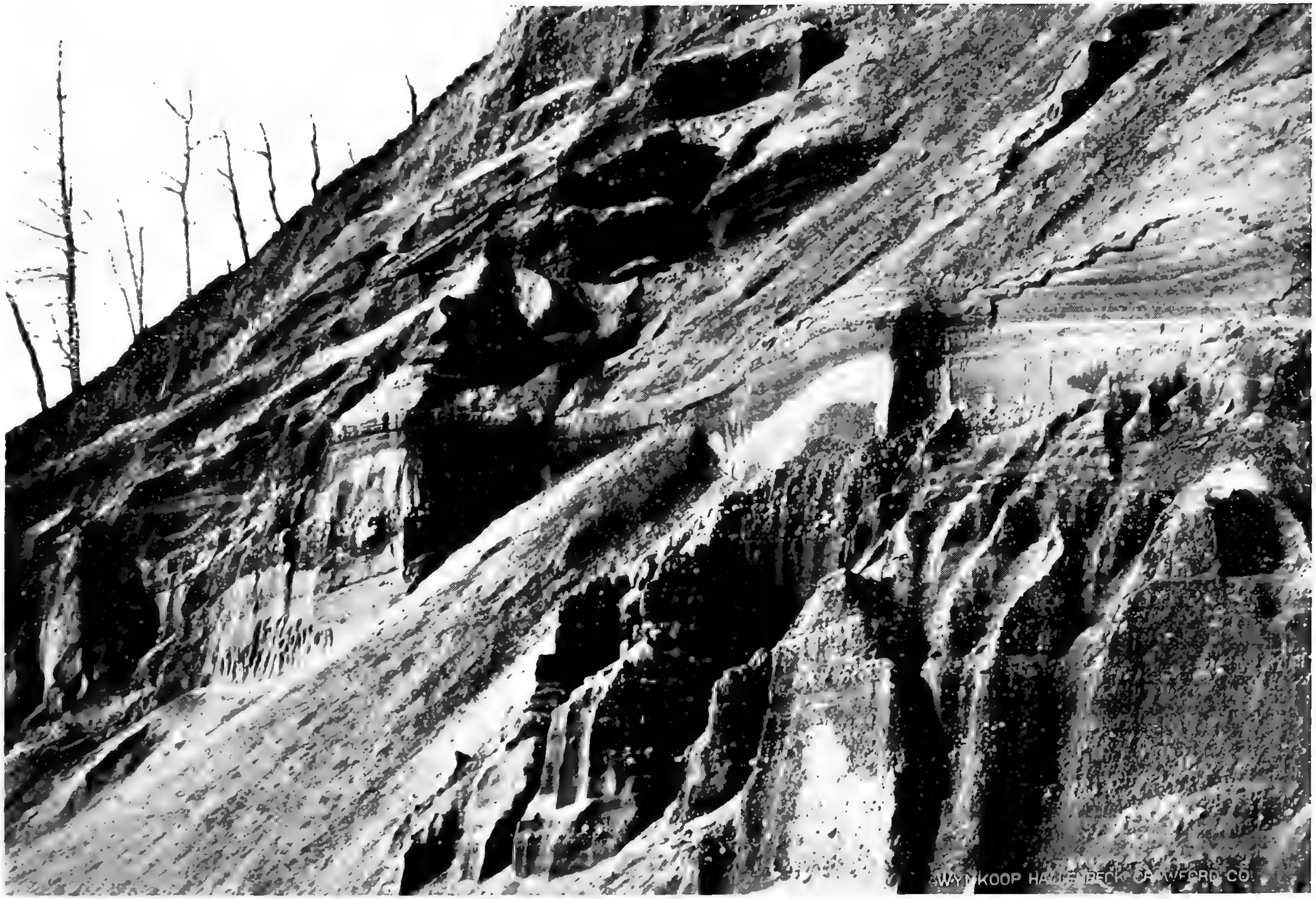
I have not observed this underlying sand and gravel reaching a greater hight than 90 to 100 feet above sea level.

From Catskill northward the clay is in most cases covered by but a foot or two of loam, but south of Catskill it is mostly a fine sand. At Catskill a terrace extends back 2 miles and probably more; it is deeply incised by Catskill and Kaaterskill creeks and smaller streams and rocky islands project above its surface at various points. The terrace can be traced up to Walkill valley to a point several miles south of New Paltz. Along the West Shore railroad track, about 150 feet south of the station, the side of the cutting consists of thin alternating layers of clay and sand 27 feet thick. Above this, in places, is 9 feet of fine, stratified, yellowish sand. The clay extends along the track for about one fourth of a mile till it meets an outcrop of Hudson river sandstone. On the south side of the Catskill mountain railroad, 100 feet from the bridge, is an exposure of sand and gravel, the pebbles being very coarse. It is presumably drift material, but the exposure is an isolated one and does not show its relation to other deposits of the vicinity. At Smith's dock, on the land of T. Brousseau near the river, the upper portion of the terrace escarpment consists of fine stratified sand, which has been excavated to a depth of 12 feet without finding clay, while farther back from the river the clay extends to within 2 feet of the terrace level.

The Hudson river shale rises steeply along the water's edge from here down to Malden, and crops out at numerous points in the terrace escarpment. The clay along here is probably not of great depth. Clay is found in the railroad cutting to the north of Malden station, about 7 feet above the track level, and clay is exposed in numerous cuttings of the West Shore railroad, from Malden to Mt Marion.

Plate 4

To face page 578



J. N. Nevius photo.

Section of quaternary sand and gravel beds, at North Albany, Albany county. This is the material which is found underlying the clay in the Hudson valley as far south as Catskill.

From Glasco to Rondout the terrace, which is perhaps one eighth of a mile broad at Glasco, narrows as it nears Rondout, and has an average hight of 150 feet. The clays, so far as could be ascertained, lie on the upturned edges of the Utica shale.

At the rear of A. S. Staples's yard hardpan underlies the clay. The overlying material at this locality consists of sand and gravel, in many instances stratified and sometimes cross-bedded. The sand in some spots is 10 to 15 feet thick and fine enough to be blown by the wind.

At Port Ewen the clay is mostly blue, resting on a mass of hardpan, and in a few places on the glaciated rock surface. According to Mr Kline, of Port Ewen, the clay around the village is nowhere over 18 feet in actual thickness and is underlain by hardpan. A point worthy of notice is the difference in level of 50 feet between the terrace at Port Ewen and at Glasco.

It has been suggested by Dr Frederick J. H. Merrill that this may be due to the fact that, when sediment is deposited in a basin its edge would be higher than the center. The Quaternary formation broadens on toward the west, and Port Ewen would be a point on the basin's edge, while Glasco is near the center.

In this connection the following well records are of interest. A boring made on the property of Isaac Tamney, at Eddyville, showed:

Sandy loam	10	feet
Quicksand	70	"
Blue clay	10	"
Gravel	..	
Total thickness	90	"

In boring another well at the same locality the following strata were passed through:

Yellow clay	10	feet
Blue clay	137	"
Gravel	5	"
Total thickness	152	"

Still another at Rosendale, on the land of R. Lefever:

Loam and yellow clay	20	feet
Sand	50	"
Blue clay	30	"
Gravel	..	
Total thickness	100	"

At Lefever Falls:

Coarse sand	40	feet
Quicksand	60	"
Blue clay	42	"
Rock	..	
Total thickness	142	"

At Rosendale plains:

Sandy soil	10	feet
Blue clay	10	"
Quicksand	10	"
Blue clay and quicksand alternating	150	"
Total thickness	180	"

We now come to a narrow portion of the river from Staatsburg to New Hamburg, where the terrace if present is of small extent, and presumably underlain by drift material.

Where the river broadens out again at Roseton, at the head of Newburgh bay, there is a thick bed of clay. It is nearly all blue and underlies the remnant of a terrace 120 feet high, which has escaped entire destruction owing to its position in a reentrant angle of the upper Cambrian limestone ridge along the river at this point. The overlying stratified sand and gravel is 10 to 15 feet thick. At Jova's upper yard the clay rests on the glaciated limestone, over whose surface are scattered several boulders of the same rock. The clay at Rose's yard is 180 feet thick, while that at Jova's has a total thickness of 240 feet. A boring of 135 feet made at Rose's yard at river level is of interest in connection with the depth of the preglacial channel of the Hudson.

Borings recently made indicate that most of the 135 feet is sandy blue clay.[1]

About 800 feet south of Roseton station the material under the terrace is a yellowish loamy clay, thinly stratified. This may be a portion of the secondary cone of the delta of Wappinger's creek at New Hamburg. North of this a cutting has been made in the terrace escarpment, the section exposed showing alternating layers of yellow and black sand.

From Newburgh to New Windsor the clay is overlain by the extensive delta deposits of Quassaic creek and Moodna river. To the east of Mrs T. Christie's yard the clay, which is mostly blue and thin layered, is overlaid by fine gravel and sand obscurely cross-stratified in places. Over this is 3 to 4 feet of sandy soil. The upper layers of the clay are wrinkled in places, probably owing to the oblique downward pressure of the overlying delta deposits. It seems likely that at this spot only a small portion of them remains, much having probably been eroded. At Lang's yard, south of Christie's, there is 4 to 6 feet of sand and gravel over the clay,

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[1] *T. A. I. M. E.* 1899. 29: 76.

of the same nature as that previously mentioned. Scattered all through the clay are cobbles of limestone. The upper strata are loamy and contorted, while underneath in the yellow clay, which is very tough, the stratification is almost entirely obliterated. At the next bank, also belonging to Lang, there is 6 feet of overlying sand and gravel. Scattered through the clay are several boulders of Calciferous sandrock, sandstone, black crystalline limestone and gneiss. The overlying material is mostly unstratified and many of the pebbles are 8 inches in diameter. At the bank of J. T. Moore the clay is very tough, and the stratification is obliterated in spots. Several ice-scratched boulders of light blue limestone, sandstone and Calciferous sandrock were found in the clay. In Moore & Lahey's bank the clay is tough and compressed, similar to the other yards. It likewise contains scratched boulders, specially of a light blue crystalline limestone. Over the clay is 2 to 4 feet of coarse sand and gravel.

In the west side of the New York, Ontario & Western railroad, where it branches off from the West Shore railroad, a cutting in the hillside shows a cross-bedded, yellowish sand and loamy clay with patches of gravel and cobblestones in it. Following along the track a few hundred feet we come to the clay bank of C. A. and A. P. Hedges. This shows an interesting section of blue clay overlain by 50 to 60 feet of cross-bedded delta deposits of sand and gravel. The clay layers are obliterated in spots and in others much contorted. To the north of Hedges's yard in the railroad cutting the clay is overlain by 5 to 6 feet of sand and coarse stones, unstratified. Following up the track on the left side just beyond the crossing of the road from Canterbury to New Windsor the embankment of sand and coarse gravel is cross-stratified, being a portion of the delta of Moodna river. The character of this embankment changes after about 400 feet to unstratified drift, containing boulders. This underlies the delta material. The upper terrace at Cornwall is underlain by boulder drift.

Its structure is well shown along the track at Cornwall. Clay

Clay at New Windsor showing glaciated boulder in it.

was observed in a meadow opposite the Roman catholic church; it was exposed in digging drainage trenches. Near this locality, but a little nearer the river, were found several mastodon bones.

At Jonespoint there was formerly a small deposit of clay, but it has been entirely worked out.

Haverstraw has three terraces, viz, at 20, 60 and 100 feet. The clay so far as known is only found underlying the two lower ones, the upper one being underlain by drift and delta deposits.

There is a deposit of clay at Stonypoint forming a portion of the 20 foot terrace. The upper layers of clay are in places loamy and undulating. Over the clay is a mass of unstratified material from 2 to 8 feet thick, and the upper surface of the clay is uneven. The overlying unstratified material is a coarse sand full of cobblestones, gneiss, schist and granite, all of them rounded but not scratched. On the hillside to the west of this deposit is a large, isolated boulder of granite. The upper terrace at Stonypoint is about 75 feet higher than the station level; a portion of this terrace remains about one eighth of a mile north of Stonypoint station on the west side of the track. On the west side of the track where it crosses Cedar Pond brook the delta structure is observable in the embankment, the upper portion of which consists of coarse sand, pebbles and cobblestones which are mostly of gneiss. The lower layers exposed at this point are quite argillaceous. A short distance below the West Haverstraw station and some 500 feet west of the track, an excavation had been made for tempering material. It exposes a fine yellowish cross-stratified sand overlain by several feet of coarse sand and cobblestones.

In T. Malley's clay bank along the shore on the north side of Grassy point, the clay is not found above tide level and is overlain by 3 to 4 feet of fine gravel. To the northeast of P. Brophy's yard is the remnant of a terrace. It is composed of obscurely cross-stratified sand and gravel, overlain by a few feet of loamy clay, very thinly stratified and the layers wavy. There is a boulder of norite in this bank; there are also cobblestones of diorite, gneiss and red sandstone. About 600 feet to the west of the yard of D. Fowler jr & Washburn the clay is being excavated in the terrace escarpment, which is here 45 to 50 feet high. It is mostly blue, thinly stratified and overlain by obscurely stratified gravel and sand. In this excavation was a small ice-scratched boulder which had been found in the clay. At J. Brennan's yard the clay is overlain by 2 to 3 feet of fine sand, and on this is a layer of indistinctly stratified fine gravel 6 to 7 feet thick, with a covering of one foot of soil. The terrace at this point is about 50 feet high. Cobbles 1 to 2 feet in diameter of granite, gneiss and pegmatite were found in this bank. Farther south at Peck's yard, several boulders of granite, limestone and sandstone were found in the clay. Those seen were in the lower portion of the bed, but I was told that several had been found in the upper portion.

Along the river behind the yards of the Excelsior and Diamond brick co. most of the overlying material has been removed by stripping, but, judging from what is left, it must have been 10 to 15 feet thick. South of Haverstraw the contact of the clay with the underlying drift can be observed, the clay thinning out as it approaches the hill. Some 2 miles south from Haverstraw, and half way between the stations of Ivy Leaf and Thiells on the New York & New Jersey railroad in the valley of Ivory creek, is a basin-shaped deposit of clay belonging to E. W. Christie. It is not over 15 feet thick as determined by boring, and has a slightly elliptic outline. The valley in which it lies is full of glacial material, and contains numerous kames, whose axes lie parallel to the direction of the valley. The clay is underlain by drift material containing boulders of quartzite, calciferous sandrock, granite, sandstone, gneiss and schist. Over the clay is 1 to 2 feet of sand containing large ice-scratched stones of quartzite, gneiss and schist. This clay deposit was probably formed in a small lake. If it were a portion of the Hudson river estuary deposits, it would indicate a much greater submergence than 100 feet, supposed for this region, for this locality is 250 feet above the level of the Hudson river. On either side of the track at Thiells are probably remnants of a terrace.

The clay bank of the Anchor brick co. at Croton landing is elliptic in outline and lies on a bed of granite, gneiss, schist, and white crystalline limestone pebbles, cemented together by clay, covered with limonite. Large pebbles are scattered through the clay, the layers of which are undulating, conforming to the shape of the underlying surface. Over the clay is 4 to 6 feet of gravel and sand. South of this yard an excavation has been made under the terrace for obtaining gravel, exposing a section of Croton delta. Projecting up into it is a mass of boulder-till.

About the middle of Croton point are the clay pits of the Underhill brick co. Their clay is overlain by the sandy beds of Croton delta. The material composing it was evidently derived from the crystalline rocks of the surrounding country. It is often micaceous and of a yellow color. Scattered through this sand are great numbers of botryoidal sand concretions, some of them forming masses 6 feet long and 3 to 4 feet wide. They show the layers of deposition of the sand.

The clay at Crugers, Montrose and Verplanck lies in hollows in the rock, being as much as 50 feet thick in some places. At Crugers it is overlain by a few feet of loam; at Montrose by stratified sand, varying in depth from 5 to 20 feet, according to borings made. Along the Hudson River railroad track below Montrose, at Morton's yard, the clay is overlain by from 8 to 10 feet of fine gravel, and cross-stratified sand of a dark gray or black color. The materials composing it are, to a great extent, ground up crystalline rocks. The same material covers the clay at McConnell & O'Brien's bank. At the clay beds of the Hudson river brick co. at Verplanck, the clay is covered by yellowish sand and fine dark colored gravel; usually they are unstratified, but in a few spots show cross-bedding.

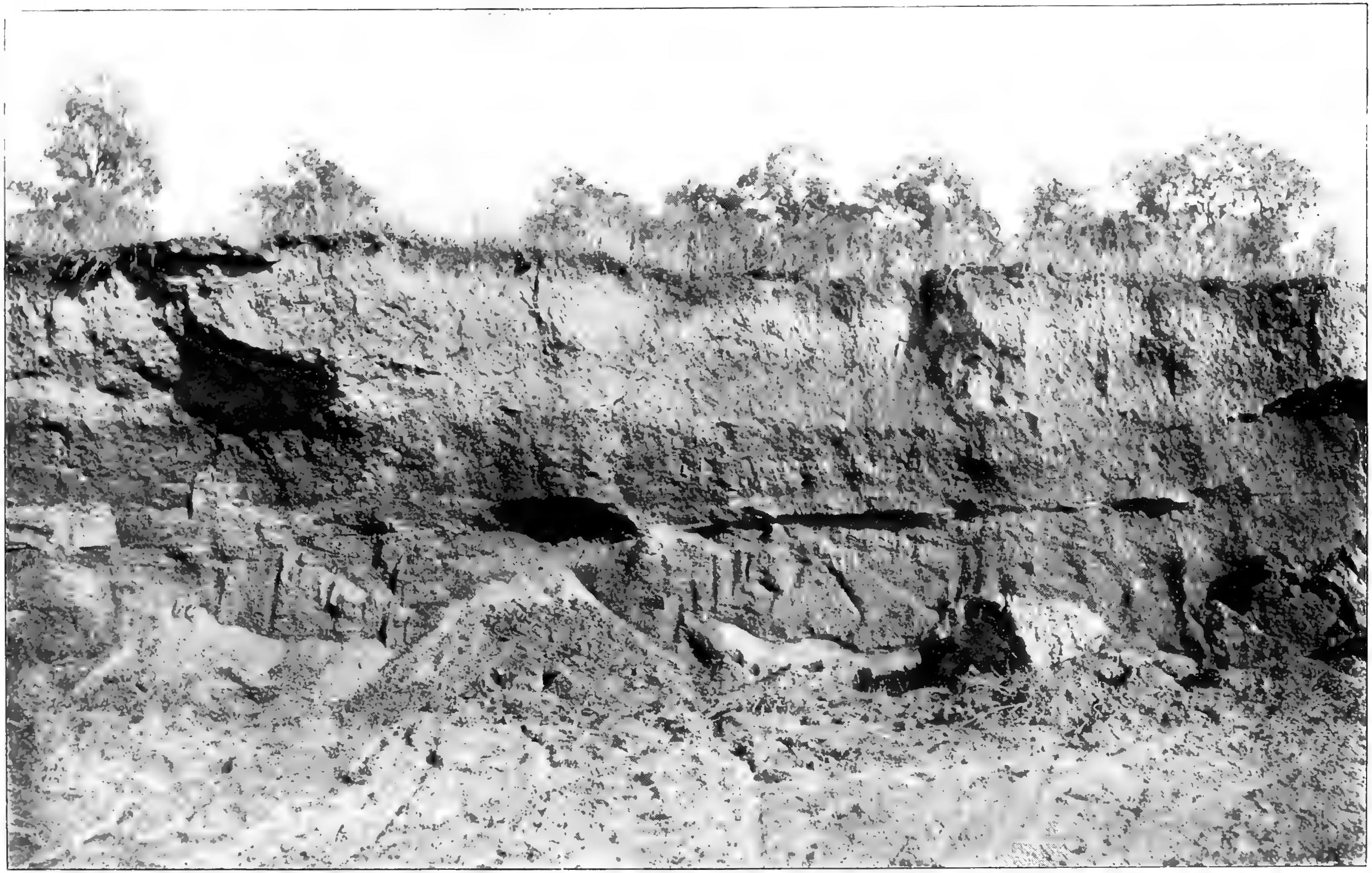
A short distance below Peekskill, at Bonner & Cole's yard, is a remnant of a 20 foot terrace. There is here a deposit of clay not extending more than 4 feet above tide, and overlain by an unstratified layer 5 feet thick, of coarse sand and cobblestones, mostly gneiss.

From Stormking station to Dutchess Junction there is a stretch of terrace, which extends back to the foot of Breakneck and Fishkill mountains. The maximum hight of it is 210 feet. Various firms are digging clay in the terrace escarpment the greater part of its length. A well of 65 feet sunk at Aldridge's yard from tide level still showed clay, and adding to this 65 feet of clay above the river level gives us a thickness of 130 feet at this point. The character and thickness of the overlying material varies somewhat. To the rear of Timoney's yard some 700 feet, the terrace has been excavated to a depth of 30 feet, exposing a mass of coarse sand, gravel and cobblestones, mostly granites, gneisses and schists. One portion of it is stratified, and at the base of the excavation at one point yellow clay has been found. At Timoney's yard there is 1 or 2 feet of loam overlying the clay and a growth of brush covers the terrace. At Van Buren's yard the upper layers of clay alternate with layers of sand; the upper 6 feet of the terrace at this point is gravel, the pebbles of it being mostly granite and gneisses. At Aldridge's yard the clay is covered by 6 to 8 feet of unstratified gravel and sand, while at another spot on top of this bank is 12 or 15 feet of fine yellow sand, which shows no stratification. The upper layers of Barnacue & Dow's clay are like those at Van Buren's, but covered by 4 feet of sand and over this in places 6 to 8 feet of coarse gravel. Nothing is known of the underlying material at these yards.

The whole of Denning's point is covered with a fine stratified yellowish sand. The clay, which lies at the base of the point, has a thin covering of loam, and the upper layers are somewhat wrinkled.

There is another stretch of terrace similar to that below Dutchess Junction and of the same hight, extending from one half mile above Fishkill to Low point. At most places the clay is covered by a few feet of loamy soil. Several boulders have been found in the clay at Brockway's yard. Several feet of loam

Plate 6



H. Ries photo.

Section one half mile northeast of Brockway's brickyard, north of Fishkill landing. It shows the contact of the loam overlying the clay and the stratified drift underlying the latter, the clay having thinned out.

overlie the clay at Lahey's, Brockway's and Dinan & Butler's yards. At J. V. Meade's yard, a short distance below Low point, the clay is covered by about 3 feet of sand, faintly stratified, and above this 6 to 8 feet of unstratified material; coarse sand, pebbles and cobblestones, some of them 18 inches in diameter. Most of them are archean rocks, but there are also fragments of shale, limestone, sandstone and a few of them contained Paleozoic fossils.

About 1000 feet south of Meade's yard is a gravel bank 8 to 15 feet thick of material similar to that overlying the clay in Meade's bank. At the base of this embankment in a few spots yellowish clay overlain by stratified sand has been struck.

The following sections are those of wells bored at Rhinebeck.

On the land of Robert Duckley:

Soil and yellow clay	10	feet
Blue clay	82	"
Rock	..	
Total thickness	92	"

On T. Reed's property:

Soil and yellow clay	20	feet
Quicksand	100	"
Hardpan	..	
Total thickness	120	"

On J. O'Brien's property:

Clay	20	feet
Quicksand	25	"
Hardpan	2	"
Gravel	...	
Total thickness	47	"

The clay deposits of Hudson, Stockport and Stuyvesant are like those at Coeymans Landing, being overlain in most places by a few feet of loam and underlain by dark sand and gravel. At Stockport two ice-scratched boulders were found in the clay; one of them 3 feet in diameter, the other three times as large. To the north of Brousseau's yard at Stuyvesant the surface material is stratified sand, 15 feet of it being exposed thus far.

Recently a number of borings have been made in the Hudson river clays in the interest of a syndicate, and these corroborate most of the observations already published. One interesting fact brought out by the sections is the abruptness of the face of the rock underlying the clays. The borings in no case attempted to go to the bottom of the deposit, but stopped when the sandy beds of clay, that seem to constitute a lower member of the deposit, were encountered. ("Economic geology of the Hudson river clays," C. C. Jones, *Trans. Amer. inst. min. eng.,* Feb. 1899)

The delta deposits of the streams tributary to the Hudson river are extremely interesting. They give us an idea of the size of the rivers flowing into the Hudson valley when it formed an estuary, and also indicate the amount of depression which took place at those localities. All three portions of a delta may be observed in the ancient deltas on the Hudson; they are the thin layers of loamy clay which form the secondary alluvial cone of the delta, the cross-stratified sand and gravel and the overlying unassorted material. This was observed at Haverstraw, New Windsor, Low point and Dutchess Junction.

The following streams between New York and Poughkeepsie have formed delta deposits; (as noted by Dr Frederick J. H. Merrill.[1]) Wappinger creek, New Hamburg; Fishkill creek; Indian creek, Coldspring; Peekskill; Croton river; Pocantico river, Tarrytown; Sawmill river, Yonkers; Tibbitt's brook, Van Cortland; Minisceongo creek, Haverstraw; Cedar pond brook, Haverstraw; Moodna river, Cornwall; and Quassaic creek, Newburgh. At the

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[1] *Amer. jour. sci.* June 1891. 3: 41.

Plate 7

H. Ries photo.

View looking north from N. Y. C. R. R. trestle at Peekskill, Westchester co. The terrace on the right is a 120 ft delta terrace.

Plate 8

To face page 589

H. Ries photo. Section of Croton river delta in railroad cut, one mile south of Croton landing, Westchester co.

present day but traces of these deposits remain, and the streams which formed them have cut down through them below tide level. Dr Merrill thinks it highly probable that these deltas once filled a large portion of the valley in the Highlands. At Roseton, as already mentioned, there is a deposit which may have come from the delta of Wappinger creek. Also at Jonespoint opposite Peekskill there is a terrace composed of transported material, which Dr Merrill for a while regarded as a portion of Peekskill delta; the size of the pebbles composing it caused him to give up this view. There is however in the upper portion of the terrace, a layer of unassorted material which is slightly separated from the rest; also at the south end of the terrace, a portion of thinly and obscurely stratified loamy clay, which may have formed a portion of the secondary cone of this delta. At Croton, Haverstraw and Cornwall, also at New Windsor, the clay is overlain by delta material, and where this occurs, specially at Croton, the upper limit of the clay is comparatively low, it having probably been eroded to a certain extent by the river entering the estuary at that point, and again it is not likely that very much clay would be deposited around the mouth of the river on account of the current. This may have been the case below Peekskill.

In general the upper limit of the clay increases northward as does the terrace level. To illustrate this point we have the following altitudes.

East side	
Croton	100
Peekskill	120
Fishkill	205
West side	
Haverstraw	100
Westpoint	185
Cornwall	200
Newburgh	205
Port Ewen	207
Schenectady	360

These measurements apply, of course, to the upper terrace, which can be traced along many portions of the river.[1]

An examination of the above figures and the distances between the points mentioned indicates an interesting fact. Between New York and Peekskill, a distance of 45 miles, the terrace rises 40 feet, or eight ninths of a foot a mile. From Peekskill to Westpoint the rise is eight feet a mile. From Westpoint to Newburgh the terraces ascend 2½ feet, and from Newburgh to Albany about five twelfths of a foot a mile. From the above it would seem that the uplift from New York to Albany did not increase uniformly, but was slightly greater along the axis of the Highlands. To determine this point definitely requires a large number of accurate terrace measurements. The following are the number of terraces noticed at the different localities.

Athens	2
Port Ewen	2
Cornwall	2
Haverstraw	2
Stonypoint	3
Peekskill	1[2]
Fishkill	2
Stormking	2
Schodack	2

The shore line of the upper terrace is generally some distance back from the river. In fact, as we go up the river, specially above Port Ewen, the shore line recedes. At Port Ewen the terrace is 207 feet above tide, but it is fully 225 feet at the base of Hussey mountain, which was an island in the estuary. The terrace extends up the Wallkill valley several miles.[3] It seems not improbable that a shore line of this Quaternary deposit will be found along the base of the Catskill mountains, or not far from there.

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[1] For detailed statement of terrace altitudes, see H. Ries. *Trans. N. Y. acad. sci.* Nov. 1891.

[2] There is possibly a second lower terrace at Peekskill.

[3] Mather. *Geol. New York,* 1st dist. 1843. p. 131.

Plate 9

To face page 591

H. Ries photo.

Quaternary plain at foot of Helderberg escarpment between Ravena and South Bethlehem, Albany co.

At Coeymans Landing the terrace is 140 feet, and it rises to 177 feet at the West Shore railroad station, about a mile from the river then a hill hides the farther continuation of it from view. Between South Bethlehem and Callanans Corners the shore line of the terrace along the base of the Helderberg escarpment is well seen.

From Catskill up to Albany the terrace at most points is very wide. At Coxsackie it extends behind the hill to the south of the town and comes down along Murder creek to Athens. From Albany an alluvial plain, belonging to this formation, spreads westward, reaching a hight of 360 feet near Schenectady. The surface of these terraces is usually a loamy soil of much agricultural value.

Following up Croton river as far as Croton lake, remnants of terraces are seen at various points, their hight above the river bed decreasing as we recede from the Hudson. The majority of these detached pieces seem to belong to a terrace formed at the same time as the 100 feet one at Croton landing. There are at a few places traces of a second and lower terrace, and beside this a third one, which is being formed by the river during its floods at the present day.

From the facts as observed, quoted above, the following may be deduced. That during the retreat of the ice sheet from the Hudson valley the glacial streams deposited as kames a great amount of ground up material, principally shale, the material found underlying the clays along the upper portions of the valley.

That subsequent to the retreat of the glacier there was a depression of the land, which, according to Dr Merrill,[1] amounted to 80 feet at New York city and near Schenectady to about 360 feet.

During this period a great amount of plastic clay was deposited, produced by glacial attrition of the shales and limestones, the latter no doubt giving to it the marly character and influencing its color.

The upper portion of the clay is more silicious, and overlying it is an extensive deposit of sand, indicating a change in the nature

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[1] *Amer. jour. sci.* June 1891.

of the material washed into the estuary. During the period of submergence much of the silicious matter washed into the estuary was deposited at the mouths of the tributary streams to form deltas.

It has been suggested by Dr Merrill[1] that the change in the estuary deposits from clay to sand might be due to the exposure by elevation of an area of land around the basin, which would afford more silicious matter.

An elevation would be accompanied by an acceleration of the streams, and much of the silicious matter transported by them would be carried farther out into the estuary and spread over its bottom, while the finer clayey sediment would be carried out to sea. A readvance of the ice, it would seem, would likewise cause an acceleration of the streams, and with the results stated above.

To account for the isolated boulders in the clay, it seems highly probable that icebergs or icefloes having stones and dirt imprisoned within their mass detached themselves from the retreating glacier, and, floating down the estuary to the sea, dropped their burdens.

The unstratified material found with it and in some cases overlying the stratified delta deposits is a matter of interest as concerns its origin. Three things may be noticed regarding it.

1 The material is sand, pebbles and cobblestones lying mixed together without any separation of the coarse from the fine.[2]

2 The pebbles and stone are rounded and do not show any scratches.

3 The materials are mostly of the same character as the rocks of the vicinity.

Now as the land rose from its submergence the velocity and with it the transporting power of the streams would increase, washing down quantities of large stones and gravel. Dr Merrill considers that a rapid flow of water took place down through the Hudson valley in the late Quaternary. This water must have come

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[1] *Amer. jour. sci.* June 1891.

[2] The only locality where stratification was observable was at Timoney's yard, near Dutchess Junction.

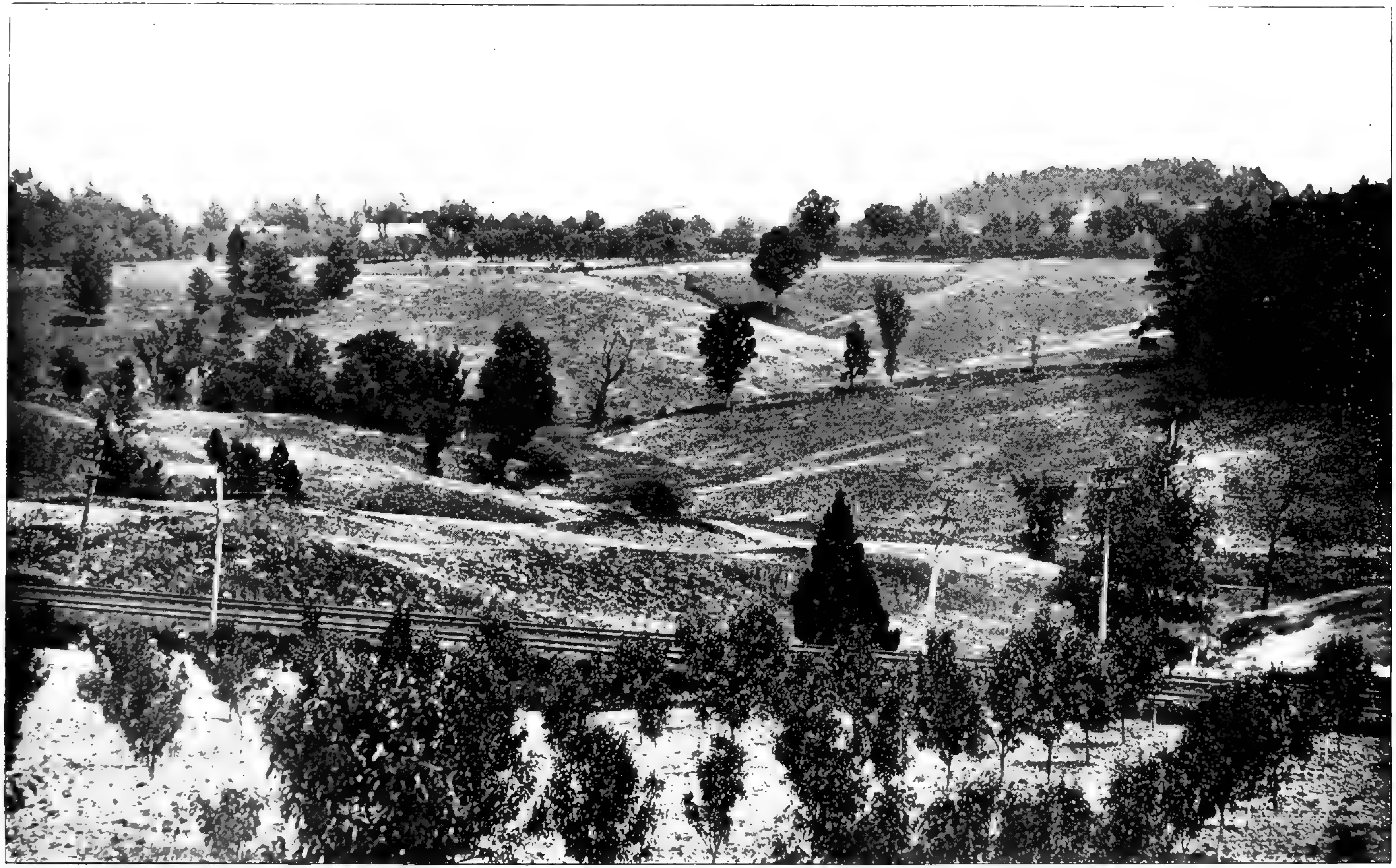
Plate 10

H. Ries photo.

Unstratified material overlying clay at Meade & Co.'s bank, north of Low point.

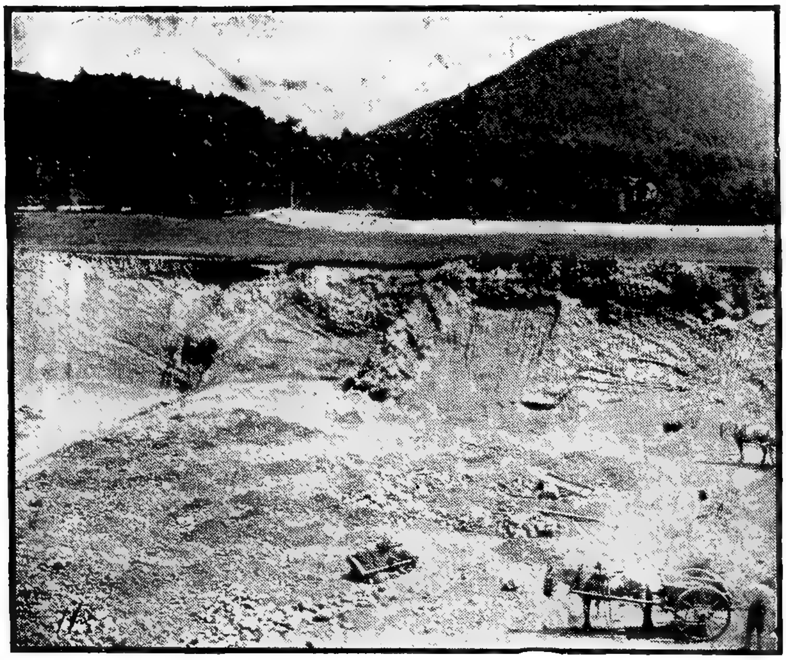
Plate 11

To face page 592



H. Ries photo.

View looking east across Champlain terrace, one mile west of Catskill. The terrace is underlain by clay and the railroad track in the foreground is the West Shore.



Terrace and sand pit, south of Dutchess Junction N. Y.

down through the valleys of the tributary streams, having a much greater velocity in their valleys than it would have after it turned into the Hudson valley, and the checking of its velocity as it reached the Hudson would cause the deposition of the greater part of its load. A large stream rushing down the valley of the Fishkill would drop its burden specially below it, where we find them heaviest as the flow of the water was toward the south. Again, Peekskill would behave in a similar manner.

A curious and interesting phenomenon is the crumpling of the clay at many localities. This disturbance often extends throughout the section, and has been caused by slips or pressure from above, as when the clay is covered by a thick delta deposit. Prof. R. P. Whitfield has told the writer of instances where the clay layers had been disturbed to a depth of several feet from the surface by the weight of boulders and large trees. In many instances there occurs a crumpled strip of clay between layers which are entirely undisturbed; this has been actually observed by the writer to have been caused by slipping of the clay.

Clay concretions. These are of common occurrence, specially in the yellow clay. They are of varying form and size. Many of them have a cylindric hole in the center, which is lined with carbonaceous material. The flat concretions are found parallel to the layers of the clay, and in many instances at a depth from the surface to which the roots penetrate.

Those found at a greater depth did not have the central cylindric cavity. They are very abundant in the yellow clay at Haverstraw. Roots penetrating the clay at this locality were surrounded by lumps of clay in the form of concentric rings. These might seem to indicate the method of formation described by Prof. J. D. Dana (*Manual of geol.* p. 628). Again in the yellow clay near the surface at Coxsackie were found some forms which were similar in appearance to what Dr J. I. Northrup has described as rhizomorphs.[1] They may be due to the roots which

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[1] *Trans. N. Y. acad. sci.* 13 Oct. 1890.

penetrate the clay, absorbing water from it and rejecting the contained lime, which deposits itself around the root forming the hard rhizomorph. Their interior structure is crystalline.

Another form of concretion is found in the delta sands at Croton point. It consists of botryoidal masses of sand, cemented by oxid of iron. Some of them show the layers of deposition of the sand. The concretions are usually small, but one mass was noticed fully 6 feet long and 4 feet wide.

Concerning the origin of these concretions various opinions are expressed by different geologists.

Organic remains are extremely rare in these clays. The writer has discovered sponge spicules, probably referable to Hyalonema or an allied genus, and which are figured. The following diatoms were also found: Navicula Gruendleri A. S.; Navicula permagna, Edw. (fragments); Melosira granulata (Ehr.) Ralfs; Nitzshia granulata Grun., all fresh water species. At Croton landing a number of impressions were found in the blue clay and on being submitted to Prof. Hall were pronounced to be worm tracks. Mather in his report[1] mentions the finding of leaves in the clay beds back of the medical college at Albany, and states that they resemble those of an aquatic plant.

Clays of the Champlain valley[2]

The clays of the Champlain valley are estuary formations of the same age as the Hudson river clays. They underlie terraces along the lake which have been elevated to a hight of 393 feet above sea level. These terraces may be traced almost continuously from Whitehall, at the head of Lake Champlain, to the northern end of the lake and beyond it, but on account of the extensive erosion which has taken place they are usually narrow, and it is only at sheltered points like Port Kent and Beauport that they become specially prominent. The section involved is

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[1] Mather. *Geol. New York*, 1st dist. 1842. p. 123.

[2] Compiled largely from Emmons's *Report geol. N. Y.*, 2 d dist.

yellowish brown sand, yellowish brown clay and stiff blue clay, the latter being rather calcareous. The upper clay is somewhat silicious, and its coloring is due to the weathering of the lower layer. This formation has a thickness of about 15 feet, but sometimes, as at Burlington, it reaches a thickness of 100 feet. Isolated boulders are occasionally found in the clays, and are considered by Emmons to have been dropped there by icebergs. The clays are usually horizontally stratified, and contortions of the layers are extremely rare. Numerous fossils have been found in the overlying sands, among them being Saxicava rugosa Lamarck and Tellina groenlandica Beck, which are very common; Tritonium anglicum, Tritonium fornicatum, Mytilus edulis Linn., Pecten islandicus Chemnitz, Mya truncata Linn., M. arenaria Linn., Nucula portlandica; the skeleton of a whale has also been found in these deposits.[1]

Openings have been made in them for the purpose of obtaining brick clays at Plattsburg and a few other localities, but, owing to the lateness of the season when I visited them, information was hard to obtain.

Long Island clays

Long Island is made up of a series of sands, gravels and clays, which form two parallel ranges of hills in the northern half of the island, while the southern half is a flat plain. The most southern of the ranges represents the limit of the drift.[2]

The clay beds are exposed along the north shore of the island and at several points along the main line of the Long Island railroad. In describing them I have gone east along the north shore and come back through the center of the island.

In a paper on the geology of Long Island, (previously cited)

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[1] The writer has found one species of diatom belonging to the genus diatoma, in the clay from Plattsburg.

[2] For a detailed account of the topography of Long Island see Mather, *Geol. New York*, 1st dist. 1843; W. Upham, *A. J. S.*, 111, 18; F. J. H. Merrill, "Geology of Long Island," *Ann. N. Y. acad. sci.* 1884.

Dr F. J. H. Merrill describes in detail the formations exposed on the island, and mentions the insufficiency of data necessary to afford definite conclusions concerning the sequence of geologic events. Examinations of the various clay outcrops on the island since made show that eight years have made considerable changes; permitting the collection of additional data and obliterating many localities described by him. With the exception of four similar deposits on the north shore, all the clay beds as exposed at the brick yards are rather unique in appearance.

The most western clay outcrop on Long Island, of which the writer has any knowledge, is on Elm point near Greatneck.[1] There is here a bed of stoneware clay over 30 feet thick, overlain by 15 to 20 feet of yellow gravel and drift. The clay is dark gray and contains streaks of lignite in a good state of preservation. In appearance the clay resembles the Cretaceous ones of New Jersey and will doubtless prove to be of the same age. The overlying yellow gravel contains sandstone concretions and also sandstone fragments containing Cretaceous leaves.[2]

There is an outcrop of clay at Glencove on the east shore of Hempstead harbor, at the mouth of Mosquito inlet. This has long been considered of Cretaceous age from the plant remains found[3] in sandstone fragments embedded in the clay. The layers of the latter are blue, red, black or yellow, and dip northeast 10°–15°. Near this locality and on the south shore of Mosquito inlet is an outcrop of pink clay, belonging to Carpenter Bros. and used for fire brick and stoneware. Dipping under it to the north at an angle of 30° is a bed of alternating layers of quartz pebbles and clay. The pebbles crush easily to a white powder. Associated with this clay is a bed of feldspathic clay called "kaolin," but the exact relations of the two deposits are not known. And similar clay also crops out from under the gravels of the west shore

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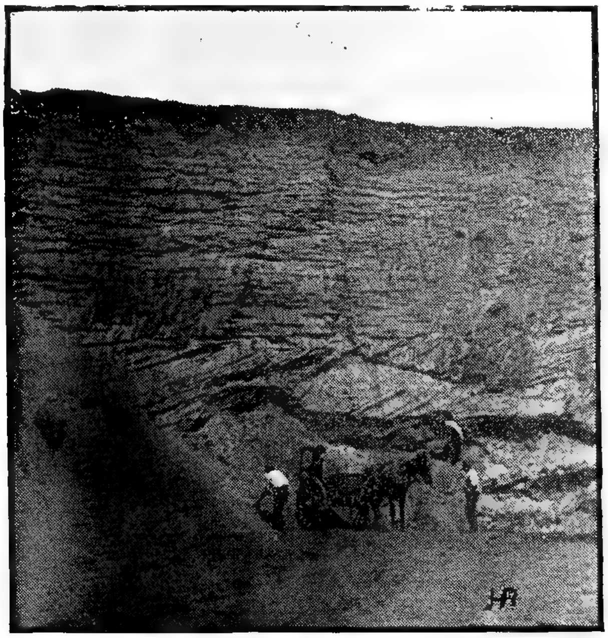
[1] H. Ries, "Notes on the clays of New York state," *Trans. N. Y. acad. sci.*, 12.

[2] C. L. Pollard, "Note on Cretaceous leaves from Elm point, L. I.," *Trans. N. Y. acad. sci.*, 13.

[3] A. Hollick, *Trans. N. Y. acad. sci.*, 12.

Plate 13

To face page 596



Stratified sands and gravels, Port Washington L. I.

of Hempstead harbor. Carpenter's clay resembles that of Cretaceous age found on Staten Island, but its age has yet to be proven. The sandstone fragments found in the clay across the inlet are found along the shore of it to Carpenter's clay bank, but none are found in it. Dr. Merrill has found plant remains in this clay, but they were not sufficiently well preserved for identification. (*See* paper previously cited.) A microscopic examination of the clay revealed the presence of the following diatoms; all freshwater forms:

Melosira granulata (Ehr.) Ralfs
Stephanodiscus Niagarae (Ehr.)
Diatoma hyemale (?) K. B.

A deposit of gray sandy clay 30 feet thick was uncovered on the north of Mosquito inlet in the spring of 1898, on the property of Mrs Helen McKenzie, but it is distinctly different in its character from that on the south side of the inlet.

On Center island in Oyster bay we find the most western of a series of clay beds which bear a great similarity to each other. The others are on West neck, at Freshpond and on Fisher's island. The clay on Center island consists of two kinds, a lower bluish clay and an upper brown sandy clay. Overlying this latter is a stratified sand. The layers of clay undulate in several directions. Dr Merrill mentions the occurrence, 1 mile north of this clay pit, of a bed of white fire clay at a depth of 25 feet under the drift and sand. The only organism thus far met in this clay is one species of diatom, viz, Stephanodiscus Niagarae (Ehr.), and a curious spiny hair.

At Jones's brick yard on the east shore of Coldspring harbor is a thick deposit of clay. The lower portion is tough and contains little sand. The upper portion is much more sandy and of a brown color. The clay bank is over 100 feet in hight, the layers having been folded under the pressure of the advancing ice sheet. A layer of diatomaceous clay occurs in the upper portion of the clay bank; its position is shown in the following section given by Dr. Merrill.[1]

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[1] *Ann. N. Y. acad. sci.* 1884.

"Till" and stratified drift	10	feet
Quartz gravel	45	"
Red and blue "loam" or sandy clay	20	"
Diatomaceous earth	3	"
Yellow and red stratified sand	20	feet
Red plastic clay	20	"
Brown plastic clay	25	"
Total	143	"

"The bed of diatomaceous earth is of undetermined extent, and appears to be replaced a little to the east by a blue clay, which, however, contains some diatoms. It is undoubtedly equivalent to the bed of ochre which overlies the sand throughout the remainder of the section."

The following diatoms, all freshwater species, occur in it.

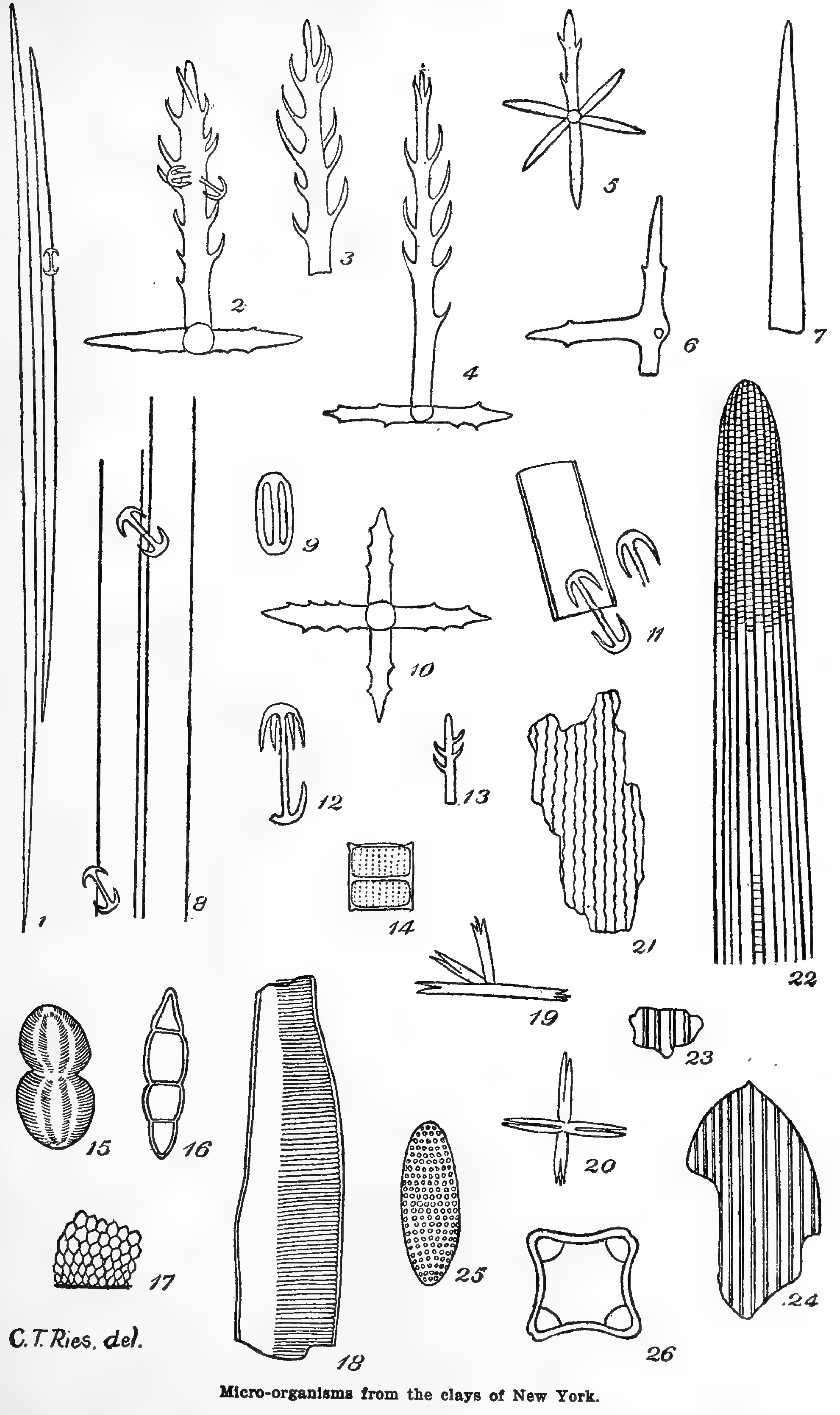
Melosira granulata (Ehr.) Ralfs
Stephanodiscus Niagarae (Ehr.)
Epithemia turgida (Ehr.) Kutz.
Encyonema ventricosum Kutz.
Cymbella delicatula Kutz.
Cymbella cuspidata Kutz.
Navicula viridis Kutz.
" *coconeiformis* Greg.
" *major* Kutz.
" *varians* Greg.
" *lata* Breb.
Eunotia monodon Ehr.
Gomphonema capitatum Ehr.
Stauroneis Phoenecenteron Ehr.
Fragilaria construans Grun.
Synedra affinis K. B.
Campyloneis Grevillei var. *regalis*.
Triceratium trifoliatum

The Melosira and Stephanodiscus are present in countless numbers. Only two specimens were found of the Triceratium, and Dr D. B. Ward, of Poughkeepsie, who has also given me much aid in the identification of my material, informs me that this species is very common in the diatomaceous earth from Wellington, New Zealand, but he has never heard of its occurrence before in America. Sponge spicules are not uncommon in Lloyd's neck diatomaceous earth, and several forms are figured. Samples of the red and brown clay from the section given above were examined, but no organic remains were found in them.

(Magnified 500 diameters, except Fig. 1, which is enlarged 250 diameters)

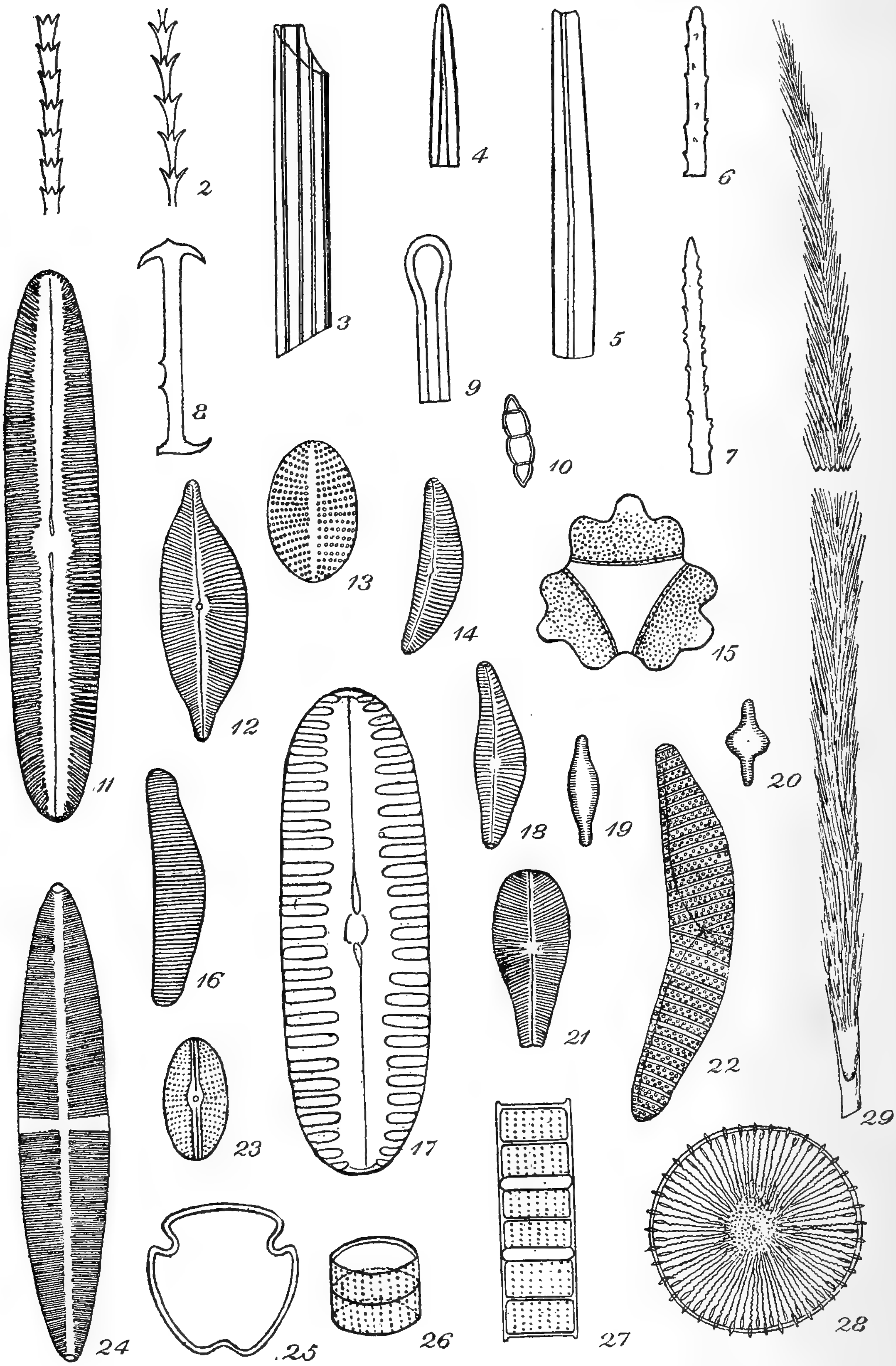
Fig. 1–13 Sponge spicules. Croton point
Fig. 14 *Melosira granulata* (Ehr.) Ralfs. Croton point
Fig. 15 *Navicula Gruendeleri* A. S. Croton point
Fig. 16 *Diatoma* sp? Plattsburg
Fig. 17 Diatom fragment from Croton point
Fig. 18 *Navicula permagna* Edw. Croton point
Fig. 19, 20 Sponge spicules. Kreischerville, S. I.
Fig. 21–24 From clay at Verplank
Fig. 25 *Nitszchia granulata* Grun. Croton point
Fig. 26 From clay at Croton point

Plate 14



Micro-organisms from the clays of New York.

Plate 15 To face page 601



C.T. Ries, del.

Micro-organisms from the clays of New York.

(Magnified 500 diameters)

FIG. 1, 2 Jointed hair. Wyandance, L. I.
FIG. 3 Ridged tube from stoneware clay. Glencove, L. I.
FIG. 4, 5 Spicules from cretaceous clay at Glencove, L. I.
FIG. 6–8 Spicules from Lloyd's neck, L. I.
FIG. 9 Spicule fragment? Farmingdale, L. I.
FIG. 10 *Diatoma hyemale.* Glencove, L. I.
FIG. 11 *Navicula viridis* Kutz. Lloyd's neck, L. I.
FIG. 12 *Cymbella cuspidata* Kutz. Lloyd's neck, L. I.
FIG. 13 *Campyloneis Grevillei* var. *regalis.* Lloyd's neck, L. I.
FIG. 14 *Cocconema parvum* W. Smith. Northport, L. I.
FIG. 15 *Triceratium trifoliatum.* Lloyd's neck, L. I.
FIG. 16 *Eunotia monodon* Ehr. Lloyd's neck, L. I.
FIG. 17 *Navicula lata* Breb. Lloyd's neck, L. I.
FIG. 18 *Encyonema ventricosum* Kutz. Lloyd's neck, L. I.
FIG. 19 *Synedra affinis* K. B. Lloyd's neck, L. I.
FIG. 20 *Fragilaria construans* Grun. Lloyd's neck, L. I.
FIG. 21 *Gomphonema capitatum* Ehr. Lloyd's neck, L. I.
FIG. 22 *Epithema turgida* (Ehr.) Kutz. Lloyd's neck, L. I.
FIG. 23 *Navicula cocconeiformis* Greg. Lloyd's neck L. I.
FIG. 24 *Stauroneis phoenecenteron* Ehr. Lloyd's neck, L. I.
FIG. 25 From clay at Northport, L. I.
FIG. 26, 27 *Melosira granulata* (Ehr.) Ralfs. Lloyd's neck and Glencove, L. I.
FIG. 28 *Stephanodiscus Niagarae* Ehr. Lloyd's neck and Glencove, L. I.
FIG. 29 From clay at Oyster bay.

Concretions are abundant in the clay on Center island and West neck. Those found at the latter locality are disc-shaped, while those found on Center island are more or less botryoidal.

Silicified yellow gravel fossils have been found by the writer in the sands on West neck,[1] and more were subsequently found in other localities by Dr Hollick.[2]

On Little neck, in Northport bay, is an extensive deposit of stoneware clay and fire sand, which has been worked for a number of years. The clay is stratified, the layers being separated by laminae of sand. In color the material varies from black to brown and yellow, and it becomes sandy in its upper portion. There is a dip of 15° se due to a slipping of the clay bank. Overlying the clay is cross-bedded fine sand and gravel, the latter containing much coarse material near the surface. Very little till covers the whole. Much fine, white fire sand occurs in portions of the bank. A careful examination of the section showed a brownish black seam of the clay, 2 feet thick, containing numerous fragments of plant remains, of which a number were sufficiently well preserved to determine the Cretaceous age of the clay beyond doubt. The species were identified for me by Dr Hollick as follows:

Protaeoides daphnogenoides Heer
Paliurus integrifolia Hollick
Laurus angusta Heer
Myrsine sp.
Williamsonia sp.
Celastrophyllum sp.
Paliurus sp.

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[1] *Trans. N. Y. acad. sci.*, 12.
[2] *Trans. N. Y. acad. sci.*, 13.

The latter resembles Paliurus Columbi (Heer); a Tertiary species (*Fl. foss, arct.* 1: 122, pl. 17, fig. 2), but is much smaller and very probably a new species. The above species are the same as those found in the middle Cretaceous clays of Staten Island N. Y., and Perth Amboy, N. J.

Three species of diatoms, all fresh water forms, were also discovered in this clay.

Melosira granulata (Ehr.) Ralfs

Diatoma hyemale K. B.

Cocconema parvum W. Smith

The occurrence of these diatoms is a matter of great interest.

While diatoms are abundant in the Tertiary, their only known occurrence in the Cretaceous is the chalk[1] which is upper Cretaceous. This being the case, their occurrence at Northport extends the known geologic range of diatoms.

At Freshpond the clay crops out along the shore for a distance of half a mile. It is brownish and red in color, the red being more sandy. Sand and gravel overlie it, and at Sammis's yard the sand, which is stained by limonite, shows a fine anticlinal fold.

One of the most interesting clay banks is that on Fisher's island. The clay is of a reddish color similar to that on West neck and Center island, and in its original condition was horizontally stratified and overlain by 20 to 30 feet of laminated sand. But the whole deposit has been disturbed by the ice sheet passing over it, and the layers have been much crumpled to a depth of about 30 feet, while below this they are undisturbed. The till overlying it is in places 30 feet thick and contains large boulders.

Dr Merrill mentions the presence on Gardiner's island,[2] of extensive beds of brick clay together with their associated sand beds, (they are not being worked) and notes the occurrence of a fossiliferous stratum. Clay is also said to outcrop near Sag Harbor and around the shore of Hog neck in Peconic bay.

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[1] Nicholson. *Manual of palaeontology.* 2: 1490.

[2] Previously cited.

Between Southold and Greenport are several deposits of a red glacial clay which is used for brick. The clay contains angular stone fragments and runs from 50 to 60 feet in thickness. About one mile and a half east of Southold is a bed of mottled blue pottery clay which has been used for a number of years in making flower pots. The depth of this deposit is not known.

At West Deerpark is a clay bank of unique appearance. In July 1892 the section showed:

	Yellow gravel	6	feet
Containing concretions	Flesh colored clay	6	“
	Red clay	1	foot
	Black clay with pyrite	4	feet
	Black sandy clay	4	“
	Red sandy clay	3	“
	Total thickness	24	“

Lenticular masses of gray sand are sometimes found in the black clay. The black clay also contains frustules of Melosira granulata, (Ehr.) Ralfs, and numbers of a jointed yellowish brown hair, resembling those of a crustacean. The black clay burns to a white brick. About 4 miles west of this locality near Farmingdale the section in Myers's clay pit is:

Sand and gravel	6	feet
Red sandy clay	6	“
Yellow and red sand, wavy lamination	2	“
Reddish yellow clay	6	“
Reddish blue clay	20	“
Micaceous sand, cross-bedded	..	
Total thickness	40	“

H. Rics photo.

Clay bank, Garden City brick co. one and one half miles north of Farmingdale L. I.

About one quarter mile south of Myers's brick yard is that of Stewart. The section at this locality (now obliterated) as given by Dr Merrill[1]:

Surface stratum yellow micaceous clay	35	feet
Reddish and sandy clay	5	"
Blue black sandy clay with nodules of white pyrites	25	"
White sand	..	
Total thickness	65	"

A local deposit of grayish blue sandy clay occurs at East Williston. It varies in depth from 6 to 20 feet and is underlain by sand. On my last visit to this locality I found a number of stems and leaf fragments in the clay but none sufficiently well preserved for identification.

There is still some doubt as to the exact conditions under which the beds of clay and gravel which form the greater portion of Long Island were deposited, but it is probable that the clays represent shallow water marine deposits of Cretaceous and Tertiary age. The overlying sands and gravels have in most instances a cross-bedded structure, with a south dip, and were probably deposited by swift currents as stated by Dr Merrill.

The age of the clays is still largely a matter of speculation, and will probably remain so in many cases unless paleontologic evidence is forthcoming. Those on Gardiner's island are quite recent, as shown by the contained fossils, and the clay on Littleneck near Northport is Cretaceous as previously noted. The proof of the age of the Glencove clay is not absolute.

Cretaceous leaves in fragments of ferruginous sandstone have been found along the north shore of Long Island from Greatneck

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[1] F. J. H. Merrill. "Geology of Long Island," *Ann. N. Y. acad. sci.* Nov. 1884.

to Montauk point,[1] but they are usually much worn and scratched and have evidently been transported from some distant source. The clays at Center island, West neck, Fresh pond and Fisher's island are very similar in appearance and composition, and are very probably of the same age, possibly Tertiary,[2] but we lack paleontologic or stratigraphic evidence. At West neck the clay underlies the yellow gravel and the latter is covered by the drift, so that is Prepleistocene.

The theory has been put forth that the Cretaceous formation on Long Island would be found north of a line joining the southern border of the Cretaceous formation of New Jersey and Marthas Vineyard,[1] and that outcrops south of this might be Tertiary; in view, however, of determining the clay at Littleneck near Northport to be Cretaceous, we must abandon this theory.

An interesting phenomenon is the tilting and crumpling of the strata on the north shore of Long Island. This disturbance is specially well shown on West neck, and was considered by Dr Merrill to be due to the pressure of the advancing ice sheet,[3] which excavated the deep narrow bays and pushed the excavated material into high hills at their head. Dr Merrill's views have been recently corroborated in a paper on "The deformation of portions of the Atlantic coast plain," by A. Hollick,[4] who, in disputing the possible orogenic origin of these folds, calls attention to the fact that they are found only along the line of the moraine, and that the beds are disturbed only to a certain depth. The disturbance is well shown at Glencove, West neck, Freshpond and on Fisher's and Gardiner's islands. It is important, however, not to confound tilting of the layers, due to slipping, as is the case on Littleneck near Northport, with that produced by the ice-thrust.

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[1] A. Hollick. "Notes on geology of north shore of Long Island," *Trans. N. Y. acad. sci.*, 13.

[2] This idea is also expressed by Dr Merrill.

[3] "Geology of Long Island." *Ann. N. Y. acad. sci.* 1884.

[4] *Trans. N. Y. acad. sci.*, 14.

Both Dana and Merrill consider Long Island sound to be of preglacial origin. The former calls attention to a channel in the southern part of the sound, which probably was that of a river draining Connecticut in preglacial times, and which emptied into Peconic bay. The latter points to the absence of till along the north shore of Long Island where the sound is wide, as evidence of the fact that most of the drift was dropped into the sound by the ice in its passage across it.

On the other hand Hollick considers that Long Island sound was dry land till the glacial period, and that the continental glacier upon its arrival on the Connecticut shore plowed up the material from the space now occupied by the sound and pushed it ahead to form the range of hills along the northern part of Long Island. It seems to the writer however that the facts do not support this theory. If we suppose the northern range of hills to be composed of material pushed up out of the area now occupied by the sound, it should everywhere show signs of disturbance. This it does not do. The high hills of sand and gravel at Port Washington for example show no signs of disturbance.

Mention should be made of a yellow gravel formation. This is found almost everywhere on Long Island, and sections in the railway cuttings frequently show a thickness of 30 or 40 feet.

Staten Island clays

The chief outcrops of clay on Staten Island are at Kreischerville, Greenridge and Arrochar. Besides the clay there are several sand beds known as "kaolin."

In many instances the clays and overlying yellow gravels have been much disturbed by the passage of the ice over them, and in some cases the sections show overthrown anticlines, as on the fingerboard road at Clifton.

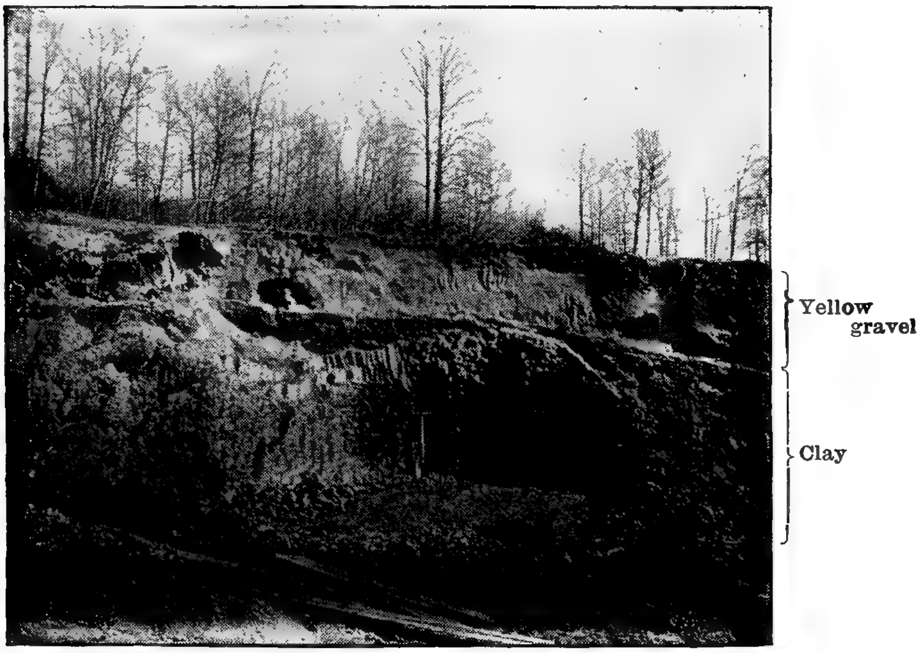
W. Kreischer informed me that the clay at Kreischerville occurs in isolated masses or pockets in the yellow gravel and sands. If such is the case, and if these beds, as is usually supposed, are a continuation of the New Jersey beds, they must be explained as follows: either the original beds have been torn apart by the ice which bore down on them, or else they have been deeply eroded by the currents which deposited the overlying sands and gravels. The writer favors the latter view.

A boring made on the site of Kreischer's fire brick factory showed:

Sand and soil	30	feet
Blue clay	90	"
White sand	2	"
Sand and clay alternating	78	"
Total thickness	200	"

Next to the church at Kreischerville is a bank of stratified sand standing some 40 feet back from the road. It appears to have been dug away considerably, but Mr Kreischer informed me that there was once a large mass of clay at this spot which was surrounded by the sand. To the north of this near the shore is a bank of blue stoneware clay overlain by yellow laminated sand, and southeast of the church is a similar bank, but the clay is of a more sandy nature. A third opening is opposite Kilmeyer's hotel at Kreischerville, and from this a yellow mottled fire clay is obtained. This latter bed is overlain by about 20 feet of sand and yellow gravel and underlain by a white sand.

A fourth opening on the shore is in a blue clay. It has always been an interesting question as to what extent Staten Island was underlain by the Cretaceous formation; the following record of a well bored for Bachman's brewery at Annandale, S. I., seems to throw some light on the subject. At a depth of 200 feet a bed of yellow gravel containing shells was struck. The gravel was 36 feet in thickness and beneath it was a bed of clay 10 feet thick. The latter was of a white and blue color and was said to resemble a fine pottery clay.



Cretaceous clay pit at Kreischerville. The yellow gravel overlies **the clay**.

The above may very possibly be some of the Cretaceous clay overlain by the yellow gravel. Borings made at various points along the shore of Arthur's kill, between Kreischer's factory and Wood & Keenan's brick yard, penetrated a blue clay at a depth of 3 or 4 feet. This latter is no doubt of very recent origin.

At the Anderson brick co.'s pit near Greenridge, the lower clay, which is of a black color, shows signs of disturbance, and slickensided surfaces are common. The upper portions of the bank are of blue and gray colors, and at one spot there is a thick seam of lignite. The clay is not sufficiently refractory for fire brick. Fragmentary plant remains were found by the writer in this pit, but they are not nearly so perfect as those found in the fire clay pit at Kreischerville, and which have been figured and described in minute detail by Dr Arthur Hollick of Columbia university.

Spicules have been observed in the fire clay at Kreischerville, Staten Island. In the kaolin found near Kreischerville were discovered a number of diatoms, which Dr Ward informs me are either Cocconeis placentula Ehr., or Cocconeis Pediculis Ehr. Their occurrence is also of great interest, as these kaolins are known to be middle Cretaceous beyond doubt.

Stony glacial clays occur also underlying the flats at Green ridge, Staten Island.

One mile and a quarter northeast of Kreischer's fire brick factory an excavation has been made for obtaining a micaceous kaolin. About 15 feet of it is exposed. A quarter of a mile north of this locality is the pit of the Staten Island kaolin co. The kaolin is evidently a continuation of that exposed in Kreischer's pit, but is apparently not as thick. The deposit has suffered disturbance by the ice sheet and the layers are intermixed with the till. At the northeast side of the excavation a bluish sandy clay containing fragments of lignite is found to underlie the kaolin.

In the spring of 1898 Kreischer Bros. opened a new pit just across the road from Kilmeyer's hotel. The clay is pure white and some of it contains 97% of clay substance. It is extremely refractory, as shown by the tests given in a later part of the report. At the time of my visit the workings were not deep enough to show the relations of the clay deposit.

As the Cretaceous clays, kaolins and yellow gravels are a continuation of the belt extending across New Jersey, the history of their deposition is the same.[1]

The following analysis of the so-called kaolin from Campbell's pit on Staten Island is given in the New Jersey clay report cited above.

Silicic acid and sand	92.70
Al_2O_3 and F_2O_3	5.70
H_2O	.70
K_2O	.35
	99.45

A point that impresses itself on one's notice is the abrupt change in color which often takes place in the clays of the Staten Island Cretaceous, the same bed at one place being brilliantly colored by iron, while only a few feet from it the clay may be perhaps black, or even nearly pure white.

The Cretaceous age of the Staten Island clays has been clearly demonstrated by the many specimens of leaves described by Dr Arthur Hollick from these beds. (*See* "Paleontology of the Cretaceous formation on Staten Island," *Trans. N. Y. acad. sci.* 1892. 11: 96–104, pl. 1–4. "Additions to the paleobotany of the Cretaceous formation on Staten Island," *Ibid.* 1892. 12 : 28–39; 1–4. "Additions to the paleobotany of the Cretaceous formation on Staten Island," no. 2, *Annals N. Y. acad. sci.* 11: 415–30)

In the last of these papers Dr Hollick states that it was previously taken for granted that the clays on Staten Island were continuous

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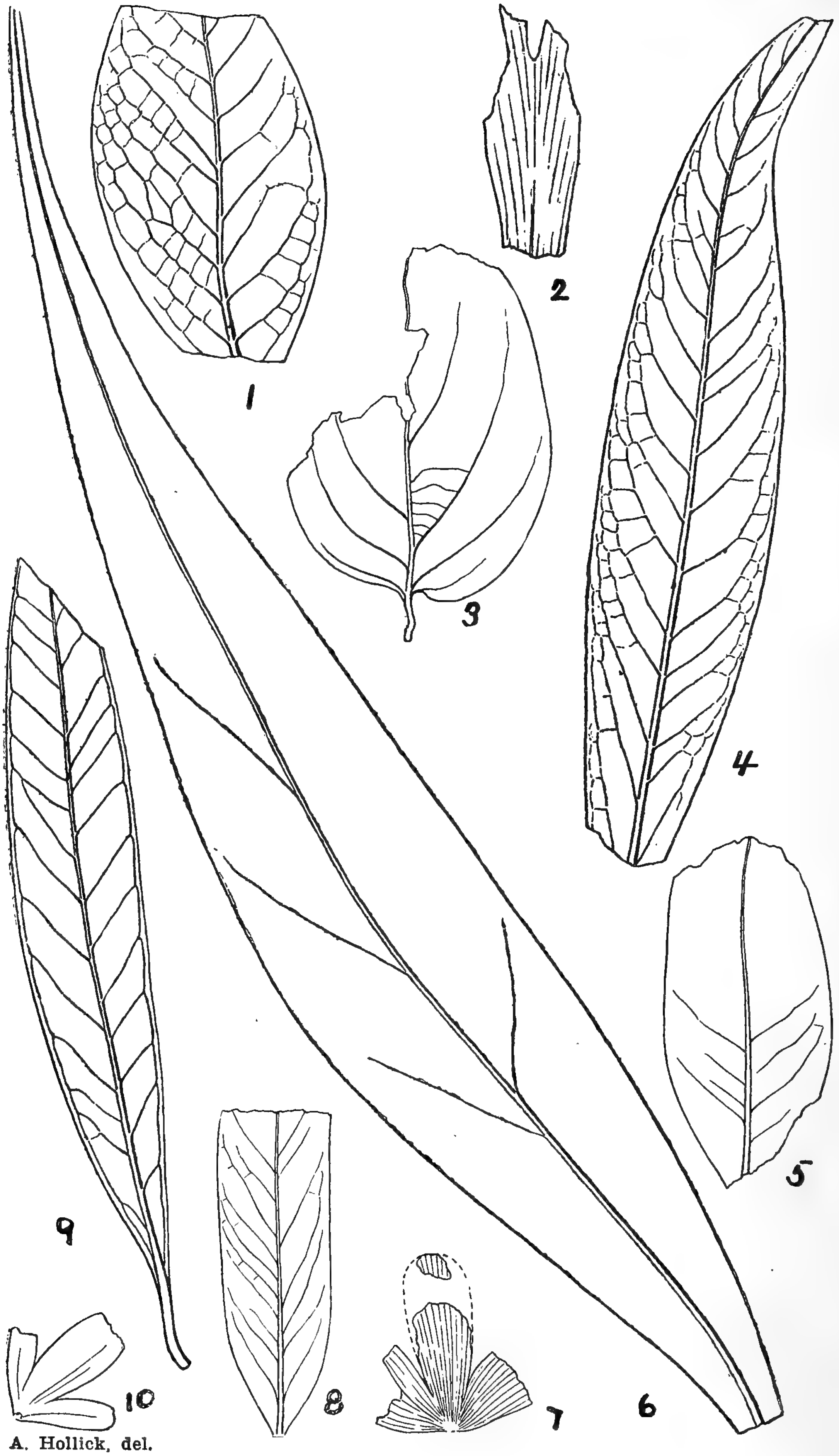
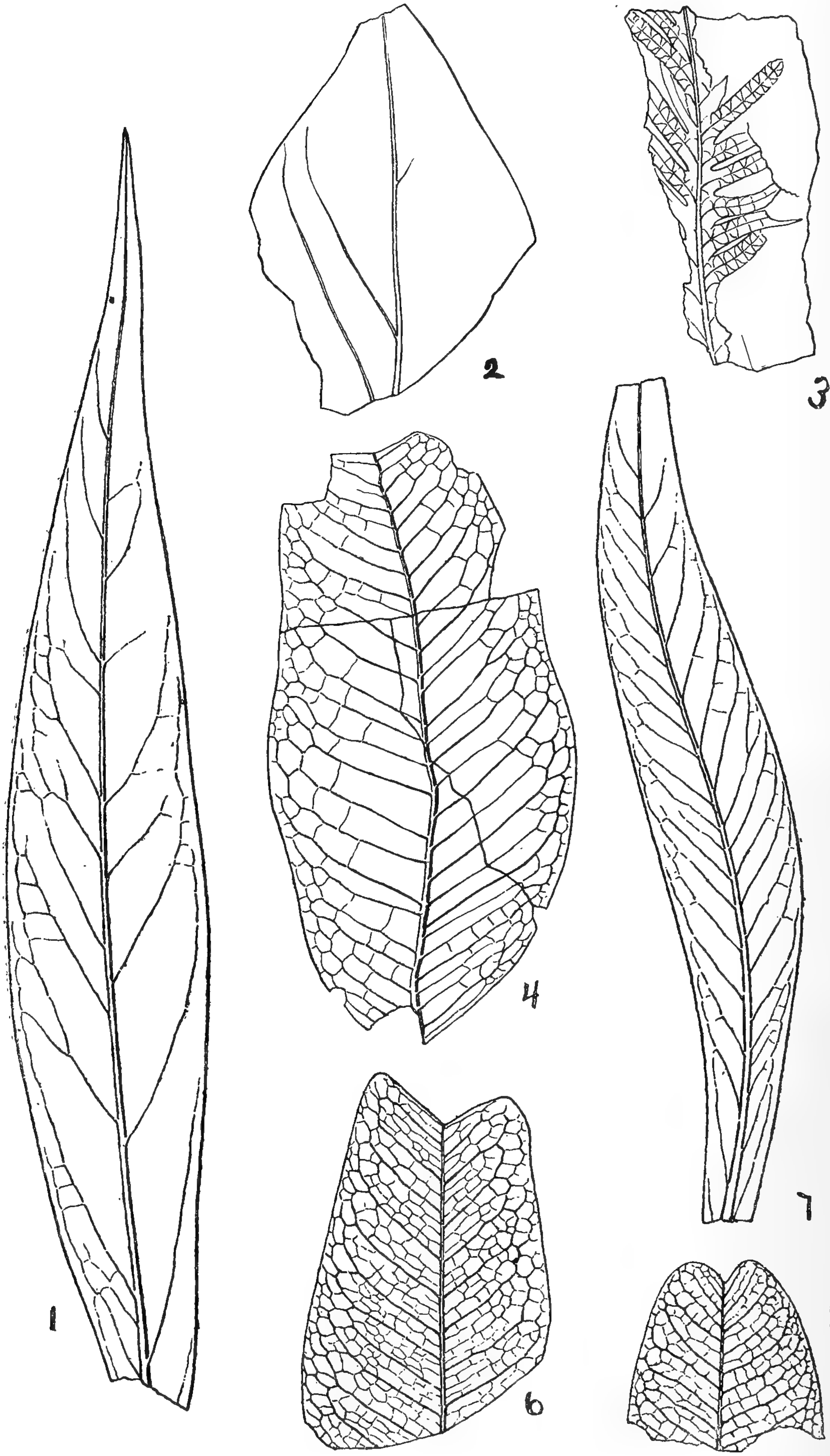
[1] *N. J. geol. sur.* 1878. G. H. Cook. Clays of New Jersey.



A. Hollick, del.

Cretaceous plant impressions from the Staten Island clays.

1 Rhamnus Rossmassleri, Ung. Tottenville.
2 Thinfeldia Lesquereuxiana, Heer. Princes Bay.
3 Pterospermites modestus, Lasq. Tottenville.
4 Laurus plutonia, Heer. Tottenville.
5 Myrsine elongata, Newb. Arrochar.
6 Protaeoides daphnogenoides, Heer. Tottenville.
7, 8 Tricalycites papyraceus, Newb. Tottenville.
9 Eucalyptus Geinitzii, Heer. Tottenville.
10 Myrica longa, Heer. Arrochar.



A. Hollick, del.

Cretaceous plant impressions from the Staten Island clays.

1 Protaeoides daphnogenoides, Heer. Tottenville.
2 Populus apiculata, Newb. (?) Arrochar.
3 Moriconia cyclotoxon, Deb. & Etts. Princes Bay.
4, 5 and 6 Liriodendropsis simplex, Newb. Tottenville and Princes Bay.
7 Laurus plutonia, Heer. Tottenville.

with those of the mainland of New Jersey and that the plants found in them would prove to be identical with those found on the mainland, but this has not turned out to be the case. Many of them are identical, but still a number have been found on the island that have not been found on the mainland, and he considers that the Staten Island beds represent a higher member of the Amboy series.

In plates 18 and 19 are given the more characteristic species taken from Dr Hollick's papers.

Occurrence of clay in the United States

In the following pages a brief summary is given of the occurrence of clay in other portions of the United States. For those desiring to obtain more detailed information the references are given in each case.

Alabama[1]

With the exception of the loams and clays used in making common and ornamental bricks, and to a limited extent paving and fire brick, the clays of Alabama are practically undeveloped.

Brick clays and loams. Material for common building brick, and that most extensively used, is the yellow loam of the second bottom or terraces of the rivers and larger streams, which traverse the coastal plain.

In the Paleozoic formation are deposits of clay and loam, partly of a residual nature or sometimes of sedimentary origin, which are frequently made into brick. Of these the ordinary red clays make a brick which is generally hard and durable.

At Oxford a clay occurs which burns to a cream colored brick. Similar clays are used in the same way near Anniston and other points in the Coosa valley region.

Vitrified brick are made from the shale occurring with the coal at Coaldale in Jefferson co. Materials of this kind also exist at other points in the Coal Measures.

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[1] E. A. Smith. "Clays of Ala.," *Ala. ind. & sci. soc.* 27. 1892. Ala. geol. surv. 1900. H. Ries. Preliminary report on clays of Ala.

The red and purple clays of the Tuscaloosa formation would probably also make a good vitrified brick.

China clays and stoneware clays. These occur in the counties of Randolph, Clay, Cleburne and others, and are sedimentary.

Among the residual deposits of the Cambrian and Silurian formations are large beds of white clay, which are sometimes associated with limonite beds, as at Rockrun.

The subcarboniferous formation contains some good deposits of white burning clay, near Fort Payne, Valleyhead, etc.

In the Cretaceous formation are important beds of clays of various qualities, which outcrop in a belt extending from Columbus, Ga., into the northwest corner of the state.

Fire clays occur and are mined at Woodstock, Bibbville, Oxford, etc.

Arkansas

In the Mesozoic regions of Arkansas are found a great variety of clays. Those occurring within the Tertiary region have been used for the manufacture of pottery, but the Cretaceous clays have not yet been employed for this purpose. Kaolin is said to occur in Pike, Pulaski, Saline, and Ouachita co., but the beds are seldom over 2 feet in thickness. (*Ark. geol. sur.* 1888. 5: 11)

The deposits of Pulaski co. are the only ones of those above mentioned that are true kaolins, the others being white burning sedimentary clays. Good brick clays are found in all second bottom streams, and bricks are made at Little Rock, Texarkana, Arkadelphia, etc. Paving bricks are made at Fort Smith.

Colorado[1]

The clay-bearing formation of Colorado may be roughly divided into the following three groups:

1 Loess, and alluvial deposits
2 Jura-Trias, and Cretaceous
3 Tertiary clays

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[1] H. Ries. *T. A. I. M. E.* 1897, p. 336.

The loess forms an extensive deposit over a large area, not of great thickness, which extends from north to south across the state and eastward from the foothills. It is generally a very sandy clay with little plasticity. Clays of similar nature to the loess are found underlying the river terraces in many of the broader valleys such as those of the Arkansas, Grand river, etc.

The Mesozoic formations extend along the eastern edge of the Rocky mountains, and also occur in some of the deeper valleys tributary to the foothill belt. They consist of a great series of interbedded shales, sandstones, and limestone of Jura-Trias and Cretaceous age, the beds being tilted at a high angle. The Jura-Trias shales have not been utilized, but the Cretaceous which overlie them have and the Tertiary or Denver beds, which carry great deposits of clay, have been mined near Golden and Boulder.

Brick clays. All of the common brick manufactured in Colorado are made either from the loess or the river clays in the valleys.

Pressed brick clays. The Cretaceous and Tertiary formations of Colorado contain an abundance of clay suitable for the manufacture of pressed brick. They are mined at Golden, Boulder, and La Junta.

Fire clays and pottery clays. These two grades of clays occur in close association interbedded with the Dakota sandstones, in the hogbacks extending along the eastern edge of the Rocky mountains. The fire clay has been extensively mined at Golden, Parkdale, and more recently at Delhi. The beds range in thickness from 4 to 18 feet.

Clay products. Common bricks are manufactured at many localities in the state. Pressed brick are only made at La Junta, Golden, Boulder and Denver. Paving bricks have been produced in small quantities, and stoneware and sewer pipe have also been produced to a limited extent. The most important clay products made in Colorado are refractory wares, such as fire brick, locomotive blocks, muffles, scorifiers and crucibles. This is naturally one of the important lines of the clay-working industry of the west, and those well made bear an excellent reputation; indeed the Denver fire clay crucibles are considered by many to be fully equal to the English.

Connecticut

Sedimentary clays of Quaternary age are found in many of the valleys in great abundance; they resemble in character those of the Hudson valley, and northern New Jersey. They form the basis of an important industry, specially in the Connecticut valley.

The clay products manufactured in Connecticut are with the exception of building brick made chiefly from clays obtained from other states.

Delaware

Kaolin of excellent quality is extensively mined at Hockessin, Newcastle co.; fire clays of Cretaceous age have also been worked in the state.

The Columbian formation affords an abundant supply of brick clays.

Florida

The clay resources of Florida may be grouped under three heads, i. e. kaolins, common brick clays, and fullers' earth. The kaolins are not such in the true sense but are really sedimentary clays, but they have a high degree of purity. Two important deposits of this material are at present known to exist in the state. The first of these at Edgar, Fla., where the bed of ball clay mined is more than 30 feet thick; the other deposit occurs near Lake City, and extends along the Palatlakaha river for a distance of about 4 miles. This deposit has been but little mined. This plastic ball clay consists of about 75% of quartz pebbles, and 25% of clay substance. The quartz is easily washed out, leaving a very pure product, which is shipped north and used by many of the manufacturers of white earthenware.

The brick clays are of course found at many localities and are most extensive at Jacksonville.

Fullers' earth was first discovered at Quincy, Fla.; it has been mined more at that point than at any other, but it is known to occur at several localities between Quincy and River Junction, as well as outcrop at several places around Tampa bay.

Georgia

Building brick are made at many localities, either from alluvial clays found in the river valleys or from residual clays which occur everywhere in the area underlain by the crystalline rocks.

Kaolin, sometimes of a pure white color, occurs in pockets in the residual earths of the Knox dolomite, while clays resulting from the decay of the Paleozoic rocks are also common, but many of them are easily fused. (J. W. Spencer. *Report on the Paleozoic formations of Georgia,* 1893) According to Prof. Spencer, the most extensive clay deposits occur along the northern belts of the Tertiary strata in the southern part of the state.

The Potomac formation specially contains many clays of a white or nearly white color, which are often of a very high refractory quality. (G. E. Ladd. *American geologist.* Ap. 1899. p. 240)

Indiana

In recent years two important contributions bearing on the clay resources of Indiana have been published by the present state geologist. (*See* 20th and 22d *ann. rep't Ind. geol. sur.*)

In speaking of the Indiana clays in general, it can be said that there are

1 Residual clays, viz, *a*) rock kaolins of Lawrence and adjoining counties, *b*) surface clays of the driftless area of southern Indiana

2 Sedimentary clays including *a*) shales and fire clays of Paleo-

zoic age, *b*) alluvial clays along the streams, *c*) drift clays of northern and central Indiana.

The clays of the coal-bearing counties support an active and rising industry, and these are found in the following counties, Fountain, Vermilion, Parke, Vigo, Clay, Owen, Sullivan, Greene, Knox, Daviess, Martin, Dubois, Pike, Gibson, Vanderburg, Warwick, Spencer and Perry.

The following represents a typical section from the Indiana Coal Measures.

		Ft	In.
1	Soil and surface drift clay	9	..
2	Blue compact shale	27	..
3	Dark bituminous shale	3	2
4	Coal	2	7
5	Fire clay	4	4
6	Drab siliceous shale	18	..
7	Sandstone	6	3
8	Dark bituminous shale	1	..
9	Coal	4	8
10	Fire clay	3	10

The fire clays no. 5 and 10 are universally present. No. 2 and 6 are considered, taken as a whole, to be the most valuable clay beds in the state.

Important clay deposits also occur in the counties of Benton, Newton, Jasper, Starke, Lake, Porter, La Porte and St Joseph.

Those of Benton co. are of glacial origin, as are those of Newton co.; most of the other counties mentioned contain glacial clays. The Porter co. clays are both glacial and marly. The latter are made into pressed brick by hydraulic brick machines. Around South Bend and St Joseph co. are thick deposits of pearl gray, marly clay of a very fine grain and plastic nature, which burn to a light yellow building brick or a greenish yellow paving brick.

Kansas

Most of the clay deposits of this state are surface beds of Quaternary age. The loess is extensively used in the eastern counties; at Pittsburg a 10 foot bed of Carboniferous shale occurs, which is used for the manufacture of fire brick and paving brick. Fire clays also occur at a number of other localities in association with the coal beds, but they have not been used to any great extent.

Kentucky

The state of Kentucky contains numerous clay deposits, many of them of excellent quality.

They are found in several geologic formations, beginning with the Cretaceous, of western Kentucky, which shows an abundance of brick clay, fire clay and pottery clays.

In the Cretaceous and the Coal Measures, clay suitable for making vitrified brick as well as fire brick, occurs.

Fire clay is found in Carter co., where it is now being mined and carried to Louisville for manufacture. Similar clays are known in the counties of Ballard, Muhlenberg, Grayson, Edmonson, Graves, Hickman, Calloway, Fulton, Bell, Boyd. Most of these clays are said to run high in silica and alumina and low in fluxes.

The clay from Graham station, in Carter co., is of high quality. A flint clay from this locality shows on analysis:

Silica	49.75
Alumina	35.16
Oxid of iron	.30
Lime	.54
Magnesia	.15
Potash and soda	.07
Water	14.03

This clay is used for making locomotive fire box tiles, cupola tile, glass furnaces, grates, boiler tiles and stove linings. Vitrified brick clay has been developed at Cloverport, and in Grayson near Millwood, about 80 miles from Louisville, it being worked at this point by the Louisville sewer co.

Potters' clay is found chiefly in the Tertiary beds which are found in the Jackson purchase. This region includes the counties of Calloway, Graves, Marshall, Hickman, Fulton, Butler, Edmonson, Grayson, Ohio and Madison. The best developed mine is that at Pyorsburg, 6 miles from Mayfield in Graves co.; the clay at this point is over 40 feet thick, a most excellent grade of ball clay.

Glass pot clays are said to exist in Bell, Marshall, McCracken, Carlisle, Hickman, Fulton and Calloway co., but their value has not yet been commercially demonstrated.

Louisiana[1]

The clays of Louisiana are all Post-tertiary and sedimentary in their origin. There are no important residual clays in the state except in one very small area. This is in the northeast corner, near the Arkansas line. Three distinct types of clay are worked in Louisiana, each being characteristic of the section of the state in which it is found. The oldest of these geologically is the mottled gray clay of southeast and southwest Louisiana. These clays are of early Columbian age, and constitute the pine flats of the coast and the second bottoms of the coastal streams. They have been worked for a long time locally for the manufacture of common building brick. But only in the last few years have they been utilized on a large scale.

The next important group of clays is of a later Columbian age and is found above the alluvial valley of the modern Mississippi river. They form a continuous bluff overlooking the river from the Mississippi state line to Baton Rouge. Thence they bear southeastward to near Lake Maurepas. These clays have been exten-

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[1] *Engineering journal.* 15 Oct. 1898. *See also* paper by H. Ries in 1st *Ann. rep't La. state geologist.*

sively worked around Baton Rouge; they make a good quality of building brick but at many places they are covered with a great thickness of loess. Similar clays of the same age form a series of bluffs on the western side of the present Mississippi valley from the Arkansas state line to the Gulf of Mexico. These clays have been worked at Marksville, Washington and New Iberia. At the latter place a good dry pressed brick is made from them.

A third group of clays comprises a series of pocket-like deposits in modern alluvium of the Red river. They probably represent abandoned portions of the river bed. In addition to these three main groups of clays, others of Lafayette age occur in northern Louisiana. Lignitic shales are also found in certain portions of northern Louisiana near Shreveport. These may perhaps be suitable for the manufacture of paving brick.

Maine

The clay industry of Maine is on the decline. There are a number of brick yards along the coast, which in former years sent their product to Boston, but the establishment of local yards around the latter city has had a bad effect on this trade. Two stoneware potteries, one at Portland, the other at Bangor, are still in operation, but they draw their material largely from other states. The clays found in Maine are all of Quaternary age.

Maryland

This state supports an active clay-working industry, but little is known concerning the raw material. Kaolin and pottery clays are said to occur at a number of localities. In the western portion of the state, at Mt Savage, occur important deposits of flint and plastic fire clays. The Devonian shales are employed for paving brick, and in the Potomac formation around Chesapeake bay, there are large quantities of clays of different grades.

Massachusetts[1]

The clays are mostly Quaternary, suitable for brick manufacture, and are extensively dug around Boston for brickmaking. Kaolin is mined at Blandford, and in the western part of the state buff burning clays occur which are adapted to the manufacture of buff brick and terra cotta:

Refractory wares and art pottery are made near Boston from clays mined in other states.

Michigan[2]

The clay-working industry of Michigan has not been developed to any extent except in the line of common brick manufacture. Much of the state is covered with glacial drift; local beds of clay are found in connection with this. In this glacial formation the lowest is the blue gravely clay from 7 to 12 feet thick, which is utilized at Springswell, near Detroit, also in Ottawa, Allegan and Barry co. The products of this clay are red, sand-molded, white, machine-pressed, red, machine-pressed, and sewer bricks. The clays of the extreme northern part of the lower peninsula of Michigan have too much lime to be of any great commercial value, but are used locally to some extent.

At Coldwater all the clays are used for cement manufacture. Ship clay is found at Rockland and Luther.

The shales associated with the coal seams are suitable in many cases for making paving brick or stoneware, and some may be semi-refractory.

Mississippi

The Eocene and Miocene are the most important clay-producing horizons in this state but beds of good quality also occur in the Carboniferous and Cretaceous. The clays have been but little used except for the manufacture of common brick and the lower grades of pottery. (*Geology of Mississippi.* 1860)

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[1] C. L. Whittle. "Clay industry of Massachusetts." *Min. Ind.* 7: 125.

[2] *E. and M. J.* 29 Aug. 1898. Also paper on Michigan shales by H. Ries in *Michigan miner* for 1899.

Missouri[1]

The clays of Missouri belong to the following classes:

Chinaware clays
Flint clays
Plastic fire clays
Pottery or stoneware clays
Shale, and brick clays

Chinaware clays. The Missouri kaolins south of the Missouri river are of Paleozoic age. The belt is worked in Cape Girardeau and Bollinger co. and extensively in Howell co. The Missouri kaolins are residual, and the interesting feature about them is that they have been derived from the decay of aluminous limestone, whereas the igneous rocks of the region furnish only impure chinaware clay. The Missouri kaolin is generally highly silicious in its composition, but this is not exceptional.

Flint clays. The flint clays of Missouri often approach closely in composition to kaolinite. They occur in the central part of the state, being abundant in the counties of Warren, Montgomery, Calloway, Osage, Franklin, Crawford and Phelps. The geologic age may be Carboniferous, Silurian or Ordovician. They form a cradle-like deposit in the limestone which has a depth of 50 to 200 feet, and 15 to 50 feet. Most of them have less than 2% of impurities. They have from 30% to 43% of alumina, and 14% to 15% of combined water, thus resembling kaolinite in their composition. They are devoid of plasticity, and in use have to be mixed with plastic clays. They generally begin to fuse at a temperature of 2300°, but do not become viscous under 2700°, and are therefore fairly refractory.

Plastic fire clays. All of these occur in the Carboniferous, associated with seams of coal. They are generally massive, dense, hard, and plastic. Those around St Louis are specially important and form the base of the enormous local development of the clay-working industry.

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[1] Mo. geol. surv., 11. H. A. Wheeler. *Clays of Missouri.*

Stoneware clays. They occur in four different geologic formations: 1) as pockets in Paleozoic limestone in the southern half of the state, similar to the flint clays; 2) as seams of some fire clays in the Coal Measures of the northwestern half of the state; 3) as beds in the Tertiary, in the southeastern corner of the state, which are by far the most prominent; 4) as local beds in the northern part of the state. These are unreliable. The stoneware industry of Missouri is at present very small, being represented by a few small scattered works.

Shales. These are the important portion of the Missouri clay materials. Important deposits exist around Kansas City, and St Louis; they are used for the manufacture of terra cotta, roofing tile, sewer pipe, drain tile, and flower pots. The paving brick industry which also depends on this material is represented by 13 plants located in the central and western region of the state.

Brick clays. These include loess clay, glacial, residual clays, and alluvial clays. The first are the most important in Missouri. They make a good grade of brick and are easily worked; they are also uniform in quality and hardness. Their chief development is along the Missouri and the Mississippi rivers, the beds of the former being sometimes as much as 200 feet in thickness. The glacial clays are variable in character. The residual ones are usually very tenacious, and crack in burning. The alluvial ones are likewise variable. The Gumbo clays are chiefly used in making railroad ballast. The northern part of the state is rich in them.

New Jersey

In 1878 the New Jersey geological survey issued an extremely valuable report on the clay resources of that state. The clays of New Jersey are Quaternary, Tertiary, and Cretaceous, the latter including beds of fire clays, fire sands, and white burning clays, which are commonly, but erroneously, called kaolins.

The clays extend across the state in a belt 5 to 8 miles wide, from Perth Amboy to Trenton; the deposits on Staten Island are a continuation of this belt.

There are three districts recognized.

The section exhibited by the clay deposits involves the following members, beginning at the bottom.

1 Raritan potters' clay bed

2 Raritan fire clay bed

3 Fire sand

4 Woodbridge fire clay, a most important bed

5 Pipe clay

6 A bed of feldspar, commonly called kaolin, being really a mixture of kaolinite with white quartzose sand, and fragments of quartz which are rounded on their edges

7 Another kaolin bed

8 South Amboy fire clay bed, 20 feet thick

9 Stoneware clay

These clays form the basis of an important fire brick and pottery industry.

The Quaternary brick clays are abundant in the region around Hackensack, near New York city.

Recently important beds of light or white burning plastic clays have been developed in the Tertiary formation of southeastern New Jersey.

Nebraska

The clay resources of this state are similar to those of Kansas. Brick clays are used locally in the vicinity of the more important towns. A fine kaolin-like clay is found on Pine creek in Cherry co.

North Carolina[1]

The clay deposits of North Carolina may be divided into

Residual: kaolins, fire clays, and impure clays

Sedimentary: coastal plain clays, of Cretaceous, or Tertiary age

Sedimentary surface clays (for brick and pottery) are found mainly along the streams and low lands in the Piedmont plateau and mountain counties.

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[1] N. C. geol. surv. H. Ries. *Clays and clay industry of North Carolina, bulletin no.* 13.

Residual clays. These occur in the western half of the state west of the line passing through Weldon, Raleigh and Rockingham. They form an almost universal mantle and vary in thickness from 3 to 20 feet. These impure residual clays are generally sandy and very porous, but with proper machinery and treatment they yield a good grade of brick.

The residual fire clays found at Pomona and Grover are coarse-grained clays with much intermixed quartz and mica.

The kaolins are of special importance and of excellent quality, the most important being at Webster, and west of Sylva.

Sedimentary clays. The coastal plain deposits of North Carolina furnish the most extensive beds of clay to be found within the state. They have been classed as belonging to Cretaceous, Eocene and Pleistocene formations. The Potomac clays of the Cretaceous are exposed at Prospect Hall on the Cape Fear river, and the Eocene beds are well shown in railroad cuts at Spoutsprings Fayetteville.

Many clays suitable for the manufacture of brick and of pottery are found underlying the river terraces farther inland, as along the Catawba, Yadkin, and the Clark rivers. Other sedimentary clays are well developed around Wilson, Goldsboro, and Fayetteville.

North Dakota

The clays of North Dakota are of Cretaceous, Tertiary, and Post-tertiary age, and abound in many sections of the state. While they are suitable for a variety of purposes, they have thus far been but little worked. (*Report of commissioner of labor and agriculture.* 1891–92)

Ohio[1]

The principal centers of development of clays are in most instances the same as those which furnish the coal. The Subcarboniferous contains valuable deposits of flint clay, which is mined

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[1] Ohio geol. sur. v. 7, pt 1. E. Orton jr. *Clays and clay-working industries of Ohio.*

at several points in Hocking co., and the Carboniferous conglomerate also contains several beds of fire clay. Other beds occur over the Sharon coal in the Massillon sandstone, and are used for making sewer pipe and pottery. Another important bed underlies the lower Mercer limestone. Several important clay deposits occur in the lower Coal Measures, the beds varying in thickness from 6 to 30 feet. The Kittanning clay and shale is the most important in the state, and is the horizon which yields the well known Mineral point fire clay. Other beds are found in the middle Kittanning and the lower and upper Freeport members of the Coal Measures.

In northern and western Ohio, the drift clays form an abundant supply of material for the making of common brick.

Pennsylvania

The most prominent clay deposits of Pennsylvania are the refractory shales and clays which occur in the Coal Measures, specially in the western portion of the state. The beds are often extensive, and occupy well marked stratigraphic positions. Among the more important of these may be mentioned the Bolivar fire clay, which occurs just under the Freeport upper Coal Measures. Another important bed of clay lies immediately under the Kittanning coal, throughout Beaver co. Another valuable bed is found near the top of conglomerate 12, and is mined in Cambria, Indiana and Beaver co.

Large quantities of true kaolin are mined in Chester and Delaware co., and the mines at Brandywine summit have been in operation for a number of years.

The brick clays are abundant and important in and around Philadelphia, where they belong to the Columbian formation; while the river terraces in the valleys of the Ohio and Beaver rivers are underlain by clay suitable for the manufacture of brick, terra cotta and stoneware.

South Dakota[1]

The clays of South Dakota are classed as brick, potters', fire clays, and fullers' earth.

Brick clay. The material most commonly used for brickmaking in South Dakota is some kind of loam such as that supplied by the loess in Union, Minnehaha, and Moody co. It is also thick in the high terraces along the Missouri, and Cheyenne rivers, and in most of the country south of the White river, in the Laramie formation, in the northwestern counties of the state. Local beds are found underlying the flood plains of the large streams.

Potters' clay. Very plastic dark clays are said to abound in the Benton and the Pierre groups of the Cretaceous.

Light colored clays abound in the White river beds, and in several horizons of the Paleozoic of the South hills, which furnish clays that are probably adapted to the potter's purposes.

Fire clays. Extensive deposits of fire clay occur in the Dakota formation, which forms a rim around the Black hills. This bed has been worked for several years, specially at Rapid City.

Fullers' earth. Beds of this material have been reported from the vicinity of Fairburn, Custer co.

Tennessee

The clay resources of this state are very similar to those of Kentucky. (R. T. Hill. *Mineral resources, U. S. geol. sur.* 1891) The Carboniferous fire clays and shales are abundant in the eastern half of the state, and pottery clays of the Eocene, and La Fayette formations are extensively developed in the western part.

Around Chattanooga, there are important factories for the manufacture of fire brick and sewer pipe.

Texas

Brick clays are abundant throughout the state. Many of the Tertiary clays are suitable for drain tile and terra cotta, specially

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[1] J. E. Todd, *E. and M. jour.* 24 Sep., 1898.

those of the timber belt and the Fayette formations, while fire clays occur in the timber belt beds in Fayette, Henderson, and Limestone co., and in the Fayette in Fayette co., but the last run rather high in impurities.

The occurrence of clays is mentioned from various localities in the report on Grimes, Brazos, and Robertson co. 4th *ann. rep't. Tex. geol. sur.*

Virginia

Brick clays are extensively worked in the vicinity of Washington, kaolin is said to occur in Augusta, Wythe, and Cumberland co., while there is the usual abundance of residual clays in those portions of the state not covered by Cretaceous and Tertiary deposits.

Wyoming[1]

All the clays of Wyoming that have any commercial importance occur in the sedimentary beds of the Jurassic and Cretaceous formations, but are also found to some extent in the Tertiary. The formations containing these clays are found flanking nearly all the mountain ranges in the state. But with the exception of their being used for the manufacture of common brick in a few localities, very little development has occurred. All the fire clay products now used in Wyoming are manufactured in Colorado; pressed brick are also shipped into the state from various points.

The loess is utilized at a number of places in Wyoming.

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[1] W. C. Knight. *E. and M. jour.* Nov. 1898.

CLAY-WORKING

Structure of clay deposits

Residual clays. The mode of origin of these has already been mentioned. Such a clay may occur either in the form of a broad mantle over bed rock, of variable depth and lateral extent, or it may occupy the position of a vein cutting across the strike of the other rocks or sometimes parallel with their bedding or lamination. Residual clays of the first type are abundant in the upland regions of the southern states and form the most abundant brickmaking material of that part of the country.

Residual deposits of the second type result commonly from the decomposition of veins of granite or feldspar. They vary in width from a few inches to several hundred feet. Their vertical extent depends in most cases on the depth to which the weathering has reached, except in the case of those kaolin deposits which have resulted from action of subterranean vapors. (*See* "Origin of clay," p. 496) Vein formations of kaolin seldom show great length, and usually pinch out in both directions. In some localities they are however known to be as much as 1000 feet long. They are commonly separated from the country rock by more or less sharp boundaries, which are preserved even though the wall rock also be decomposed, as it usually is. They frequently branch, and at times contain lenses of quartz, which resist the weathering agencies and stand out in bold relief on the surface. It rarely pays to work a vein under 6 feet in width.

Sedimentary clays. These occur in the form of beds either close to the surface or interstratified with other deposits which have been formed by water, such as sandstones. Deposits of sedimentary clay do not pass gradually into the underlying rock as residual clays do. In many parts of the United States sedimentary clays form lens-shaped masses which are surrounded on all sides by sand. The clay beds of Staten Island well illustrate this point, and the conditions observed are caused by variations in the velocity of the currents which laid down the materials, sand being deposited when the velocity of the current was swift and clay when the water was quiet.

All of the New York clays are of sedimentary origin except those occurring along the New York-Connecticut border line near Amenia and Sharon.

Prospecting and exploring

In prospecting for clay the topography is often of much help. In the northern and western portions of the state the clay is generally found in the bottoms of broad valleys. An example of this is the Genesee valley. Again at other localities the clay is found underlying terraces along the sides of the valleys, as in the Hudson valley and along Lake Champlain. Deposits of a similar character will be found along the Delaware and Susquehanna rivers. A terrace however does not necessarily indicate the presence of clay, for some of the Hudson valley terraces are underlain by till.

On Long Island for example the clay is found almost entirely along the north shore; it no doubt underlies most of the island, but on the southern side there is in most instances such a covering of sand as to make it useless. The presence of clay can often be detected in railroad cuttings, in the sides of gullies or ravines. In many instances however the occurrence of clay is only suspected; then borings must be made with an auger to determine its presence. As a deposit of clay is seldom of uniform thickness throughout its extent, a sufficient number of borings should be made in order fully to determine this point; a bed of clay may be 40 feet deep at one point and thin out to 5 or 6 feet within a distance of 15 feet. The writer has seen several instances in which expensive plants have been erected and come to a speedy end, simply because the clay gave out, whereas the disaster might have been avoided by previous exploration. Another important point to determine is the presence of sand for molding and tempering. Many of the clays in this state can not be made into brick without the addition of sand. Along the Hudson river and on Long Island tempering sand is a much needed article, but fortunately it is near at hand. With molding sand it is different, for wherever soft mud machines are used it is necessary. Very often it can be obtained from some neighboring hill, but sometimes it has to be brought long distances.

Having determined by boring or otherwise, the extent and thickness of the clay at the locality where the brick yard is to be established, the next step is to strip a portion of the surface to a sufficient depth to expose the clay.

The amount of stripping to be done varies. On Long Island it is sometimes as much as 20 or 30 feet. Along the Hudson valley it varies from a foot or two of loam, or 3 or 4 feet of sand up to 15 or 20 feet. In both these regions the sand can be used for tempering, though the quantity stripped is far in excess of the demand. At some points in the Hudson valley the surface is covered with scrubby trees troublesome to remove. In the northern and western portions of the state, there is at most places only a foot or two of soil covering the clay.

When a yard is first started, the stripping, whatever its character, can be used for filling.

Natural drainage is always an extremely desirable thing, for having to keep the clay pit clear of water only adds to the cost of production. Neighboring streams and springs are often a constant source of annoyance, specially if the clay deposit is situated in a valley. They are chiefly troublesome when the sand bed, which often underlies the clay, is struck and allows the water to run in and flood the workings.

The presence of a sufficient quantity of clay or shale does not insure quality, and before erecting a clay-working plant, it is necessary to examine into the quality of the clay and its possible applications.

The laboratory methods of investigation have reached a high degree of development at the present day, and by such means much information can be gained concerning the quality of the material. If these results are promising, it is worth while sending several barrels of the clay to different works, in order to test it on a practical scale.

Analyses, with our present knowledge of clays, are of more value in the case of high grade materials.

Methods of working

1 The clay is dug at any convenient spot in the bank, usually at the base, working inward; thus in the case of a high bank eventually leaving quite a steep face. The bank is apt to slide sooner or later and the men begin again at the base of the slip and work inward. There is one disadvantage in this method, that the several qualities of clay, if it be in strata, become mixed, which is not desirable in all cases. It has, however, the advantage of making the haulage all on one level. Of course, in this method, haulage by cart is the most convenient. Cost, 25–30c a thousand brick for about 500 feet of lead.

2 A second method, one rarely used, is to loosen the clay by means of plows and bring it to the yard by scraper, provided of course the clay bank adjoins the yard. Very few yards employ this method. It costs about 20c a thousand brick to plow the clay and bring it down with scrapers. To this must be added the price of getting the clay from the heaps to the molding machines, a distance of about 50 feet. In plowing clay, the bank is usually worked at an angle of about 30 degrees. This method has no special advantage. The clay is more broken up and is exposed to the weather for several days; this adds materially to the quality of pressed brick, but for common brick it is of little importance. This method is sometimes used where the deposit is extensive and shallow, wheel scrapers being used in case the haul is not long enough to require a locomotive.

3 **Working in benches.** This method is one commonly used where the bank is over 25 feet high. The benches are 6 to 8 feet

wide and 7 to 9 feet high. Roads lead up to the separate benches, and each bench is worked in advance of the lower one.

Where the clay has streaks of quicksand the roads have to be planked. If the bank is below water level there is the additional expense of pumping. This method is of importance along the Hudson river, where many of the clay banks are of considerable hight, and the use of benches often prevents a slide of the clay.

4 **Steam shovel.** Though this method of mining has been successfully practised at many western localities, the only place in this state where it has been tried is Croton landing in the Hudson valley. These clays do not as a rule stand well with a vertical face, and as a result the bank slid, burying the shovel. Where the clay bank contains several different layers of clay, which are mixed together for making brick, the steam shovel is a good thing, as it digs from bottom to top of the bank at each stroke. Steam shovels are an economical means of mining soft shale, where the capacity of the yard warrants it, and may also be used for clay.

5 **Dredging.** This method like the preceding is only practised at Haverstraw and Croton point. The dredged clay is dropped into hoppers, which, when full, are run up inclined planes on shore and dumped. Cost 12–15c a thousand delivered on shore; then 12c for haulage to ring pits.

6 **Undermining.** Many brick manufacturers use this method of mining their clay, specially when the latter is tough. Wedges are driven in on the upper surface, a foot or two from the edge; at the same time the face is undermined by picking, to a distance of 2 or 3 feet. It is not advisable to work a bank more than 20 feet high by this means, and in almost any case it is a rather dangerous method to employ.

7 **Blasting** is very often resorted to in banks of tough clay and always in the case of a shale bank. A small charge of dynamite usually suffices to bring down a large quantity of the material.

8 **Haulage.** The brick manufacturer generally establishes his plant near the supply of clay, so that the haulage distance is from

100 to 300 feet. Within these limits it is economical to use one horse carts, but above 300 or 400 feet there are other means of haulage which will generally be found cheaper. There are exceptions where carts are used for hauling long distances; for instance, at Port Ewen on the Hudson the clay is carted 900 feet in some cases, and at Haverstraw some of the firms bring their clay a distance of a quarter of a mile in one horse carts. The character of the Hudson valley clay banks is such that train haulage would not be practicable, as the tracks would have to be shifted so often.

Cars. As a rule where the haulage distance exceeds 500 feet cars are used. They are run on tracks and drawn by horses; if possible the track is laid down grade from the bank to the yard. Sometimes the loaded cars are run down to the yard by gravity, the horses being only required to draw them back when empty. Cost 10c a cubic yard for about 500 feet lead.

Locomotive haulage. This is a cheap method where the scale of operations warrants it; that is to say, for a yard having an annual capacity of 15,000,000 or upward. The cost by this method is about 5c or 7c a thousand brick (about one and a quarter to one and a half cubic yards of clay being reckoned to a thousand brick) for a distance of 600 or 800 feet. It is necessary, of course, to have cars filled with clay ready for the engine as soon as the empty ones are drawn back; otherwise the expense would become great if the engine had to spend much time waiting. The cost given above does not include wear and tear on plant.

Wire rope haulage. A few yards use this method where the haulage distance is small; the winding drum is placed under the machine shed near the pug mill or crushers; side or bottom dumping cars are used.

Gravity planes may also be mentioned, but they are less used than they might be.

Purification of clay

In the manufacture of common clay bricks it is seldom necessary to give much time to the preparation of the clay, but in the case of better grades of ware, such as front brick and terra cotta, the preparation of the clay is often a matter of the greatest importance, in order to provide a mass of material which will be homogeneous throughout, and whose physical properties shall not vary. It sometimes happens that this operation means simply the breaking up of the clay thoroughly or the loosening of all the clay particles. The greater the care with which these operations are carried on the more homogeneous will be the material and the better the grade of the wares produced.

Removal of foreign matter

This can be sometimes rendered harmless either by distributing it in a finely divided condition through the clay, or by the addition of chemicals, or sometimes it may be removed entirely, the method employed depending on the character of the clay.

Cleansing clay. This includes the removal of roots, pyrite, lime pebbles, and similar substances. The simplest method is by handpicking, which is slow and incomplete. The custom followed at the present day is either to dry the clay and pass it through a sieve of the proper mesh, or to treat it to a washing process or even to an air separation.

Cleaning dried clay. Most clays are naturally moist, but when occurring in the form of shale the percentage of water is usually very low; very sandy clays are also apt to run low in moisture. With dried clays, the purification can be accomplished by first pulverizing the material, and then allowing the product to fall through a strong air current, the effect of this being to separate the particles according to their specific gravity, those of clay being carried farthest, while heavier particles, such as pyrite, are dropped first, a fairly complete separation taking place.

Wet process of purification. This is done by subjecting the clay to a washing process. (*See* "Preparation," p. 799)

Separation of iron particles. In the manufacture of certain products, and also certain glazes, it is necessary that the material used shall be thoroughly free from iron, as in burning, this element makes itself very noticeable; slight specks of it might mar the ware sufficiently to make it unsalable. The removal of iron grains is accomplished by means of a strong magnet, which in case the clay is used in the form of a slip, is suspended in it, or, if powdered clay is used the powder is allowed to pass over the poles of the magnet; in either case the iron particles are extracted, the magnet being cleaned from time to time.

Purification of fluxes and grogs

Many of the materials belonging to either of these two classes are often more or less dirty and can be cleaned by washing. If the grogs used, however, contain appreciable particles of iron, it is best to remove these by hand picking as far as possible, before the material is powdered for use. Feldspar having a red or yellow color frequently contains iron oxid, and such should not be used if the feldspar is to be used in the manufacture of light colored or colorless glazes, while if it is to be used for dark glazes the iron oxid contents are of less importance.

Many red feldspars, however, when calcined became pure white, showing that the coloration is not due to iron.

USES OF CLAY

Characters of brick clays

Under this head is included a very wide range of materials, depending on the quality of the product to be made.

For common building brick almost any clay of good plasticity will do, and this very fact has been most extensively abused by brick manufacturers, encouraged by indifference on the part of contractors who are very often inclined to regard common brick as simply so many cubic feet of burned clay, little attention being paid to the quality of the product.

As the different kinds of brick can not all be made from the same kind of clay, it will be best to consider separately the requisites of the clays used for these different types.

Clays for common bricks. For this purpose the more impure clays are generally utilized, and in general those which burn to a red color. Calcareous clays are often employed, specially around Chicago. Such clays produce a buff product. Many morainic clays of south central New York are of this nature.

Clays for making common brick should burn to a good red color at a temperature not greater than 2000° F. or 2100° F. They should also have sufficient fluxes to cement the clay particles together, forming a hard dense body, when subjected to the above amount of heat. From 5% to 7% of iron is desirable, as this amount has been found to exert the best coloring action. A large amount of lime is undesirable, for it brings the temperatures of fusion and incipient vitrification too close together, though with care a good brick can be made from a clay containing 20% to 25% of carbonate of lime. (Seger's *Ges. Schrift.* p. 265) The celebrated Milwaukee brick contain 22% of lime carbonate and the clays used for making front brick at Canandaigua, N. Y., have 20%-23%.

The tendency of lime as previously stated is to lessen the shrinkage of the clay in the burning, and it will be the more injurious the less finely divided its condition; consequently if a brick clay contains lime it should be seen to that the substance is finely and evenly disseminated throughout the material, for if in lumps it is very apt to split the burned brick. Many brick clays which contain lime pebbles are often dried and screened before using.

Sand decreases both the plasticity and the tensile strength of the clay as well as the shrinkage. This fact is frequently known and utilized by the manufacturer to diminish the shrinkage of his clay in both drying and burning, consequently reducing the danger of obtaining a warped or cracked product. Some clays will stand as much as 25% of sand. The coarser the sand, the more marked will be its effect on the shrinkage. On the other hand, if the grains of sand are angular and of too large size, they may of themselves produce a cracking of the ware; and it should be borne in mind that there is danger of adding too much sand to a clay, for the tendency will be to produce a weak, porous brick, specially if the latter is hand-molded.

Fine-grained clays and very plastic ones generally need to be dried very slowly, the reason being that on account of the smallness of the pores the moisture can not escape readily, and the outer portion of the brick dries and shrinks more quickly than the interior, with the resultant cracking. Rapid drying may be prevented somewhat by adding salt water to the clay, and this is a common practice in parts of Missouri. (*Mo. geol. sur.* 11: 481)

Fine-grained clays often have to be heated slowly in the early stages of burning, though if such a clay contains an abundance of fine sand particles, the contrary is possible.

The range of constitutents in brick clays from various states can be seen from the following table.

North Carolina

	Range	Average
Silica	52 — 70	60%
Alumina	13 — 28	18%
Ferric oxid	1.5 — 11.5	60%
Lime	.1 — 2.5	.60%
Magnesia	.1 — 1.5	.40%
Alkalis	.2 — 4.5	20%
Water	4 — 12	7%
Total fluxes	3.5 — 17.5	9%

Missouri

	Range	Average
Silica and fluxes combined	12 — 30	15%
Silica (sand)	20 — 60	55%
Alumina	11 — 25	14%
Water (combined)	3 — 9	4%
Water (moisture)	0 — 6	2%
Ferric oxid	2.5 — 8	4%
Lime	.5 — 7	1.50%
Magnesia	.3 — 8	1%
Alkalis	2 — 7	3.50%

New York

	Range	Average
Silica	45.12 — 69.73	54.28%
Alumina	11.33 — 24.45	18.81%
Ferric oxid	1.90 — 10.90	5.92%
Lime	.23 — 15.38	4.87%
Magnesia	.10 — 8.24	2.95%
Alkalis	.48 — 9.82	5.43%
Water	.90 — 12.67	6.906%
Moisture	4.50 — 8.26	5.41%

The following gives the maximum, minimum and average percentage of the different constituents in the brick clay analyses given in the tables at the end of the report.

	Range	Average
Silica	34.35 — 90.877	49.27%
Alumina	22.14 — 44.00	22.774%
Ferric oxid	.126 — 33.12	5.311%
Lime	.024 — 23.20	2.017%
Magnesia	.02 — 11.03	2.66%
Alkalis	.17 — 15.32	2.768%
Water	.05 — 13.60	5.749%
Moisture	.17 — 9.64	2.502%

Clay for pressed brick. In addition to the characters mentioned under common brick clays, it is highly necessary that the materials used should burn to a uniform color. They should be as free as possible from soluble salts, specially if the product is not vitrified.

Many different grades of clay are utilized, but chief among them may be mentioned white burning clays, buff burning clays (either calcareous or semi-refractory), red burning clays, commonly high in iron oxid.

Semi-refractory, or refractory clays, form an important source of material for making front brick, not only on account of the buff color to which they burn, but also because this color permits the admixture of manganese for the production of mottled and speckled effects and various shades producible by the addition of the same material in powdered form.

The shrinkage of the clay in burning should be regular and even, in order that the finished bricks may all be very nearly of the same size.

Burning of brick clay

Brick clays when burned exhibit a variety of shades and colors whose existence is influenced by several causes, such as the amount of ferric oxid in a clay, the percentage of other constituents associated with it, the composition of the fire gases, the degree of sintering and the temperature of the kiln.

The red coloration usually caused by iron is well known, and the other effects of iron are mentioned on page 517. An excess of lime, magnesia or alumina tends to exert a bleaching action on the iron, and produce a buff tint.

It is asserted by Seger (*Ges. Schrift.* p. 282) that it requires 5% of ferric oxid to give a pronounced red color, which increases with the amount of iron, up to about 20%.

Knowing the effect of the different ingredients on the color of the burned clay, it is possible when certain results are desired to add the ingredients to the clay in case they are lacking. Thus a red burning clay might be changed to a buff burning one by adding to it a white or whitish burning clay containing a high amount of alumina, and, depending on the amount added, we should get shades passing from red through brown, yellowish brown, to yellow. Marl produces a similar result.

The fire gases may be either reducing or oxidizing, and during the burning of a kiln these conditions are apt to alternate at times, but while cooling down the action of the fire is with few exceptions oxidizing.

One effect of the sintering is to cause the clay to shrink more and become denser, and this of itself is sufficient to deepen the color.

The color to which a clay naturally burns as a result of its constituents, is best shown on the fractured surface of a brick, as the fire gases have not been able to exert any effect on the interior of the product.

The surface coloration of a burned brick may often be the same as that of the interior portion, but at other times it may differ from it. This is due to the accumulation of soluble salts, which have been drawn from the interior of the brick to the surface, either in burning, water-smoking or drying.

Another cause of difference in color between the surface and interior of the burned brick may be due to the deposition of foreign substances brought there by the fire gases, which may exert a colorizing action either by their presence alone or by their forming a glaze on the surface of the brick as a result of their union with the silica in it. This is often to be seen on the surface of arch brick in an up-draft kiln, and on the surface of the brick which line the bag walls of any down-draft kiln.

The coloration of most brick is due to iron; unless the brick is heated beyond vitrification it is probable that much of the iron remains in the ferric condition.

With ferric oxid in a clay it is possible to obtain all shades ranging from pink to reddish black, and with an excess of lime all shades of yellow, while manganese, which sometimes accompanies the iron in small amounts, tends to give a brownish coloration.

Ferrous oxid produces colors ranging from green to black.

It should also be remembered that with any given amount of iron in a clay, the higher the temperature to which the material is exposed the deeper will be the color obtained. Iron in the ferric condition tends to color the mass red as long as it is at all porous, but with the beginning of fusion it generally passes over to black.

When the clay also contains carbonate of lime, the latter serves as a flux, and causes fusion to set in at a lower temperature than it otherwise would, the result being the formation of a complex silicate, containing iron, alumina and lime, which with the proper proportion of iron and lime shows a yellow color. Up to the time that fusion sets in the ferric oxid still imparts its red color to the clay, but as the heat rises, this gradually turns to flesh red, white, yellow, and finally yellowish green, and at viscosity passes to green, and sometimes black.

The coloration which is induced superficially is a matter of great importance, and, as before stated, it may be due either to a coating of soluble salts, or a deposit of impurities from the fire gases. The former are described under "Efflorescence on bricks," p. 679.

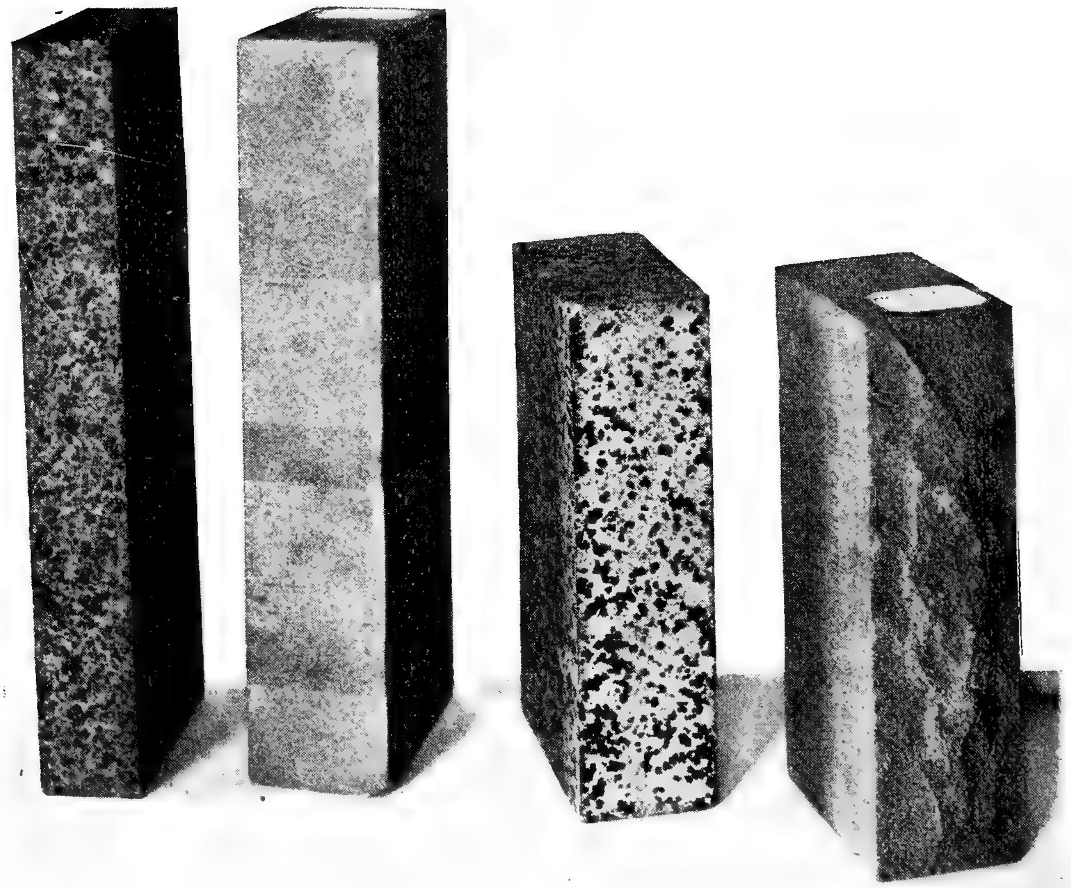
The discoloration caused by the action of fire gases on the clay is far more pronounced in the case of buff ware. In red burning clays the effect is often marked by a superficial reduction of the iron which the clay contains, or a slagging of the surface due to the deposition of fusible impurities, specially alkalis, from the fire gases.

In calcareous clays many of the elements of the material show a strong affinity for the sulfuric acid of the fire gas; the result of this is that sulfate of lime is formed on the surface, and the ferric oxid, not being able to unite with the lime, imparts a red color to the brick. In the interior the color of the brick remains yellow, for the sulfuric acid gas has not been able to penetrate to that point and take the lime away from the iron. This point can be easily proved by determining the amount of sulfur in the yellow and the red portion of the brick, and, if the theory is correct, the latter should show the greater amount of the acid. That this is so is well shown by two clays analyses made by Seger (*Ges. Schrift.* p. 277). The outer or red portion of the brick which he analyzed showed 14.43% of sulfuric acid, while the inner or yellow portion showed only 1.04%.

One fact that this emphasizes is that in burning calcareous clays it is important that coal should be used which contains but a very small percentage of sulfur.

The slower the burning proceeds, the more completely will the iron in all portions of the clay be oxidized, and the greater the access of air the brighter will be the red color.

The time required in drying and burning is affected not only by the clay, but also by the process. The more water which has to be driven off in the kiln, the slower must the burning proceed, unless the clay is coarse-grained.



C. M. Doyle, photo.

Different varieties of brick

1 Roman tile.
2 Norman tile.
3 Dry pressed brick speckled with manganese.
4 Rock faced.

THE BRICKMAKING INDUSTRY

Three kinds of brick are manufactured in New York, common, front and paving brick.

Common brick. Many works dealing with clay products state, in an interesting way, what are the requisites of a good common brick, but as a rule few conform to the requirements laid down.

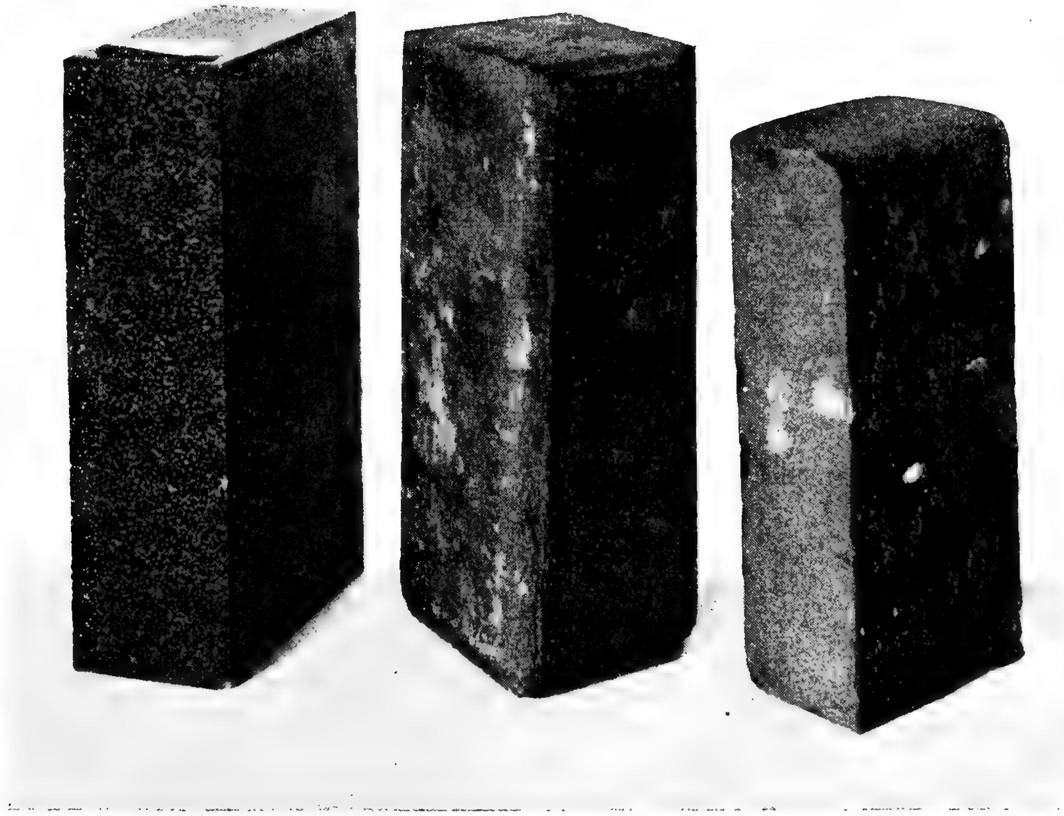
Most common brick are fairly regular in shape, but here the similarity to one another ends. They show a wide variation in size, and there is no law requiring a standard size, though there should be one. The National brickmakers association and the American institute of architects have adopted a standard size of $2\frac{1}{4}$x$4\frac{1}{8}$x$8\frac{1}{4}$ inches. If these dimensions be compared with those given in the table below, considerable difference will be observed in some cases. It is to be remembered of course, that, with a given clay and a given mold, the brick will be smaller the harder it is burned and in some clays the difference will be appreciable.

Common brick should be of uniform texture, hard, and give a clear ringing sound when struck. The compactness and uniformity of texture are largely influenced by the method of molding. Soft mud bricks when properly burned are very resistant to frost action. The absorption of common brick should not exceed 15%.

They should also have a crushing strength of not less than 3000 pounds a square inch.

The following table gives the dimensions of a number of bricks made in New York state, also their absorption after 24 hours' immersion.

	Size of brick	WEIGHT BEFORE SOAKING		WEIGHT AFTER SOAKING		Percentage of water absorbed	
		Lb.	Oz.	Lb.	Oz.		
East Williston	....	4	$1\frac{1}{2}$	4	6	6.7	Soft mud
Southold	$2\frac{1}{8} \times 3\frac{3}{8} \times 7\frac{1}{2}$	3	$12\frac{1}{2}$	4	3	10.7	Soft mud
Farmingdale	$2\frac{3}{16} \times 3\frac{1}{2} \times 7\frac{5}{8}$	3	$11\frac{1}{2}$	3	$15\frac{1}{2}$	7.0	Soft mud
Croton, W. A. U.	$2\frac{5}{16} \times 3\frac{5}{8} \times 8\frac{3}{16}$	4	6	5	$\frac{1}{2}$	15.4	Soft mud
Haverstraw	$2\frac{3}{16} \times 3\frac{7}{16} \times 7\frac{7}{8}$	3	11	....	....	......	Soft mud
Syracuse	$2\frac{2}{8} \times 3\frac{13}{16} \times 7\frac{6}{8}$	....	....	....	....	......	Soft mud
Warners	$2\frac{3}{16} \times 2\frac{7}{8} \times 8\frac{3}{16}$	5	11	5	17	6.3	Stiff mud
Canandaigua	$2\frac{3}{8} \times 4 \times 8$	5	$\frac{1}{2}$	6	$4\frac{1}{2}$	24.8	Dry clay
Rome	$2\frac{3}{16} \times 3\frac{3}{8} \times 7\frac{6}{8}$	3	8	4	$1\frac{1}{2}$	17.9	Common
Rome	$2 \times 3\frac{15}{16} \times 7\frac{13}{16}$	4	3	4	5	2.9	Stiff mud
Owasco	$2\frac{1}{2} \times 4\frac{1}{4} \times 8\frac{3}{4}$	5	$\frac{1}{2}$	5	14	16.7	Repressed
Saratoga	$2\frac{3}{16} \times 3\frac{3}{4} \times 2\frac{3}{16}$	4	$2\frac{1}{2}$	4	$8\frac{1}{2}$	9.0	Soft mud
Buffalo	$2\frac{1}{4} \times 3\frac{1}{4} \times 8\frac{1}{8}$	4	$13\frac{1}{2}$	....	....	......	Soft mud
Dunkirk	$2\frac{3}{16} \times 3\frac{11}{16} \times 7\frac{3}{16}$	4	$3\frac{1}{2}$	4	14	15.5	Soft mud
Jamestown	$2\frac{1}{2} \times 4 \times 8\frac{1}{4}$	4	11	5	$5\frac{1}{2}$	14.0	Soft mud
Hornellsville	$2\frac{3}{8} \times 4\frac{1}{8} \times 8\frac{3}{8}$	7	2	7	4	1.7	Stiff mud
Newfield (yellow)	$2\frac{3}{16} \times 3\frac{7}{8} \times 7\frac{13}{16}$	5	$5\frac{1}{2}$	5	7	2.9	Stiff mud
Newfield (cream)	$2\frac{3}{16} \times 4\frac{1}{10} \times 8\frac{1}{4}$	5	8	6	$5\frac{1}{2}$	15.3	Stiff mud
Jewettville	$2\frac{3}{8} \times 4 \times 8\frac{1}{4}$	5	$11\frac{1}{2}$	6	1	5.4	Dry clay



1 2 3

C. M. Doyle, photo.

Different varieties of brick

1 Flashed brick.
2 Repressed paving brick.
3 Soft mud brick.

Most common brick are made by the soft mud process, but many are molded by the stiff mud process. In the burning of a kiln full of such brick, some receive more heat than others, a certain proportion become discolored, while the remainder may be slightly misshapen by the weight of the overlying mass of bricks. It is thus possible to sort the contents of any one kiln into a number of different grades, the more important of which are as follows:

Salmon brick; soft brick. These are insufficiently burned brick, which are not hard enough to be used in outside walls, but can be used for backing or filling in.

Arch brick are those from the arches of the kiln, or portions nearest to the fires. These are consequently burned the hardest.

Stock brick. These generally represent the best, from a kiln of common brick. They are carefully sorted both as to color and shape and consequently command a higher price.

Sewer or cistern brick are the harder burned bricks of a common kiln, which, owing to their impervious character as the result of hard firing, are well adapted for damp situations.

Washed brick. At those yards where the drying is done by the open air, the surface of the bricks sometimes becomes roughened by the beating action of rain. Such bricks when burned are just as strong as unwashed ones, but they have usually been discarded, excepting during certain intervals when they happened to catch the fancy of some architects.

Pressed brick. The name of these is due to the fact that the green brick is sometimes subjected to pressure after molding, to impart a smooth surface and sharp edges to it.

Under this term are also included products of a variety of shades and colors and of variable form.

The plain colors include white, buff, yellow, gray, brown and red, as well as numerous intermediate shades.

Mixed colors are commonly produced by the addition of some metallic oxid, such as manganese, or a ferruginous shale, to a light burning clay. The addition of finely powdered manganese oxid to a buff burning clay produces a gray color.

Speckled bricks are obtained by adding the manganese in a finely granular condition.

Mottled bricks. In these the manganese is added in larger particles. Ferruginous shale is sometimes employed, and pyrite has also produced the same appearance.

These manganese brick are used to an enormous extent at the present day. On account of their mottled appearance and rough surface they are considered by many to produce a much softer appearance and richer color than the plain pressed brick.

Roman tile or Pompeian brick. So called on account of size and shape, in which they are similar to those used in Roman times. Their dimensions are 12x4x1½ inches. They are made either plain or speckled, and either dry pressed or of stiff muds.

Norman tile. These differ from the preceding simply in being 2 instead of 1½ inches thick.

Ornamental brick include all those of irregular or fancy shape. Their chief use is for cornices, sills, panels, etc., and they are made in the same shades and colors as the ordinary forms of pressed brick. By reason of their elaborate form they often command high prices, and $50–$60 a thousand is not uncommonly demanded.

Flashed brick. On some pressed brick one edge shows a darkened and slightly fused appearance, brought about by setting the brick with this edge exposed, and then causing a reducing action in the kiln near the end of the burning, by shutting off as much air from the fires as possible.

The number of ornamental shapes produced runs up into the hundreds, and many manufacturers carry a very large number in stock.

Rock face brick. These are produced by trimming the edge of a pressed brick with chisel and hammer, in imitation of stone. Their beauty is a matter of individual taste.

Pressed brick are usually molded either by the dry press, semi-dry press, or stiff mud process. In the last case, they have to be repressed. The prevalent custom is to burn them in down-draft kilns.

Crushing strength of bricks

Many of the bricks manufactured in New York show a crushing strength which is far greater than is necessary, but some, specially common brick, often approach the limit pretty closely. The succeeding tests made by different persons give the strength of a number from different localities.

The following are the results of some tests made by H. Williams M. E., at Cornell university, on bricks from New York state, made by different methods from the same clay. Half bricks were tested in each case, and plaster of paris put between surfaces of bricks and plates of machine.

		Ultimate strength	
		Total	Per square inch
		Pounds	*Pounds*
1	Wire-cut brick	59 800	3 385
2	Red brick, dry-clay process, Glens Falls	34 660	3 580
3	Stiff mud, side cut, repressed, buff, Glens Falls	104 360	6 510
4	Soft mud, repressed red brick, Glens Falls	117 100	5 365
5.	Dry pressed buff brick, Glens Falls	83 680	5 800
6	Soft mud brick, W. W. Parry, Rome	115 300	4 470
7	Stiff mud, repressed, W. W. Parry, Rome	240 000	8 760

Tests of Haverstraw brick made by M. Abbott. No packing was put between brick and plate of testing machine.

		Crushing strength ni lb. per sq. in.
Whole brick tested on end	Maximum	3 060
	Minimum	1 600
	Average	2 065
Half brick tested on flat side	Maximum	4 153
	Minimum	2 669
	Average	3 371
Half brick tested on edge	Maximum	6 400
	Minimum	2 900
	Average	4 612

Tests of Newfield brick made at Cornell university.

	Lb. per sq. in.
Repressed brick	14 990
Common	9 300
Common	10 900
Common from top clay	7 880

Some years ago E. S. Fickes made a number of crushing and absorption tests of common brick (*Eng. news.* 1894. 32:495), from which the following tests of New York products are derived.

Locality	Total absorption	Pressure per sq. in at crushing	Material	Machine
Rochester	12.2%	8 460	Clay and sand	Soft mud; hard; common
Fishkill	14.8%	5 840	Clay	Soft mud
Troy	15.1%	4 400	Clay and sand	Soft mud; hard; common

Tests of building and other brick

A large series of shearing, crushing and absorption tests have been made at the Watertown (Massachusetts) arsenal on material obtained mostly from the World's Columbian exposition, some of these being made to show the strength of the same kind of bricks when tested in different positions. (*Tests of metals,* 1894, United States war department)

Tests made to show relative strength of bricks according to the direction in which tested

BRICKS TESTED FLATWISE

Hight	Surface area	Ultimate strength		Average
		Total	Per square inch	
Inches	*Sq. inches*	*Pounds*	*Pounds*	*Pounds*
2.16	27.63	308 400	11 162	11 173
2.10	27.26	367 800	13 492	
2.19	27.77	298 500	10 749	
2.21	27.90	259 200	9 290	

BRICKS TESTED EDGEWISE

Hight	Surface area	Ultimate strength		Average
		Total	Per square inch	
Inches	*Sq. inches*	*Pounds*	*Pounds*	*Pounds*
3.58	16.37	124 800	7 623	8 978
3.60	17.15	159 100	9 277	
3.57	16.98	114 000	6 714	
3.48	16.54	203 400	12 297	

BRICKS TESTED ENDWISE

7.73	7.37	59 200	8 032	6 927
7.72	7.83	45 700	5 837	
7.75	7.85	51 600	6 573	
7.71	7.54	54 800	7 268	

Tests to determine relative strength of bricks tested singly, in pairs, threes, fours and fives, set in plaster of paris joints and compressed surfaces

Number in pile	Hight of pile	Sectional area	Ultimate strength		Average
			Total	Per square inch	
	Sq. in.	*Sq. in.*	*Pounds*	*Pounds*	*Pounds*
1	2.20	28.95	458 500	15 837	12 469
1	2.12	29.56	269 000	9 100	
2	4.40	29.41	178 500	6 069	6 440
2	4.35	29.33	199 800	6 812	
3	6.48	29.14	127 200	4 365	5 096
3	6.60	29.10	169 600	5 828	
4	8.75	29.29	122 100	4 168	4 478
4	8.88	29.22	139 900	4 788	
5	10.95	28.94	131 100	4 530	4 131
5	10.85	29.60	110 500	3 733	

Building brick industry in New York state

Common brick are made at many localities, the most important region being that of the Hudson river valley.

Pressed brick in plain colors and mottled brick are made by B. Kreischer's Sons at Kreischerville, S. I.; New York architectural terra cotta co., New York city; Eastern hydraulic pressed brick co., Canandaigua; while plain brick are manufactured by the Glens Falls brick and terra cotta co., Glens Falls; the Corning brick co., Corning; Brush and Schmidt, Jewettville; Campbell brick co., Newfield.

Enameled brick. These have a very extensive use at the present day, specially for the interior of buildings, where a smooth surface is often desirable, but one which shows a variety of color. The body of enameled brick usually consists of a hard burned fire clay, or semi-fire clay, the surface of which is covered by a glaze of one color. Two difficulties with which the manufacturer of enamel brick has to contend are the production of a perfectly flat surface of enamel, and a glaze which shall be free from cracks or crazes; the latter are due to the body and the glaze having a different coefficient of expansion.

Enamel brick are made of two different sizes, known as the English and the American size, the former being 9x4½x3, the latter 8⅜x4¼x2⅜.

Many manufacturers are able to produce a wide range of colors; the number is constantly being added to. Owing to the expense of manufacture, the cost of these bricks is usually high, and varies from $60 to $90 a thousand.

The body of the brick is usually made of several different clays, and much depends on the selection of the proper material. On this mixture the method of burning sometimes also depends.

The clays used for the body of the brick are molded either by the soft mud, dry press, or stiff mud process. The glaze is sometimes applied to green bricks before being burned; or at other times the brick is first fired, the glaze then applied, and the two subjected to a second burning, which is at a lower temperature than the first. The one is known as the single fire process, the other as the double fire process.

Enamel bricks are usually made with an indentation on the upper and lower faces. In laying a wall the mortar is put in this space, in such quantity that when the bricks are pressed together a thin layer of it is forced out toward the edges and furnishes sufficient binding material. This does away with "pointing" at the joints, and a wall properly laid should show almost no mortar between the courses. In consequence of this mode of laying, every brick should be true to the standard size in order to secure a regular and perfect bond. It is, therefore, necessary to know the exact shrinkage that occurs in burning, and to allow for it by giving to the dies used in pressing the brick the proper amount of "over size."

In a good enamel brick the enamel should adhere so tenaciously to the body that it will not separate or crack under pressure till the body of the brick fails.

The matter of glazing and enameling is the most difficult part of the whole process of manufacture, and as such is kept secret by the maker as far as the details are concerned. In general it may be said, however, that the enamel is simply a mixture of clays similar to that used in making good porcelain, which is applied to the surface of the brick in the condition of a thick liquid or slip. This enamel, when dry, is coated with a fusible glaze, such as is used for ordinary porcelain.

Enamel brick are usually burned in saggers, placed in a downdraft kiln, or sometimes even in a muffle kiln. The double fire method mentioned above greatly increases the cost of manufacture.

Glazed brick. By this we understand a brick which is covered by a transparent glaze, and not an opaque enamel.

The best results are probably obtained by glazing vitrified bricks, as porous ones are seldom able to resist the weather, specially in severe climates.

If the glaze is applied to green brick, which is by far the cheapest method and the two burned together, the glaze will often show crazing under certain conditions, and it is found that there should be a certain amount of agreement between the composition of the clays and that of the brick, so that they will not only have a similar expansion and contraction when burned, but will show the proper relation between their fusing points, and the glaze will not fuse much, or not at all, below the temperature at which the brick vitrifies.

In the first place it is of course necessary that the brick shall not contain an excess of lime, so that it can be vitrified without fusing; and having found a clay of the right kind, it then remains to find a glaze which it will carry without causing it to craze.

One way to arrive at this experimentally is to take a clay whose rational composition is known, and by the addition to it of different quantities of, say, quartz sand, feldspar and lime, make mixtures which will show considerable range in a rational composition. Add-

Plate 22

To face page 652

H. Ries photo.

Clay bank, Rochester brick and tile co., Rochester. The clay is first loosened with plows, and then loaded on cars in which it is drawn to the works.

Plate 23

To face page 653

H. Ries photo.

Dry pan and Blake crusher, Horsehead brick co. The former is used for grinding the shale and the latter for crushing the harder portions of it.

ing quartz and feldspar to clay is rather expensive, and these two could probably be replaced by the use of a feldspathic quartz sand.

Experiments of this nature carried out by Hecht (*Thonindustrie zeitung.* 1894. p. 309) indicated that it is undesirable in most cases to decrease the clay substance below 30%, and that if the clay contain over 50% most of the glazes adhere with difficulty.

He found that colored glazes with a formula

$$\left\{ \begin{array}{l} .3_2KO \\ .7CaO \end{array} \right\} .5\ Al_2O_34Si\ O_2$$

held on mixtures whose rational composition was:

Clay substance	50	50	50	50	40	30	30	30	30	30	30
Quartz	40	30	20	10	50	60	50	40	30	20	10
Feldspar ...	5	15	25	35	5	5	15	25	35	45	55
Lime carbonate ...	5	5	5	5	5	5	5	5	5	5	5

Hecht in his experiments used iron, and pink glazes, because they represented extremes of composition. He found that the glazes held best when the clay substance was 30%. As the clay substance increased, the adhesion of tee clay decreased, and it did the same with an increase of the feldspar, while it adhered better as the quartz increased in amount.

The tendency of the glaze to craze also becomes greater with the size of the quartz grain, the reason being that the greater the grain the more difficult it is for a thorough chemical action to take place between the particles of the clay and those of the brick.

Methods of manufacturing brick

Bricks are usually made by one of the following four processes.

Soft mud
Stiff mud or wire-cut
Dry press
Semi-dry press

The processes are not wholly distinct from each other, as there are machines that may be used as well in connection with one as the other. For instance, in preparing the clay for molding in a stiff mud machine, we may use either a pug mill or a pan crusher, though the latter belongs preferably to the dry clay process. Whatever be the method, the manufacture of clay into brick involves the following steps, preparation, molding, drying, burning. Below is a classified arrangement of the stages in the process of brickmaking and machines used.

Methods

- Mining the clay
  - Digging by pick or shovel at any portion of bank
  - Bench working
  - Undermining
  - Steam shovel
  - Plows and scrapers
  - Dredging

Machines used

- Haulage
  - Carts
  - Cars on tracks, drawn by horses
  - Steam
  - Wire rope planes
    - Self-acting
    - Steam power
- Preparing and tempering
  - Crushers
    - Rolls
    - Jaw crushers
  - Soak pits
  - Ring pits
  - Pug mills
    - Single
    - Double
      - Horizontal
      - Vertical
  - Pan crushers
    - Wet pans
    - Dry pans
  - Disintegrators
  - Ball mills
  - Screens
    - Inclined
    - Rotary
    - Shaking

- Molding
  - Soft mud machines
    - Hand power
    - Horse power
    - Steam power
  - Stiff mud machines
    - Auger
    - Plunger
  - Dry press
  - Semi-dry press
  - Represses

- Drying
  - Open yards, sun-dried
  - Covered yards, air-dried
  - Pallets
  - Tunnels heated by
    - Steam pipes circulating within
    - Hot blast
    - Hot air from coal fire through flues underneath

- Kilns
  - Intermittent
    - Down-draft
      - Rectangular
      - Circular
        - One or more chimneys according to make
    - Up-draft
      - Scovekilns
      - Clamps
  - Continuous
    - Straight
    - Circular

Preparation of clay

Few clays are found in nature in a condition such that they can be fed directly to the molding machines; consequently they have to be first loosened up. This breaking up of the clay mass can be done by weathering, namely spreading the clay out in a thin layer and exposing it to atmospheric action, the effect of this being thoroughly to separate clay particles. This is a very thorough method of preparation, but takes a long time and, if the clay contains pyrite, the development of soluble sulfates is often brought about. A quicker method of breaking up the clay is by means of some form of machine such as the disintegrator, ball mill, or dry pan. According to the type of machine used, it is possible to disintegrate a clay in its dry, plastic, or even very wet condition. There are many devices for this kind of work, but only a few need be mentioned.

Dry methods of preparation

Crushers. The Blake type of crusher, which is frequently used for breaking up hard shales or old brick, consists of two jaws, the one fixed, the other fastened at its lower end, while the upper end moves back and forth at a rapid rate. Such crushers are strong and effective, but have a rather limited use at clay-working establishments.

Pan crushers. Of these there are two classes, dry pan crushers and wet pan crushers. The former pulverizes the material as it comes from the bank, the latter tempers it with water. In either case the crushers consist of a circular pan in which two iron wheels revolve on a horizontal axis. They are made to revolve by friction against the pan, which is rotated by steam power. In a dry pan the bottom is perforated; the wheels weigh 2000 to 5000 pounds each. The wet pan has a solid bottom, in which there is a door through which the material can escape when sufficiently tempered.

A good dry pan will grind 100 tons in 10 hours through one eighth inch screens.[1]

Two scrapers are placed in front of the rollers to throw the material in their path.

Disintegrators. These, of which the Stedman disintegrator is a good type, consist of several series of concentric drums which revolve in different directions. The material to be pulverized is fed into the disintegrator by means of a hopper, and as soon as it enters is caught between the staves of the first drum, and thrown by this against the next inner one, which revolves in the opposite direction, and from this one against a third inside of the second, revolving in the same direction as the first. The clay particles by being violently thrown against the staves and against each other are

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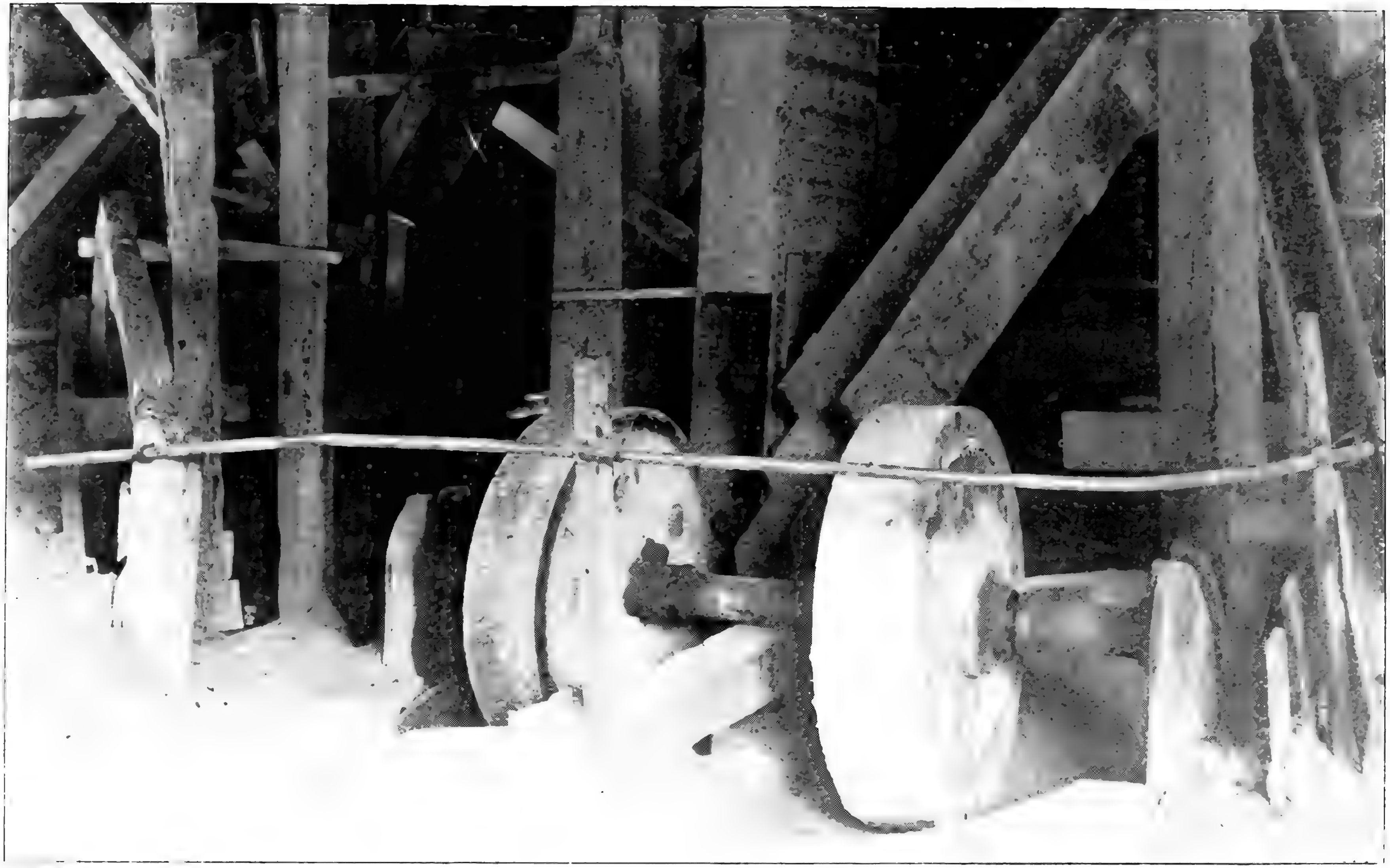
[1] Ohio geol. sur. 1893 p. 142. E. Orton jr. *Clays and clay-working industries of Ohio.*

Plate 24 To face page 656



H. Ries photo.

Dry pan, Newfield brick works. At the rear of the left hand wheel is seen the bucket elevator which carries the crushed material up to the screens, and those particles which do not pass through, come back down the chute on the right to be reground.

rapidly reduced to a fine state of division, the whole operation taking not over one or two seconds. The material is then discharged on an endless belt, and carried to the screens. The disintegrator is inclosed in a metal case. The series of drums, the velocity with which they revolve, and the strength and the arrangement of the staves depend on the hardness of the material to be pulverized, and also on the degree of fineness to which it is to be reduced. By varying the velocity of the disintegrator a coarser or finer product is obtained.

The capacity of this type of machine is very great, but it also requires considerable power to operate it. According to capacity disintegrators can pulverize in one hour from 8000 to 28,000 pounds of material, such as shale, gypsum, etc. They require 2½ to 4 horse power for every ton of material pulverized in an hour.

Ball mills. These consist of a large drum which revolves on a horizontal axis. This drum contains balls of varying diameter which roll over each other, and as the drum revolves comminute the particles of material. The material is introduced through a door in the side of the drum, the door is then closed, and the drum, being set in motion, is turned till the material is ground to sufficient fineness. It is then discharged on the sieve, and particles which will not pass through are returned to the drum together with fresh material.

Ball mills were at first constructed with a comparatively small capacity, but recently mills have been constructed that discharge the pulverized material continuously. A still more recent modification consists in introducing the charge at one end of the cylinder, allowing it to pass the whole length of the mill and issue at the opposite end. As the breaking up of the particles in the ball mill is the result primarily of the action of the balls rolling over them, it will easily be seen that the product of this machine will show a considerable variation in the size of its grains, and that the thorough pulverization will be obtained only by keeping the material a long while in the mill. This objection therefore, adapts the ball mills particularly to the production of such materials as exhibit coarse article and fine grains, such as grogs for instance.

The material to be ground in ball mills must be air-dried and only in those of the intermittent type can damp or wet material be introduced. This is necessary, for instance, in the case of glazes. If the material to be ground must be kept from contact with iron, the interior of the cylinder is lined with porcelain, and instead of iron balls porcelain or flint ones are used. The capacity of ball mills is highly variable, depending on the fineness of the product desired, the hardness of the material to be ground, and also on the size of the mill, therefore the hourly production will vary in the case of grog between 1500 and 3000 pounds. In this case, for every 2000 pounds ground in an hour, three to 10 horse power is required.

Wet methods of preparation

The clay can commonly be tempered directly as it comes from the bank instead of being pulverized, which is always necessary in the case of shales.

The wet methods employed are:

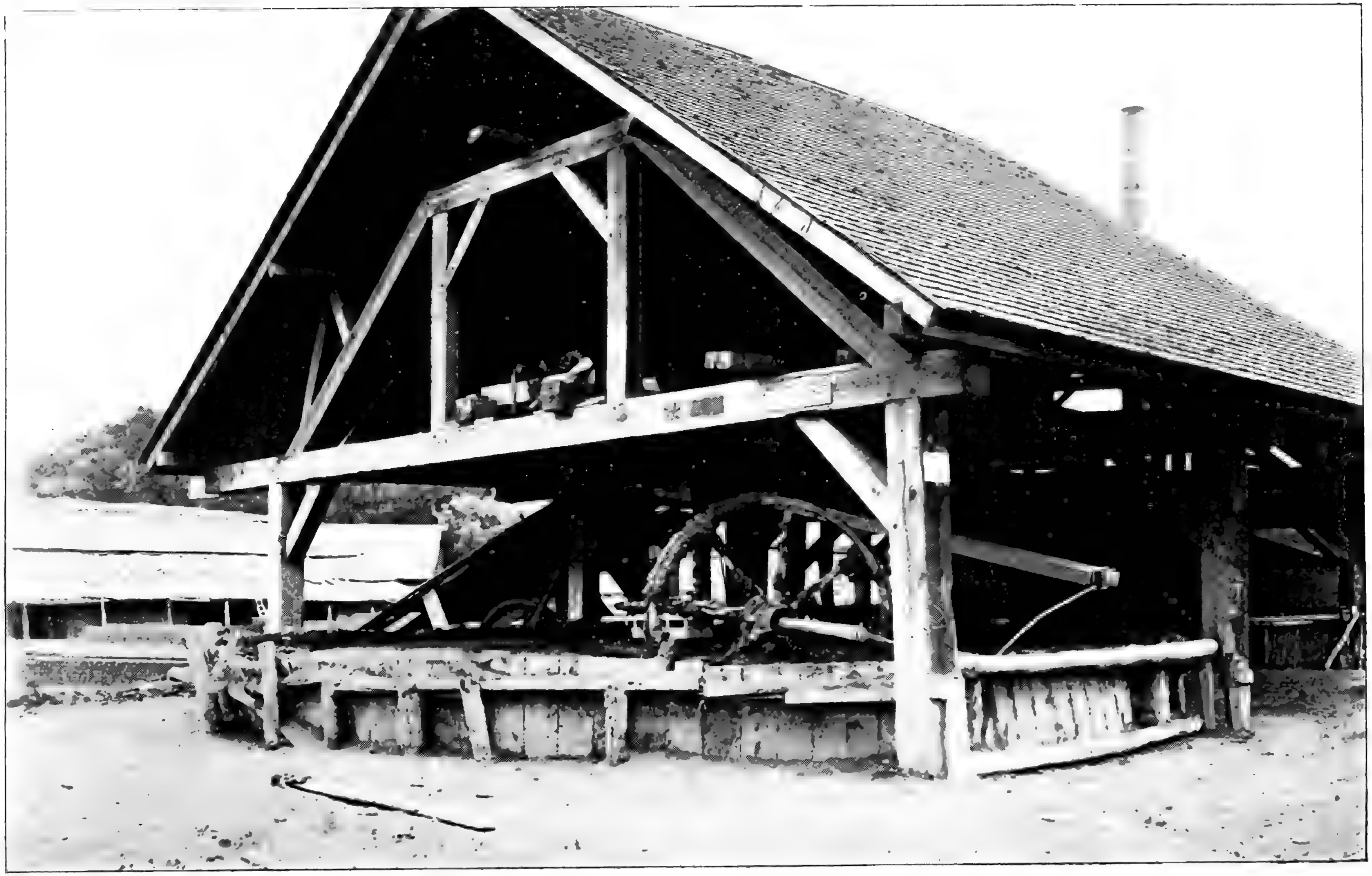
Soak pits. These are the most primitive contrivances at present used for the preparation of clays. There is a rectangular pit about 5 feet deep and 6 feet square. The Long Island pits are usually rectangular in shape. Into this the clay and sand are dumped, water poured on and the mass allowed to soak over night, so as thoroughly to soften it. The following morning the softened material is shoveled into the machine. Two men — pit shovelers — do this, and it is highly important that they be men of intelligence and attend to their work, seeing that the right proportions of clay and sand are shoveled into the machine. From one third to one quarter is the amount of sand added. The operation of mixing the clay and sand is called tempering; the addition of sand is in most cases not necessary, as the majority of clays have sufficient of it naturally. The object of the addition of sand is to counteract the effect of the alumina, by preventing a too great and uneven shrink-

Plate 25

H. Ries photo.

Soak pit in which the clay, sand and coal dust are mixed with water before being shoveled into the molding machine. Rose, Rose & co., Roseton.

Plate 26 To face page 659



H. Ries photo.

Ring-pit, for tempering clay, Ferrier and Golden, Catskill.

age of the brick. Coal dust is also added by some manufacturers; the advantage derived by its use will be mentioned under the head of burning.

When soak pits are used, two men dig the clay in the afternoon at the bank, while a third man levels off the material as it is dumped into the pit and also adds the requisite amount of water. He is called the temperer. In the morning the two diggers of the previous afternoon shovel the clay from the soak pit into the machine.

In many large brickyards separate gangs of men do the pit shoveling and digging of the clay.

Ring pits. These temper the clay more thoroughly than soak pits, but are not so extensively used, possibly because it costs a trifle more to operate them. A ring pit, as its name implies, is circular, 25 to 30 feet in diameter, 3 feet deep and lined with boards or brick. In this there revolves an iron wheel, 6 feet in diameter and so geared that it travels from the center to the circumference of the pit and then toward the center again. In this manner the clay is thoroughly broken up and mixed with the sand and coal dust, if the latter be added. The pitful is tempered in about six hours; a pit holds sufficient for about 30,000 brick. The tempering is usually done in the afternoon so as to have the material ready for the next morning. When the tempering is finished, a board is attached by ropes to the wheel and dragged round the pit a few times to smooth the surface of the clay; a thin crust forms on the surface and prevents the moisture in the underlying material from evaporating.

The working of ring pits is similar to that of soak pits, the only difference being that the temperer previously mentioned is generally employed in the morning to wheel the clay from the ring pit to the molding machine.

As a rule there are two ring pits to a machine, so that while the clay is being shoveled from one pit to the machine, the other pit is tempering clay for the next day, or two pits and two machines are used, but each pit in this case holds enough material for the daily use of two machines.

Pug mill. This machine, like the ring pit just described, is used for thoroughly mixing the clay, or clay and sand as the case may be, before introducing it into the machine. It consists essentially of a semi-cylindric trough, 6 to 10 feet long, in which revolves a shaft, bearing knives set spirally around it, or a worm screw 6 or more inches wide. The material is put in at one end, and the knives or thread mix it up. At the same time it is worked along to the other end of the trough, from which it is discharged into the machine. The pug mill may be closed or open; the former is better as there is a more uniform pressure on the clay while it is being tempered, and a more thorough mixing results. Water is also added from a faucet at the upper end of the trough till the clay is in the right condition. The angle of the knives with relation to the shaft can be changed so that the clay can be moved along slower or faster as desired. The trough of the pug mill is of iron or wood, usually the former. A pug mill, according to its size, will in 10 hours temper clay enough for from 25,000 to 60,000 brick. Pug mills take up less room than ring pits and do not require as much power to operate them. They will also, if desired, discharge the clay directly into the molding machine. They are used chiefly with stiff mud machines.

In some works a double form of pug mill is used. This has two axles bearing knives, instead of one. They revolve in opposite directions. (pl. 106[27])

Screens

When clay is molded in the dry condition, or when shale is used instead of soft, plastic clay, it is important that the material be first ground to the proper degree of fineness.

As the material comes from the dry pan or other apparatus used to pulverize it, it is carried to screens, which allow the sufficiently fine material to pass through while those particles which are too coarse go back to the crushing machine.

Three general types of machine are used, inclined, rotary, and

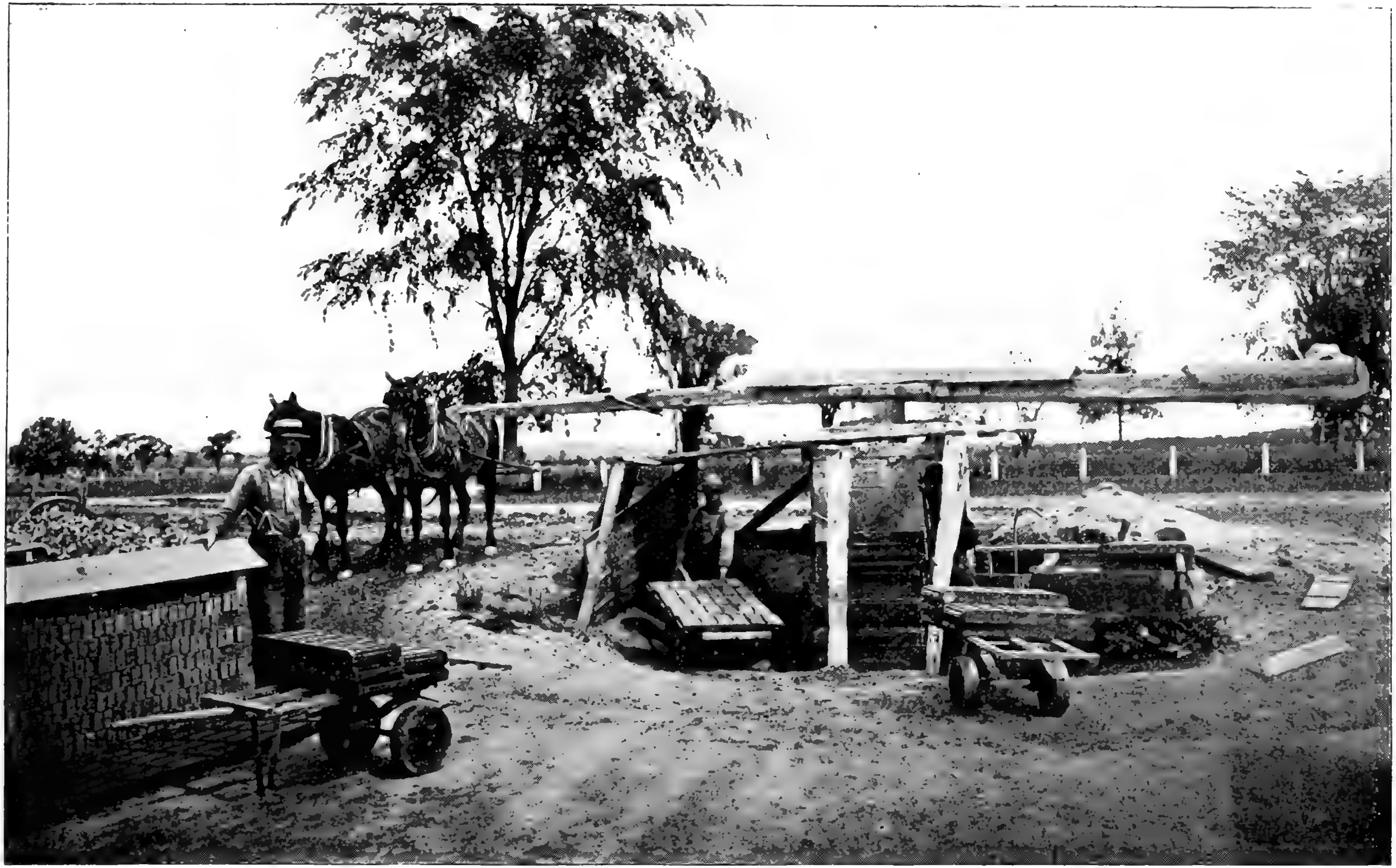
Plate 27

To face page 660

H. Ries photo.

Clay conveyor (a), crushing rolls (b), and pug mill (c). Rochester brick and tile co.

Plate 28



H. Ries photo.

Horse power soft mud brick machine. To right of machine is truck with empty molds. The boy on left has a truckload of filled molds ready to be dumped on the drying yard. J. Oulmet, Plattsburg.

shaking. The inclined screens are usually 10 to 14 feet long, have a bottom of either wire cloth or perforated metal, and are usually provided with a tapping device to keep them from becoming clogged. Such screens are simple and cheap, but have a small capacity.

The rotary screens are commonly of wire cloth, and have a cylindric or octagonal form. They are usually provided on the inner side with brushes to keep them clean.

Shaking screens are fixed at one end, while to the other end is attached a crank and piston or an eccentric, which operates them. Such screens are cheap and simple in operation.

While all of these screens are designed to perform their work automatically, nevertheless very few of them can be left without attention for any length of time, for powdered clay, no matter how dry it is apparently, shows the greatest tendency to clog the meshes of almost any screen.

Molding

Soft mud process

This is the most prevalent method in New York state.

The clay is mixed with water to the consistency of a soft mud, and is either forced into a wooden mold by hand, or molded in a machine, operated by steam or horse power.

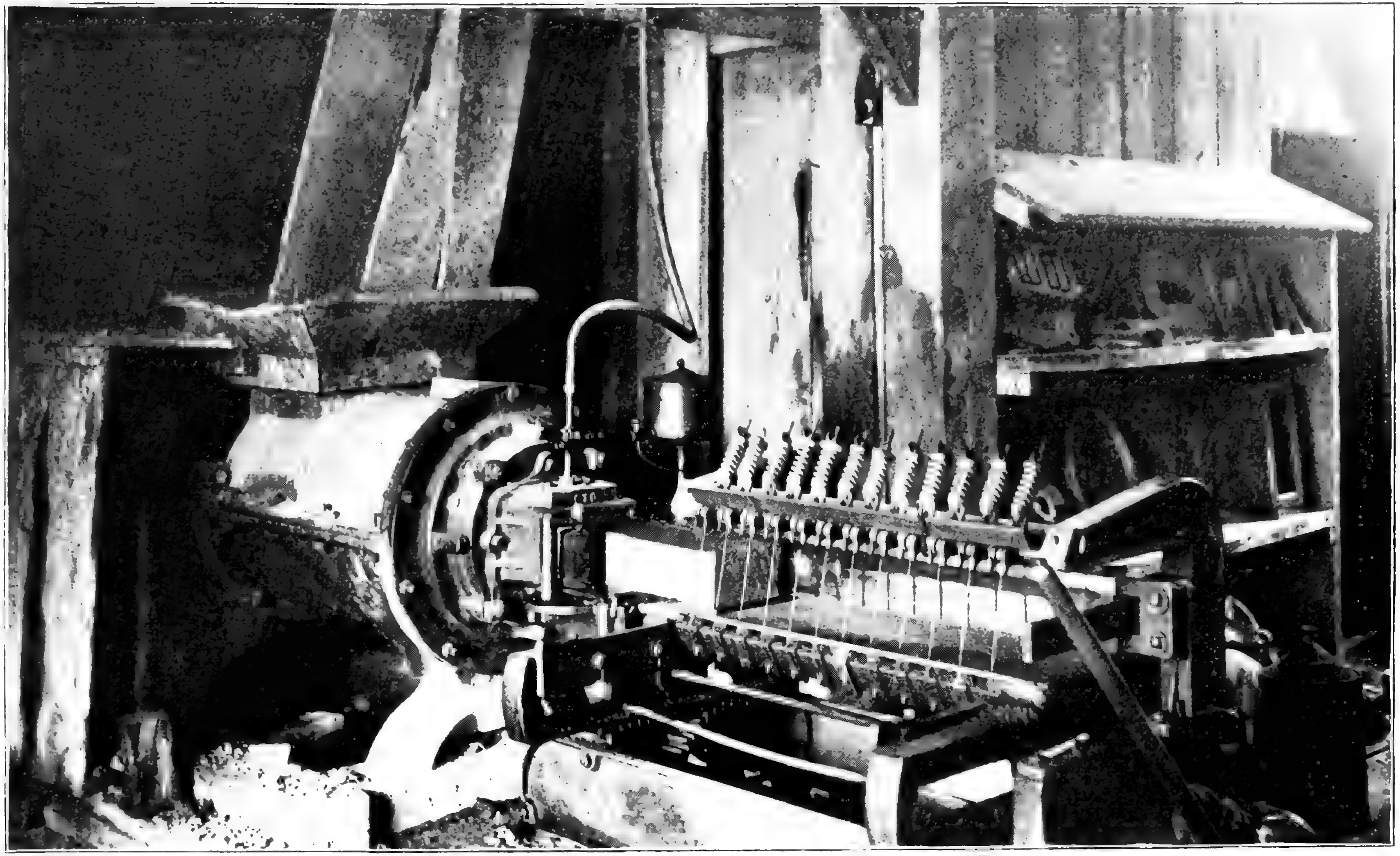
There are a number of different types of machines but the fundamental principle of all is the same. A soft mud machine consists essentially of an upright box of wood or iron and generally of a rectangular shape. In this is a vertical shaft bearing several knives horizontally. Attached to the bottom of the shaft is a device such as a curved arm, which forces the clay into the press box. The molds are put in at the rear of the machine and fed forward underneath the press box automatically. The empty mold sliding into place shoves out the filled one. The molds before being placed in the machine are sanded either by a boy, or else in an automatic mold sanding machine in order to prevent the clay from sticking. The clay is fed to the machine at the upper end of the box. Often there is a pug mill attached to the machine. In all these machines the material gets an additional amount of mixing by the knives on the vertical shaft. In fact many brick manufacturers consider that the soft mud machine tempers the clay sufficiently to enable them to dispense with a pug mill or ring pit and use the old-fashioned soak pit. That they can make a very fair common brick thus is not disputed, but it is certain that with a thorough tempering of the clay, a better brick would be obtained in most cases. There is one type of machine, the Adams, used by several manufacturers on the Hudson river, which does not temper the clay, but simply forces it into the press box. Some form of tempering machine must, therefore, be used in connection with it. These soft mud machines have a capacity of about 5000 brick an hour, six being molded at a time.

Steam power is generally used to run the machines, but some of the smaller yards use horse power; this, of course, is much slower and not economical except for a yard of a small capacity. Some soft mud machines are more powerful than others, and indeed this is necessary. For instance a brick dried on pallets needs a much greater pressure applied to it, and has to be molded from stiffer material than one dried in the sun in the yard.

Four men are required to tend the machine. A "molder" who scrapes off the top of the mold as it is delivered from the machine and watches the consistency of the tempered clay, to see that it keeps uniform; a "mold lander" who takes the mold from the delivery table and places it on the truck; a "sander" who sands the molds before putting them in the machine, and a boy to watch the machine and stop it when necessary. Beside this there are four "truckmen" who wheel the bricks from the machine to the yard, where they are dumped on the drying floor by two "mold setters". In the afternoon these men are employed in hacking the bricks and wheeling the dry ones to the kiln.

Stiff mud or wire-cut machines. Their name indicates the nature of the process. The clay is tempered quite stiff, and

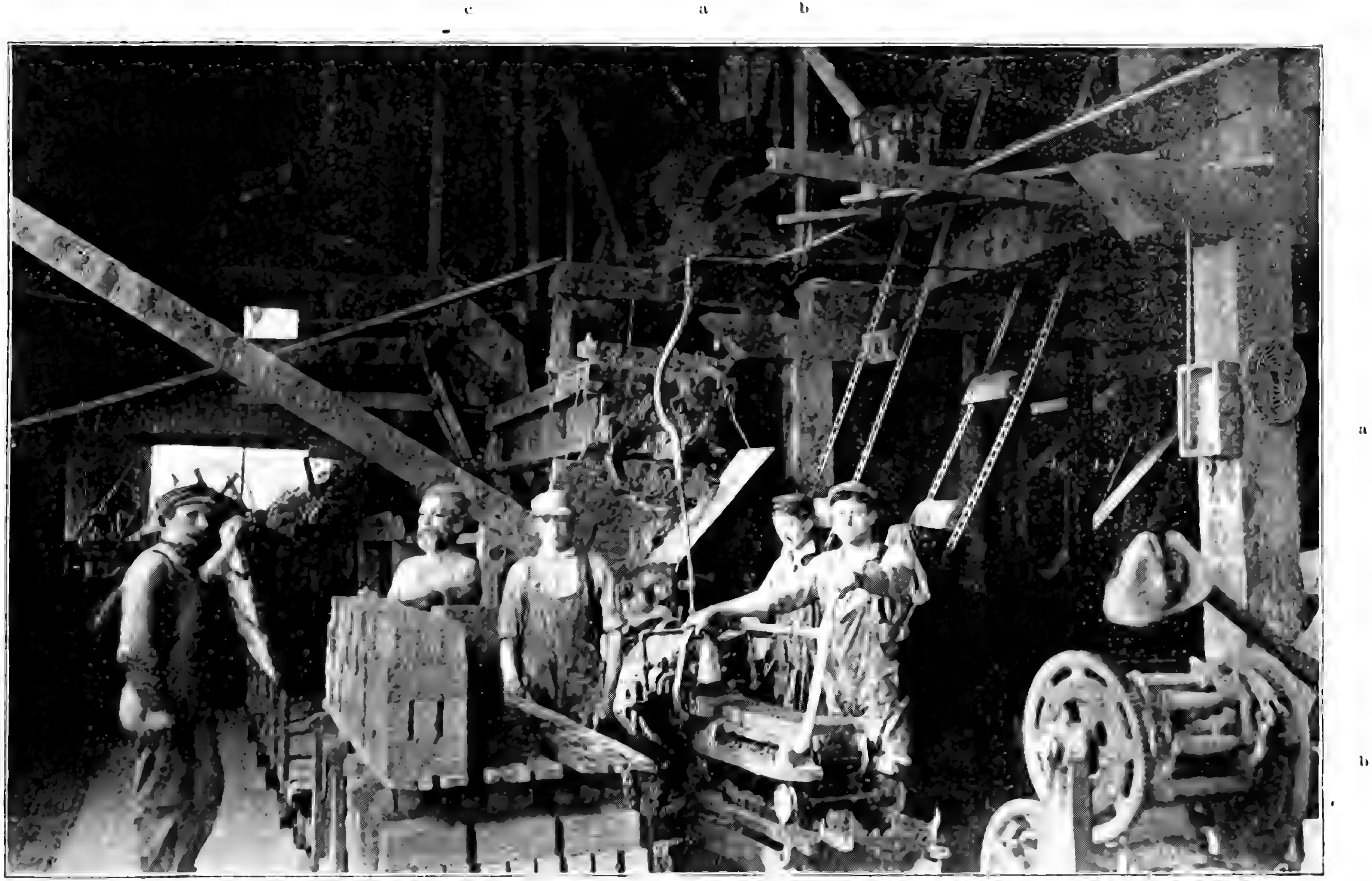
Plate 29



H. Ries photo.

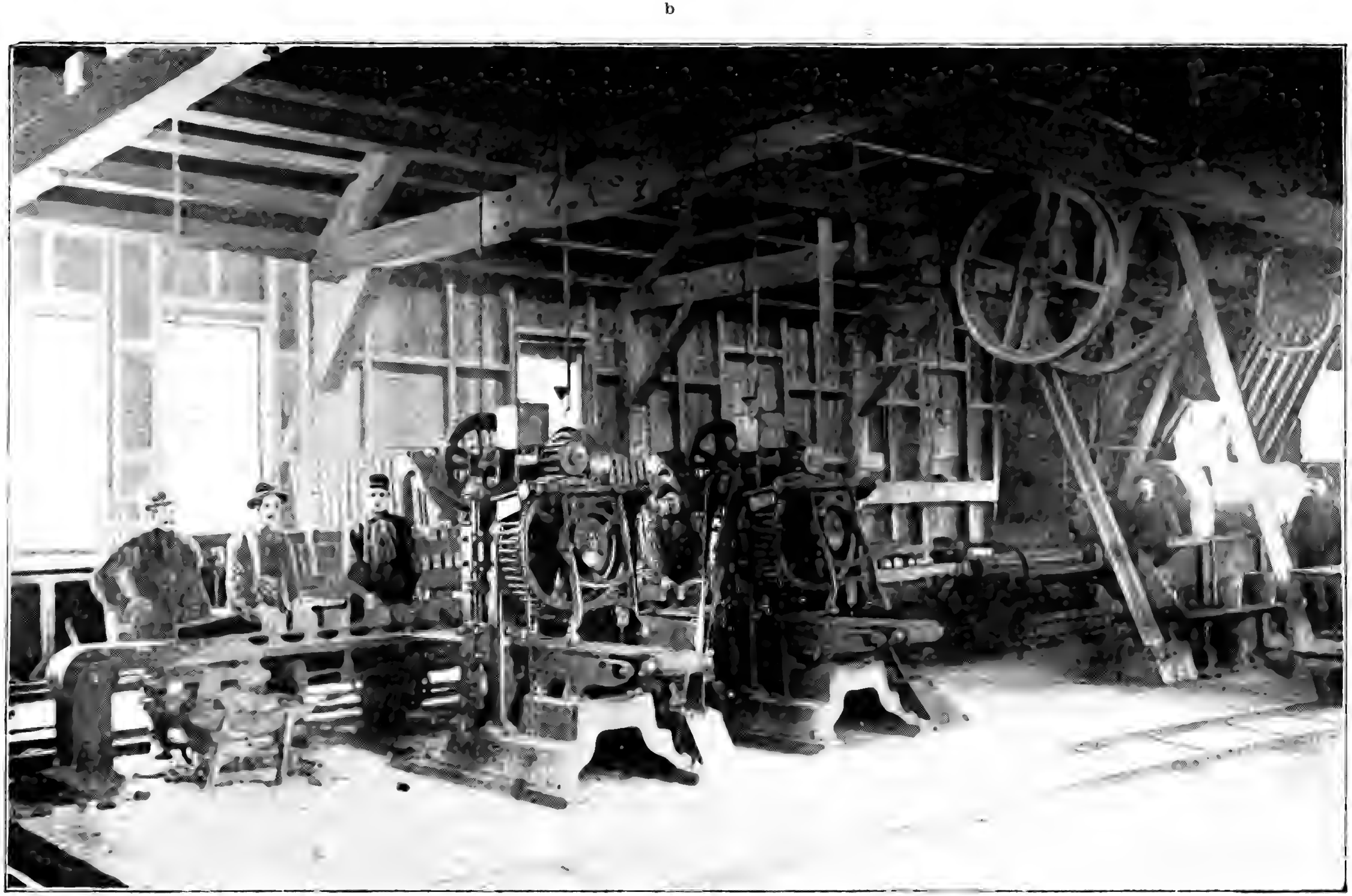
Stiff mud brick-making machine, with cutting table. Brush & Schmidt, Jewettville. The bar of clay is seen issuing from the machine.

Plate 30



H. Ries photo.

Molding stiff mud brick, Onondaga vitrified brick co., Warners. On top of the machine is the pug mill (a); the clay is seen issuing from the machine (b) onto the cutting table, and the formed bricks are put on the cars (c) to be taken to the drying chambers



H. Ries photo. Stiff mud machine (a), and represses (b). Jamestown shale paving brick works. Jamestown.

charged into the machine, from which it is forced in the form of a rectangular bar whose cross-section has the same area as the greatest plane surface, or the end of the brick. The bar of clay as it issues from the machine is received on the cutting table, and either is cut up into brick by means of a series of parallel wires set in a frame which slides across the cutting table, in which case the machine stops when the bar has issued a certain length, or the bar of clay issues continuously, and is cut up by means of wires on a revolving frame.

The plunger machine consists of a large iron cylinder into which the clay is charged. From this it is forced out through the die.

The auger machine consists of a cylinder with a conical end. In this is a horizontal shaft bearing a screw or knife blades so set that their action will force the clay forward. At the forward end of the shaft is an iron screw which forces the clay out through the die. The clay is fed at the large end of the cylinder. It will thus be seen that the clay undergoes a large amount of compression and that considerable power is required to force it through the die.

Auger machines are either end-cut or side-cut, depending on whether the area of the cross-section of the bar of clay corresponds to the end or side of a brick; and consequently the mouthpieces vary in size and shape of cross-section, according to the kind of brick or other product to be turned out.

Mouthpieces are generally made of steel, are steam-heated, and, in order to prevent the formation of a serrated edge on the emerging bar of clay, much attention is given to the internal shape of the die. When a bar of clay emerges from a rectangular opening, there is more friction at the corners than in the center of the bar or on the sides, and for this reason the internal form of the mouthpiece should be such that a sufficient quantity of clay will be forced toward the corner of the die to preserve an equal velocity in all portions of the emerging clay stream. At times the mouthpieces or dies are watered or oiled in order to facilitate the issuance of the clay. The practice of steam-heating the die is rather an American one.

The effect of a difference in velocity between the central and outer portions of the clay stream is to produce a laminated structure in the brick. Plastic clays laminate more than lean ones, and even the same clay may laminate more with one die than with another. Irregularity of clay supply may be still another cause. In common brick laminations are less harmful than in paving brick; repressing may at times obliterate them to a large extent. The auger machine is extensively used at the present day, specially in the manufacture of paving brick. It has a large capacity, 60,000 brick being not an unusual output for 10 hours. The capacity of the auger machine is often increased by causing two streams of clay to issue from it, and certain machines are said to have produced 150,000 brick a day. Plunger machines have a capacity of 25,000 to 30,000 a day.

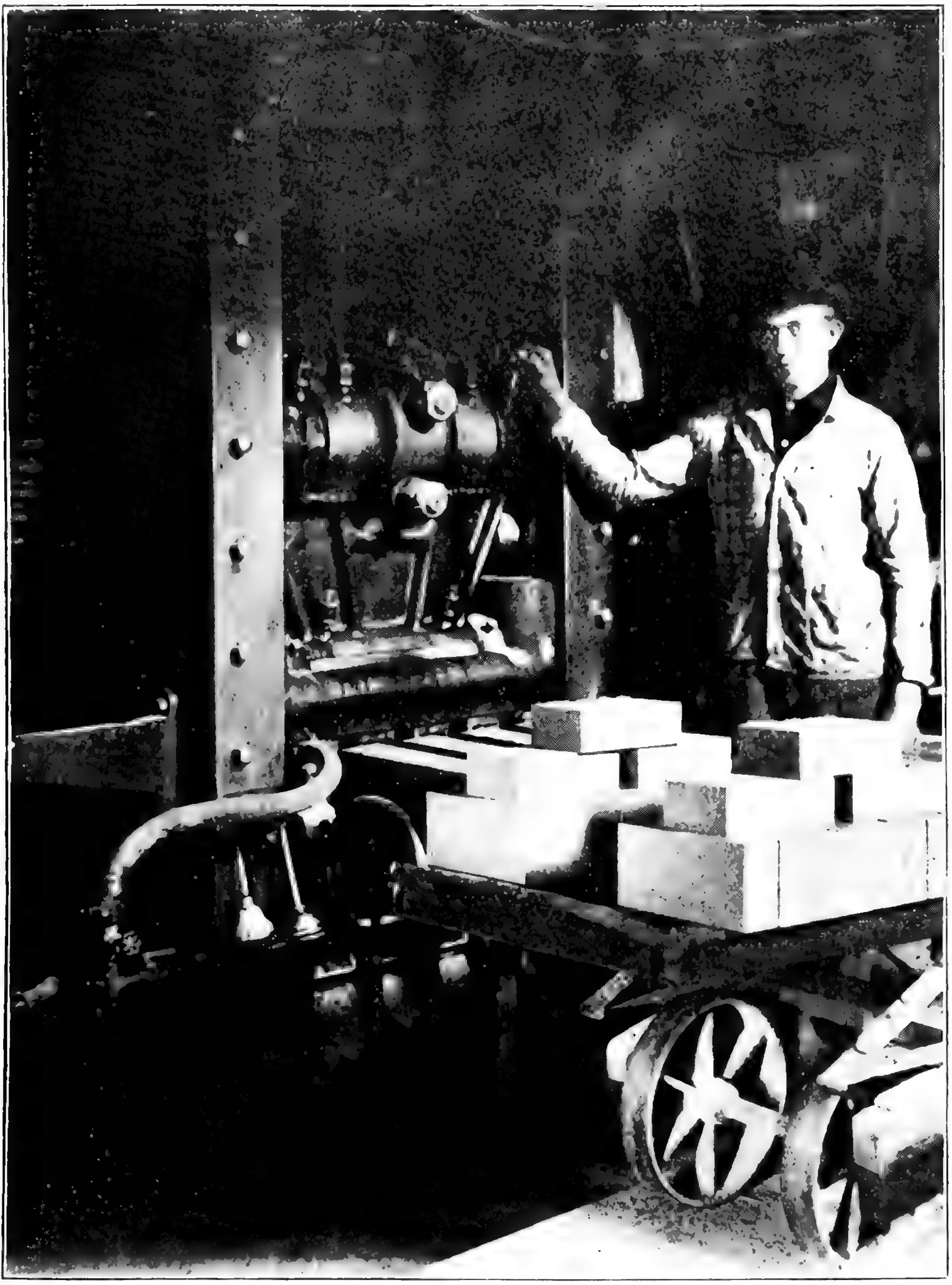
Building brick are mostly side-cut, while paving brick are commonly end-cut.

If the brick are to be facing, they are repressed, for the purpose of straightening their edges and smoothing the surface.

Dry clay process

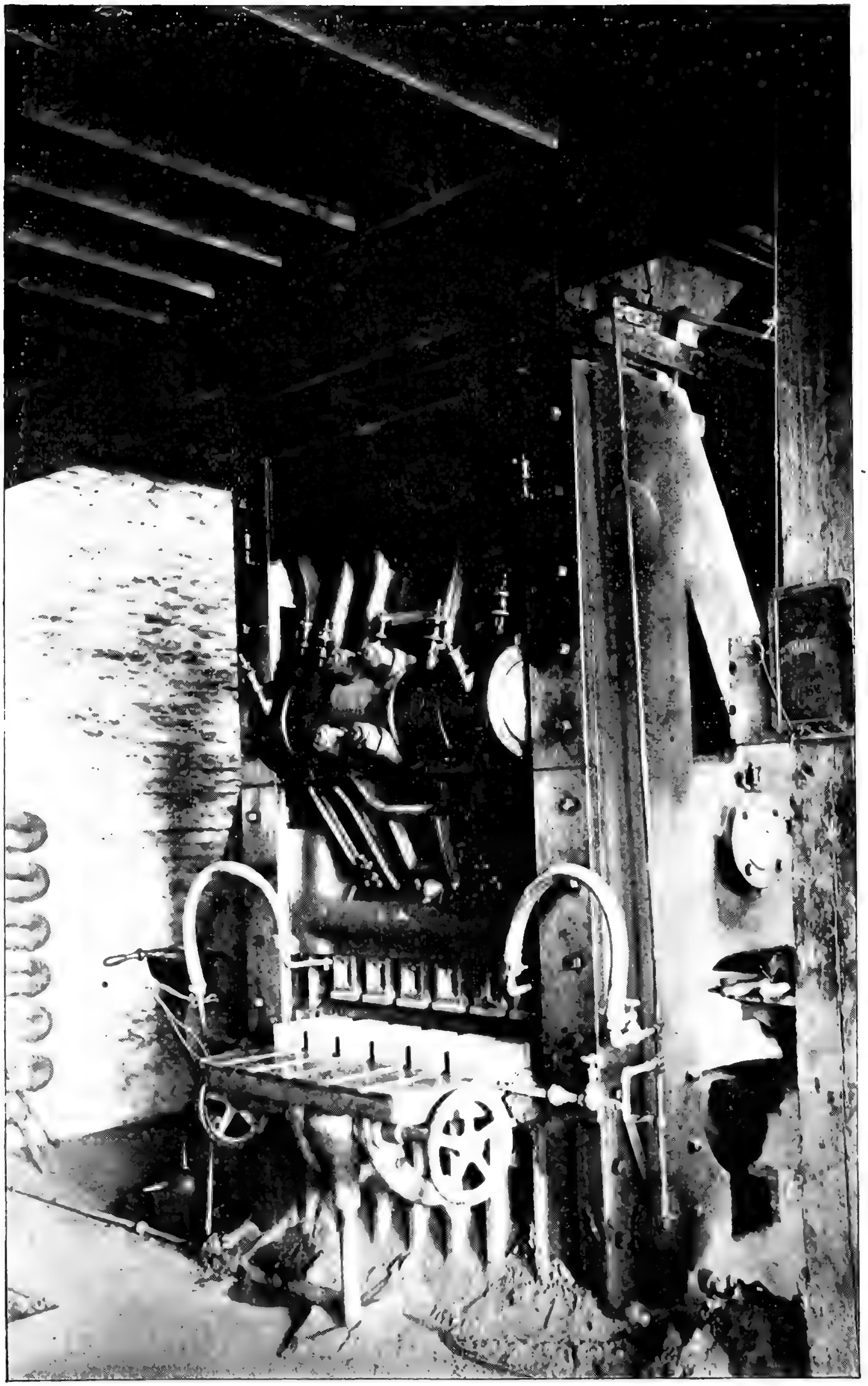
The use of this method in the United States dates back 15 or 20 years, to its introduction at Louisville, Ky. In New York it has not been in use over nine years. There are five dry press in works in the state. The clay after being dug is usually stored in sheds to dry. When ready for use it is taken out and charged into the disintegrator or dry pan, both of which have been described under "Preparation of clay."

After passing from the disintegrator the powdered clay is carried by an elevator to the upper story, where it is discharged on a long screen inclined at an angle of about 45°. The material which has been ground fine enough passes through the sieve and down into the hopper over the molding machine. The tailings fall into a hopper at the lower end of the sieve and are carried back to the disintegrator.



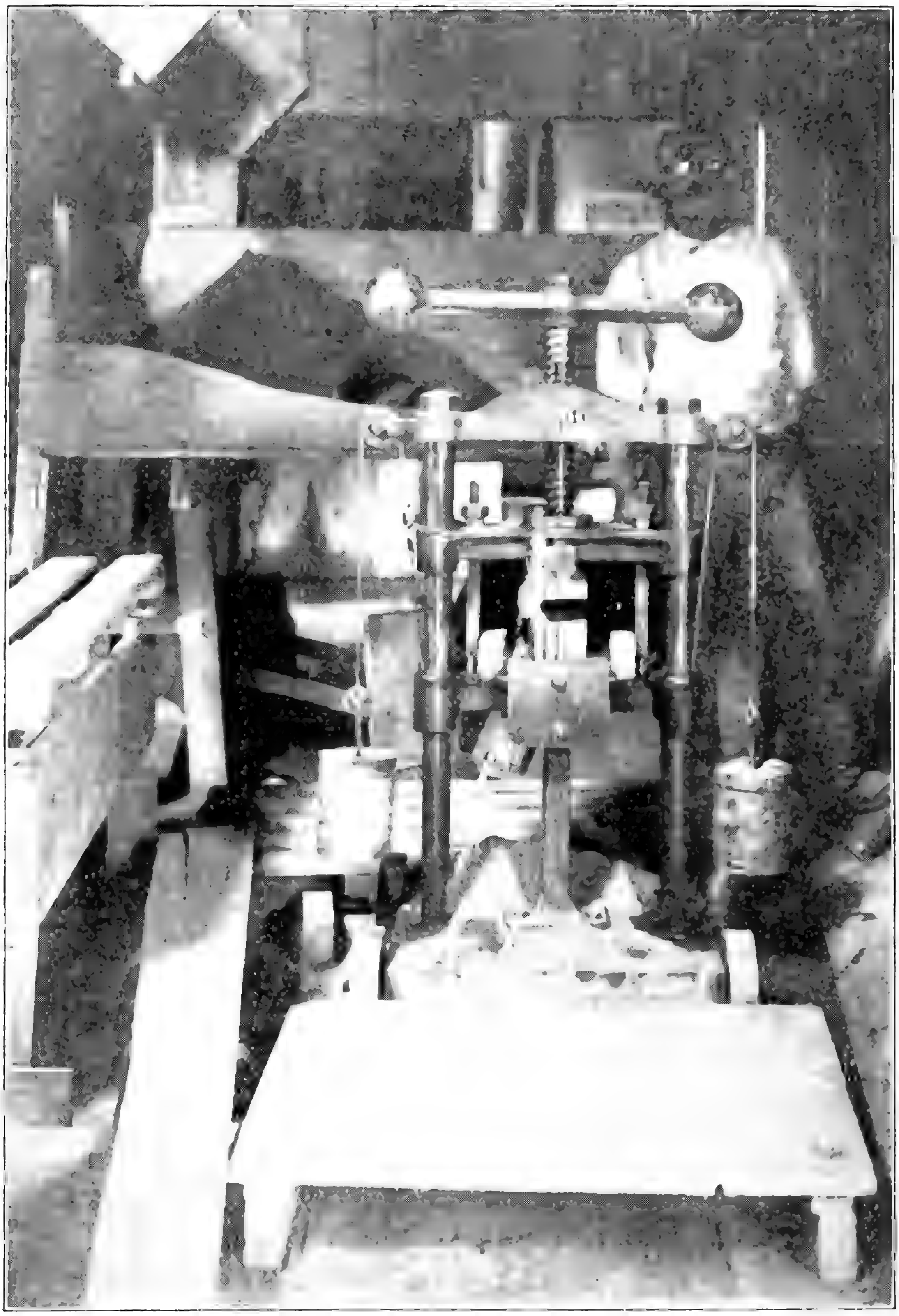
H. Ries photo.

Simpson dry press brick machine, Brush & Schmidt, Jewettville, Erie county. The plungers are at the lowest point of the stroke, and molded bricks are on the wagon ready to be taken to the drying tunnels.



H. Ries photo.

Boyd dry press brick machine, Garden City brick co., Farmingdale Long Island. The plungers are at the highest point of their stroke and the six bricks which have just been molded are pushed forward automatically on two of the delivery tables.



H. Ries photo.

Hand power dry press machine for molding ornamental shapes. A molded brick has just been pushed out of the mold. Brush & Schmidt, Jewettville.

The molding machine consists of a massive frame of forged steel about 8 feet high. 3 feet up from the ground is the delivery table, into which the press box is sunk. Connected with the hopper above the machine by means of two canvas tubes is the charger. This slides back and forth on the table. It is filled on the backward stroke and on its forward stroke lets the clay fall into the mold box. The charger then recedes to be refilled and at the same time a plunger comes down pressing the clay into the mold. As the upper plunger descends, a lower plunger which forms the bottom of the mold moves upward, so that the clay receives pressure from above and below. The upper plunger then rises, and the lower plunger ascends till the lower surface of the brick is even with the table. Again the charger comes forward, shoving the green brick forward on the table, the lower plunger drops and the mold box is once more filled with clay. The faces of the mold are of hard steel heated by steam to prevent adherence of the clay. Air holes are also made in the dies, but are apt to become clogged up. The pressure from above is applied by a toggle-joint arrangement, and it is maintained by the manufacturers of the Boyd dry clay presses that the pressure exerted on each brick is 150 tons. One to six bricks can be molded at a time, according to capacity of machine. On a four brick machine about 20,000 are molded in a day.

The hydraulic dry press machine is in use at Canandaigua, N. Y. In this, the pressure is produced by a pair of hydraulic rams, acting from both above and below. The pressure delivered at first is light, being only 240 pounds the square inch (*Missouri clays, Mo. geol. sur.* 11: 502), and this is followed by a pressure of 3700 pounds, which completes the pressing.

A difficulty encountered in the dry press and semi-dry press methods is the imprisonment of air in the brick under pressure, with the result that the compressed air tends to split the brick when the pressure is released. This can be obviated partly by allowing the plunger to descend very slowly, giving the air time to escape, and also by leaving small vent holes in the top and bottom of the mold.

The molded brick are shoved forward on the table by the charger, are placed on cars and either taken to drying chambers or set directly in the kiln. The green brick require great care in handling as they are very tender. Drying must be done very slowly to prevent cracking. Burning is usually done in down-draft kilns. The manner of burning does not differ essentially from that followed for other makes of brick. By setting directly in the kiln without previous drying it takes longer to water-smoke. This in any case should be done very slowly and the burning should not be pushed till water-smoking is entirely finished. It is calculated by some that one sixth to one quarter more fuel is required to burn dry clay bricks than those made by other processes. Burning in a down-draft kiln is more expensive than in an up-draft one, but a much greater percentage of good bricks is obtained. It is consequently better for burning pressed brick.

The type of kiln used varies.

It is essential for the production of good dry pressed bricks that the moisture contents of the raw material shall be pretty constant and the degree of fineness shall always remain the same. The first condition is obtained by drying the clay in sheds, the second by screening the material, after it is ground.

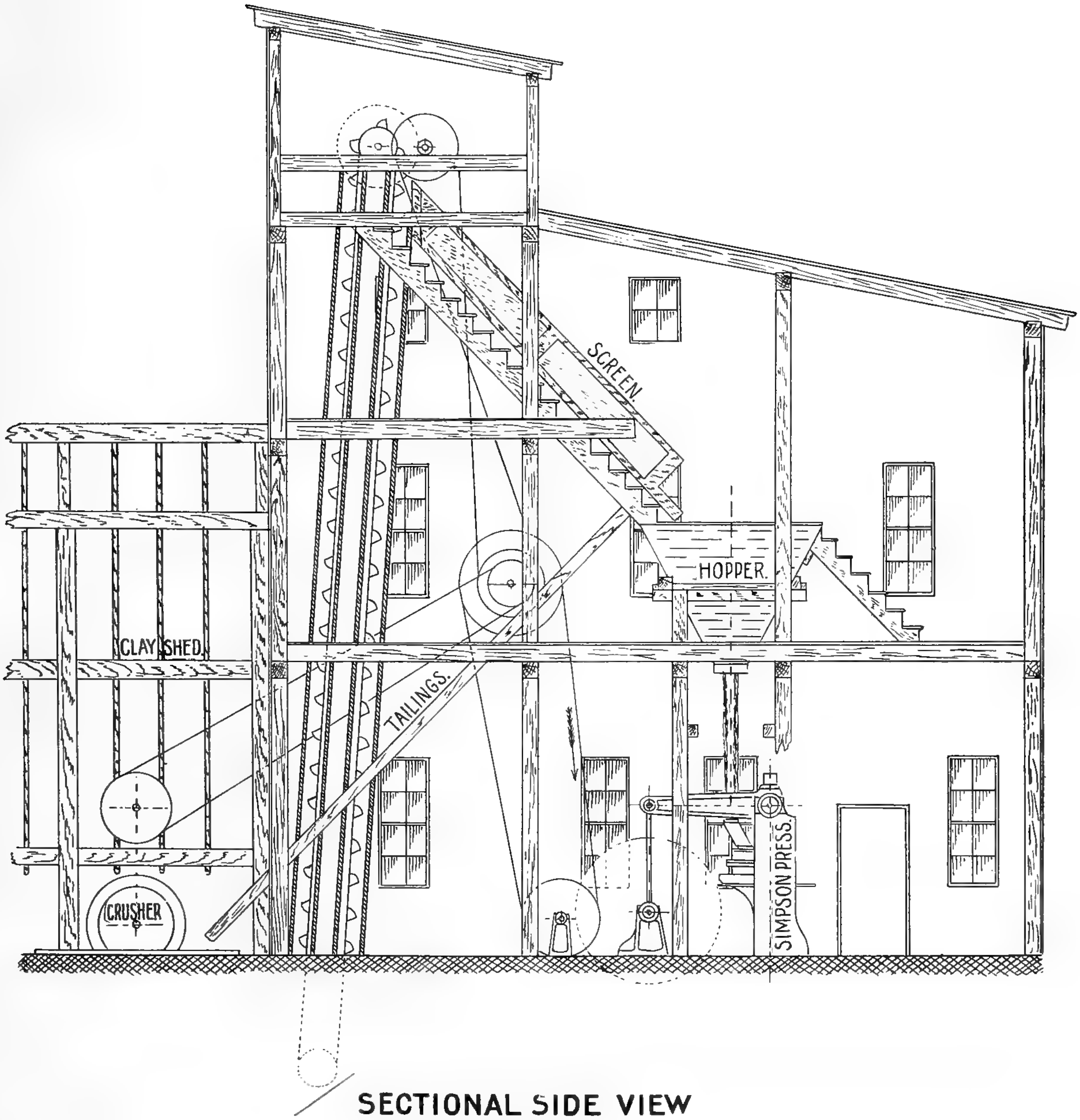
The manufacture of brick by the dry press process has certain advantages over the stiff mud or soft mud process.

1 Drying racks and drying sheds are not needed, which means a certain saving of capital and cost for repairs.

2 The production of brick by this method is cheaper, and the bricks produced have a more constant and even form.

3 Labor is cheaper than in the case of the other methods, as there is less handling to be done, the bricks being carried directly from the molding machine to the kiln.

The forms of the bricks molded on dry press machines are not restricted to rectangular shapes, but ornamental patterns can also be produced, which in the case of plastic methods can be formed only in plaster molds.



SECTIONAL SIDE VIEW
OF DRY PRESS BRICK PLANT

Semi-dry process

This differs but little from the dry process. The clay usually has a slight amount of moisture added to it.

Clays adaptable to the different molding methods

Few clays give good results with all the methods of molding just described, and the same clay will not necessarily make a good brick with any machine of the same general type. This is specially true of stiff mud machines. For the dry press process a wide range of clays can be used, for it works with sandy ones, or with plastic materials. Coarse sandy clays however do not lend themselves readily to dry pressing, on account of their very slight cohesive strength.

As an illustration of the wide range of clays used, we may compare the two following clays, no. 1 being a clay used to a large extent for making brick in western Illinois, no. 2 a black clay from Wyandance, L. I.

Both feel gritty, but neither contains particles large enough to be retained by a 100 mesh sieve.

When subjected to a mechanical separation they yielded.

	No. 1	No. 2
Fine sand	5%	84%
Clay substance and silt	95%	16%
	100%	100%

The other physical tests of no. 2 are given on page 740.

Those of no. 1 are: water reuqired for mixing 16%; air shrinkage 6%. Incipient fusion began at .04 with 8% shrinkage; vitrification at 4, with a total shrinkage of 12%; at cone 6 viscosity began. The soluble salts amounted to .09%. The tensile strength ranged from 150 to 175 pounds a square inch.

If the product from the dry press machine is properly burned, it gives a good brick, but if not, it is apt to be easily disintegrated by the frost. Owing to their greater density, dry press brick have to be burned more slowly than those made by other methods.

The stiff mud process is adaptable mainly, if the best results are desired, to clays of moderate or good plasticity, which will dry in a reasonable time. As the clay in flowing through the die requires much tenacity to escape tear, very siliceous clays are not desirable, and on the other hand very plastic ones tend to develop laminations in the brick. The capacity of the stiff mud machines is very great and their use is increasing, though it is already extensive.

Repressing of bricks

Paving brick and front brick are sometimes repressed, the object being to give sharper edges and angles in the case of the latter, and in both cases to produce a brick of more regular size and greater density.

The repressing is done in a machine known as the repress, operated either by hand or steam power. (pl. 36.) In the hand power machine only one brick is repressed at a time, and one man and a boy can generally repress about 2000 a day. In a steam power machine two bricks are repressed at a time, and the capacity is about 25,000 a day of 10 hours. In each case the pressure is applied vertically, and the dies and other parts of the machine have to be oiled frequently to keep the clay from sticking.

Repressing reduces the volume of the brick somewhat, thus in one case a brick before being repressed in a steam power machine measured $8\frac{3}{4} \times 4\frac{3}{8} \times 3\frac{1}{8}$ inches, and after it $8\frac{11}{16} \times 4\frac{3}{8} \times 2\frac{7}{8}$.

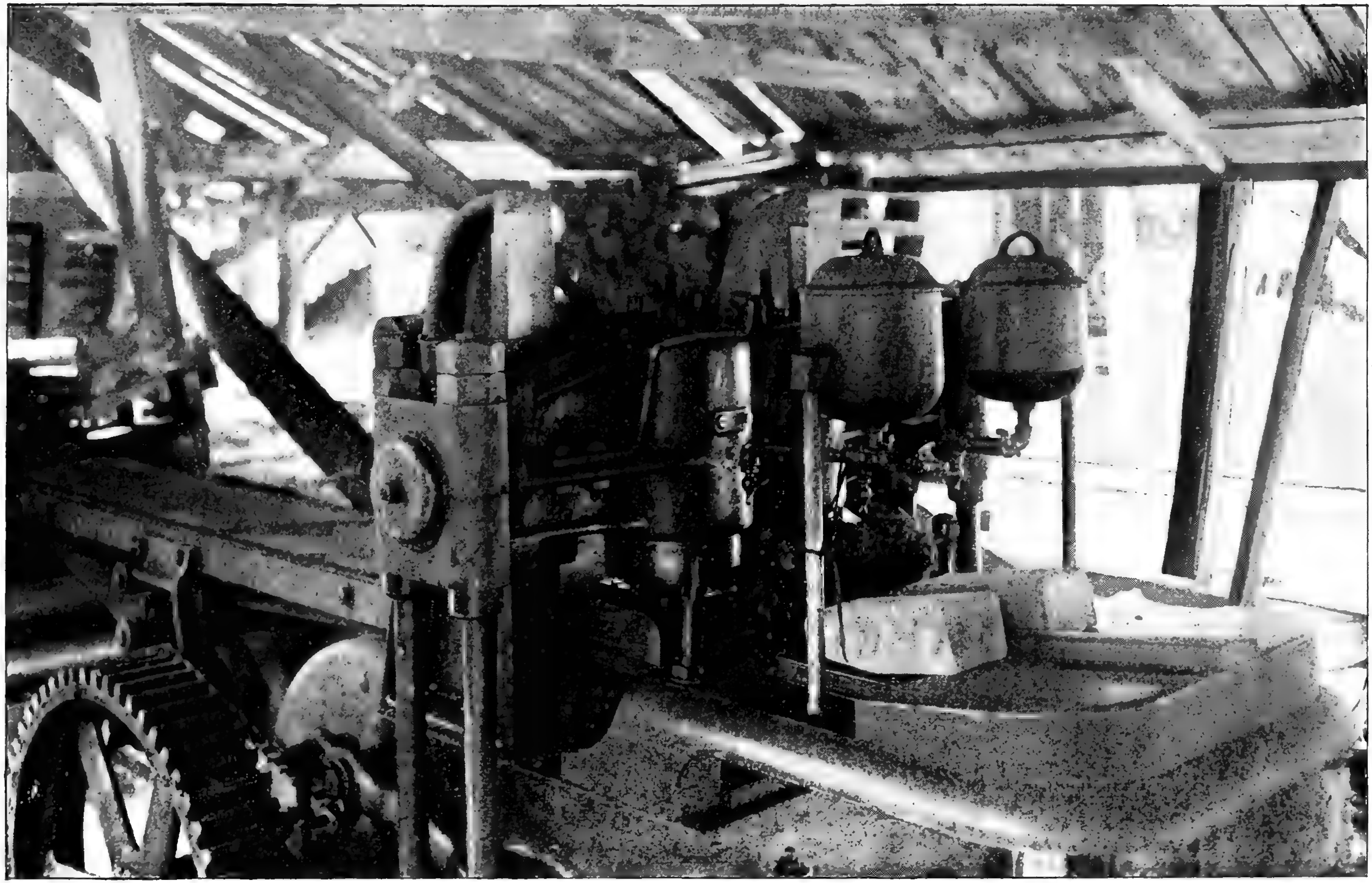
Drying

The methods employed have already been enumerated in the table given on page 655.

With few exceptions artificial drying is used only in connection with the stiff mud and dry press process. The drying of bricks should never be hurried, as bricks dried too quickly are apt to crack; but some clays can be dried much more rapidly than others, and so the drying capacity of the plant does not need to be as great as in the case of clays that dry slowly.

Plate 36

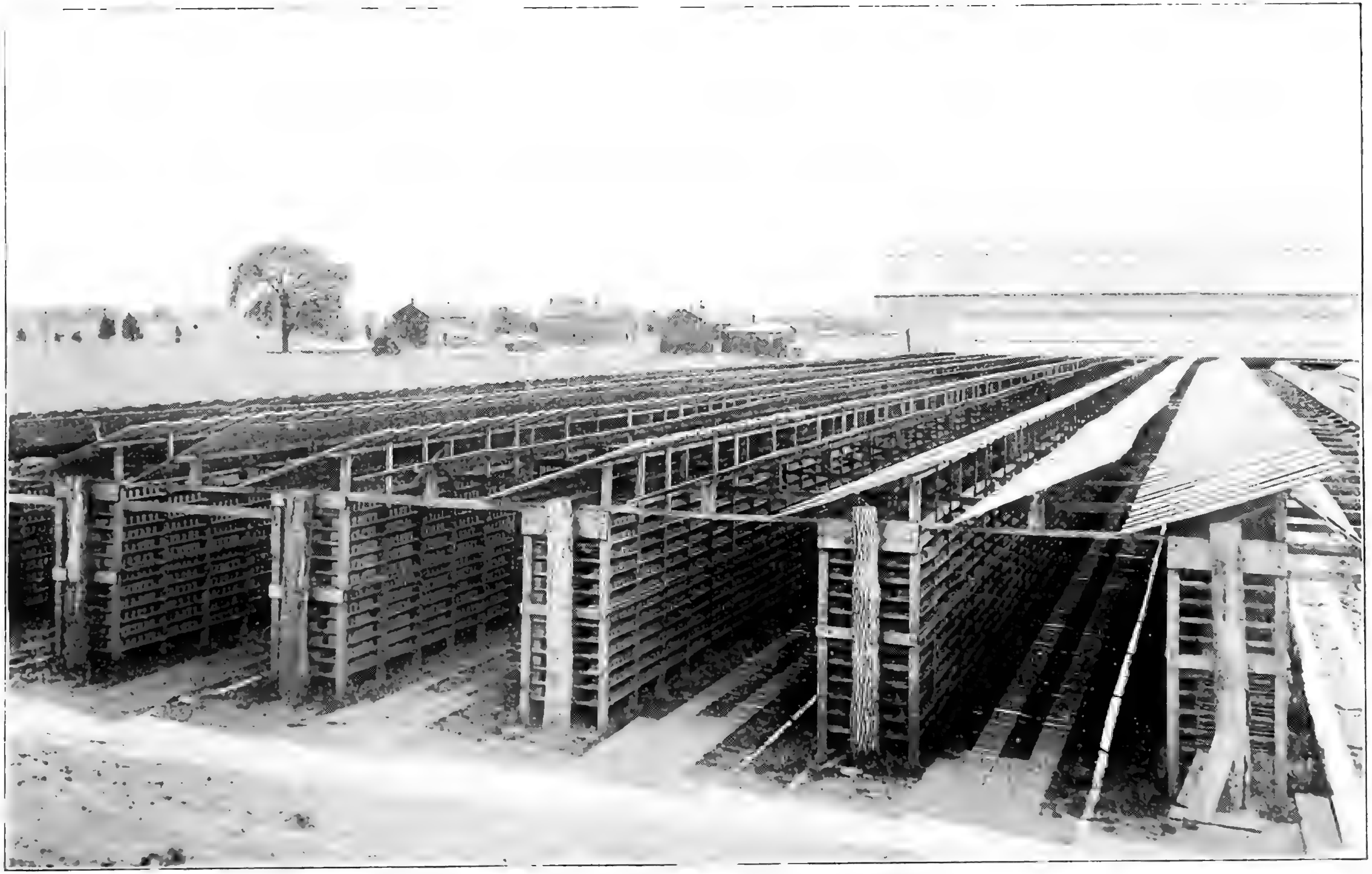
To face page 668



H. Ries photo.

Steam power repressing machine, showing the bricks entering the machine at the front. Newfield brick works, near Newfield station.

Plate 37



H. Ries photo.

Pallet driers with adjustable roof to let in sunlight, or if necessary exclude rain. Rochester brick and tile co.

Coarse-grained sandy clays permit rapid drying, while very plastic ones must be dried with exceeding care. Fine-grained, sandy clays may require slow drying, as the pores are so small that the water can not escape rapidly, but it is not necessary to follow an invariable method in the burning.

Bricks made by the soft mud process are usually dried in one of three ways viz:

1 Open yards
2 Pallet yards
3 Covered yards

The first method is the most used, the second next and the third least. In the first method the bricks are spread out on a hard floor, in the open air. This floor, which is about 200 feet long, is of brick, with a thin covering of sand, and is the "yard" proper. At one end of it are the molding machines, at the other end the kiln sheds. The yard usually drains toward one end, or from the center toward both. After a day's production has been spread out, the boy who tended the machine in the morning goes along the rows and stamps them with a piece of board set on the end of a long handle. This is termed "spatting". After this the bricks are turned on edge by another boy who goes along the rows with a special tool, turning six bricks at a time. The next morning, if the weather has been pleasant, the bricks are "hacked", that is to say they are piled on one another in a double row 11 to 15 courses high along the sides of the yard and left till sufficiently dry to put in the kiln and burn. In case of rain the hacks are covered with planking.

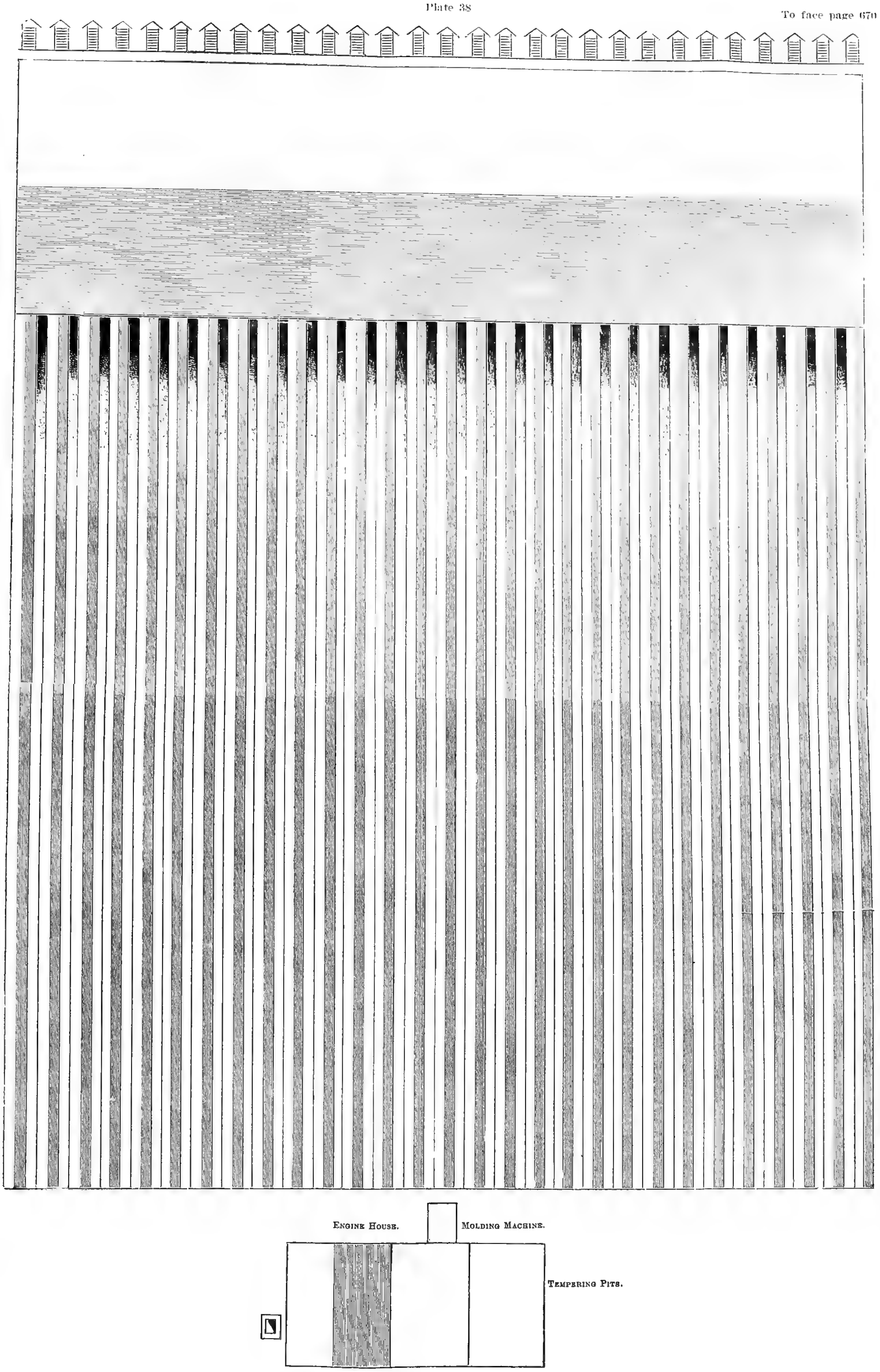
The disadvantage of open yards is that the bricks are exposed to the rain, and if a shower comes while they are spread out on the yard, they become "washed", getting a rough, uneven surface. Washed brick are quite as strong as unwashed ones, but they bring 50 to 75c less a thousand. The washed brick amount to about 15% of the total production.

Covered yards. These differ from the former simply in the addition of a roof. This roof is in hinged sections, which on pleasant days can be opened upward, allowing the sunlight to enter, and closed to prevent washing of the brick in case of rain; but the bricks do not dry so fast, and, therefore, more drying room is needed for a yard of the same capacity. There is also the expense of erecting the sectional covering.

Pallet driers. By this method the bricks are dumped directly on "pallets" as they come from the machine. These are pieces of board long enough to hold six bricks. The pallets are set on rack or cribs till the bricks are sufficiently dry to be set up in the kiln. There are both advantages and disadvantages to this method. As the bricks can not be spatted to keep them in proper shape, they must be firm enough to retain this themselves, consequently the clay must be molded stiffer, and to do this we must have strong machinery. Furthermore, a molding sand must be used which will allow the brick to slip readily from the mold, as it has been forced in tighter than a brick which is to be dried on an open yard. There is, of course, the expense of setting up the racks, but on the other hand the capacity of the yard is increased, the brick, though drying slower, are not subjected to a sudden drying, such as the sun of a hot summer's day is apt to give, and, therefore, perhaps warp or crack the brick. The brick are only subjected to one handling between machine and kiln. Some manufacturers say that it is cheaper to make bricks on a pallet yard. A machine called a "pallet-squarer" has been invented by Mr Swain of the Croton brick co. which is said to take the place of the spatting tool.

Tunnel driers. With this method, green bricks are usually piled on cars and are run into heated tunnels to dry. The tunnels are about 100 feet long and constructed of either brick, iron or wood. If soft mud bricks are dried in tunnels, the cars must have racks on which to set the pallets bearing the bricks. Stiff mud bricks can, however, be set on each other, setting the bricks of two successive courses at right angles to each other. Each car carries about

Plate 38



PLAN OF PALLET YARD.

Plate 39

H. Ries photo.

Tunnel driers. A car of green bricks is being put into one of the tunnels, while on the right are seen empty cars whose load of bricks after drying has been put into the kiln and which are now being brought back to the molding machine to receive a new load of green bricks. Onondaga vitrified brick co., Warners.

360 brick. Tracks are laid from the machines through the tunnels to the kilns. The tracks are laid in two directions only, at right angles to each other, and turntables are placed at the points where tracks intersect. The tunnels are about 5 feet high and 4 feet wide. Several methods are used to heat the tunnels. There may be a fireplace at one end and a system of parallel flues under the tunnel to conduct the heat. A second method is to use steam heat, the pipes being laid along underneath the floor of each tunnel or along the sides. Exhaust steam is used in the day time and live steam during the night. Another method is to heat the tunnel by a hot blast. In a good drier the natural draft should be sufficient to draw the air through the tunnels. Six or more of these drying tunnels are usually set side by side. Artificial drying takes from 24 to 40 hours. The longer the clay takes to dry, the greater will be the number of tunnels needed for a given capacity. The green brick are put in at the end nearest the machine and the cars with the dry ones drawn out at the opposite end. It is of importance that the capacity of the driers shall not exceed that of the kilns. Artificial driers have the advantage of permitting a plant to be run all winter. The cost of flue driers is set at 25c a thousand brick with coal at $2.50 a ton.

Floor driers. Bricks are sometimes dried on floors, which are either of brick or wood. Brick floors are often heated by flues, which pass under them their entire length, conducting the heat from the fireplace at one end to a chimney at the other. Such floors are cheap, but the heat is very unequal at the two ends, and a large amount of labor is involved in handling the material. In some cases the bricks are dried simply by reason of a current of air passing over them, no hot air flues being used.

Wooden floors either solid or slatted, such as those used in drying sewer pipe, may be used, but the cost of laying them is great, and the bricks, as in the case of brick floors, require much handling.

A very common custom abroad, not used in this country, consists in having a series of pallet racks built along the top of the kiln, specially if a continuous one is used. This method works best where the kiln is placed in the lower story of the factory, while the molding machine is on the second floor, or in other words on the same level as the top of the kiln. The bricks when molded are set on the cars, and wheeled directly to the pallet racks. When dry, they are loaded on barrows or cars, and sent down to the kiln on an elevator. The one disadvantage in this method lies in the extra handling of the bricks. The cost of the drying tunnel is however done away with.

Burning

In the burning of clay, the chemically combined water and also any carbonic acid which may be present are driven off, while the organic materials contained in the clay are also burned. As a result of this, the clay loses more or less weight, which in calcareous clays may be as much as 20%, and the porosity increases as a rule with the amount of loss on ignition; but, if the temperature is elevated enough to soften any of the clay particles, the various grains of the mass will draw together, more or less, and the porosity will be diminished. The hardness of the material will also be increased, and this is specially true of calcareous clays. In the case of common brick it is always the finest particles of the clay that soften when a temperature of about 1000° F. is reached, but the small particles of quartz sand do not soften, and therefore form the skeleton of the mass, thus enabling the brick to hold its form. As at this temperature the quartz sand expands as much as 16%, and consequently decreases in specific gravity, there will be a certain amount of decrease in the porosity from this cause. We therefore can obtain thoroughly dense brick from sandy clays, without the burning process being accompanied by any material amount of shrinkage, the quartz having aided in rendering the clays more dense.

In the burning the clay changes from a comparatively soft condition to one of rock-like hardness. The amount of heat applied in burning and the temperature to which the kiln is raised depend

Plate 40

H. Ries photo.

Drying floor heated by hot air flues. The bricks on it are stiff mud ones. Brush & Schmidt, Jewettville on the nature of the clay used and the grade of product desired. Common bricks for instance may not require a temperature of more than 1800° F., while other wares may have to be burned at a temperature of 2300° F. or 2500° F.

In the burning process a number of different things exert more or less influence and consequently must be taken into consideration. Among these we may mention the character of the clay, the character of the fuel, the type of kiln to be used, the temperature employed, the composition of the fire gases, etc.

The detailed changes which the clay undergoes, when burned have already been mentioned.

In burning, the wares are piled up in the kiln, as in the case of common brick, and front brick, or they may have to be inclosed in receptacles to protect them from the action of fire gases, and they may sometimes need to be partially inclosed by means of fire brick slabs in order to prevent the exertion of any excessive pressure on them, which would cause them to lose their form.

Some clays are burned only to a condition of incipient fusion, while others are burned to a stage of vitrification. Common brick are an example of the former, paving brick of the latter.

The type of kiln used varies with the product and also with the locality, but in every case it is either up-draft or down-draft. In the former case the fire passes from the bottom of the kiln upward through the ware and out at the top, escaping either at many points or through a chimney. In the latter case the fire is conducted to the top of the kiln first by means of " pockets " or " bags " on the interior wall, passes downward through the ware and then out through flues in the floor of the kiln to the stack. All kilns are also either continuous or intermittent in their action. In the former the heat from the cooling chamber is conducted through those which have not yet been burned, and is used to heat them up. Both the up-draft and down-draft kilns are either rectangular or round in form, the former having a larger capacity. The different types of kiln are mentioned in more detail farther on.

The principle of burning is much the same in the different kilns, but the burning can be better regulated in closed kilns. In down-draft kilns the bricks in the upper portion of the kiln receive the greatest amount of heat, whereas in a scove-kiln or clamp, the arch bricks, which have to bear the weight of the overlying bricks, are heated the most and often become crushed out of shape. The rectangular can not be bound together as well as circular kilns, this being of course necessary in order to prevent a bulging of the walls during burning.

Most of the manufacturers who make common bricks by the soft mud process, burn them in temporary, up-draft kilns, or scove-kilns, as they are properly called, but the use of kilns of the Endaly type as well as continuous ones is extending rapidly.

Scove-kilns. In these the bricks are set up and burnt in " arches ", several of which go to make up a kiln. The number of bricks in an arch varies from 35,000 to 40,000. An arch is about 40 courses high, and about 15 arches make up a kiln. The open portion of the arch is about 14 courses high; the bricks above the arch are set three one way and then three on top at right angles. They are kept slightly separated by putting small pieces of clay between them. The first row of brick on top of the arch is called the tie course, and the first 14 courses, including the tie course, above the arch are called the " lower bench ", and the rest of the courses above are called the " upper bench ". When the arch and lower and upper benches have been set, brick are laid flat over the top of the kiln; this is the " raw platting "; and then on top of this is laid burnt bricks at right angles to those of the raw platting, which is the " burnt platting ". Hanging from the roof of the kiln shed at the same level are a number of bricks which serve as a guide for hight in building the kiln. A wall of two thicknesses of " double-coal " brick is put around the outside of the kiln, scoving the kiln it is called, and this is " daubed " over with mud. The daub is to prevent any air entering except through the doors. The latter consist of an iron frame about 14 inches high, with an iron plate to

Plate 41

To face page 674

H. Ries photo.

Scove kiln, showing method of setting bricks for burning, the fire being built at both ends of the archways running through the mass. At the farther end is seen the wall of brick which surrounds the whole and is daubed over with mud for the purpose of retaining the heat in the mass and preventing the entrance of cold air. J. Ouimet, Plattsburg.

close the opening; the frames are set in the courses of double-coal brick, at the bottom of the arch on both sides of the kiln. Double-coal brick have six or seven times as much coal dust in them as others and are used for placing around the outside of the kilns. The combustion of the coal in them, the manufacturer claims, supplies the necessary amount of heat to the outer portion of the kilns which are not sufficiently heated by the arch fires. Double-coal bricks sell for about $2.50 a thousand, and usually bear some distinguishing stamp, but they are not as strong as the other brick. It takes two setters and four wheelers about one day to set an arch of 35,000 brick; two men will daub the outside of a 15 arch kiln in one day.

Having "walled-up" the kiln with double-coal brick and daubed it over, the next step is to start the fires and burn the bricks. The principle of the process is essentially the same, whether wood, coal or oil is used as fuel.

First, every alternate brick of the "burnt platting" is stood on end to allow the "water-smoke" or steam to escape as quickly as possible. A fire is then started in the mouth of each arch. When coal is used the fire is started on the windward side of the kiln so as to allow the smoke to blow through the arches.

The fire is also started from the other end of the arch, and the two fires are then built up slowly till they meet in the middle. The time of crossing the fires varies; with machine-made bricks the fires should not be crossed as quickly as with handmade ones. Along the Hudson the time of crossing is from 40 to 60 hours. The steam should escape evenly all around the top, and the upper limit of the fire should follow directly on it, the steam acting as a blanket, and its lower limit should be even. It is the duty of the foreman to watch the burning carefully, and increase or ease up the steam in any one arch, according as it is coming off too slowly or too rapidly. The fires are increased till the "water-smoke" changes to a bluish black smoke, and at this point the fire can be seen at night time coming from the top of the kiln.

The kiln is now "hot" and the bricks commence to shrink or "settle" and all the platting is turned down. Up to this point care must be used to increase the heat gradually. The bricks now get their heaviest heat, and the oxids of iron are changed to the anhydrous peroxid, giving the bricks their red color. If the heat in the arches is too great the bricks run, stick together or become distorted and cracked. After the firing has been done the doors are all closed and plastered over to prevent any air from entering.

If the bricks are put into the kiln before they are sufficiently dried, or if they are heated too quickly, they are liable to crack.

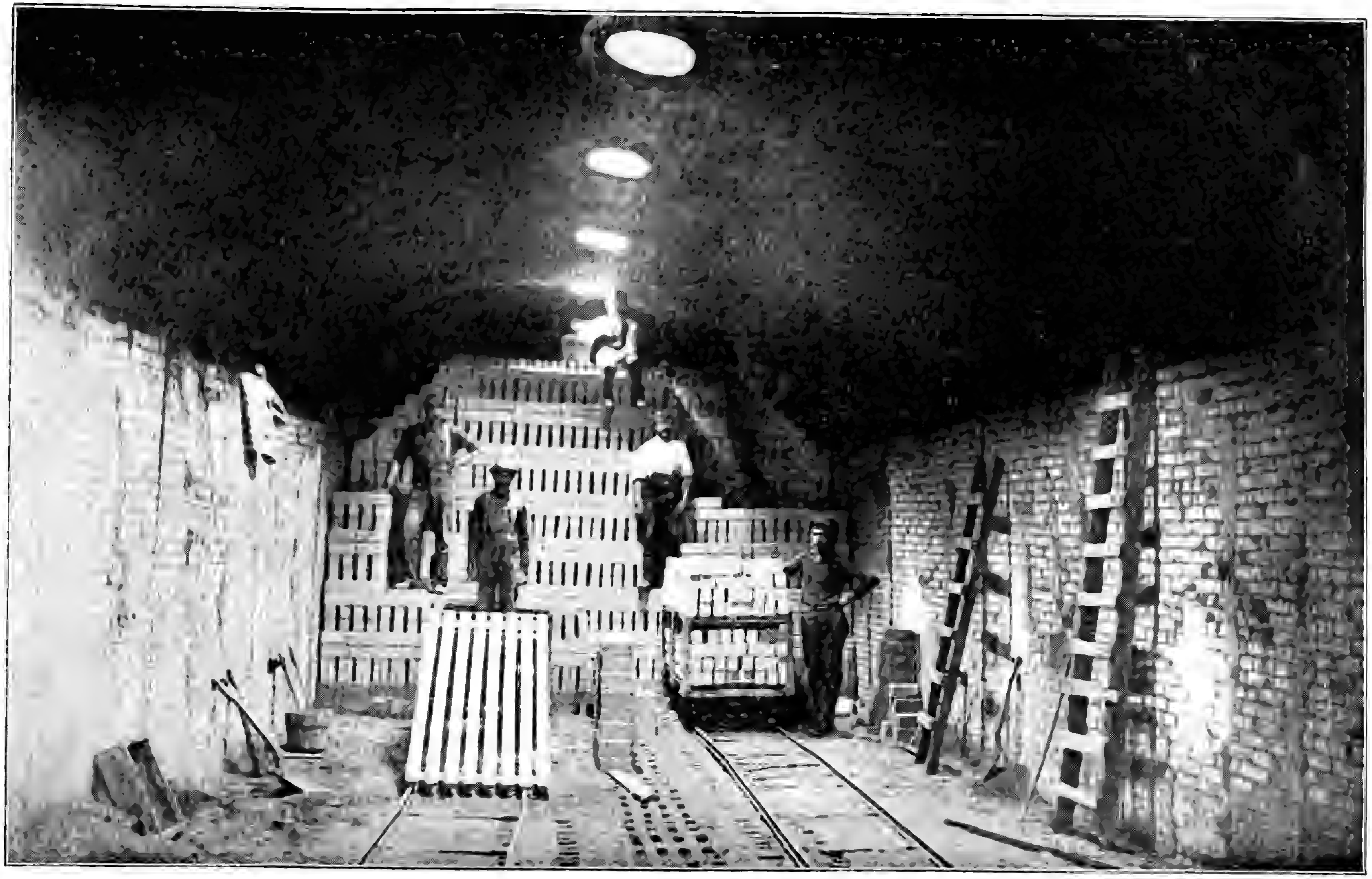
In the case of coal, grates have to be put in a few inches above the level of the floor, and for oil, burners are needed.

After a kiln of bricks has been burned, the ends of the arch bricks are often black, caused by the particles of dust and carbon which have been carried upward sticking to the brick when they were in a soft condition, due to the high degree of heat.

As to the action of the coal dust in the brick. At first while the brick contains water, there is no access for the air to the particles of coal. However, as the firing proceeds, the water is driven off, leaving the brick porous, allowing the air to enter for the combustion of the coal. Particles of lime and lumps of clay cause a splitting of the brick. Insufficiently burnt bricks are called "pale" and sell for $3.75 a thousand.

The kilns take several days to cool, and, when cool, the bricks are put on wheelbarrows, and taken to the freight cars, or barges, and then shipped to the market. If the kiln shed is not situated along the dock, the barrows are put on a car, which is run down a track to the scow. The time of burning is from five to seven days with wood and four to five days with oil. The cost of burning with wood is 60 to 75c a thousand brick, and with coal the cost of burning is 40 to 50c. Burning with wood is the cheapest method as far as implements are concerned. With coal there is the cost of grates and with oil there is a royalty of $1.60 to be paid on every burner. The latter is, however, the cheapest method as

Plate 42



H. Ries photo.

Interior view of down draft kiln, Graves type, showing the green brick being set. Jamestown shale paving-brick works.

regards the price of fuel. The great majority of the yards along the Hudson use wood, a few use coal and two or three use oil. With coal and oil the heat can be better regulated than with wood. Another important point is the amount of pale brick produced. In scove-kilns there is sometimes a loss of as much as 50,000 to 75,000 in a clamp of 500,000 bricks, while in a permanent kiln such as the Wingard or one similar, the amount of pale brick is said to be not usually over 25,000. Again in the case of permanent kilns, it takes no more, if not less, time to set the bricks and there is less daubing to be done. Regarding the amount of labor required in burning, one man is supposed to tend three arches.

Up-draft permanent kilns. These differ from scove-kilns only in having permanent side walls. They are open at the tops and ends, and the latter have to be walled up before the burning commences. Kilns of this type are used to a large extent for burning common brick, but they are little used for front, stock, or ornamental brick, as the percentage of salmon brick produced usually amounts to from 20% to 35%. The brick are set in the same manner as in scove-kilns, and the burning proceeds on the same principle.

In up-draft kilns the bricks forming the arches are exposed to the direct action of the flames, and are usually overburned, so that they are twisted or crushed out of shape, and often covered by a layer of ashes which have stuck to their surface. They are known as "arch" or "eye" brick. The salmon brick are generally to be found in the upper courses of the kiln, and they together with the arch brick may at times form an appreciable percentage of the product.

Up-draft kilns are cheaper to construct, and easier to keep in repair than the down-draft kilns, for the latter have the bag walls on the interior and usually an arched roof, both of which require constant attention, and at times may necessitate expensive repairs.

Down-draft kilns. In these the fire is conducted along the interior to the top of the kiln by means of bags, or "pockets" as they are called, before they are allowed to escape into the kiln. The fire then passes downward through the product and out through the openings in the floor of the kiln to the flues, and from these to the stack, or chimneys. The hight of the bags on the inside wall of the kiln varies, and depends partly on the type of kiln, and largely on the individual opinion of the manufacturer.

There may be one main stack or, sometimes, there are several small ones on each kiln. The down-draft kilns are either rectangular or round in shape. The average capacity of the former is about 150,000 brick, while that of the latter varies with the diameter, which is from 15 to 25 feet.

The percentage of salmon brick is much smaller in a down-draft than in an up-draft kiln, and seldom exceeds 15%. Those bricks which are on the top of the kiln receive the greatest amount of heat, but as there is no pressure on them they do not become misshapen, and consequently on account of their great hardness and density are often sold under the name of "rough hard" and serve excellently for use in damp situations and for sewer work.

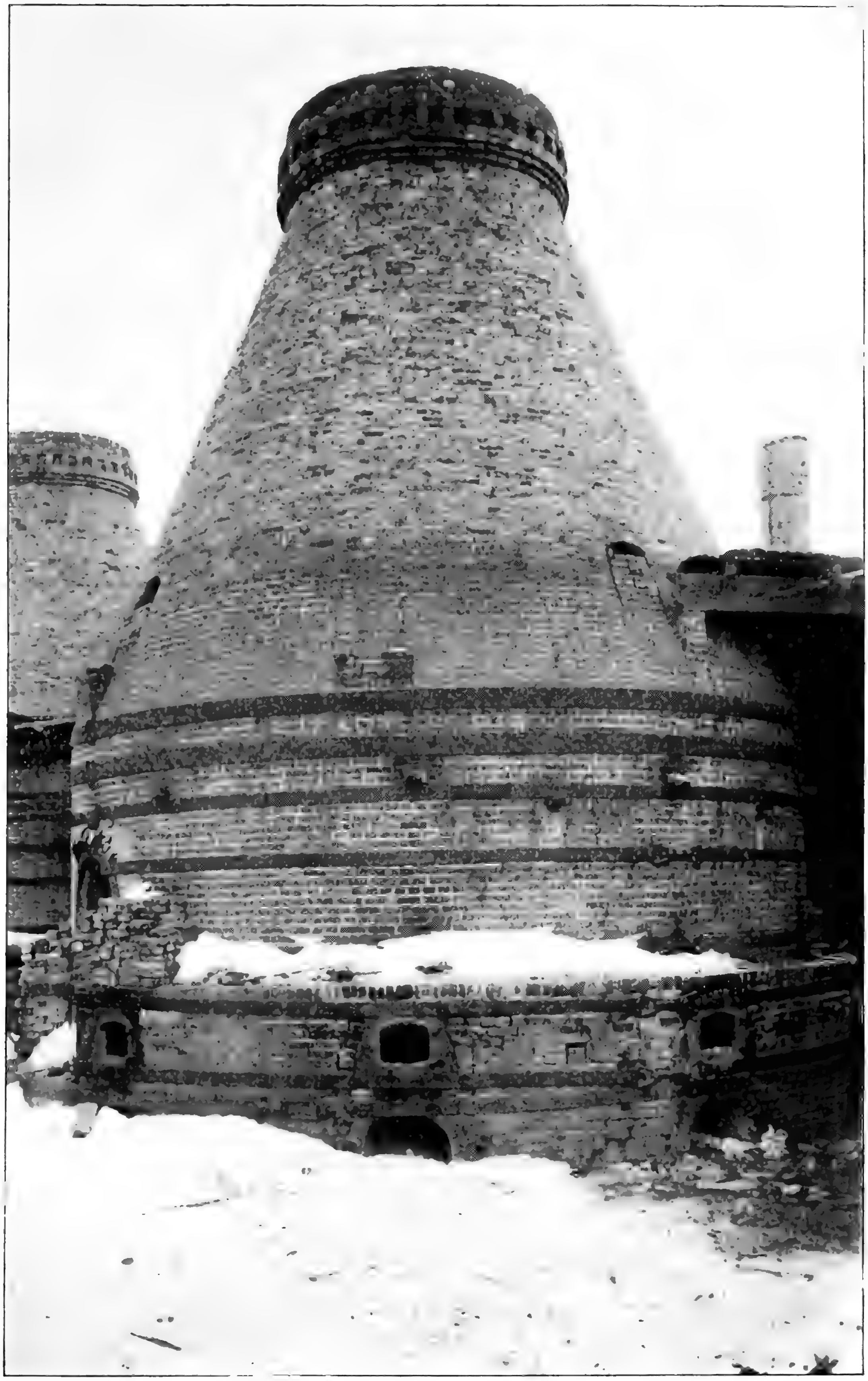
Several types of down-draft kiln are illustrated in the report.

Down-draft kilns sometimes have two sets of fireplaces, the one connecting with the bags on the inside of the kiln and the other leading directly into the interior. The kiln may thus be worked either as an up or a down-draft, the former being used during the water-smoking and the latter during the burning.

Continuous kilns. These consist of a series of chambers separated by either temporary or permanent walls. The fire is started in the first, and as the burning proceeds the heat from the burning chamber is conducted through the succeeding ones either through flues in the wall or pipes connecting the openings in the roof of the kiln. In this way, by means of the exhaust heat, the temperature of the succeeding chambers is raised, so that less fuel is required. The heat from a burning chamber can not as a rule be carried safely through

H. Ries photo.

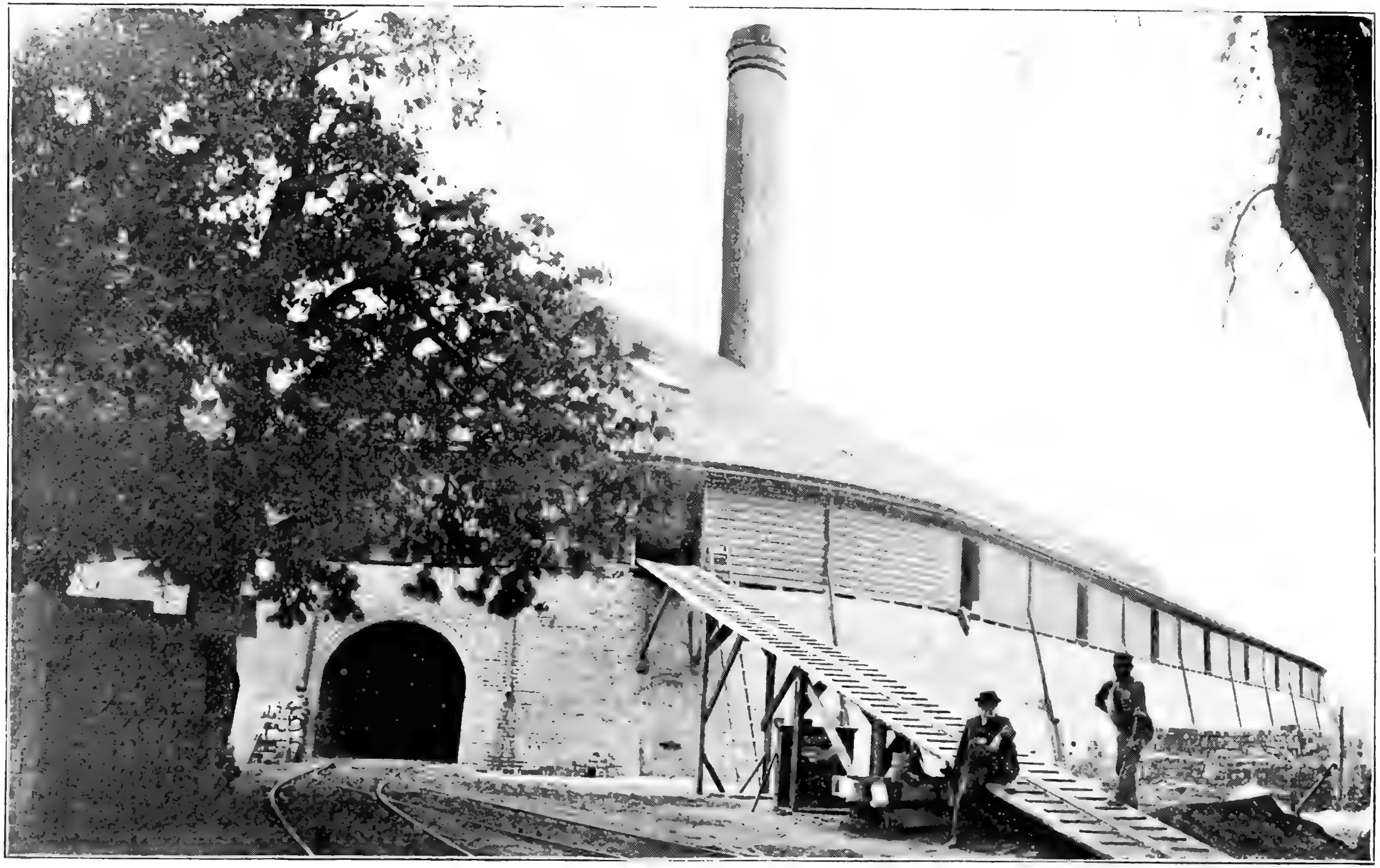
Down draft kiln, Flood type, Garden City brick co., Farmingdale Long Island. The kiln is just being discharged.



H. Ries photo.

Circular down draft kiln for burning brick and hollow bricks. Onondaga vitrified brick co., Warners.

Plate 45

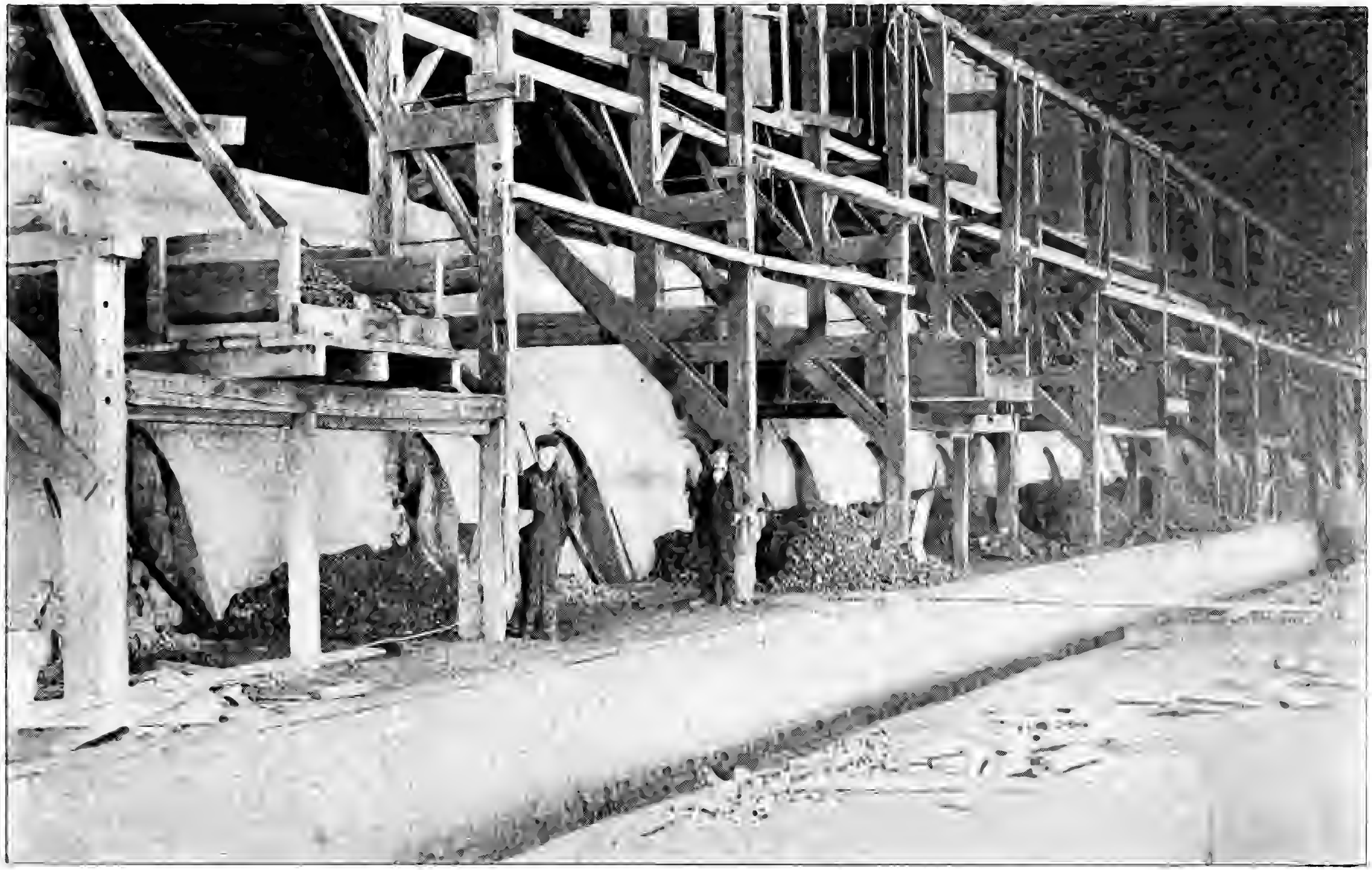


H. Ries photo.

Continuous kiln, Haight type, Eastern paving-brick co., Catskill.

Plate 46

To face page 679

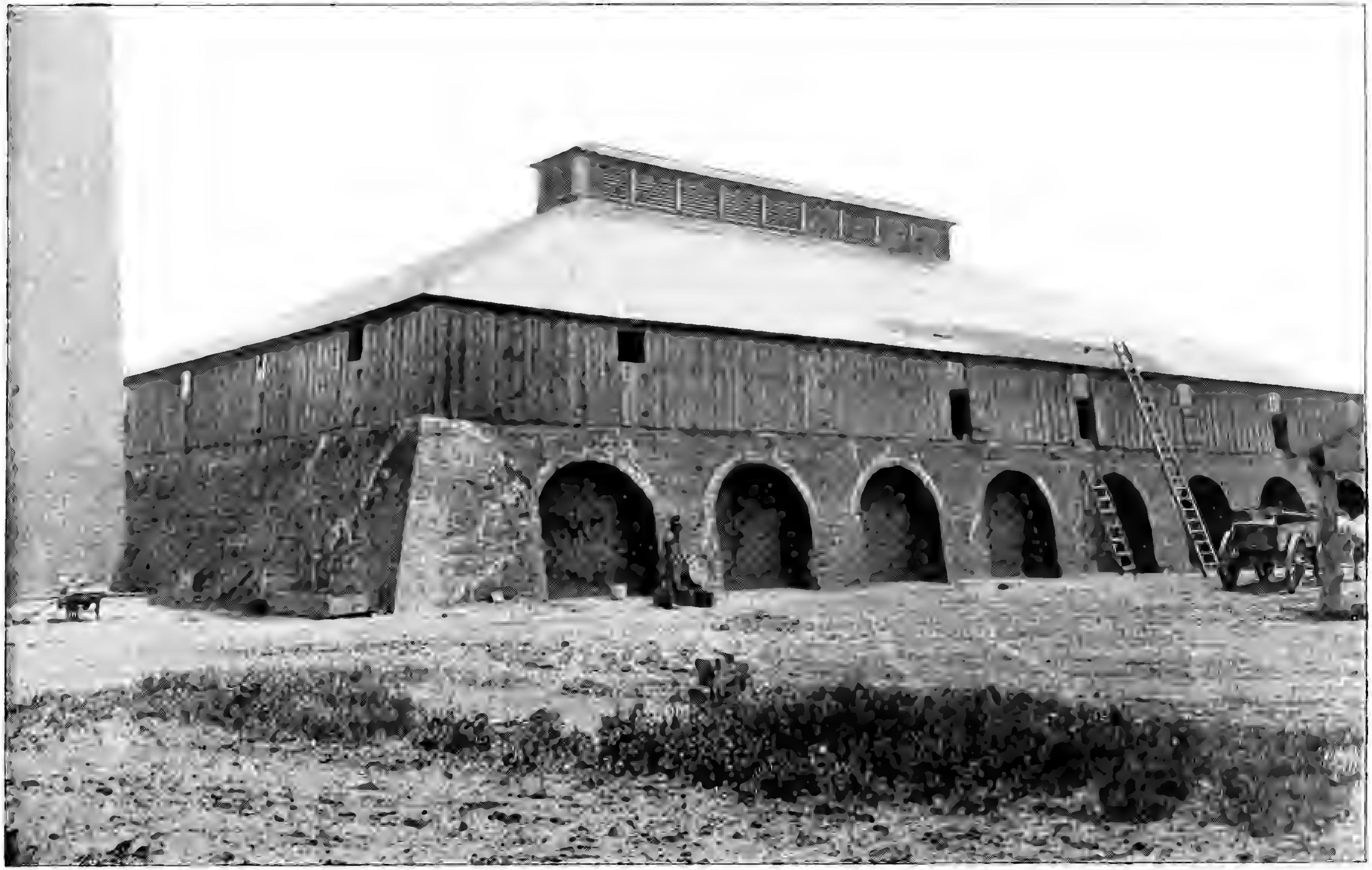


H. Ries photo.

Continuous kiln, Haight type, Horseheads brick co., Horseheads. In the foreground is depressed track so that bricks when taken from the kiln can be loaded directly on to the cars.

Plate 47

To face page 679



H. Ries photo.

Continuous kiln, Wilford type, Rochester brick and tile co., Rochester.

three or four chambers before conducting it off to the stack, for the reason that the hot air collects moisture from the bricks in those chambers which are being heated up, and if not drawn off when nearly saturated, and before it has cooled down too much, it will begin to deposit moisture and soften the green bricks.

Each chamber has a capacity of 20,000 to 22,000 brick. When the partitions between are permanent they are of brick, but the temporary ones are built of heavy paper.

The manner of firing varies. In the original kiln not only did it take place through doors at the bottom, but coal slack was also fed into the kiln through openings in the top. Many manufacturers no longer pursue the method of top firing.

In New York state continuous kilns are used for burning common and paving brick.

Sorting

After the bricks are burned they have in every case to be carefully sorted, for no kiln produces 100% of bricks which are alike. The product of a kiln of common building brick is usually sorted into stock, hard, rough hard, salmon or pale.

In burning a kiln of pressed brick, while the percentage of properly burned ones is very much larger than in the case of common brick, still there is often a considerable range in the intensity of the color, and therefore pressed brick have always to be carefully sorted according to the shade. There are numerous shades and colors which the manufacturer is able to produce with any clay or mixture of clays that he is in the habit of using, but in addition, always, a certain number of bricks are of off shades, or show other blemishes due to improper firing; and these are generally sold at much lower rates.

Efflorescence on bricks

It is a well known fact that many bricks develop a white coat either during the drying and burning or after the brick have been set in the wall. The popular term for this white coating or efflorescence is "saltpeter", and when it occurs in burning the manufacturer at times erroneously ascribes it to water-smoking.

The efflorescence is usually due to the presence of soluble salts, specially sulfates, which are formed either in the clay or during some stage of the manufacture. Any moisture present in the clay or product dissolves these compounds and on evaporation carries them to the surface of the ware.

The subject has been discussed in some detail in the *Brickbuilder,* from which the following points are taken.[1]

1 **Formation of efflorescence in the clay beds, etc.** Most clays contain mineral salts in greater or less quantities, which chemical analysis has shown to be sulfates of lime and magnesia, less frequently of iron and alkalis. The formation of these sulfates is generally due to the decomposition of iron pyrite contained in the clay, and it will be seen that the more thoroughly this material is distributed throughout the clay the more easily it will be subjected to complete decomposition, and the greater amount of soluble sulfates will be formed. All clays do not contain iron pyrites. In any one clay bank the pyrites may be more abundant in some layers than in others. It may be present in equal quantities in all layers, but its decomposition may have proceeded to a greater extent in those beds which are the most weathered. This fact has been brought out by Dr Gerlach's observations. One of these was that clay which had been allowed to lie for months in the open air left behind on the ground where it had been large quantities of beautiful gypsum crystals; but the omission of the intermediate operation of allowing the clay to weather after it has been dug will not necessarily prevent the formation of these soluble sulfates, for the same decomposition of the pyrites may occur if the green bricks are allowed to stand a long time in the drying-room, in the presence of moisture. The prevention therefore would seem to be in the ordinary molding of the clay and the drying and burning of the bricks as quickly as possible. This oxidation and decomposition of iron pyrites is there-

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[1] O. Gerlach. *Brickbuilder*. 1898. p. 59. *et seq.*

fore according to Dr Gerlach the main cause of sulfates, which give rise to “ white wash ”. Sulfates may also come from the sulfur contained in the water used in the tempering of the clay, such waters often containing gypsum, and, as many clays often require 30% or perhaps more of water to render them plastic, it is easily seen that the clay may receive a large addition of lime sulfate. This sulfate might be present in the mineral coloring matter added to the bricks. Rapid drying causes the water to evaporate more quickly and a lesser amount of the dissolved sulfates is apt to be brought to the surface of the ware.

2 Sulfates arising during water-smoking and burning. In the water-smoking of a kiln those bricks nearest the fireplaces will lose their moisture first, and before the bricks farthest from the fireplace are heated to a temperature sufficient to convert their moisture into steam; therefore much of the watery vapor driven off from the bricks which were heated first will be deposited on the surface of those farthest from the fireplace, and be absorbed by them to a certain extent. If it happens that these green bricks contain soluble sulfates, the deposition of this condensed vapor on them will tend to increase the sulfates in solution, and when their water is driven off all the sulfates will be carried to the surface in solution and deposited there. This condensation of the water will be harmless, if the clay contains no soluble sulfates or if the contained soluble sulfates have been previously rendered insoluble by the addition of the proper chemicals. Another source of difficulty may come from the use of sulfurous fuel, for it is known that many coals contain more or less iron pyrite. This sulfurous acid gas in passing through the kiln will only too willingly attack carbonates present in the clay and form sulfurous salts, which as the heat of the kiln increases, come to the surface, and are there oxidized to sulfuric salts or sulfates, these causing efflorescence or discoloration.

Efflorescences formed on burned ware. It not infrequently happens that clay products come from the kiln apparently free from any superficial discoloration and later develop one when subjected to moisture. This is generally due to the formation of salts during burning, and they are specially annoying on account of their tardy appearance. The salts formed during drying do not necessarily arise simply from the combination of sulfur in the fire gases with bases in the clay, but may also be due to iron pyrite which, during burning, aids in the formation of white washing sulfates in the interior of the bricks. The formation of white washing sulfates during burning is described by Gerlach as follows: "A part of the sulfur in the iron pyrite is loosely combined with the iron, and oxidation of this part begins at approximately 650° F., whereas the other parts burn at ordinary heat. The products of disintegration are oxid of iron, and sulfurous acid gas. This chemical reaction is expressed as follows: 1) $FeS_2 + 2O_2 = FeS + SO_2$, and 2) $2FeS+7O=Fe_2O_3\ 2SO_2$. The sulfurous acid gas SO_2 when heated in contact with solid porous bodies is oxidized by the superfluous oxygen of the air of combustion to sulfuric acid, or converts existing oxids into sulfuric salts. It was for a long time erroneously believed that the presence of water or watery vapor was necessary for the formation of sulfates." Gerlach's conclusion is that it follows that white washing sulfates are formed in large quantities only when sulfurous acids and carbonate of lime or other carbonates occur together in chemical action. Sulfurous acid has no injurious effect on clay containing no carbonates of lime, magnesia, or alkalis; such clays accordingly can be burned with sulfurous coal without any fear of white washing sulfates, while clay containing carbonate of lime requires a fuel free from sulfur.

Gerlach sums up the causes of efflorescences as follows.

White efflorescence

Source 1 The green clay
- *a* Caused by the presence of sulfates in the clay
- *b* Caused by the formation of sulfates during the storage of the clay

Source 2 The manufacturing

- *a* During molding
  - 1) By presence of sulfates in the water or coloring matter
  - 2) By formation of sulfates during the drying
- *b* During burning
  - 1) During water-smoking
  - 2) During firing

Source 3 Environment of the bricks and buildings

- *a* Caused by the absorption of saline solutions from the soil of the place of storage
- *b* Caused by the absorption of soluble salts from the soil on which the building stands

Yellow and green efflorescence

1 Organic in character — caused by the action of vegetable micro-organisms

2 Inorganic in character — caused by soluble vanadinate salts

White efflorescence. Sulfates are seldom present in large quantities, but according to Gerlach .1 to .05% is sufficient to produce an annoying white incrustation. This is prevented by rendering the sulfate insoluble. The most effective way is by the addition of some barium compound, specially the carbonate or chlorid. When barium salts come in contact with sulfates, barium sulfate is formed, a combination which is absolutely insoluble in water. This is expressed by the following chemical reaction.

$$CaSO_4+BaCO_3=CaCO_3+BaSO_4,$$
$$CaSO_4+BaC_2=CalCl_2+BaSO_4$$

Thus it will be seen that in both cases we get insoluble compounds, which are harmless. If the cost plays any part in the use of them, it will be generally found that barium chlorid is the cheaper.

Method of use. As carbonate of barium is insoluble in water, in order to make it thoroughly and uniformly effective, it must be mixed in with the clay very thoroughly, and in as finely divided a condition as possible, because it will only act where it comes in immediate contact with the soluble sulfates. While only a small quantity of barium salt is required, still to insure thorough mixing, 10 to 20 times the necessary amount should be employed, and it can be used without any injurious results. The following example is given by Gerlach. The clay must first be thoroughly analyzed to determine the amount of sulfates. If, for example, the clay contained .1% of sulfate of lime, this would mean that one pound contained .4 of a gram, and theoretically every gram of sulfate of lime needs 1.45 grams of barium carbonate to render it insoluble; therefore theoretically a pound of clay would require .6 of a gram of barium carbonate, or for safety six or seven grams should be used for every pound of clay. This would be about one hundred pounds for every thousand bricks, based on the supposition that a green brick weighs seven pounds. As a pound of barium carbonate costs 2½c, the amount of it required for a thousand brick would cost $2.50. It is cheaper to use barium chlorid for the reason that the salt is soluble in water, and hence can be distributed more evenly, with the use of a smaller quantity. The chemical reaction takes place much more quickly when the barium chlorid is used. There is the objection to it that as near as possible the theoretic amount must be used, for, if any of it remains in the clay, without reacting with any sulfate, it will form an incrustation on the surface of the brick. To give an example of the use of chlorid of barium, we may take again a clay containing .1% of calcium sulfate. This would require theoretically 1.8 grams of crystallized barium chlorid and, passing over the intermediate stages of the calculation, a thousand bricks would require 57.4 kilograms of barium chlorid. If barium cost 2½c a pound, a thousand brick would require an extra outlay of only 32c, in using barium chlorid. Chlorid of lime is also formed, but this has no injurious effect provided the clay is heated to such a temperature as will cause the lime to unite with other bases and silica, and form a complex silicate. If heated high enough to decompose the chlorid of lime, it might be that its subsequent slaking would be injurious.

If the clay treated with the barium chlorid is used at once, no efflorescence will result, either on the unburned or the burned brick, but if the clay thus treated is allowed to lie for any length of time, large quantities of iron pyrite may be decomposed with the formation of additonal sulfates. It frequently happens that the discolorations on bricks appear near the edges and corners. This is due to the fact that the waters evaporate most readily from these points. The more quickly the water is evaporated, the less will be the quantity of soluble deposit on the surface. Incrustations which appear during drying are found more commonly on bricks made from very plastic clays, and which owing to their density do not allow the water to evaporate quickly. In sandy clays, the incrustation is at a minimum. This explanation is believed to account for the appearance of efflorescence on the surface of pressed bricks more than on rough surfaces.

Cost of production

This item varies considerably, depending on a variety of circumstances, such as the method of manufacture employed, cost of labor, locality, etc. Brick manufacturers are generally unwilling to give information on this subject, and the figures given, therefore, can only be considered approximate. The use of improved machinery and methods will often lower the cost of production considerably, but this generally requires a much greater outlay of capital than seems to be in most instances available. By the hand power method the cost of manufacture is $3.75 to $4 a thousand delivered at the yard. On Long Island, where the soft mud process is almost exclusively used, the cost is said to be $3 a thousand delivered at the yard. Hudson river manufacturers quote the cost at $5 a thousand delivered in New York city; this figure includes $1.25 for transportation and 25c a thousand for commission.

The brick yard is usually owned by the manufacturer but the clay bank is worked on one of two bases:

1 The manufacturer owns the bank. This is by far the best and most profitable arrangement.

2 The brickmaker pays a certain rental, usually 9% or 10%.

3 The owner of the clay bank gets so much a thousand brick. At Haverstraw this varies, for instance, from 25c to $1.25 a thousand. With this arrangement the manufacturer is bound to a certain amount of production.

Of the three methods of manufacturing brick, the soft mud process is the cheapest as far as first cost of plant is concerned, but it is probably not the cheapest in operation, as more labor is required. The other two methods used, the stiff mud and dry clay, require considerable outlay of capital. Less labor is required for operating either of the last-mentioned plants. The actual cost of production by either of these methods I have not been able to obtain. It is doubtful if the dry clay process is the cheapest, as the manufacturers of this class of machinery assert, for the economy gained, due to the shortness of the method, is probably counterbalanced by the increased time of burning and consequently greater amount of fuel used. With the soft mud process one man to 1000 brick is what the manufacturer figures, that is, if the yard has a capacity of 50,000 a day, a force of 50 hands is required to operate the yard.

As regards fuel, for instance, a saving of 30c can easily be made by using coal instead of wood; gas is considered about 25c cheaper a thousand than coal. Farther economy may be effected by the use of the proper class of machinery for haulage. Carts can usually be employed economically up to 400 feet; beyond this it will usually pay to lay tracks and use cars hauled by horses. Above 600 feet steam haulage has been found economical. Self-acting planes and cable haulage have been used to advantage in a few instances.

Common brick are made from shale at many localities in the southern part of the state, and sell just as cheaply as clay brick.

Detailed account of brick yards

As the brick yards are scattered all over the state, a division of them into groups for convenience is more or less arbitrary. However, the following classification has been made.

Brick yards of eastern New York
" central New York from Schenectady to Buffalo
" Oswego, Jefferson and St Lawrence co.
" southern New York
" Long Island
" Staten Island

Most of the bricks manufactured in the state are sold in local markets. In the case of the Hudson valley bricks, the market of New York city receives the larger proportion, and the competition has been so keen and the supply so great that prices have often been depressed accordingly.

Brick yards of eastern New York

Hudson valley. Extending up the Hudson river valley from Croton to Albany and even to Glens Falls, is a more or less continuous deposit of clay which can safely be said to be one of the most extensive in the United States, and which furnishes the material for the greatest brickmaking region in either Europe or America.

The geologic relations have already been described in the chapter on the "Geology of the clay deposits", and the detailed description of the beds as seen at the different yards is given later, so that all that need be mentioned here is the physical character of the clay used, and this can be treated in a general manner for the reason that the constancy in character of the Hudson valley clays, specially between Croton point and Albany is remarkable. Throughout their extent they present the same type of marly clay, of a blue gray color, except where the upper beds are weathered, the color there being yellow, owing to the presence of limonite. These clays contain a great quantity of fine grit, and a large amount of clay substance, as shown by the mechanical analysis given below. The fine grit is not uniformly distributed through the clay but is in thin layers which cause the clay to split very evenly and readily.

These clays are sticky when mixed with water, but they are by no means to be called highly plastic; indeed, when worked up with water the mass shows a certain resistance to mobility that is hard to describe, but is not unlike a mass of powdered feldspar in its behavior.

When thrown into water the clay slakes quite readily to a flocculent mass.

Two samples were tested physically, the one from Rose's yard at Roseton above Newburgh, and the other from the Brockway brick co.'s yard above Fishkill.

The sample from the bank of the Brockway brick co. (109) worked up to a sticky, but not highly plastic mass with 29% of water. The bricklets showed an air shrinkage of 5%–6%.

The tensile strength of air-dried briquettes was 75 to 90 pounds a square inch, but some reached 120 pounds a square inch.

The clay also gave .2% of soluble salts.

In burning, the clay burned red with increasing depth of color as the temperature was raised and at viscosity passed to a brownish glass. Incipient fusion occurred at cone .05 with a total shrinkage of 8%. Vitrification at cone .04 with a shrinkage of 15%. Viscosity took place at cone .01.

The clay from Roseton was very similar in its behavior to the previous one.

The air shrinkage was 5%. Incipient fusion occurred at cone .05, vitrification at cone .04 with a total shrinkage of 14%. At .01 the clay became viscous. The tensile strength ranged from 75 to 93 pounds a square inch.

The soluble salts amounted to .3%.

A mechanical analysis of the clay from the bank of the Brockway brick co. yielded

Clay substance	49.83%
Silt and very fine sand	28.30%
Fine sand	21.75%

Many attempts have been made to utilize the vast deposits of clay found in the Hudson valley for other purposes than common brick, but thus far only cases of failure are recorded. Two other uses to which the clay is adapted, are as a natural glaze for pottery (*see* "Pottery manufacture"), and in the manufacture of Portland cement.

It is also a curious fact that, though the Hudson valley is the seat of such an enormous industry, nevertheless the methods employed, and machinery used are anything but modern. This is partly due to the fact that the clay does not stand treatment by other methods. Stiff mud machines seem to be barred out completely by the nature of the material, but why the old, out-of-date scove-kilns still hold their own is a matter which is hard to explain.

Detailed account of Hudson river yards[1]

Croton Landing, Westchester co. There are three yards, all situated on Croton point and having a yearly capacity of 61,000,000 brick. The yards of the Anchor brick co. are located at the base of the point, a short distance south of the station and along the railroad track. One yard is situated a few feet above river level, the other 90 feet above it on a delta terrace. The clay deposit adjoins this yard. It is basin-shaped, and varies in depth from 40 to 70 feet. The clay is mostly blue, and is underlain by hard pan, the pebbles of which are cemented by clay stained with limonite. The present excavation is about 40 feet deep and the bottom of it is 40 feet above mean tide. Borings show an additional depth of 35 feet in the center. The stripping amounts to about 10 feet of loamy clay and sand, and streaks of gravel are not uncommon in the clay.

The deposit is worked in benches having a long working face, and these benches converge to one point at the eastern end of the pit, from which a single track is laid up to the tempering machine.

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[1] The detailed field work on these clays was done in 1891 and 1892, and, while the yards have in some instances changed hands since then, still it was thought better to leave the names in use at the earlier period mentioned.

Tracks are also laid along the benches, and as the working face recedes the tracks are shifted with crowbars. The cars are brought down to the working face by gravity, or a small engine which is chiefly used to draw them to the tempering pits. A temporary track is laid over the ring pits, on which the cars can be run to facilitate dumping. Those cars containing clay for the lower yard are run on to a self-acting inclined plane, and on this the empty cars and tempering sand for the upper yard are also brought up. The tempering sand is dug by a steam shovel, at the base of the terrace escarpment. The bricks are dried on covered yards and burnt in a special type of kiln. It consists of two walls of best quality brick, about 15 feet high and 14 inches thick. The lower portion of the walls containing the doors are 2 feet thick, and the two walls are about 20 feet apart. The two ends have to be walled up with double-coal bricks after the kiln is filled. Coal is the fuel used. The bricks when burnt are loaded on cars and run down to the dock, those from the upper yard going on the gravity plane. The tempering sand is discharged by the shovel into small cars, which are drawn up an incline to the top of a framework and dumped, the sand falling through a series of screens into cars below.

The Croton brick co. has two yards, an open and a pallet yard; and obtains all its clay from the river with a scoop dredge. It is dumped into cars on a scow, which, when full, are run up an inclined plane on the shore and dumped. The clay is thus exposed to the weather for several months before it is used. It costs about 15c a cubic yard to deliver the clay on shore and 10c a cubic yard to haul it to the pits. Tempering sand is obtained from the escarpment of the delta terrace just south of the yard. At the pallet yard they use a hand machine to square the green bricks on the racks, that consists of two plates of steel, attached to which, at right angles and on the same side of the plates, are 12 smaller ones, 4 inches high. Attached to the large plates are two handles. The two large plates slide back and forth on each other and so that the small plates can be brought together. This machine is set on six bricks at a time and by moving the handles the plates press against the brick, squaring the corners. It is said a boy can square a pitful of brick (35,000) in a day. The molding machines have an endless chain with buckets attached to them for feeding the sand. This leaves only the clay to be shoveled into the machine, and the feeding of the two uniformly and continuously gives a more evenly tempered mixture. It will be seen in this case that no soak pit or ring pit is used — the molding machine does all the mixing. The molding sand is dried by spreading it out on the kiln floor, it being thought that it dries quicker this way than if it were banked up against the kiln, as is commonly done.

The W. A. Underhill brick yards are situated midway between the base and end of Croton point. There are two yards, both covered. The brick made at this yard are sold mostly for fronts, selling for $14 a thousand. The clay bank lies between the two yards; it has a hight of 40 feet above mean tide and extends 15 feet below it. At the last-mentioned depth the blue clay stops and is followed by 2 feet of yellow clay, several inches of quicksand, through which spring water enters, and finally hardpan. There is a stripping of fine sand, which varies from 10 to 20 feet in thickness. Some portions of this sand are found to make a better brick when mixed with the clay than others. The clay is mined in benches, and narrow tracks are laid along the working face. Side dump cars are used to haul the clay, being run in trains of three, drawn by four mules. The tracks are laid around the ring pits, so that the clay may be easily discharged into them.

Crugers, Montrose and Verplanck, Westchester co. These three localities lie so connected and their clay banks are so similar that they are best described together. The clay is extremely variable in depth, which is due to the great irregularity of the face of the underlying rocks; it is both blue and yellow. No special method is used in mining the clay, it being dug at any convenient spot till the underlying rock is reached and then the bank is attacked at another point. At Montrose and Crugers the clay is overlain in places by a moderately fine sand and gravel, cross-bedded in places. The clay varies from 6 to 50 feet in thickness. It extends in places to an altitude of 90 feet, as at McConnell & O'Brien's bank, while at others, as McGuire's bank, it only reaches a hight of 6 feet above mean tide. At the latter place the clay is overlain by 10 feet of sand and coarse gravel and has been excavated to 10 feet below mean tide.

A partial analysis of the buff clay from McConnell & O'Brien's clay bank at Verplanck is given below.

Silica	50.92
Alumina	26.87[1]
Peroxid of iron	4.90
Lime	2.52
Magnesia	1.56

King & Lynch's yard is situated on George point near Montrose. The bank is about 700 feet distant, and the clay is hauled in cars drawn by horses. At most of the yards the haulage is down grade. Fisher's clay bank at Crugers is overlain by 2 feet of loam. This is used to supply part of the tempering material and the rest is obtained from Jonespoint. At the yards on Verplanck point horse power is chiefly used to operate the machinery. Most of the yards at this locality obtain their clay from the pits of the Hudson river brick co. This clay bank is worked in benches. The haulage distance is about one half a mile. It is done either in carts or in cars run on tracks and drawn by horses.

Along the New York Central railroad a short distance south of Montrose station are the yards of C. Hyatt and J. Morton. Mr Morton also has a covered yard on Verplanck point where front brick are made. Their banks are practically a continuation of each other. The clay is both blue and yellow and is overlain by several feet of coarse sand. Hyatt uses steam power and Morton

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[1] Alumina is probably too high.—*H. Ries*

Plate 48 To face page 693

H. Ries photo. General view of brick clay pits at Haverstraw.

horse power to run his machinery. The bricks are loaded on cars and shipped to various points along the Central railroad.

Peekskill, Westchester co. Bonner & Cole's brick yard lies between the river and the railroad about three quarters of a mile south of Peekskill. The clay lies below tide level. It is said that borings have shown a thickness of 50 feet. There is on the average a stripping of 5 feet of gravel and cobblestones.

South of this yard are two others, viz, Oldfield Bros. and the Bonner brick co. Their clay is similar to Bonner & Cole's, but rises to a greater hight above tide level.

Haverstraw, Rockland co., is one of the great brick manufacturing centers of New York state, there being 42 brick yards, with a yearly capacity of 238,000,000 bricks. The yards are situated in a line along the river stretching from the lower end of Haverstraw village northward around Grassy Point, to Stonypoint. A few of them are situated along Minisceongo creek. Most of the yards along the river are digging their clay below tide level. At the south end of the village a dam was built at an expense of $30,000, reclaiming thereby 12 acres of clay land from the river. And more recently clay has been dredged from the river bottom. The last-mentioned bed of clay is underlain by till and modified drift, from which tempering sand is obtained. The clay within this inclosure has been excavated to a depth of 20 feet below mean tide. In the pits of the Excelsior brick co. they have reached a depth of 35 feet below river level; in Donnelly & Son's pit, 45 feet, and west of Washburn's yard, 40 feet. A pipe well was sunk from mean tide level 100 feet through blue clay, in the Excelsior co.'s clay, and at this depth struck bed rock or a large boulder.

The clay in these pits is rather sandy on top, but is said to improve with the depth. It is mostly blue. Streaks of quicksand are always liable to be encountered. In those pits situated along the river and to the rear of the yards, there is no expense of stripping unless the excavation is widened, but there are two important items of expense, viz, pumps to keep the water out of the pits, and the maintenance of corduroy roads leading down into the pits. The clay is dug at any convenient point within the excavation and hauled in carts to the yard. About one quarter of a mile west of the river, where the terrace is 40 to 50 feet high, clay is being dug from the escarpment to supply the yards of J. D. Shankey, Buckley & Carroll, Philip Goldrick, R. Malley, and J. Brennan. Some of the yards situated on Minisceongo creek have to haul their clay 400 to 500 yards. Where the clay is obtained from the terrace escarpment there is in most cases a stripping of from 6 to 10 feet of sand and gravel. This is screened and used for tempering. The Excelsior company has tried to use clay dredged from the river, but gave it up after one season's trial for reasons unknown. Most of the brickmakers at Haverstraw temper their clay in soak pits and burn their bricks with wood. They all use open yards for drying except the Diamond brick co. which has recently put in a tunnel drier. The Excelsior company has a covered yard, and Bennett, Rowan & Scott use pallet driers. At most of the yards barges can be brought to within a few feet of the kilns, and those yards not situated directly on the water put the barrows, loaded with brick, on flat cars and run them down to the dock.

Stonypoint, Rockland co. This is practically a part of Haverstraw. There are four yards here. They obtain their clay from one large shallow excavation on the west side of the West Shore railroad track and 500 feet north of Stonypoint railroad station. The clay has to be carted from 100 to 300 yards, and when the excavation is widened there is a stripping of 3 to 6 feet of sand and cobblestones. Corduroy roads have also to be used. The four yards are situated along the water front. One of them, Riley & Clark's, uses stationary kilns. Riley & Rose have a covered yard, the other three firms dry their bricks on open yards. The clay bank is owned by T. Tompkins & Son.

The following are some tests of Haverstraw brick made by M. Abbott at the time the East river bridge was being completed. No packing was put between the brick and plate of testing machine.

		Crushing strength to the square inch *Pounds*
Whole brick tested on end	Maximum	3 060
	Minimum	1 600
	Average	2 065
Half brick tested on flat side	Maximum	4 153
	Minimum	2 669
	Average	3 371
Half brick tested on edge	Maximum	6 400
	Minimum	2 900
	Average	4 612

Had the surfaces been ground parallel and cardboard or blotting paper been put between the face of the brick and plate of machine, higher results would no doubt have been obtained.

Thiells, Rockland co. About two miles south from Haverstraw and half way between the stations of Ivy Leaf and Thiells, on the New York and New Jersey railroad, is the brick yard of Felter & Mather. The clay deposit is basin-shaped, about 15 feet thick, as determined by boring, and has a slightly elliptic outline. The clay is chiefly of a blue color, the upper portion being weathered to yellow. It is overlain by a few feet of drift containing small boulders and underlain by similar material. The tempering sand is obtained from a bank on the opposite side of the railroad about 1000 feet from the yard. Tempering is done in ring pits; the bricks are molded in soft mud machines and dried on an open yard. Burning is done in scove-kilns. The product is shipped to various towns along the line of the railroad in New Jersey.

Coldspring, Putnam co. A brick yard was in operation north of this town for a number of years, but has been shut down on account of the clay giving out.

Stormking, Dutchess co. About 1000 feet north of the station is a clay deposit, chiefly yellow. It is worked by Mosher Bros. The bank has slid considerably; it has a vertical hight of 50 to 60 feet.

Cornwall on the Hudson, Orange co. C. A. & A. P. Hedges are the only brick manufacturers here. Their yard is situated on the West Shore railroad about a mile north of Cornwall station. They have 27 acres of clay land. Blue and yellow clay are found in the bank, the main portion of which is covered by delta deposits of Moodna river. The clay layers are much compressed in places, making it difficult to excavate and necessitating the use of picks. The bank is worked in benches and the clay has to be hauled about 300 feet to the machines. The stripped sand can be used for tempering. Many bricks are shipped to points on the New York, Ontario and Western railroad.

New Windsor, Orange co. There are six yards here. They obtain their clay from the escarpment of a terrace 110 feet high. Their clay is both blue and yellow. Streaks of quicksand occur in the blue. The yellow is dry and tough, and has to be worked by undermining. In thickness the clay varies from 20 to 60 feet; the layers are in many places contorted, and in some cases the stratification has been obliterated. Overlying the clay are gravel and sand; the latter is used for tempering. Most of the New Windsor clay permits the addition of very little water in tempering. Ring pits and Adams machines are used at these yards. The yards are all situated along the river, and ship their product on barges or by the West Shore railroad.

Dutchess Junction, Dutchess co. There are several brick manufacturing firms having yards along the river south of Dutchess Junction. They obtain their clay from the escarpment of an 80 foot terrace which extends from a short distance north of Stormking to Dutchess Junction. The clay has a fairly uniform thickness; the upper 4 to 8 feet are yellow, the rest blue. The greatest thickness of clay known for this locality is at Aldridge

Plate 49

To face page 697

H. Ries photo.

Clay bank of Brockway brick co., North of Fishkill landing.

Bros.' yard, where a well was sunk 65 feet through the clay, which, added to the hight of the bank (65 feet), gives us a total thickness of 130 feet at this point. The clay is usually covered by gravel, and by sand in some cases sufficiently fine to be used for tempering or even molding. It is worked in benches, and the haulage distance is 200 to 300 feet. At Timoney's clay bank there is some extra labor in stripping the scrub oaks and other bushes which cover the surface of the terrace.

Fishkill, Dutchess co. Harris & Ginley's yard is situated about one quarter of a mile below the town. The clay bank is leased from the New England railroad co. It was formerly quite thick, but clay having been dug for 50 years but a small portion of the bank remains. The clay has a maximum thickness of 45 feet. Streaks of quicksand occur throughout the clay; it is underlain by hardpan and shale.

The other yards at this locality are situated along the river from a point about half a mile above Fishkill up to Low Point station. One of the yards is just north of Low Point. The most southern one is that of Aldridge & Sherman, with 600 feet water front. The clay land of these two firms belongs to the W. E. Verplanck estate. Next on the north are works of the Brockway brick co., with 1200 feet of water front. This firm owns its clay bank. The bricks are dried on pallets. The next two yards belonging to Lahey Bros., (650 feet water front) and Dinan & Butler (475 feet water front), respectively, lease their clay bank from the W. E. Verplanck estate. Dinan & Butler have a pallet yard. The five above-named firms obtain their clay just east of the yards from the escarpment of a 90 foot terrace; it is both blue and yellow and overlain by 4 to 6 feet of loam, sand and gravel. A short distance north of Dinan & Butler's yard is that of J. V. Meade. About 20 feet of clay are exposed in the bank, which adjoins the yard. The clay is overlain by 4 to 6 feet of sand and cobblestones. The sand is screened and used for tempering.

C. G. Griggs & Co.'s brick yard is located along the river about half a mile north of Low Point station. An opening has been made for clay about 800 feet east of the yard; the clay as exposed at present is 20 feet thick and overlain by 2 feet of loam. 100 feet farther east, and at a slightly higher level, sand for tempering has been dug to a depth of 8 feet without finding clay. The clay is hauled in carts to the yard.

Roseton, Orange co. There is a remnant of a terrace at this locality 120 feet high. From this J. J. Jova and Rose & Co. obtain their clay. The former has 80 acres, the latter 40. The clay is mostly blue and rises to a hight of 100 feet above the river. At Jova's upper yard it is underlain by limestone and overlain by sand. On top of the clay at his lower yard are 10 to 15 feet of sand and gravel.

A well was sunk from river level at Jova's, passing through the following:

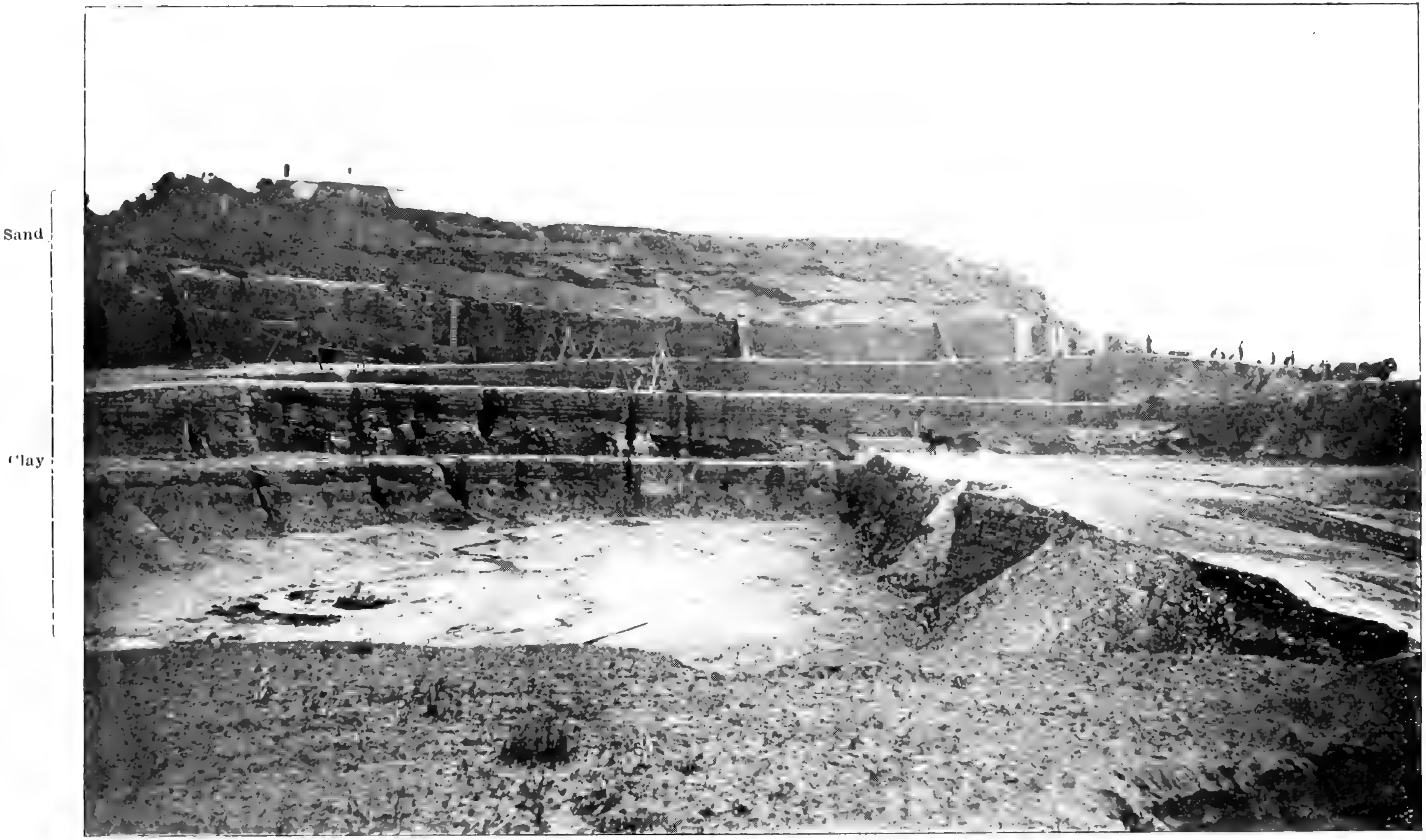
Blue clay	80	feet
Quicksand	25	"
Loose sand and gravel	75	"
	180	"

Adding to the above section 100 feet of clay above river level gives us a total thickness of 180 feet of clay. At Rose & Co.'s yard, which adjoins Jova's on the south, it is said, a well was sunk 135 feet through blue clay. Adding to this 108 feet of clay above mean tide gives us a bed of clay 243 feet thick. The terrace which the clay underlies at Roseton extends back from the river several hundred feet into a reentrant angle of the hill. The clay contains little sand and is worked in benches. Carts are used to haul the clay. South of Roseton station is a bank of sand of alternating yellow and grayish black layers, which has been used for tempering, but is said not to give as good results as that on Jova's premises.

H. Ries photo.

General view of brick yards and clay bank, Rose, Rose & co., Roseton. In the background is the terraced clay bank at the base of which are the eight molding machines, between which and the long kiln sheds are the open yards on which the bricks are seen drying in the sun.

Plate 51



H. Ries photo.

Clay bank of Rose & co., Roseton.

Port Ewen, Ulster co. S. D. Coykendall's yard lies near the junction of Rondout creek and Hudson river. The bank is just west of the yard. There is a considerable stripping of fine sand and the clay slides quite easily. It is dug at any convenient point of the bank. The overlying sand can be used for tempering and molding. Oil is used for burning the bricks. A short distance farther south along the river is J. Kline's yard. He obtains his clay from various points in the terrace escarpment and in some cases hauls it nearly a quarter of a mile. Mr Kline has made borings at various points along the river and the terrace and in the escarpment in the vicinity of his yard, and says that at none of them has he found over 18 feet of clay. Beneath it was hardpan. This would seem to indicate that the central mass of the embankment is rock, overlain by hardpan, and that on this the clay is laid down. In many places the clay is covered by 10 to 20 feet of fine, stratified sand.

The following is an analysis of the blue clay near Rondout which is used for the manufacture of cement.

Silica	57.8
Peroxid of iron and alumina	22.6
Lime	4.85
Magnesia	2.07
Water and alkalis	12.68
	100.00

East Kingston, Ulster co. There are eight brick manufacturing firms at this locality, viz, Streeter & Hendricks, D. S. Manchester, Brigham Bros., C. A. Schultz, A. S. Staples, R. Maine & Co., Terry Bros. and W. Hutton. They all obtain their clay from the terrace escarpment which extends from Glasco to Rondout. (For thickness of clay see table.) At Streeter & Hendricks's yard the clay lies some 300 yards from the river. They obtain their tempering sand from Wilbur. Manchester's bank is similar. At

Brigham Bros.' yard the clay is yellow, being weathered through to its base. It has a thickness of 10 feet and rests on an uneven ridge of shale. On account of its toughness it is worked by undermining, as is the case with other yards along here where clay is being dug. C. A. Schultz has an exposure of clay 80 feet thick, overlain in spots by sand that can be used for tempering. Next on the south is A. S. Staples's yard. The bank has been excavated to a lower level than the preceding one. The clay is underlain by hardpan. R. Maine & Co. have five acres of clay land. The terrace here is quite narrow. At Terry Bros.' yard the clay, which is mostly blue, has been excavated sufficiently to expose the limestone against which the terrace lies. At Hutton's yard the blue clay is exposed from 8 feet above mean tide, to 110 feet above it; overlying this is 10 feet of yellow clay and then 15 feet of sand. It will be seen from the limits quoted above and in the table, that the thickness of the clay between Glasco and Rondout varies considerably, amounting to 120 feet in places, while in others it is not over 15 or 20 feet. This is due to the great irregularity of the underlying rock surface.

Smiths Dock, Ulster co. The only yard here is that of Theodore Brousseau. He has about 90 acres of clay land. The clay, which is mined with plow and scrapers, is obtained from the terrace east of the yard. It is mostly blue and covered by a few feet of loam. The yard lies some 700 feet from the river and the bricks are carted down to the dock. Brousseau's property extends west to the West Shore railroad, and the farms north and south of him are underlain by clay.

Malden, Ulster co. The clay at Cooney & Farrell's yard to the north of the village is mostly yellow, and lies 10 to 20 feet thick on the upturned edges of the Hudson river shales. This yard was started in 1891.

Glasco, Ulster co. Washburn Bros. This firm is one of the largest producers along the river, having a yearly capacity of 50,000,000. They have about 150 acres of land, a large part of

Plate 52

To face page 700

H. Ries photo.

Champlain clay resting against glaciated surface, of Helderberg limestone. Terry Bros. brick yard, East Kingston.

it being situated along the river. Their clay is mostly blue and rises in a bank to the hight of 130 feet. It has been excavated to 8 feet above mean tide. The upper 10 feet is yellow sand; a thin strip of yellow clay separates it from the red. The lower third of the bank is somewhat sandy; the best results are obtained by a mixture of the upper and lower portions of the clay. Both pallets and open yards are used for drying; the former at the yard situated on the terrace. A short distance below Washburn Bros. is F. M. Van Dusen's yard. The clay is blue, 70 feet thick and is underlain by shale whose surface is glaciated. Several feet of loam overlie the clay. Tempering sand is brought from Wilbur on Rondout creek. J. Porter's yard adjoins Van Dusen's on the south. The clay lies on a ridge of shale which rises steeply from the shore to a hight of 60 feet. The brick yard is at the foot of the cliff and was started in 1891. Plows and scrapers are used to mine the clay, which is of a yellow color, and overlain by 3 feet of loam. Carts are used for hauling the clay. About a mile below this are the yards of C. H. Littlefield, A. Rose & Co. and D. C. Overbaugh. The three are close together. A ridge of shale rises steeply from the river and behind this the clay lies. The terrace here is 150 feet high, and borings which have been made show a depth of 60 feet (*see* table). The clay is quite dry, and mostly yellow. It is worked by picks and undermining. Carts haul it to the edge of the cliff, where it is sent down shoots to the tempering pits. The drying is done on pallets at Rose's yard.

Arlington, Dutchess co. Flagler & Allen. The clay deposit, which is yellow, is situated half a mile east of Poughkeepsie and has an extent of about 40 acres of clay, it averages from 6 to 8 feet in depth. This is easily worked, there being only a stripping of 6 inches of sod. Underneath the yellow is considerable blue clay. The yellow is of course the weathered portion. The clay is tempered in soak pits and about 20,000 brick are made daily. The machinery is run by horse power. Repressed brick are also made. The clay burns a cherry red.

H. R. Rose's brick yard is also situated in this town and about 3 miles east of the Hudson river. The clay deposit, which has an extent of 60 acres, is yellow in color and 8 feet thick. A blue clay is said to underlie the yellow. The bricks are molded in soft mud machines operated by horse power.

Barrytown, Dutchess co. There are deposits of clay along the river at this locality but they are not being worked. The following is an analysis of them.

Silica	59.81
Peroxid of iron and alumina	22.00
Lime	4.35
Magnesia	2.29
Moisture	.37
Combined water and organic matter	7.89
Alkalis, not determined	....
	96.71

Catskill, Greene co. Alexander McLean's yard is situated on Water st., east of the wagon bridge. He has 12 acres of clay land. The clay is mostly blue with yellow and red on top, and is about 90 feet thick.

A partial analysis of the blue clay is as follows:

Silica	50.60
Alumina	21.00
Peroxid of iron	7.35
Lime	3.75
Magnesia	.96

The upper portion of the clay bank is a tough material and has to be worked with a pick. A gray black sand of the same structure and appearance as that at Coeymans underlies the clay. At this locality, however, it contains too much lime to use it for tempering. Mr McLean has to bring his tempering sand from Jonespoint at the cost of 40c a cubic yard. The manufacture of drain tile, hollow brick and sewer pipe has been attempted with this clay, but was given up, it is said, for financial reasons. Ferier & Golden's yard is situated on the opposite side of the street from McLean's, and their clay bank is practically a continuation of his. Their tempering sand is carted from near the West Shore railroad station, a distance of about three quarters of a mile. Drying is done in tunnels. The bricks are burnt with wood, though it is said that petroleum was used for a while successfully. The bricks are run down to the dock on cars. Lying along the creek north of the bridge is the Derbyshire brick co.'s yard. Most of the drying is done under sheds. The clay is both blue and yellow and is dug in a rather steep face, often causing it to slide. The blue has been excavated to 38 feet from tide level, and its upper limit is 82 feet above tide; over this is 12 feet of yellow clay and 3 feet of loam. The tempering sand is obtained about half a mile from the works. As at the preceding yard, the bricks are loaded on cars at the kiln and run down to the dock.

Hudson, Columbia co. There are three yards at this town. J. Fitzgerald's Sons' yard is situated in a reentrant curve of the shore, and about 300 yards east of it is the yard of Arkison Bros. The former is no longer in operation. Both these firms obtain their clay from different faces of the same hill. The clay, which is fairly dry, is mined with plows and scrapers. It is blue and yellow, from 70 to 80 feet thick, overlain by 2 feet of loam, and underlain by grayish black sand.

W. E. Bartlett's brick yard is also situated along the shore, about one quarter of a mile north of Hudson. The clay is similar to that farther down at Fitzgerald's. Scrubby pines cover the surface at this locality. The bank is worked in benches. Ring pits are used for tempering.

Stuyvesant, Columbia co. Walsh Bros. have two yards situated along the river midway between Stuyvesant and Coxsackie. All the clay thus far mined is yellow in color, very tough and unstratified. It is worked by picks and carted down to the yards. The bank which is 30 feet in hight is located on the hillside some 500 feet east of the yard. It is probably underlain by the sand and gravel which crops out in the terrace escarpment behind the yard, and which is used for tempering.

Coxsackie, Greene co. There is only one yard here, that of F. W. Noble. It is situated at an elevation of 100 feet above the river, and about a quarter of a mile north of the village. The clay bank adjoins the yard and is 35 feet high. Both blue and yellow clay are used. Shale underlies it. The clay is quite dry and is broken up by undermining. Soak pits are used for tempering. There is an exposure of blue clay in the terrace escarpment south of Coxsackie.

Athens, Greene co. Of the three yards at this locality, situated about half a mile north of the village and adjoining each other, only two are running. The most southern one is that of William Ryder, situated 80 feet above tide level and about 500 feet from the river. Mr Ryder owns 12 acres of clay land. The clay, which has not been excavated below the level of the yard, runs up to 125 feet above mean tide, and is both blue and yellow with about 6 feet of loam covering. A well was sunk 18 feet below the level of the yard, without reaching the bottom of the clay. The clay is mined by plows and scrapers. The upper 6 feet of loam is mixed with the clay. The bricks when taken from the kilns are sent on cars down to the shore, where they are loaded on barges for shipment to New York city. Adjoining this yard on the north is that of Mr. Porter, not worked. A few hundred feet north of this, on the south side of Murder creek, is the yard of I. R. Porter. Though the yard is situated near the shore, the water is not deep enough for the brick barges, and the bricks have to be carted some 200 yards to the dock. The clay bank adjoins the yards and is mined by plows and scrapers. Horse power machines are used.

Coeymans Landing, Albany co. There are two brick yards at this town; they lie north of the town along the river shore and adjoin each other. The one nearest town belongs to Sutton & Suderly, and is worked by them and four other persons. Their clay is obtained from the bank west of the yard. It is both blue and yellow, chiefly the former, with streaks of fine sand.

The following partial analysis has been made of Sutton & Suderly's clay.

Silica	51.10
Alumina	17.65
Peroxid of iron	6.47
Lime	7.45
Magnesia	.87

Being of a soft nature, the clay is dug with shovels at any convenient point at the base of the bank, which is 120 feet in hight. A charge of dynamite is usually exploded in the bank in the spring, thus bringing down a large mass of clay to a level with the yard. The clay does not have to be hauled more than 150 feet to the machines. A drivepipe well sunk near the owners' barn on top of the terrace (140 feet above mean tide) some 300 feet back from the river, showed 70 feet of clay and 60 feet of sand. The sand underlying the clay is of a grayish black color, consisting chiefly of grains of quartz and shale, the latter predominating.[1] Grains of garnet and feldspar, and large pebbles of quartz are scattered through it. The sand after being screened is used for tempering. The upper limit of the underlying sand varies, at the north end of the property rising to within a few feet of the terrace level, while some 300 feet south of this the clay has been excavated to 15 feet above mean tide without striking sand.

Adjoining Sutton & Suderly on the north are the brick works of Corwin & Cullough, sublet by them to T. Finnegan and Delaney & Lavender. The clay, which is obtained just west of the yard, has been excavated to 7 feet above mean tide and bottom not yet

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[1] This underlying material is much faulted owing to the pressure of the clay above it.

reached. It contains several veins of fine sand. Both yellow and blue clay are present. At the south end of the yard the escarpment of the terrace is drift containing small boulders. The tempering sand is obtained from this bank.

There are outcrops of clay on the land of Mr Bronk, to the north of Corwin & Cullough's yard; also on the Lawson property to east of the white iron bridge crossing Coeymans creek. This latter locality lies some 800 feet from the river, and would be somewhat more expensive to work. Again, on Main street, just south of the residence of Miss Wolf, there is an exposure of clay on the hillside some 400 feet from the river.

Albany, Albany co. There are several yards situated on the outskirts of the city. The clay banks, which are all of the same nature, belong to the Hudson river estuary formation, being stratified and blue or gray in color with the upper portions weathered yellow or red. M. H. Bender's[1] yard is on Delaware avenue, near Dove street. He manufactures common and pressed brick, and drain tile. The upper loamy clay can be used only for common brick; the lower blue and some of the yellow are used for the other products. Auger machines are used for better grade brick and tile, and the latter are made of several sizes. Scove-kilns are used for burning the brick and down-draft kilns for the tile. The latter kilns hold 60,000 small size tiles or 35,000 assorted size. It takes three wheelers and two setters two and a half days to fill the kiln, and burning occupies four days. The tiles after molding are first dried on shelves under a closed shed.

Adjoining Bender's yard are those of J. Babcock, E. Smith, J. C. Moore and D. H. Stanwix.[1] They make common brick chiefly, and their clay banks are the same as Bender's. All are open yards.

T. McCarthy's[1] yard is situated on First avenue. The clay bank is about 15 feet thick and covers an area of about 10 acres. It is chiefly blue. The stripping is a light soil and sand underlies the clay. The bricks are manufactured by the soft mud process.

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[1] Since this report was written the Bender, Stanwix and McCarthy yards are closed.

Alfred Hunter's yard is situated on Van Woert street near Pearl. The clay is blue with yellow on top. About 40 feet of clay is at present exposed. There are only a few inches of soil to be stripped. The bottom has not yet been reached. Ring pits and soft mud machines are used and the bricks are dried in the sun. Burning is done in scove-kilns. Albany and vicinity consume most of the product.

The brick yard of A. Poutre is on Van Woert street between Lark and Knox. The clay is blue in color and about 25 feet thick. It is overlain by a loose soil; the bottom has not yet been reached. Soft mud machines operated by steam power are used; the bricks are dried on open yards and burned in scove-kilns. Albany consumes most of the product.

Rensselaer, Rensselaer co. Mrs. T. Rigney's yard is at East Greenbush on the east side of the Boston and Albany railroad. The clay, which is blue and yellow, has a thickness of about 90 feet. Loam overlies the clay; the bottom has not yet been reached. The machinery is run by horse power. Rensselaer and New York city are the chief markets for the product.

Troy, Rensselaer co. Alexander Ferguson's brick yard is situated on Hoosick above 1st street. The clay bank is about 40 feet high and runs in an east and west direction; it is deeply incised at either end by two streams. The clay, as is common to these Hudson estuary deposits, is stratified, yellow in the upper portion and blue clay in the lower. The blue contains some quicksand. A stronger and better colored brick is made from the tough upper clay, but it shrinks considerably in burning. On the other hand the blue clay makes a smoother but not as strong brick, but one of more even shape. Underlying the clay is slate rock, which has been used for building purposes.

J. B. Roberts's bank is about 20 feet in thickness. The clay, which is mostly yellow, is covered with a foot of loam and underlain by gravel. Capacity, 2,000,000.

Cohoes, Albany co. J. E. Murray. Yard situated between Crescent and Cohoes, on west side of Erie canal. The clay is chiefly blue, the upper few feet being yellow. It rises in a bank to 50 feet in hight. It is underlain by rock and there is a slight covering of loam. The bricks are molded by steam power machines, and dried in the sun. The product is sold in Cohoes and vicinity. J. E. Murray also operates the brick yard formerly belonging to N. Gardonas.

J. Baeby. The clay bank is about 40 feet high, 400 feet long and about 250 feet from the yard. Mr Baeby has about 40 acres of clay land. The clay is yellow on top and blue beneath. It is covered by about 4 inches of soil and underlain by gravel. One yard is operated by horse, the other by steam power.

Lansingburg, Rensselaer co. T. F. Morrisey has a horse power yard situated along the old turnpike near the railroad. The clay bank is 75 feet high, there being about six acres of clay land. The upper third of the bank is red, the lower two thirds blue. About 30 feet of sand underlies the clay.

Crescent, Saratoga co. Newton Bros. have a bank of clay 30 feet thick, the upper 6 feet being gray, the rest blue. There is a stripping of 2 to 4 feet of sand, which can be used for tempering. The blue and yellow clay, together with a certain portion of sand, are tempered in the pug mill. The bricks are molded on a Martin soft mud machine and dried on pallets for about five days. Burning is done in scove-kilns; the product is loaded on the Erie canal boats at the yard.

Mechanicville brick co., Saratoga co. The brick yard is situated on the Champlain canal in the town of Half Moon, about a mile south of Mechanicville. The clay bank is 50 feet high. The upper 10 feet is yellow and under this is blue clay; the latter is underlain by sand. The bank adjoins the yard and is worked in benches; the clay is hauled in carts to the ring pits. Soft mud machines are used, the brick are dried on pallets and burned in clamps.

Saratoga, C. L. Williams. The yard is situated about one mile from the town, 600 feet from the Delaware and Hudson railroad. Mr Williams has about 50 acres of clay land, the clay running 6 feet thick. It is blue, with the upper portion of it weathered to yellow. There is a stripping of about 1 foot of loam. The clay is put through a crusher first; it is then pugged and molded. The bricks are dried on pallets, the racks having a capacity of 260,000. Wood is used for burning, being obtained from a lot of 200 acres near the yard. The product is chiefly used locally.

The other brick yard at Saratoga is owned by D. Davidson. It is situated at the outskirts of the town, just west of Judge Hilton's yard. The clay bank, which is about 28 feet thick, is about 150 feet from the yard; it is stratified, the layers being from 1 to 8 inches thick and separated by thin laminae of sand. The clay is of a light brown color, being underlain by calciferous limestone and overlain by a foot of soil. Mr Davidson has 22 acres of clay land. Tempering is done in ring pits and the clay is molded in a soft mud machine. Drying is done in an open yard, and burning in scove-kilns. The fuel used is hard wood.

Other eastern yards

Hoosick Falls, Rensselaer co. John Dolan's clay bank is about 40 feet high and has an extent of six acres. It is used for making building brick. The product is consumed in the vicinity.

Middle Granville, Washington co. J. H. Pepper is the only manufacturer at this locality. His clay bank is 45 feet high, and 2000 feet long. The clay is blue, and scattered through it are some streaks of sand. A bed of gray sand 20 feet in thickness underlies the clay and is in turn underlain by slate.

Plattsburg, Clinton co. There are several yards here. That of J. Ouimet lies at the north end of the town. It is an open yard and the bricks are made by horse power. The clay which is hard and tough is of a yellowish brown and red color and is mined with plows.

Charles Vaughn's yard is similar to the preceding, and is at the south end of the town. The clay is 10 feet thick.

Gilliland & Day's yard is situated on Indian bay, 6 miles south of Plattsburg. The bricks are also molded by hand power.

All these yards sell most of their brick at Plattsburg.

The following is an analysis of the clay at J. Ouimet's brick yard.

Silica	65.14
Alumina	13.38
Peroxid of iron	7.65
Lime	2.18
Magnesia	2.36
Alkalis	8.51
	99.22

Oswego, Jefferson and St Lawrence co. yards

Gouverneur, St Lawrence co. The brick yard of G. R. Thompson is situated east of the village and on the eastern bank of the Oswegatchie river. The clay bank rises to a hight of 10 feet above the river and the section exposed is:

Sand	4	feet
Gray clay	8	"
Blue	6	"
	18	"

A Martin soft mud brick machine is used and the bricks are dried under sheds. The product finds a ready sale in the local market.

A pallet yard has recently been started at this locality.

Carthage, Jefferson co. Wrape & Peck. The brick yard and clay pit are situated in the Black river valley near the town of

Carthage. The clay deposit, which is several hundred acres in extent and about 5 feet thick, is of a gray color with streaks of brown. The bricks are molded in wet mud machines and put in steam driers. Local market consumes most of the product.

Potsdam, St Lawrence co. D. W. Finnimore's brick yard is situated a few rods outside of the village limits. The clay is of a blue color and 6 to 8 feet deep. It is overlain by 1 to 2 feet of dark sandy soil and underlain by gravel. The yard is equipped with a Quaker soft mud machine, and a Kells & Son's dry press machine. The product is used locally.

Watertown, Jefferson co. At the north end of the town on Main street are the works of the Watertown pressed brick co. They have about 20 acres of clay, red in color, horizontally stratified and averaging about 20 feet in thickness. It is underlain by Trenton limestone. The tempering sand has to be carted nearly 3 miles. Analysis of the clay shows:

Silica	64.39
Alumina	14.40
Peroxid of iron	5.00
Lime	3.60
Magnesia	1.31
Alaklis	4.66
Water and organic matter	6.64
	100.00

The clay is rather tough. It is loaded on cars which are drawn by cable some 75 feet, up into the machine shed, where it is dumped into a disintegrator. It next goes to the pug mill for tempering, and is molded in a Martin machine. Drying is done on pallets and burning in scove-kilns, the latter occupying about seven days. The consumption is chiefly local.

Ogdensburg, St Lawrence co. Paige Bros.' yard is on Cedar cor. Canton street, at the southwest end of town. The clay is of a deep blue color, the upper 10 feet being somewhat sandy. It has been bored to a depth of 60 feet in places, but this depth is not constant, and in spots the underlying limestone rises to within a few feet of the surface. The sand for tempering has to be brought 2 miles. The following is an analysis of the clay.

Silica	49.20
Alumina	17.47
Peroxid of iron	6.23
Lime	7.86
Magnesia	4.87
Alkalis	9.82
	95.45

Only common brick are made. Soft mud machines are used. Drying is done in the sun and burning in scove-kilns. The bricks have been largely used in the asylum buildings at Ogdensburg.

Madrid, St Lawrence co. Three miles north of the depot is the brick yard of Robert Watson. The clay is of a blue color and about 20 feet thick. The section is

Yellow sand	3	feet
Blue clay	20	"

The bottom has not yet been struck. Horse power is used for operating the machinery. The clay has to be tempered with sand. Drying is done on pallets or in the sun. Burning takes about one week. The consumption is local.

Raymondville, St Lawrence co. William Coats's works are at Raymondville, about 7 miles north of Norwood. The clay bank lies on the east side of the Racket river. It is about 25 feet in thickness and there is a covering of 12 feet of fine sand. The clay is rather tough and requires an admixture about one third sand for making brick. An abundance of unworked clay is still in sight.

Central New York yards

St Johnsville, Montgomery co. J. S. Smith is the only brick manufacturer in this town. The clay bank is 60 feet high, and the following is the section involved.

Loam	1 foot
Fine sand	7 feet
Dark building sand	3 “
Gray clay	1 foot
Quicksand	4 feet
Hardpan	1 foot
Blue clay	75 feet
Total thickness	92 feet

Only common brick are manufactured.

Fonda, Montgomery co. W. Davenport's brick yard is about one mile west of the village on the north side of the New York central railroad. The clay bank lies to the north of the yard, is 12 feet high, and yellow in color. The brick are molded in soft mud machines operated by horse power, dried on open yards and burnt in scove-kilns. The product is sold in Montgomery co. Drain tile are also manufactured.

Dolgeville, Herkimer co. A. C. Kyser has a bed of clay about 50 acres in extent, and 30 feet thick. He manufactures ordinary building brick, which are consumed by the local market.

The clay is tempered in a pug mill with the addition of a certain amount of sand, and passes thence to a Quaker soft mud machine. Drying is done on an open yard, and the bricks are burned in a scove-kiln. The latter operation takes five to eight days.

South Trenton, Oneida co. H. L. Garrett has manufactured brick at this locality for 45 years. His clay bed is several acres in extent and about 4 feet thick. The clay is blue below and yellow and red in the upper portion of the bed, on account of weathering. It is slightly stratified. Underlying the clay is slate.

Amsterdam, Montgomery co. H. C. Grimes's brick yard is located on Florida avenue. The clay deposit underlies a tract of about 20 acres, and the section is as follows:

Soil	1-3	feet
Yellow clay	6	"
Blue clay	..	

Common bricks are manufactured.

The clay is first passed through a Cotts disintegrator and is then molded on a soft mud machine. Drying is done on pallets. This yard has been in operation 16 years.

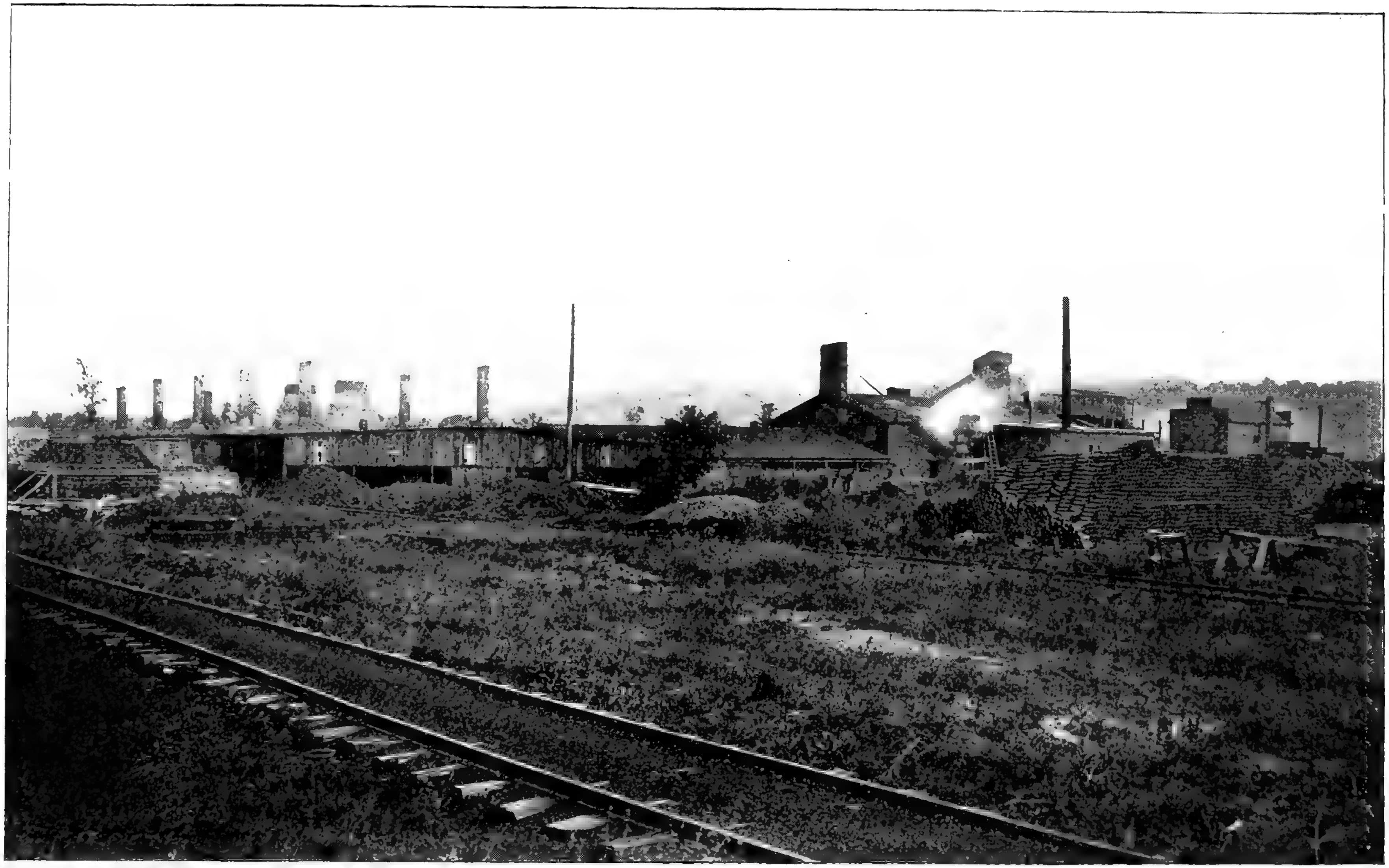
Gloversville, Fulton co. H. McDuffie's brick yard is situated on the outskirts of the town. The clay, which is of a dark brown color, is in a bed 2½ feet thick. It is underlain by hardpan and overlain by a thin soil. The bricks are made by the soft mud process, being molded in horse power machines.

W. A. Stoutner. His clay bank is about 3 feet thick, underlain by hardpan and overlain by a few inches of soil. The clay is reddish brown and burns to a red color. The brick are made on a Peekskill hand power machine. The brickmaking season at Gloversville runs from about the middle of May to the end of September. The Eureka pressed brick co. also operates here.

Ilion, Herkimer co. S. E. Coe. Brick yard situated along the Erie canal, with the West Shore railroad crossing the property. Mr Coe has about 10 acres of clay land, the clay running in depth from 8 to 15 feet. It is of three different colors, black, gray and blue. The latter makes the stronger brick. No stripping to be done except a few feet of black soil.

Rome, Oneida co. W. Armstrong's yard is located on the edge of the town and along the Rome and Clinton branch of the New York, Ontario and Western railroad. The clay deposit is about 25 acres in extent; the clay is of a dark gray color and 7 to 10 feet deep. The bricks are molded in soft mud machines.

Plate 53



H. Ries photo.

General view of works of Onondaga vitrified brick co., Warners.

W. W. Parry. Yard located near the town; the clay is obtained from the flats bordering the Mohawk river; the bed of it is from 6 to 9 feet deep. It is underlain by gravel, which rises to near the surface in many places. A light loam covers the clay. For making brick, the clay is mixed from top to bottom. Both soft and stiff mud machines are used and burning is done in scove kilns.

Deerfield, Oneida co. G. F. Weaver's Sons' yard is situated on the Mohawk river about a quarter of a mile from the New York Central railroad depot. Their clay deposit is about 40 acres in extent, and has been worked to a depth of 10 feet.

South Bay. C. Stephens has brick and tile works at this town. The clay deposit is from 20 to 25 feet deep and underlies a tract of 800 acres bordering on Oneida lake. Underlying the clay is a fine and closely cemented blue gravel. The Elmira, Cortland and Northern railroad passes through the property. Chiefly drain tile are manufactured. These works were established in the spring of 1891.

Canastota, Madison co. M. Ballou has a brick yard at this locality.

Syracuse, Onondaga co. At the northeast end of the town is an extensive deposit of clay, underlying the low lands at the end of Onondaga lake. It is worked by several brick manufacturers. The yards are mostly on N. 7th street. The first is that of T. Nolan, a horse power yard; adjoining him is the yard of Preston Bros., also a horse power yard. Next comes F. H. Kennedy, at whose yard the bricks are molded by hand. C. H. Merrick has a steam power yard on S. Salina, and farther out on the Cicero plank-road are the brick works of J. Brophy.

The clay is stratified, red above and blue below. In the center of the flat land it runs 7 to 10 feet deep, while at the edges it thins out to 2 feet. It is underlain by sand and gravel.

The New York paving brick co. (See under Paving brick.)

Warner, Onondaga co. The Onondaga vitrified pressed brick co. This yard uses both shale and clay. The works are situated about half a mile east of Warner along the West Shore track.

Analyses of the shale have been made and are given below.

COMPOSITION	Calcareous layer in shale bank	A green brick. Being a mixture of the different shales	Red shale	Blue shale	Clay
Silica	25.40	54.25	52.30	57.79	45.35
Alumina	9.46	16.89	18.85	16.15	12.19
Peroxid of iron	2.24	5.81	6.55	5.20	4.41
Lime	22.81	4.34	3.36	2.73	10.99
Magnesia	10.39	5.21	4.49	4.67	6.38
Carbonic acid	20.96	4.30	3.04	3.42	7.24
Potash	.95	2.95	4.65	4.11	3.26
Soda	.....	.83	1.35	1.22	1.14
Water and organic matter	7.60	5.01	5.30	4.50	8.90
Oxid of manganese	.....	.....	Trace	Trace	.....
Total	99.81	99.59	99.89	99.79	99.86

Analyst, Dr H. Froehling, Richmond, Va.

The samples were all dried at 212° F.

It may be of interest in this connection to give the composition of some other clays found at Warner, which are used in the manufacture of cement. The following are only partial analyses.

Silica	45.12	43.19	46.00	41.78	41.70	44.00
Oxid of iron and alumina	13.79	14.62	25.02	16.09	18.24	17.33
Lime	12.91	12.36	7.13	12.40	12.71	11.74
Magnesia	7.21	7.05	3.67	5.83	6.02	6.83

The last analyses would indicate a rather fusible clay. The clay used by the Onondaga co. is dug in a field adjoining the works. It has a pinkish color, stratified and runs about 15 feet in depth.

The shale used belongs to the Salina formation and is obtained from the hillside about 1000 feet from the yard. It is of various shades of red, green, and some gray, and disintegrates very rapidly. The whole mass is traversed by numerous seams, so that a small blast brings down a large portion of the bank in small fragments. Tracks are laid from the brick yard up to the working face, the base of which is 35 feet higher than the yard. The loaded cars run down to the dry pans by gravity and are hauled back when emptied by a horse. Carts are used to haul the clay. Dry pans grind the shale — about one quarter clay and three quarters shale are mixed in a wet pan. A man shovels the mixture on an endless belt which carries it to the molding machine. The yard is fitted with both a plunger and auger stiff mud machine, the former being side-cut, the latter end-cut. The green bricks are placed on cars and run into the drying tunnels. These are of brick, heated by coal fires, the heat passing through flues under the tunnel. Round kilns are used for the burning, which takes about five days. The kilns have a capacity of about 60,000. Soft coal is used for burning.

The company manufactures paving brick, hollow brick and terra cotta lumber for fireproofing.

Baldwinsville, Onondaga co. Seneca river brick co. The works are four miles west of Baldwinsville on the south bank of the Seneca river. Their clay bed is 6 acres in extent. It is blue clay weathered to red in the upper portion and the blue is stratified. Gravel underlies the clay. The red clay is chiefly used, as it burns to a better colored brick than the blue. The dry press process is used and the bricks are burnt in kilns of the Flood type. These are of both up and down-draft. They are 18 by 54 feet and have 20 inch walls, which are lined with fire brick from the doors up. There are four fireplaces on each of the long sides and between these is a series of smaller ones connected with a set of flues opening into the lower part of the kiln to give an up-draft. Wood fires are started in these smaller fireplaces for water-smoking. The larger openings, connecting with individual pockets on the inner wall of the kiln, lead the fire into the upper portions first, whence it passes downward through the kiln and off through a large flue at the bottom. Water-smoking takes 10 days and burning 8 days, the whole time for burning, water-smoking and cooling taking about three weeks. The molded bricks are set directly in the kiln on coming from the machine.

Oswego Falls. W. D. Edgarton. The brick yard is situated on the Syracuse and Oswego railroad, 11 miles from Oswego. The clay varies from 3 to 5 feet in thickness and is yellow. It is underlain by gravel. A few inches of soil has to be stripped. The lower portions of the clay make the better brick. Soft mud machines are used and both common and repressed brick are made.

Weedsport, Cayuga co. There is a brick yard at this locality belonging to Mrs C. S. Gilette, but it is not in operation.

Auburn, Cayuga co. John Harvey's brick yard is situated on the outskirts of the town.

Owasco, Cayuga co. A. Lester has a brick and tile yard near the village. It is described under the head of drain tile.

Seneca Falls, Seneca co. There is only one brick yard at this locality, that of F. Siegfried. His clay bed is about 12 feet thick, the upper 7 feet being used for brick and the lower 5 feet for tile. Gravel underlies the clay and there is a covering of a few inches of soil. The machinery is run by horse power and the product is sold locally.

Geneva, Cayuga co. Five firms manufacture brick in this locality. They are W. G. Dove, C. Bennett, Goodwin & Delamater, Mrs Baldwin, and the Torrey park land co. The last-mentioned company began operations in the spring of 1892; its brick yard is some distance from the town.

Lyons, Wayne co. The clay bed of F. Borck is about 8 feet deep. The upper portion of the deposit is yellow, the rest is blue. Quicksand underlies the latter. Soft mud machines are used to mold the brick.

Plate 54

To face page 719

J. O. Martin, photo.

N. Y. state veterinary college, Ithaca. Terra cotta made by N. Y. architectural terra cotta co., Astoria L. I. Bricks made by the N. Y. hydraulic pressed brick co., Canandaigua.

Western New York yards

Canandaigua, Ontario co. The New York hydraulic brick co.'s works are about three quarters of a mile southwest of the station; their property adjoins the New York Central railroad track. The clay deposit, which covers several acres, is basin-shaped and has a known depth of at least 20 feet. It is of a blue color, weathered to red above, and on top of it is about a foot of peat. The clay after being dug in the fall is stored under a shed till spring, when it is molded by a hydraulic dry press machine. The brick are set directly in the kilns, which are of the Graves type. The blue clay burns buff and the other clay a red, so that by mixing the two a speckled brick is obtained. This firm has not been in operation very long.

The upper clay is quite siliceous, as the following analysis shows, and is similar in composition to the red terra cotta clay at Glens Falls. The composition is as follows:

Silica	62.23
Alumina	16.01
Peroxid of iron	6.96
Lime	1.24
Magnesia	2.21
Alkalis	5.08
Water (est.)	5.30
	99.03

A physical test of this clay showed that it required 22% of water to work it up. The air shrinkage was 8%, and at incipient fusion it was 15%, this point being at cone .05. The clay vitrified at cone .03, with a total shrinkage of 16%, while viscosity began at cone 1. The clay contains .15% of soluble salts. The mechanical analysis gave:

Clay substance and silt	79.55
Fine sand	20.68
	100.23

The buff burning or lower clay is distinctly marly in its character. As might be expected, it takes only 18.50% water to work it up, but still is quite plastic. The air shrinkage is 6%, and at cone .08, 5%. The clay vitrifies at cone 1 with 14% shrinkage, and becomes viscous nearly at cone 2. It burns buff, but with viscosity this passes into greenish yellow. The tensile strength ranges from 95 to 110 pounds a square inch. The clay contains .7% soluble salts.

Rochester, Monroe co. The Rochester brick and tile manufacturing co. is on Monroe street, at the eastern end of the city. Adjoining this is the German brick and tile co. The clay is reddish in color, 4 to 5 feet thick and underlain by hardpan. Lime pebbles occur in the lower portions. Molding sand is obtained from a neighboring eskar.

The following is an analysis of this clay.

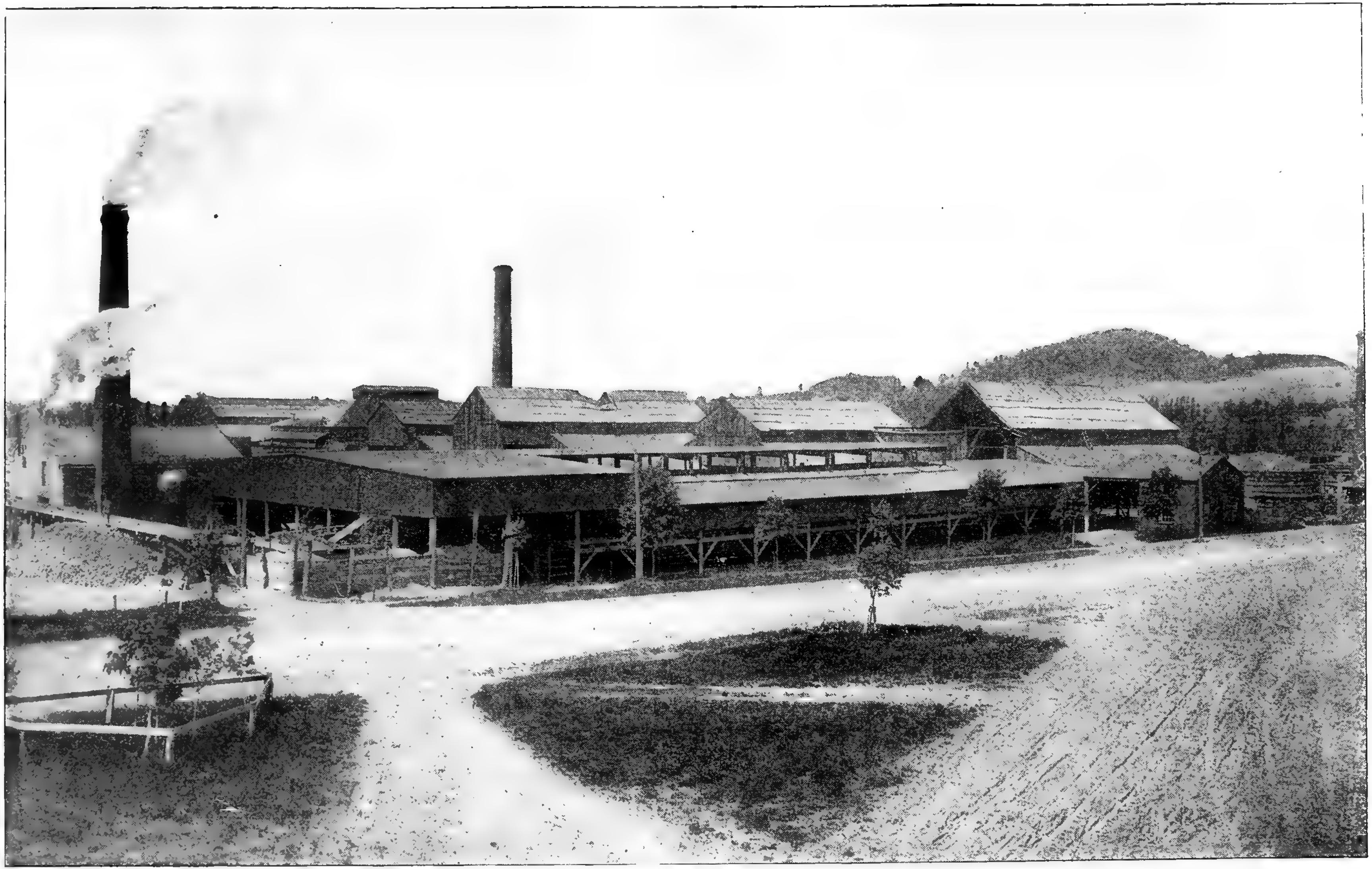
Silica	50.55
Alumina	15.46
Peroxid of iron	4.38
Lime	10.95
Magnesia	3.35
Alkalis	6.30
	90.99

The whole flat area to the west and northwest of the yards was formerly underlain by clay, but so much of it has been dug over that the pit is now nearly a quarter of a mile from the works. The section in the present clay pit involves:

Loam	18 inches
Sandy clay	2 feet
Fat clay	4 feet
Hardpan	..

Plate 55

To face page 720



H. Ries photo.

General view of Rochester brick and tile co.'s works.

The clay (Pl. 22) is dug by means of a plow and loaded on cars, which are drawn to the yard by horses, where it is discharged either into the rolls for the soft mud machine or is carried to a conveyer that discharges it into a series of rolls and pug mills (Pl. 27), which temper it for the stiff mud machine. The latter is used only for drain tile and hollow bricks.

All the drying is done on pallet racks, some of which are provided with a movable roof to allow the sunlight to enter (Pl. 37). The kilns are mostly of the Wingard type, but there are also four round down-draft kilns for burning the hollow ware, and a continuous kiln (Pl. 47) which is used for burning common brick.

The product finds a ready market in Rochester.

The lower clay alone is used for making tile, while a mixture of the top and bottom clays works best in making the bricks.

The lower or tile clay, as it is called, is very plastic, but requires only 20% of water to temper it. The air shrinkage is 9½%, and the tensile strength of the air-dried briquettes ranges from 100 to 130 pounds a square inch with an average of 120 pounds.

Incipient fusion occurs at cone .05, vitrification at .01, and viscosity at cone 2-3. At incipient fusion the total shrinkage was 12% and the color red; at vitrification, 16%. The soluble salts were .5%. The brick mixture is more sandy, but is also very plastic, and yet not so tenacious. It takes 18% of water to work it up, and the bricklets have an air shrinkage of 7½%. The tensile strength ranges from 110 to 120 pounds a square inch. Incipient fusion occurs at cone .05 with a shrinkage of 10%. The clay vitrifies at cone .01 with a total shrinkage of 16%, and a deep red color. It becomes viscous at cone 2-3.

A mechanical analysis of the clay gave:

Clay and silt	72.90
Fine sand	27.85
	100.75

The soluble salts were .35%.

Maplewood, Monroe co. Robert Gay's yard lies along the New York Central railroad. His clay is very similar to that just described, but somewhat lighter colored. It is underlain by quicksand. This clay is used at Rochester to mix with Jersey fire clay in the manufacture of sewer pipe.

Clarkson, Monroe co. M. Parker's brick plant is on the northern side of the ridge road, at Clarkson, one mile north of Brockport. The clay is a shallow, loamy deposit, and is owned by J. Sigler. The yard is an open one and both brick and drain tile are made. The molding sand is obtained from near the depot at Brockport. Product consumed locally.

Albion, Orleans co. There is a small yard about a mile north of the town but nothing is known concerning it.

Lockport. The Lockport brick co.'s yard is at the northeast end of the town. The upper portion of the clay is being used. It is red in color, due to weathering. The clay is molded as taken from the bank, the bricks are dried on pallets and burnt in scove-kilns. Product used locally.

La Salle, Niagara co. Tompkins & Smith run a small yard at this locality. Clay is very similar to that at Tonawanda. It is underlain by hardpan. Rolls are used to crush the lime pebbles in the clay before molding it. The product is marketed in the vicinity.

Tonawanda, Niagara co. To the southeast of the town is the brick plant of Martin Riesterer. The clay is of a red color passing downward into blue and has a thickness of about 5 feet. Only common brick are manufactured; the consumption is chiefly local. The burning is done with coal.

Lancaster, Erie co. There are two yards here, the Buffalo star brick co., near the Erie depot, and the Lancaster brick co., about 2 miles farther out. In the former's bank the clay is of a blue color below and weathered to red on top. Limestone pebbles are common in the clay, and for the purpose of separating them, the clay is stored in sheds to dry during the winter and passed through a barrel sieve before being used the following spring and summer.

Plows are used to mine the clay; coke and coal are used to burn the brick in stationary kilns with one fire to each arch.

The bank of the Lancaster brick co. is similar to the one just mentioned, showing:

8 feet red clay
½ foot blue clay
4 feet gray clay
Rock

Limestone pebbles are also present and the clay after drying is screened. The bricks are burned in stationary kilns, coke being used for the water-smoking and coal for the subsequent firing.

Buffalo, Erie co. At East Buffalo is an extensive series of flats underlain by red clay which varies in depth from 6 to 20 feet. The following firms situated chiefly on Clinton street use the clay for making brick: Charles Berrick & Sons, Brush Bros., H. Dietschler & Son, F. Haake, L. Kirkover, Schusler & Co., G. W. Schmidt. Their combined production in 1892 was 65,000,000 brick. The clay is said to rest on the underlying rock.

The following is an analysis of it.

Silica	57.36
Alumina	16.20
Peroxid of iron	4.55
Lime	5.34
Magnesia	3.90
Alkalis	6.98
	94.33

Pebbles of limestone are scattered through it in places, and at a few spots several feet of yellow sand, suitable for molding or tempering, covers the clay. Below the limit of weathering the clay is blue, which does not give as nice a colored brick as the red. The addition of tempering sand is not considered necessary. Soak pits and soft mud machines are used. All the yards dry their brick on pallets and burn them in stationary kilns, using coal fuel. One fire is made to burn one, two or three arches, according to the construction of the kiln. The burning takes nine days. Buffalo and its vicinity consume a large portion of the product.

Jewettville, Erie co. Brush & Schmidt started a brick yard at this locality in 1892. It is situated along the Buffalo, Rochester and Pennsylvania railroad, about a quarter of a mile northwest of the station (pl. 56). The material used is Hamilton shale. It is of a grayish color and is easily worked. An opening has been made next to the yard and at the same level. A black, gritty shale crops out farther up on the hill, but this has not yet been used. The shale is loaded on cars and run into the machine shed, where it is crushed in a dry pan and then molded. The yard is equipped with a Boyd dry press, and stiff mud machine. The dry press bricks are dried in tunnels, and the others on brick floors. Special shapes are molded in a hand power press. The burning is done in up-draft kilns.

Springbrook, Erie co. There are extensive deposits of clay and shale at Springbrook, on the land of E. B. Northrup, but they are not worked.

Evans, Erie co. William Bolton has a horse power yard here. The clay is a local deposit, chiefly blue in color, and the lower portions are stratified. It is underlain by sand and hardpan. The yard is run in accordance with the local demand for brick.

Southern and eastern New York yards

Dunkirk, Chautauqua co. William Hilton's yard is situated in the valley, about a mile west of the town. The clay deposit is about 20 feet thick, and is underlain by rock. The upper 6 feet is yellow and below this is blue. Stones are found scattered through the clay and have to be separated. The yellow clay gives a better colored brick, while the blue clay shrinks more, but is said to give a harder product. The blue clay obtained from the main clay bank has to be tempered with sand; it has, however, not been much

Plate 56

H. Ries photo.

General view Brush & Schmidt brick works, Jewettville.

used up to the present time. Rolls are used to crush the stones and the clay is tempered in a pug mill. Mr Hilton uses a soft mud machine of his own manufacture. The brick are dried on pallets — the burning, which takes eight to 11 days, is done in scove-kilns. Coke is used for water-smoking and coal for subsequent firing. Most of the brick are used in the vicinity.

Jamestown, Chautauqua co. Two yards are in operation 4 miles east of this town, those of C. A. Morley and M. J. Mecusker & Son. The two yards adjoin each other, and the deposit of clay worked by them is of considerable size. In addition to brick, Mecusker & Son make drain tile and hollow brick. The clay deposit is basin-shaped. A boring near the water works showed:

Yellow sand	4 feet
Quicksand	6 inches
Yellow clay	5 feet
Blue clay	70 "
Hard pan	———

The Jamestown shale paving brick works are mentioned under "Paving brick" and "Shales".

Randolph, Cattaraugus co. J. Turner owns a brick clay deposit at this town, but has ceased working it.

Hornellsville, Steuben co. The Hornellsville brick and tile co. has its works at the north end of the town, which have been running one season. It uses a Chemung shale for making brick, and has turned its attention thus far to paving brick. The shale is mined about a mile from the works. It contains several thin layers of sandstone which can not be used. The process as followed here consists of grinding the shale in a dry pan, molding in a stiff mud, side-cut machine and then repressing. Drying takes about 24 hours, and is done in chambers heated by a hot blast. Burning is done in down-draft cupola kilns and takes seven to 10 days. The paving brick are in extensive use in Elmira.

An analysis of this clay made by C. Richardson in the office of the engineering commissioners, at Washington, showed:

Silica	64.45
Alumina	17.77
Peroxid of iron	7.04
Lime	.58
Magnesia	1.85
Potash	2.52
Soda	1.95
Insol. in acid	88.74

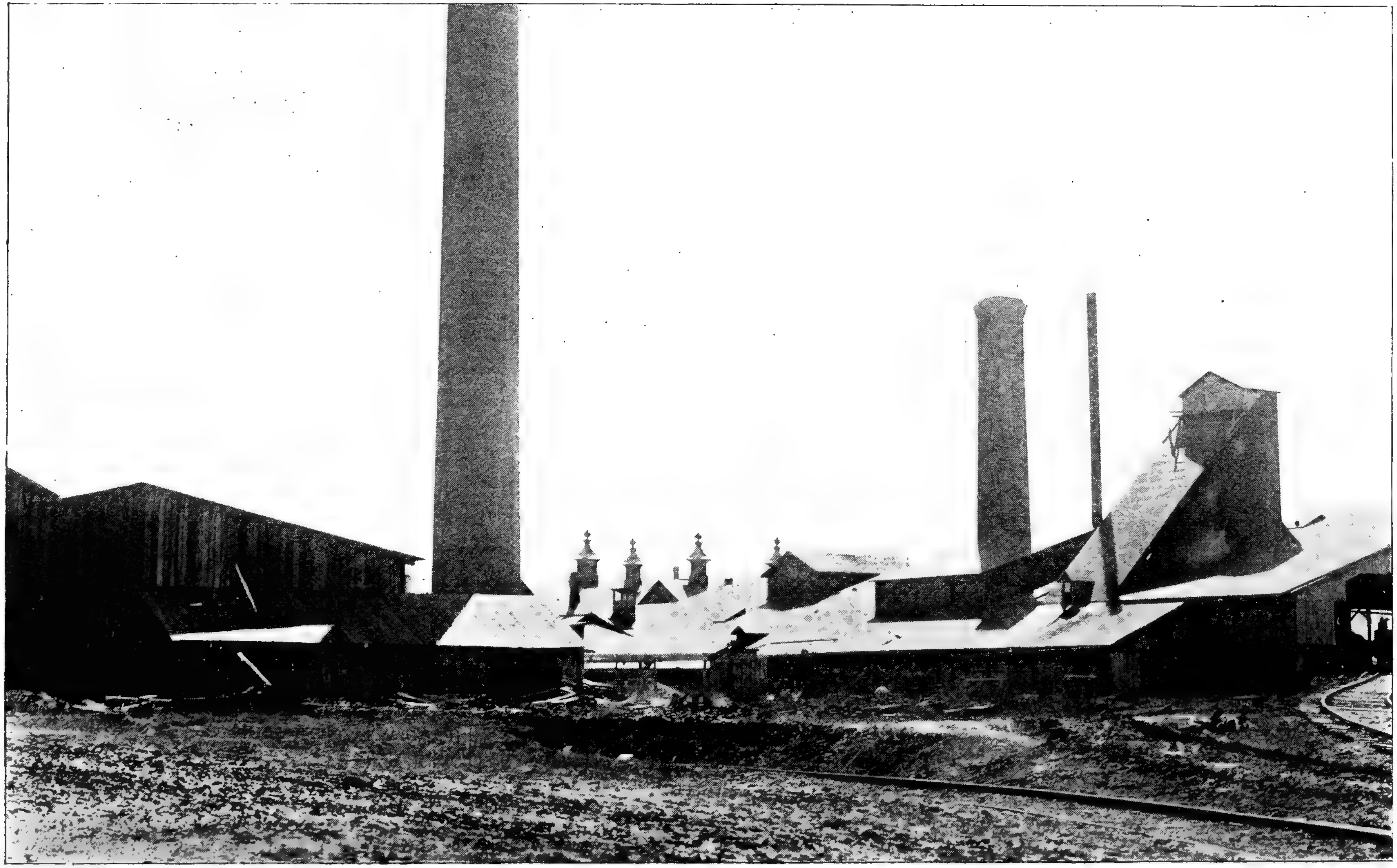
W. H. Signor owns the other yard at Hornellsville. His clay bank is owned by M. Adsit. It is a shallow deposit, not over 7 feet thick and underlain by quicksand, the latter allowing the inflow of water from the neighboring stream. The bricks are molded by an auger machine, dried in the sun and burnt in scove-kilns, the burning occupying about seven days.

Alfred, Steuben co. Alfred clay co. This is another yard using a shale, which is in the same geologic horizon as that at Hornellsville. The works are on the Erie railroad a few hundred yards south of the station. They have but recently commenced operations. A semi-dry clay brick is made. To dampen the ground clay, it is discharged from the hopper into a long box of square cross-section in which a worm screw revolves. The axis of the screw is hollow and has nipples projecting into the tube three fourths of an inch, so that, if any of the steam which is injected to dampen the clay condenses, it will not escape into the clay. The shale used is mined near the yard and hauled in carts to the dry pan. Burning is done in a continuous kiln.

Bigflats, Chemung co. Near the village is an extensive bed of clay owned by J. R. Lowe. It underlies an area of about 50 acres. Excavations have been carried to a depth of 15 feet without reaching the bottom of the deposit. The clay is of a bluish gray color.

Plate 57

To face page 727



H. Ries photo.

General view of Horseheads brick co.

Mr Lowe manufactures drain tile only, most of which are for private use.

Horseheads, Chemung co. The Horseheads brick co. has a clay deposit several acres in extent, having an average thickness of about 20 feet. There is a covering of about 10 inches of soil, and underlying the clay are sand and gravel. At present the material used is chiefly shale. (*See also* under " Shale," p. 839.)

The shale bank is on the north side of the valley and the shale is brought over to the works in cars. The softer portions are crushed in a dry pan, but hard pieces are crushed in a Blake crusher. The yard, which turns out common brick, has a capacity of 40,000 a day. The soft mud process and tunnel driers are used, and burning is done in a Haigh continuous kiln.

Elmira. P. J. Weyer is manufacturing common brick from the same kind of shale as is used at Horseheads, but the quarry is at a higher elevation. The bricks are burned in a Wilford continuous kiln.

Breesport, Chemung co.[1] About a mile and a half south of the town are the yards of the Empire state brick co., Locy Bros., and P. M. C. Townsend. The bank from which they obtain their clay lies along the eastern side of the valley. It is about half a mile long and has a hight of 50 feet. It is chiefly of a bluish color and is stratified in places.

We give herewith the analysis of the clay:

Silica	52.48
Alumina	16.78
Peroxid of iron	6.79
Lime	6.63
Magnesia	3.59
Alkalis	7.16
	93.43

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[1] Since this was written for the original report in 1895, the yards have been dismantled.

At Locy's yard, where borings show the clay to be 30 feet thick, a red clay also occurs. Yellow sand overlies the clay at several points, which can be used for molding. The yards of Locy Bros. and Townsend are open ones. At the Empire state co.'s yard tunnel driers are used, the clay being mixed in a wet pan and then discharged through an opening in the floor of the latter on an endless belt which carries it up to the molding machine. The brick are burnt in scove-kilns.

Spencer, Tioga co. W. H. Bostwick's yard is about a mile south of the village. The clay which is dug in a field adjoining the works, is a tough reddish material 4 to 6 feet thick. It is underlain by sand and gravel. The bricks are dried on pallets and burned in stationary up-draft kilns.

Newfield, Tompkins co. F. C. Campbell's brick yard is about one mile north of the station along the Lehigh valley railroad. Adjoining the yard is the clay bank which rises to a hight of about 50 feet. The clay is of a bluish color, and forms an enormous, stratified, lenticular mass, which is imbedded in the terminal moraine crossing the valley at that point. The upper portions contain more sand.

An analysis of this clay showed:

Silica	51.30
Alumina	12.21
Peroxid of iron	3.32
Lime	11.63
Magnesia	4.73
Alkalis	4.33
Organic matter	1.50
	89.02

Notwithstanding the high percentage of lime, which gives the brick its cream color, a very strong brick is produced. Covering the clay is several feet of yellowish stratified sand. Lime pebbles occur in the clay, and a special apparatus is used to extract them. The clay and a certain percentage of shale are ground in a dry pan, then carried up to an inclined screen. Those particles which pass through are mixed by means of wheels and scrapers attached to a revolving arm. The bricks are molded on stiff mud machines and repressed on a hand-power machine. Chamber driers are used and burning done in down-draft kilns, scove-kilns or a continuous kiln. The clay burns to a buff brick; farther burning at a higher heat gives a hard, greenish yellow brick, which is smaller, but sold for paving purposes. The pavers made at this yard are a mixture of clay and shale, while the building brick are clay alone. The following is a report of tests made on these brick in the laboratory at Cornell university. All the bricks were tested on edge, as used for the purpose of paving. The sides were dressed to parallel planes on an emery wheel, so as to get a uniform bearing over every part. Single layers of thick paper were placed between the brick and the machine.

	No. 1	No. 2	No. 3	No. 4
Weight of brick in pounds	4.86	5.14	5.1	5.00
Dimensions	$7\frac{3}{4}\times3\frac{5}{8}\times2\frac{3}{16}$	$8\times3\frac{7}{8}\times2\frac{5}{16}$	$8\times4\times2\frac{2}{19}$	$7\frac{3}{4}\times3\frac{3}{4}\times2\frac{5}{16}$
Cubic contents	61.35 cu. in.	70.7	74.	67.20
Area strained	16.95 sq. in.	18.5	18.5	17.92
Hight of column	$3\frac{5}{8}$	$3\frac{7}{8}$	4.	$3\frac{3}{4}$
Total stress				
First crack	208 000	84 000	56 000	48 000
Splinters fly	250 000	....	133 000	108 000
Crushed	254 000	172 000	180 000	141 200
Stress by square inch				
First crack	12 230	4 580	3 508	2 600
Splinters fly	14 800	....	8 362	6 000
Crushed	14 990	9 300	10 909	7 880
Color of brick	Light cream Homogen. columnar.	Light cream Black vitrified	Light cream Homogeneous	Light cream Homogeneous
Fracture				
Position of 1st fracture	One corner..	Central.....	Central.....	At one end.
Direction of fracture	Vertical	Diagonal....	Vertical.. ..	Vertical ....
Kind of brick	Repressed...	Common....	Common....	Common T. of soil.
Specific gravity	2.18	2.01	1.91	2.07
Weight to cubic foot	136.9	125.6	118.8	129.0

This clay is one of the few very calcareous ones that are used in New York state. It is very plastic and gritty, and dries to a hard dense mass. When worked up from the air-dried condition it takes 22% of water. The bricklets shrink 5% in air drying — the air-dried briquettes show a tensile strength of from 105 to 175 pounds the square inch, with an average of 118 pounds, which is very fair.

Incipient fusion occurs at cone .05, with a shrinkage of 8%; vitrification at once .02, with 10% shrinkage, while viscosity began at cone .01. The clay burns buff, which turns to greenish yellow on vitrifying. Soluble salts, .5%.

Homer, Cortland co. The brick yard at this locality belongs to Horace Hall of Cortland. His clay bed underlies the flat lands near the village of Homer; and is from 3 to 5 feet thick. Quicksand underlies the clay; overlying it is a dark soil 2 to 6 inches thick. The clay is of a bluish color.

Binghamton, Broome co. There are two yards in this town, viz, Wells & Brigham's and the Ogden brick co.'s. Their clay beds are similar, both being shallow deposits 6 to 8 feet thick, underlain by sand and gravel. The former of the two is a pallet yard, the other uses a tunnel drier. Their product is consumed locally.

Brookfield, Madison co. The Brookfield brick co. is the only firm manufacturing brick at this locality.

Oneonta, Otsego co. Two firms are manufacturing brick at this locality, J. Denton & Son, and Crandall & Marble. The works of the latter firm are situated on the Albany and Susquehanna railroad near the village of Oneonta. Two kinds of clay are used; one of them from a bank, 5 to 20 feet in thickness, the other from a surface deposit 3 to 5 feet in depth. The latter bed is underlain by sand. The product is consumed by the local market.

Goshen, Orange co. P. Hayne has a clay deposit 55 feet deep, underlain by black gravel. There is a slight stripping of sod. Both drain tile and brick are made from the clay.

Florida, Orange co. W. H. Vernon's brick yard and clay deposit are situated in the valley near the town. The clay bed is 10 feet thick, blue in color and tough. The upper 3 feet is weathered to a red clay, which makes a better brick. The blue is of sufficient purity for making pottery. Underneath the clay is sand and hardpan.

Oakland valley, Sullivan co. A small deposit of clay at this locality was used for some time for making earthenware.

About one eighth sand had to be added to the clay for brick or tile ware. The sand, which is of a bright yellow color, is in banks along the Navesink river, near the clay beds. This clay is also said to be available for paint. Oakland valley is about 12 miles from Port Jervis.

New Paltz, Ulster co. New Paltz brick co. The brick yard is located on the outskirts of the town and near the Wallkill Valley railroad, with which it is connected by a switch. The clay deposit is yellow, red and blue in color, and varies in depth from 15 to 50 feet. It underlies a tract of 6 acres. The natural separation of the clay in 4 to 8 inch layers facilitates the digging of it. There is a thin stratum of overlying sand which has to be first stripped. Soft mud machines operated by horse power are used for molding.

Warwick, Orange co. Though there are no brick yards in this vicinity, extensive deposits of clay are undoubtedly present. A sample of clay from the Drowned lands, lying along the Wallkill river in Orange co., was analyzed in the laboratory of the New Jersey geological survey with the following results:

Silicic acid in combination	28.9
Quartz	22.9
Silicic acid free	1.2
Titanic acid	1.5
Oxid of alumina	23.1
Peroxid of iron	7.2
Lime	.7

Magnesia	2.6
Potash	4.1
Water	9.7
	100.9

The clay is said to exist in large quantity, forming a thick layer at this point in the alluvial district of the Drowned lands, and underlying much of the black muck surface of this district. The specimen sent was thoroughly air-dried, was slate gray in color, and showed a little fine gritty sand. It contains too much oxid of iron and potash for a refractory or fine material. Washing out the fine sand might enable it to be used in some styles of paper facing. It is most interesting as the basis of a valuable, enduring and fertile soil, and if properly drained it would be unsurpassed for tillage or pasturage; as such, it furnishes another argument for the drainage of this tract of Drowned lands.

Long Island and Staten Island yards

East Williston, Queens co. W. & J. Post have two yards at this locality. Their clay pit is in a field some 500 feet west of the yard on the land of H. M. Willis. The clay has been excavated to a depth of about 15 feet. It is chiefly a bluish clay and can be easily dug. The clay is extremely silicious, as the following analysis shows, but the percentage of lime, magnesia and iron is low.

Silica	69.73
Alumina	16.42
Peroxid of iron	2.58
Lime	1.66
Magnesia	.69
Alkalis	6.27
	97.35

Carts are used to haul it to the yard. Pumps have to be used to keep out the water which comes up through the underlying sand. The clay is tempered without the addition of sand in ring pits run by horse power. The bricks are dried either on the open yard or on pallets and burnt in scove-kilns with wood. They are shipped on the Long Island railroad, which passes by the yard.

Oyster Bay, Queens co. An extensive deposit of clay is being worked on Center island, in Oyster bay, by Dunn, Dolan & Co. They manufacture common brick. The bank adjoins the yard, and the clay, which is in thin layers, separated by fine laminae of sand, is of a bluish color in the lower portions of the deposit, brownish above. The brown clay is more sandy; there is 6 or 8 feet of it. Over the brown is a less gritty and tougher clay, which runs nearly to the surface. The total hight of the bank is about 25 feet, but the front is broken up into several wide benches. Springs issue from several sandy spots in the blue clay. In making the brick the different grades of clay are mixed together, a certain proportion of sand, and some coal dust added. Ring pits are used for tempering. The brick are dried on an open yard and burned in scove-kilns. They settle 8 to 10 inches in burning.

West neck, Suffolk co. The clay at this locality rises in a bank to a hight of over 100 feet. There are three yards but only two are active. Both are along the east shore of Coldspring Harbor. The most southern one belongs to Dr Jones. The clay in this bank is of a red and brown color, there being about 25 feet of the latter at the bottom, while above it is the red, which is of a more sandy nature. There is an upper covering of 15 or 20 feet of yellow gravel and sand, which after screening is used for tempering. This latter is done in ring pits. All the machinery is run by horse power. The bricks are dried on an open yard and burnt in scove-kilns. The product is loaded on schooners and sent to New England and New York city. The lower brown clay has been used for coarser grades of pottery. Its composition is given below.

Plate 58

To face page 735

H. Ries photo.

Clay bank at Hammond's brick yard on West Neck, Cold Spring Harbor.

Silica	61.01
Alumina	19.23
Peroxid of iron	5.43
Lime	.96
Magnesia	1.88
Alkalis	4.60
	93.11

Adjoining Jones's yard is that of Crossman Bros. It is leased by William Hammond. The clay in his bank is similar to that of Jones. The yard is also an open one, steam power being used for running the machines; the tempering is done in rectangular pits.

Freshpond, Suffolk co. This locality is about 4 miles east of Northport on the north shore of the island. There are two yards, about a mile apart. The most eastern belongs to G. Longbottom. It is situated some 500 feet from the shore and about 50 feet above Long Island sound. The clay bank is about 200 feet west of the yard and at the same level. A section in the summer of 1892 showed

Sand and gravel	4 feet
Red sandy clay	8 "
Red clay	6 "

The overlying sand and gravel is stratified and dips east. It is screened for tempering. Carts are used for hauling the clay to the machines. Molding sand is obtained from Hackensack. The clay and sand are shoveled directly into a vertical pug-mill, from which they pass to the molding machine. Coal dust is also added in tempering. The product is loaded on cars, run down to schooners at the dock and shipped to Connecticut. Adjoining Longbottom's yard is the inactive plant of Provost.

About a mile west of Longbottom's, situated along the shore, is the yard of R. Sammis. His land extends 2000 feet along the shore and in the whole of that distance the clay crops out from underneath the sands and gravels. The lower portion of the clay is a bluish red, the upper, red in color and somewhat more gritty. The clay is rather tough but not so dry as Longbottom's. The carting is done along the shore; the overlying sands which are highly stained with iron are used for tempering. A cutting has been made in the cliff just east of the yard for tempering sand. The bricks are burnt with wood.

Greenport, Suffolk co. The works of the Long Island brick co. are some 2 miles west of Greenport on the shore of Pike's cove, opposite Shelter island. Its clay is a glacial deposit of red color, rather tough and contains numerous stones. Mr Sage, the owner, claims a depth of 64 feet for the deposit in places. Several openings have been made in it, one of them 24 feet deep. It is said to thin out to the east of the yard, where it is found to be underlain by hardpan. It is undermined, the working face being about 8 feet high; and the clay is hauled to the machines in carts. It is tempered in soak pits, with the addition of one third its volume of sand. Hematite is also added in order to produce a good color in burning. The bricks are dried on pallets or on open yards. They are burnt in scove-kilns, loaded on schooners and shipped largely to Connecticut. Many also go to points on Long Island.

Southold, Suffolk co. 2 miles east of the village is C. L. Sandford's yard. The clay is similar to Sage's. Mr Sanford has about 29 acres of clay. It is worked chiefly by undermining, the working face being about 10 feet in hight. In places, gravel is scattered through it, but in others it is very free from stones. Borings have shown a depth of 65 feet of clay. The clay and coal dust are put into rectangular soak pits and from these are shoveled into the machine, the tempering sand not being added till then. The drying is done on pallets, whose total capacity is 154,000. Most of the product goes to Connecticut by schooner.

Below is given an analysis of the clay.

Silica	59.05
Alumina	22.11
Peroxid of iron	6.54
Lime	2.19
Magnesia	2.64
Alkalis	6.22
	98.75

The plasticity of the clay is quite well shown by the amount of water required to work it up, viz, 40%. The air shrinkage was 8%; when burned at .08, which is about the temperature attained in the scove-kilns, the shrinkage was 9%. At this point, however, incipient fusion had barely begun. When heated above this point the shrinkage increased quite rapidly, so that at vitrification, which occurred at cone 1, the total shrinkage was 16%. At incipient fusion the clay burns red; at vitrification a very deep red. Viscosity occurs at cone 4. The high shrinkage of this clay would probably interfere with its use alone for vitrified wares. The tensile strength of the air-dried briquettes ranged from 133 to 140 pounds a square inch, but one gave a minimum of 108 pounds. The clay contains .7% of soluble salts.

Fishers Island, Suffolk co. The extensive deposit of clay at this locality is worked by the Fishers Island brick manufacturing co., whose plant has a capacity of about 15,000,000. The yards are situated on the north shore of the island between Clay point and Hawks neck point. About 1500 feet from the shore is the bank of clay of a reddish color and thinly stratified, the layers of clay being separated by very thin ones of sand. In most places, however, the mass has been disturbed by glacial movements. There is a stripping of 20 or 30 feet of a whitish sand, the finer portions of which can be used for tempering. Their present working face is 30 feet above tide at its base, and the clay, it is declared, has a depth of 40 feet at least, below this, as shown by borings. A sample from the upper half of the bank showed the following composition:

Silica	53.77
Alumina	20.49
Peroxid of iron	9.23
Magnesia	4.22
Lime	2.04
Alkalis	9.60
	99.35

The clay, which is said to improve with the depth, is worked by undermining. It is then loaded on carts and hauled about 200 feet to a platform, underneath which cars are run to receive the clay and sand. These cars, in trains of three or four, are drawn to the yard by four horses, the grade being slightly descending. Tempering is done in large rectangular soak pits; open yards are used for drying the brick, or it is done on pallets. A small quantity of hematite is added to the molding sand. The bricks are burnt in scove-kilns with wood. Most of the product goes to Connecticut and Rhode Island.

Farmingdale, Suffolk co. M. Meyers's yard lies about 1 mile north of the village, along the southern edge of the moraine, on a branch track of the railroad. The clay pit is some 300 feet from the yard, and several feet lower. The clay is chiefly a reddish yellow and very plastic, but tough in places. The lower portions are quite free from sand. Mr. Meyers claims a thickness of at least 25 feet of clay in addition to the 10 feet exposed. At the entrance to the pit the clay is seen to be underlain by a bluish white micaceous sand, which is cross-bedded and dips under the clay at a very steep angle. Hauling the clay is done in carts, the tempering in ring pits with the addition of sand and coal dust. Soft mud machines are used, and the drying is done on pallets. The pallet racks have sectional roofs which are hinged and can be lifted by a lever for the purpose of admitting more sunlight. The bricks are burnt with wood in clamps; the product is shipped to various points on Long Island.

Below is given an analysis of the lower clay.

Silica	62.39
Alumina	23.60
Oxid of iron	3.39
Lime	.70
Magnesia	.10
Alkalis	5.89
	96.07

The physical properties of the two clays from Meyers's bank are as follows:

Upper clay. While this differs from the lower clay in color, because of the higher oxidation of the iron oxid, at the same time it is more sandy, containing a large amount of very fine sand and mica scales. It is quite plastic and tough, but not very tenacious, as shown by its low tensile strength, which ranges from 20 to 25 pounds a square inch. It took 34.70% of water to work it up; the bricklets showed an air shrinkage of 6%. At cone .08 the clay burns bright, but not dark red, with a total shrinkage of 7%. Incipient fusion occurred at cone .05 with a total shrinkage of 10%. The clay had a shrinkage of 14% when vitrification began at cone 1. It became viscous at cone 4. The soluble salts amounted to .14%.

Bottom clay. This is more plastic and slightly more tenacious than the top clay, but otherwise does not differ from it very much. It absorbed 28% of water in tempering — the air-dried briquettes had a tensile strength ranging from 30 to 40 pounds a square inch. The air shrinkage was 8%. At cone .08 it amounted to 8½%, at cone .05 to 10%. Incipient fusion occurred at cone .04, vitrification at 1, with 15% shrinkage. Viscosity at 5. Percentage of soluble salts, .20%.

About one mile north of the depot is the yard of the Garden City brick company. This is on the site of the old Stewart yard, but the plant is a modern one. The clay however is obtained from the opening that supplied Stewart's yard.

In the mining of the clay three kinds are recognized: 1) top sandy clay; 2) middle clay and 3) black bottom clay. (For section of bank, see chapter on "Geology of clay deposits in New York", p. 605)

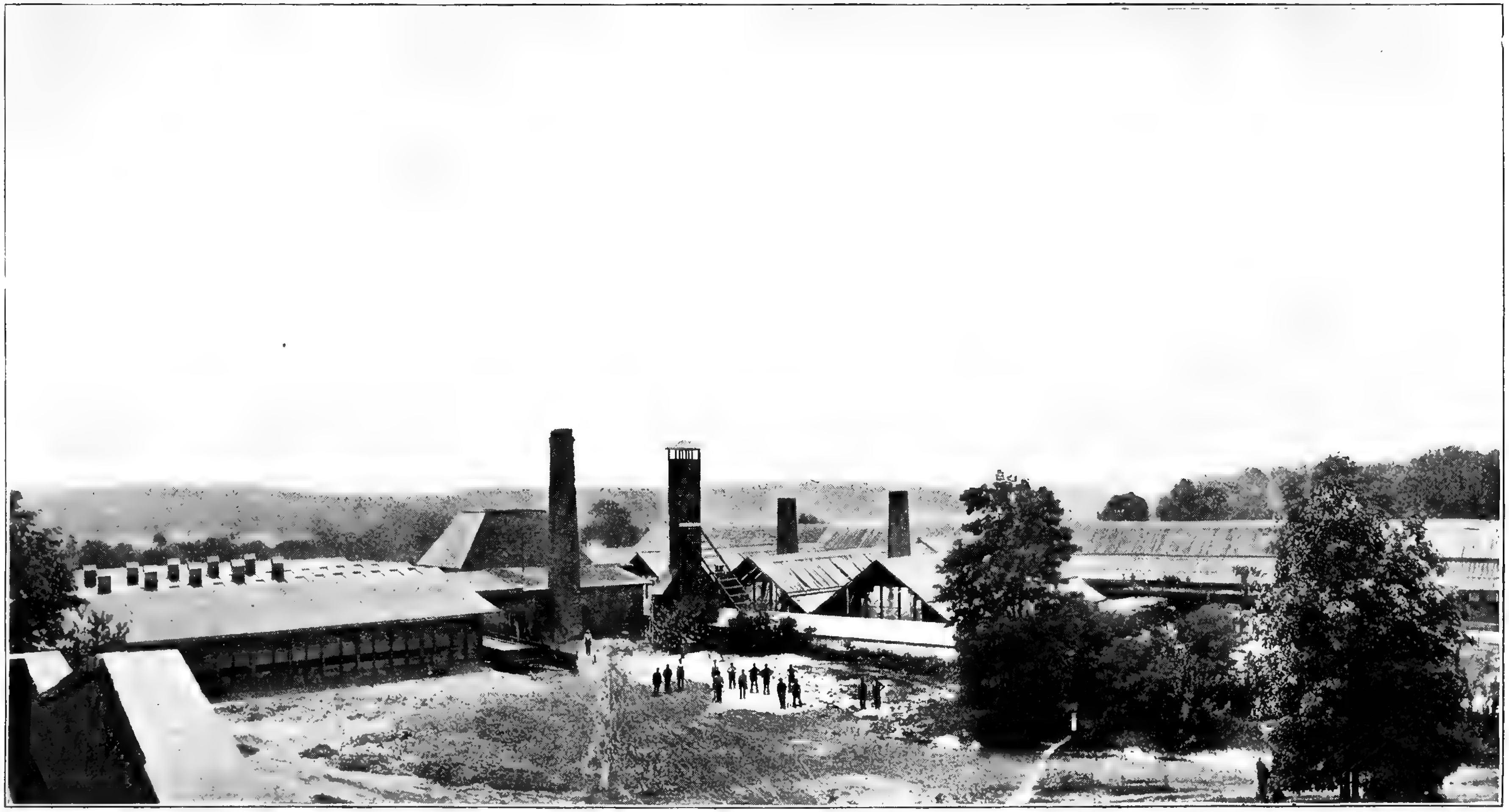
No analyses of the clay have been made, but no. 1 and a mixture of 2 and 3 have been tested. No. 1 is a red burning, gritty clay, with an abundance of fine mica scales. With 31% of water it worked up to a very plastic mass, that had an air shrinkage of 5%. The tensile strength was low and ranged from 50 to 60 pounds a square inch. The mechanical analysis gave 15.44 sand, 83.75 clay substance and silt. In burning, incipient fusion occurred at cone .03, with 11% shrinkage; vitrification at cone 2, with 14% shrinkage, and viscosity at cone 5. Soluble salts, .54%.

The mixture of 2 and 3 showed similar properties, but hardened at a somewhat lower temperature. The tensile strength was from 40 to 50 pounds a square inch; the clay was slightly more gritty than the top part, but was equally plastic; 33% of water was required to temper it; the air shrinkage was 6% at cone .04; incipient fusion occurred with a shrinkage of 12%; vitrification began at 1, the shrinkage was 16%. The clay grew viscous at 5. The color of the burned clay is light red, but deepens on hard firing. The soluble salts amounted to .2%.

The bricks made at these works are all dry pressed; the product is used chiefly in Brooklyn.

By mixing the clays, with addition of manganese, and by hard or soft burning, the colors buff, pink, gray, brown, red, and speckled, are produced.

Plate 59



H. Ries photo.

General view, Garden City brick co., Farmingdale.

Plate 60

H. Ries photo.

Black sandy clay, (Cretaceous ? Age) Wyandance.

The company has recently begun to use a white burning clay obtained near West Deerpark, formerly used in the brickworks at that locality.

In July 1899, a large opening had been made at the base of the hill about half a mile northwest of West Deerpark station. The section exposed at that time showed:

Yellow gravel	4	feet
Black clay, with some yellow streaks	4	"
Black clay with white sand in streaks	4	"
Sand	2	"
	14	"

The clay is loaded on carts and hauled to a siding about 500 feet distant, whence it is taken by train to the works. About 600 feet east of the present bank, a second one is being opened up. The same clay also crops out at the base of the embankment, where the road from Farmingdale to the Garden City brick co.'s works crosses the railroad siding leading up to the works.

There is probably an abundance of this clay between Farmingdale and Wyandance, but at most places there is a heavy overburden of sand and yellow gravel, usually not less than 15 feet, except at the pit from which clay is now being dug.

The highly sandy nature of the clay is indicated by a mechanical analysis of the material which yielded:

Fine sand	84%
Clay substance and silt	16%
	100%

All of the sand passed through a 100 mesh sieve. In spite of its highly silicious nature the clay is fairly plastic, and 23% of water was required to work it up. Scattered through the clay are scales of mica, and occasional grains of pyrite. The shrinkage in drying is 8%; up to cone 3, 11%, and cone 6, 15%. At the former cone the clay became incipiently fused; the color was yellowish white. At the latter it had deepened in color, and began to assume a reddish hue on the approach of vitrification. It fused at cone 10.

This clay is used for making front brick by the dry press process. It is doubtful however if it would work in a stiff mud machine without tearing as it issued from the die.

The clay contains .15% of soluble salts.

The following analysis was made by H. Ries from a sample collected in 1899

Silica	60.20
Alumina	23.07
Ferric oxid	1.45
Lime	1.20
Magnesia	tr
Alkalis	3.05
Loss on ign.	10.10
	99.07

Staten Island has two yards where common brick are manufactured. One belongs to McCabe Bros. at Greenridge. Their deposit is a stony glacial clay of a red color, and lies to the northwest of the yard. Small boulders are scattered sparingly through it; the upper portion is somewhat loamy. Borings have penetrated the clay to a depth of 25 feet and stratification appears with the depth. No sand or coal is added to the clay in tempering. It is first passed through rolls 2 feet in diameter, the one making 60, the other 600 revolutions a minute, and having an opening of half an inch. This partially breaks up the stones. The crushed material falls on a belt and is carried up to a pug mill, where the water is added before it passes to the machine. Drying the bricks is done either in the sun or in tunnels. In the latter the bricks shrink more. The tunnels are heated by coal fires. Wood is used for burning. The kiln settles about 4 inches. The products go to New York city and the vicinity.

Wood & Keenan's yard is situated on the shore of Arthurs kill, opposite Carteret. It is an open yard of greater capacity than its output. The clay is of the same character as McCabe's. It is tough and has to be worked with picks. The pit is about 10 feet deep. Ring pits are used for tempering and the bricks are burnt with wood. New York city and Newark are the chief markets.

The New York Anderson pressed brick co. has its works at Kreischerville adjoining Kreischer's fire brick factory. Various styles of ornamental and pressed brick are made. The clay is obtained from a pit near Greenridge. It is of a black and gray color. The pit is worked in benches, the clay being hoisted in buckets and loaded on cars which are run down to the works.

The works have not been in operation for several years.

Paving brick

The total number of paving brick produced in the United States in 1897 was 435,851,000, valued at $3,582,037. Of this amount New York produced 28,145,000, valued at $309,564, an average price of $11 a thousand.

One reason that paving brick have not been made in greater quantities is that New York lies in a region abundantly supplied with stone which can be used for the same purpose. Nevertheless many cities of the state have adopted brick pavements, among them Binghamton, Lockport, Buffalo, Rochester, Syracuse, Troy, Watertown, Ithaca, Corning, Elmira, Dunkirk, Jamestown, Tonawanda, Niagara Falls, and Brooklyn. Paving brick were formerly made only of fire clay, and indeed this was considered the only material fit to be used. At the present time however the material most used is either shale or clay (preferably the former) which burns to a vitrified body.

The clays used should have sufficient fluxing impurities to enable them to burn to a dense impervious body at a moderate temperature. The following average composition is given by Wheeler for a paving brick clay, being deduced from 50 sources.[1]

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[1] *Vitrified paving brick.* 1895. Indianapolis.

	Min. per cent	Max. per cent	Average
Moisture	.5	3.0	1.5
Silica	49.0	75.0	56.0
Alumina	11.0	25.0	22.5
Ferric oxid	2.0	9.0	6.7
Lime	.2	3.5	1.2
Magnesia	.1	3.0	1.4
Alkalis	1.0	5.5	3.7
Water (loss on ign.)	3.0	13.0	7.0
Total fluxes	.....	.....	13.0

In addition to having the proper chemical composition, it should also possess the necessary physical properties.

Proper plasticity is of vital importance, but its excessive development is equally injurious. The reason plasticity has such importance is that clay when molded by the stiff mud process is very apt to tear when issuing from the die, unless of proper plasticity. Excessive plasticity tends to produce a laminated brick when auger machines are used. The effect of these laminations will be seen in the tests given below.

As paving brick, unless made of fire clay, should be burned to the point of vitrification, it is essential that in clays used for this purpose the points of viscosity and incipient fusion should lie well apart, not less than 250° F. and preferably 400° F.[1]

The color of a paving brick is no indication of its quality.

The clay should not show any disposition to blister as the point of vitrification is approached, but this is likely to occur if an excess of iron is present.

In order to demonstrate somewhat definitely what are the characters of a good paving brick shale, the tests of a sample utilized in Illinois for the manufacture of paving blocks is given herewith.

The shale is rather fine-grained, and breaks up quite easily in grinding. It was ground to pass through a 30 mesh sieve. 28% of

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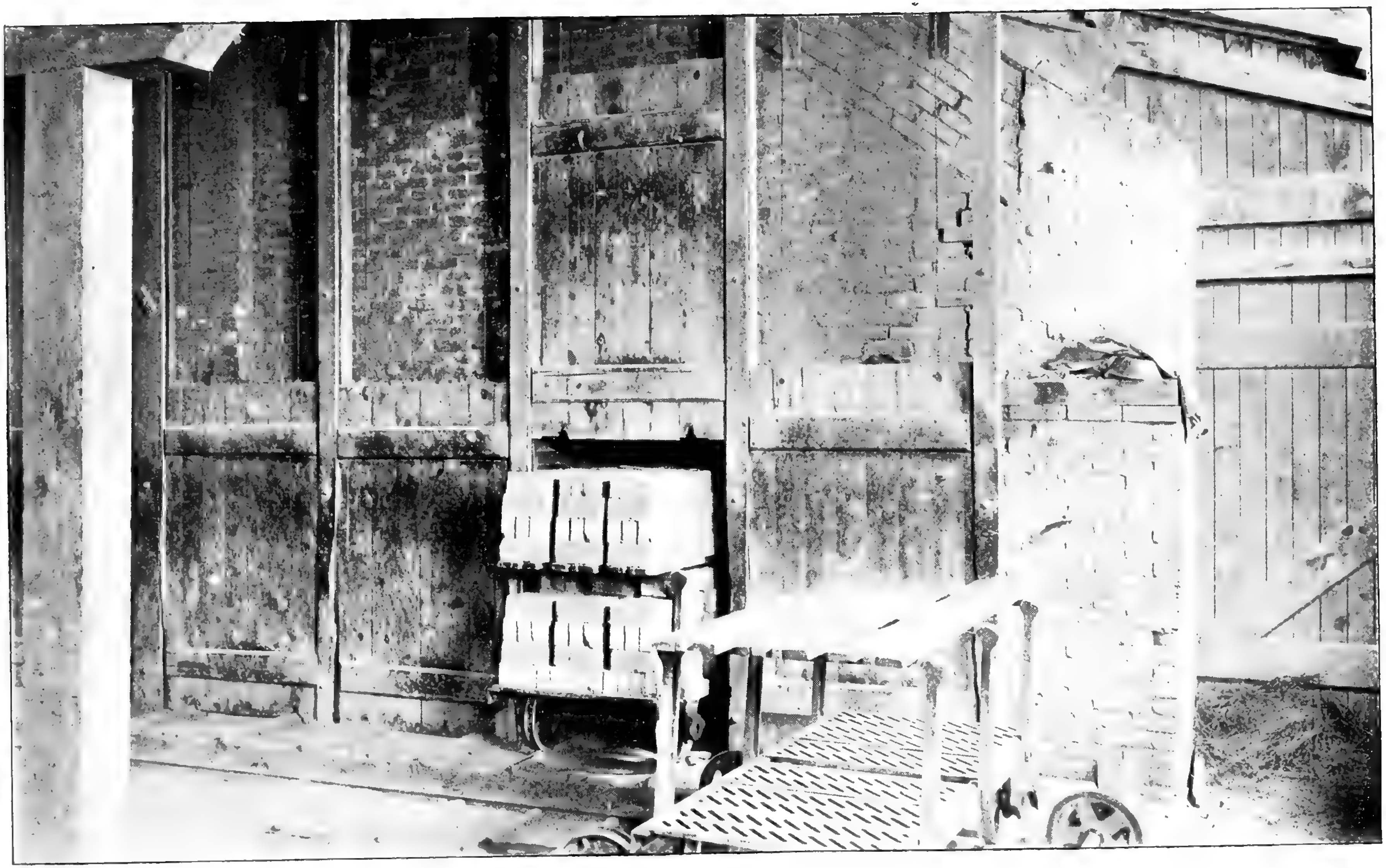
[1] Olchewsky in *Post. chem. tech. analyse.* 1890; Wheeler in *Vitrified paving brick.* 1895.

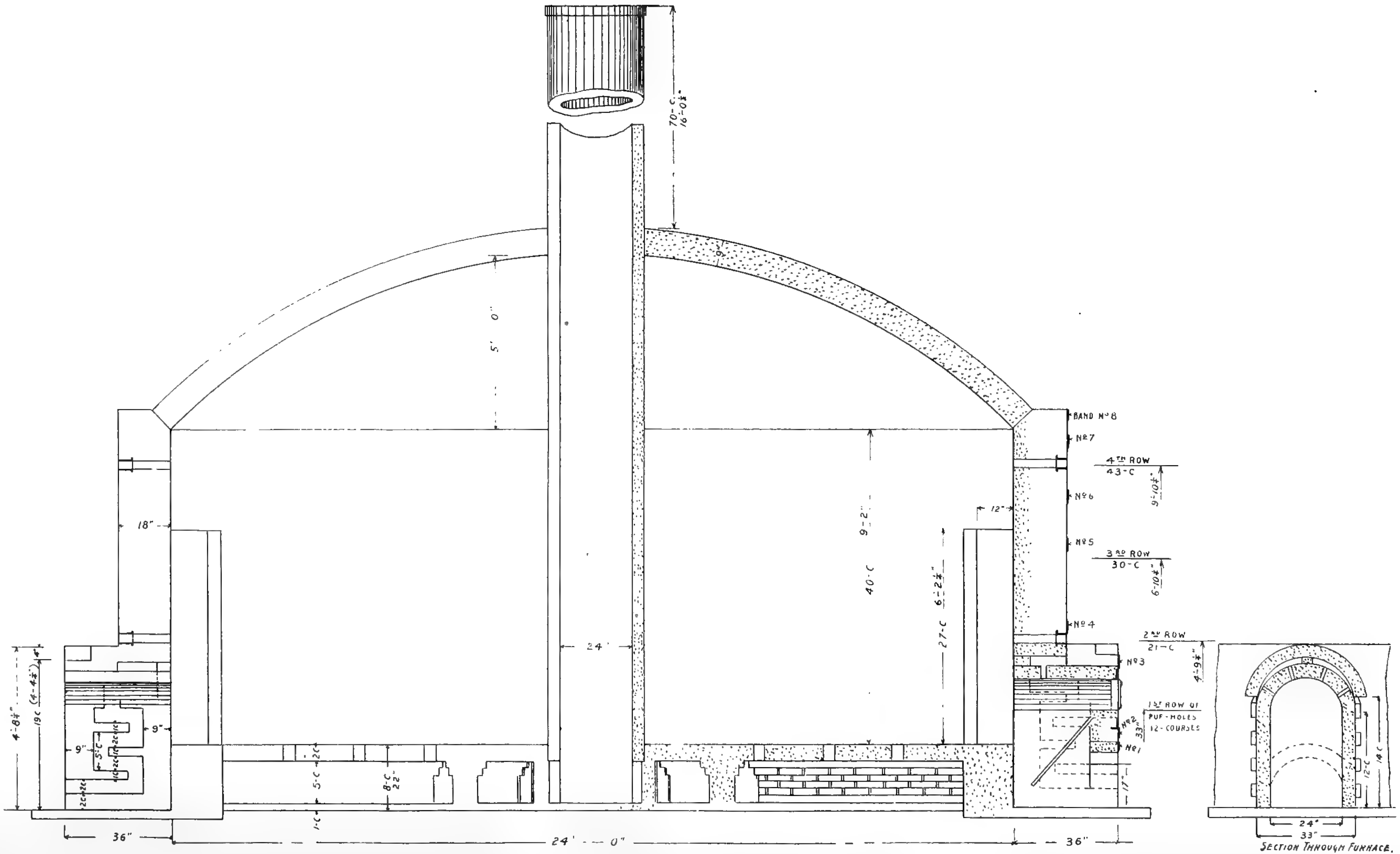
Plate 61

To face page 744



H. Ries photo.

Entrance to drying tunnels for paving brick, Onondaga vitrified brick co., Warners.



Vertical Section.

Sectional view of a down draft kiln for burning paving brick or tile.

water was required to work it up. The air shrinkage was 4%. Up to cone .03 it was 10%. It vitrified at 2 and became viscous at 5. The tensile strength was from 60 to 70 pounds a square inch.

Manufacture of paving brick

Shale is used more than clay in the manufacture of paving brick. It has to be prepared first by crushing in a dry pan, then screened. This screened clay is mixed with water and tempered either in a pug mill or in a wet pan. (For description *see* " Manufacture of common brick ", p. 653)

Paving brick are commonly molded in an auger machine; they are either end-cut or side-cut. At a few factories the soft mud method is used, but in this state it is only employed at Syracuse. Repressing the green brick is commonly practised, but there is a difference of opinion as to whether it improves the quality of the brick, though the experiments given on the following pages tend to indicate that the end-cut repressed brick are the strongest, while still more recent tests somewhat disfavor this view.

The green brick are usually piled on cars and dried in tunnels.

Paving brick should be burned in down-draft kilns, as they give better results than the up-draft kilns, and there is no loss from crushed, overburned brick.

The type of kiln used in this state is either the rectangular down-draft kiln or a continuous one. The latter is extending in favor, as it is the more economical and yields good results. Circular kilns are but little used in this state for burning paving brick.

Tests of paving brick

For a long period there has been some difference of opinion as to what constitutes the qualities requisite for a paving brick. Engineers have frequently laid considerable stress on the crushing test and the color. The latter is of no value as a guide; the former beyond certain limits is to be looked on in the same way. With a view, therefore, to determine what the requisite qualifications of a paving brick should be, and if possible to adopt a set of standard specifications, a committee was appointed by the National brickmakers association two years ago. After a series of exhaustive tests their report has recently been submitted.

The subjects which the committee took up for consideration were:

1 Rattling, as a measure of toughness and wearing power

2 Absorption, as a measure of vitrification and resistance to freezing

3 Cross-breaking, as a measure of structural perfection and freedom from defects due to manufacture

4 Crushing, as a farther indication of the same factor

5 Hardness, as a confirmatory test of vitrification

6 Specific gravity, as a guide to the density and fineness of the material

The rattler. A series of experiments made by varying the charge, size of rattler, number of revolutions a minute, and time of rattling showed that

1 Not less than 10% nor more than 15% of the volume of the rattler need be filled with the cubic contents of the charge.

2 It must be rattled for not less than 1000 and preferably not less than 2000 revolutions.

3 The length of the chamber is immaterial.

4 The diameter of the chamber must be between 26 and 30 inches.

5 The speed of revolution, between 24 and 36 revolutions a minute, is immaterial if the test is terminated when the requisite number of revolutions have been made.

The use of cast iron and granite as abrasive and filling materials was also tested and found to be unsatisfactory. Large bricks showed less wear than small ones; normally burned, less than overburned or underburned ones.

Absorption test. A series of tests showed that even after drying 48 hours at above 110° C. a brick continued to lose water, and that immersed brick showed redundant gain in weight even after six months' immersion, though the great bulk of the water was taken in the first week.

Broken bricks absorb more water than whole ones, and small pieces from the interior of the brick absorb more proportionately than large ones.

The following conclusions were reached.

1 That to obtain accurate absorption figures, a hard brick will require not less than four days' drying and eight weeks' soaking.

2 That only roughly approximate figures are obtained within time limits which would be short enough to make the figures useful for ordinary competitive tests of material for immediate use.

3 That only rattled bricks should be used for the absorption test. as the absorptive power of brick in use is increased by its chipping and grinding under traffic.

4 No relation seems to exist between loss by rattling and percentage of absorption.

As a result of the committee's experiments the following specifications were adopted.

Specifications for abrasion test

1 *Dimensions of the machine.* The standard machine shall be 28 inches in diameter and 20 inches in length, measured inside the rattling chamber. Other machines may be used, varying in diameter between 26 and 30 inches, and in length from 18 to 24 inches, but if this is done, a record of it must be attached to the official report. Long rattlers may be cut up into sections of suitable length by the insertion of iron diaphragms at proper points.

2 *Construction of the machine.* The barrel shall be supported on trunnions at either end; in no case shall a shaft pass through the rattling chamber. The cross section of the barrel shall be a regular polygon, having 14 sides. The heads and staves shall be composed of gray cast iron, not chilled or casehardened. There shall be a space of one fourth of an inch between the staves for the escape of dust and small pieces of waste. Other machines may

be used, having 12 to 16 staves, with openings from one eighth to three eighths of an inch between the staves, but if this is done a record of it must be attached to the official report of the test.

3 *Composition of the charge.* All tests must be made on charges composed of one kind of material at a time. No test shall be considered official where two or more different bricks or materials have been used to compose a charge.

4 *Quantity of the charge.* The quantity of the charge shall be estimated by its bulk and not by its weight. The bulk of the standard charge shall be equal to 15% of the cubic contents of the rattling chamber, and the number of whole brick whose united volume comes nearest to this amount shall constitute a charge.

5 *Revolutions of the charge.* The number of revolutions of a standard test shall be 1800, and the speed of rotation shall be 30 a minute. The belt power shall be sufficient to rotate the rattler at the same speed whether charged or empty. Other speeds of rotation between 24 and 36 revolutions a minute may be used, but in this case a record of the speed must be attached to the official report.

6 *Conditions of the charge.* The bricks composing a charge shall be dry and clean, and, as nearly as may be possible, in the condition in which they are drawn from the kiln.

7 *Calculation of the results.* The loss shall be calculated in percentage of the weight of the dry brick composing the charge, and no result shall be considered as official unless it is the average of two distinct and complete tests, made on separate charges of brick.

Specifications for absorption test

1 The number of bricks for a standard test shall be five.

2 The test must be conducted on rattled bricks. If none such are available, the whole bricks must be broken in halves before treatment.

3 The bricks should be dried for 48 hours at a temperature ranging from 230° to 250° F. before weighing for the initial dry weight.

4 The bricks should be soaked for 48 hours, completely immersed, in pure water.

5 After soaking, and before weighing, the bricks must be wiped dry from surplus water.

6 The difference in weight must be determined on scales sensitive to 1 gram.

7 The increase in weight due to water absorbed shall be calculated in percentage of the initial dry weight.

The commission which drew up these specifications considers that any brick which will satisfy the requirements of reasonable mechanical tests will not absorb sufficient water to prove injurious to it in service, and that for such brick the absorption test should be abandoned as unnecessary, if not actually misleading.

Specifications for cross-breaking tests

1 Support the brick on edge, or as laid in pavement, on hardened steel knife edges, rounded longitudinally to a radius of 12 inches and transversely to a radius of one eighth of an inch, and bolted in position so as to secure a span of 6 inches.

2 Apply the load to the middle of the top face through a hardened steel knife edge, straight longitudinally and rounded transversely to a radius of $\frac{1}{16}$ inch.

3 Apply the load at a uniform rate of increase till fracture ensues.

4 Compute the modulus of rupture by the formula

$$f=\frac{3\ w\ l}{l\ b\ d^2},$$

in which

$f =$ modulus of rupture in pounds a square inch

$w =$ total breaking load in pounds

$l =$ length of span in inches $= 6$

$b =$ breadth of brick in inches

$d =$ depth of brick in inches

5 Samples for test must be free from all visible irregularities

of surface or deformities of shape, and their upper and under faces must be practically parallel.

6 Not fewer than 10 bricks shall be broken, and the average of all be taken for a standard test.

Specifications for crushing test

1 The crushing test should be made on half bricks, loaded edgewise, or as they are laid in the street. If the machine used is unable to crush a full half brick, the area may be reduced by chipping off, keeping the form of the piece to be tested as nearly prismatic as possible. A machine of at least 100,000 pounds' capacity should be used, and the specimen should not be reduced below 4 square inches of area in cross-section at right angles to the direction of load.

2 The upper and lower surfaces should preferably be ground o true and parallel planes. If this is not done they should be bedded in plaster of paris while in the testing machine, which should be allowed to harden 10 minutes under the weight of the crushing planes only, before the load is applied.

3 The load should be applied at a uniform rate of increase to the point of rupture.

4 Not less than an average obtained from five tests on five different bricks shall constitute a standard test.

It was resolved by the commission that "from the experimental work done so far by this commission, or by others so far as is known to us, in the application of the cross-breaking and crushing tests to paving brick, it is not possible to show any close relationship between the qualities necessary for a good paving material and high structural strength as indicated by either of these tests".

Effect of structure on wearing power of paving brick[1]

Recent experiments by Prof. Edward Orton jr on bricks made from the same shale, but molded on different machines and burned

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[1] *Clayworker*, February and March 1897.

together in the same kiln, show that end-cut bricks possess a decided superiority over side-cut bricks, and also show the marked advantage of repressing end-cut and the disadvantage of repressing side-cut bricks.

Rattling tests made by Prof. Edward Orton jr on paving bricks

Description	Loss in weight at the end of— 1000 revolutions	Loss in weight at the end of— 2000 revolutions	Average modulus of rupture
	Per cent	*Per cent*	*Pounds*
END-CUT BRICKS			
Repressed	18.23	26.67	2 525
Plain	21.05	28.48	2 425
Average of both	19.54	27.00	2 463
SIDE-CUT BRICKS			
Repressed	26.51	35.30	2 347
Plain	22.73	31.42	2 346
Average of both	24.43	32.90	2 347
DRY PRESSED BRICKS			
Coarse	19.40	25.20	2 507
Medium	23.80	28.26	2 740
Fine	20.07	29.71	2 687
Average of all	21.09	27.72	2 644

As regards the crushing test, experiments given below show that, even with the same material, a wide range of results is obtained, depending on the method of preparing the surface.

Prof. I. O. Baker prepared a number as follows:

1 Grinding as nearly flat as possible on convex side of emery stone and crushing between self-adjusting, parallel cast iron plates.

2 Removing the irregularities of surface and crushing between blotting paper.

3 Removing the irregularities of surface and crushing between straw boards.

4 Removing irregularities, coating with plaster of paris and placing under slight pressure till set (12–24 hrs), and then crushing.

5 Coating with plaster of paris which was afterward ground down, on a sand paper disk, to the surface of the brick so as to leave a minimum thickness with a perfectly flat surface, and then crushing.

After a number of experiments no great difference was found between the first three, but difficulties connected with the last two rendered them worthless. With a uniform grade of brick the first three methods gave 7000 to 9000 pounds as the crushing strength of cubes. Some samples of the same lot of brick were prepared on a rubbing bed at marble works, and the strength of these carefully prepared cubes ranged from 16,000 to 21,000 pounds a square inch, showing that a very small difference in flatness of surface makes a great difference in the apparent strength.

At a recent meeting of the National brick manufacturers association, Gomer Jones, city engineer of Geneva, N. Y., advocated the following method for testing the resistance of paving brick to abrasion.

A rattler of the usual type has the staves fitted with two longitudinal pockets each, in which the bricks are inserted and held end to end. These pockets are 3 inches deep, leaving about one inch of brick protruding. "When all the staves are in place, the interior of the rattler is virtually solid brick lined. During rotation the attack of the abrading material is at right angles to the length of the brick, and confined to the surfaces and edges which are exposed in actual use; there is sufficient space between the brick for the escape of any dust or waste, and incidentally allowing the abrading material free access to the unsupported edges of the brick under test, thus establishing the conditions of position and line of wear produced when brick are laid with sand filler in the street ".

The charge adopted by Mr Jones consists of 150 pounds of cast-iron cubes, each ½ inch each way, and weighing .87 of a pound. The rattler is revolved 3000 times. Bricks which are considered standard lose 5% of weight; these would be condemned if found on the street.

Mr Jones analyzes the action of his rattler as follows. First, the ascending side of the rattler carries up part of the charge of cubes, imparting to them its velocity. When carried beyond the center they are thrown toward the opposite side of the rattler chamber, and therefore strike on the unprotected surface of the brick, chipping the edges, cutting into the surface, and doing all that the calks of a horse's shoe can do. Second, as only part of the charge of cubes can be carried upward by the ascending side of the rattler chamber, the rest slide and roll over the surface of the brick at the lowest point, grinding and wearing them away.

Thus we have:

1 Brick in position as in the street

2 Continual raining of iron cubes on the surface — analogous to the shock of horses' feet

3 Attrition and rolling wear as of wagons

4 Wear confined to the narrow surface of the brick — as in the street

5 Uniform and standard abrading material

6 Like conditions for testing any material from fire clay to shale

7 Influences of change of form minimized

8 Weight, cross-section, form and structure estimated at true value, as they are all reduced to surface and resisting quality of material.

As only one edge is subjected to abrasion, it is possible to multiply the loss of weight suffered by one brick by the number required to lay a yard and thus ascertain the number of pounds of material that would be lost from a square yard of pavement laid in the street.

Mr Jones gives the following test made at Geneva. 16 different samples were at his disposal; in order to eliminate the weakest, he put two of each kind of brick into the staves of the machine, with the usual charge and number of revolutions. The result was that, while the strongest material lost less than 3%, the weakest lost 7.35%. The wire-cut brick failed to develop as much strength as the same material repressed. In one instance, the difference of abrasion was as between 3.59% in the case of repressed brick and 6.26% for common wire-cut brick. The large fire clay blocks also failed in comparison with the smaller repressed fire clay bricks.

Some of the comparative results reached by Mr Jones's test were as follows:

	Abrasive loss
Shale block no. 1	2.46%
Medina sandstone block	3.61%
Fire clay block no. 2	3.2%
Fire clay block no. 3	4.6%

The method adopted by Mr Jones is undoubtedly from all appearances very reasonable, but, in order to determine whether it or the old method of testing the resistance of brick to abrasion is the better, it will be necessary to carry on a long series of parallel tests on the same material, using both methods. Steps have already been taken to do this, by the National brickmakers association.

More recently Prof. Talbot of the University of Illinois has brought forth a third method of testing paving brick which differs from the standard test of the National brickmakers association in placing a certain number of bricks in the standard N. B. M. A. rattler, along with cast iron shot of two sizes, the larger weighing about 7½ pounds, the smaller about 1 pound.

A committee lately appointed by the association referred to above found that, while the Jones device gives more accordant or uniform results for any given make of brick, and while it is distinctly more sensitive in indicating the softer grades of brick, the device as now manufactured embodies objectionable features which the committee think can be remedied. As between the present standard N. B. M. A. test described above, and the Talbot standard test, the committee found that the latter is much more sensitive in selecting the soft brick, and also gives more uniform results than the present standard.

The committee therefore recommended the abandoning of the present N. B. M. A. test, and the adopting of the Talbot standard test, which is to be carried out as follows:

1 All brick shall be thoroughly dried before testing in the rattler.

2 The present standard rattler, 28 inches in diameter, and 20 inches long, shall be retained. It is preferably made of steel plates in place of cast iron, which peels and ultimately breaks under the wearing action on the inside. The rattler shall be run not less than 28 nor more than 30 revolutions a minute for 1800 revolutions.

3 The charge to be placed in the rattler shall consist of nine paving blocks or 12 paving bricks together with 300 pounds of shot made of ordinary machinery cast iron. This shot shall be of two sizes; the larger size to weigh about 7½ pounds, and to be 2½ inches square and 4½ inches long, with slightly rounded edges; the smaller sizes to be cubes, 1½ inches on a side, with rounded edges. Farther, the individual pieces of cast iron shall be replaced by new ones when they have lost $\frac{1}{10}$ of their original weight. One fourth (75 pounds) of the short charge shall be always composed of the large cast iron blocks, and three fourths (225 pounds) of the small cast iron blocks.

New York paving brick industry

Most of the paving brick manufactured in this state are made from shale. The localities are as follows.

Corning. The Corning brick and terra cotta company manufactures a paving brick from the Chemung shales. The brick are molded in auger side-cut machines and repressed. The shale from this locality is mentioned in chapter on " Shale ", p. 839.

Catskill. The works of the Eastern paving brick company rank next in size to those at Syracuse. The material used is a mixture of Hamilton shale and Quaternary clay, both of which are obtained at Cairo. They are brought to the works by railroad. After crushing and mixing, the bricks are molded in auger machines, and burned either in rectangular down-draft kilns or in a continuous one built according to the design of Mr Haight, superintendent at the factory.

A view of this kiln, which is in successful operation, is shown in pl. 45.

Hornellsville. The Preston brick co. manufactures brick from Chemung shale. The quarries are located on the Erie railroad about one mile from Hornellsville. The bricks are molded in a side-cut auger machine, but are not repressed. They are dried in tunnels and burned in circular down-draft kilns. (pl. 44)

The material is described under " Shale ", p. 839.

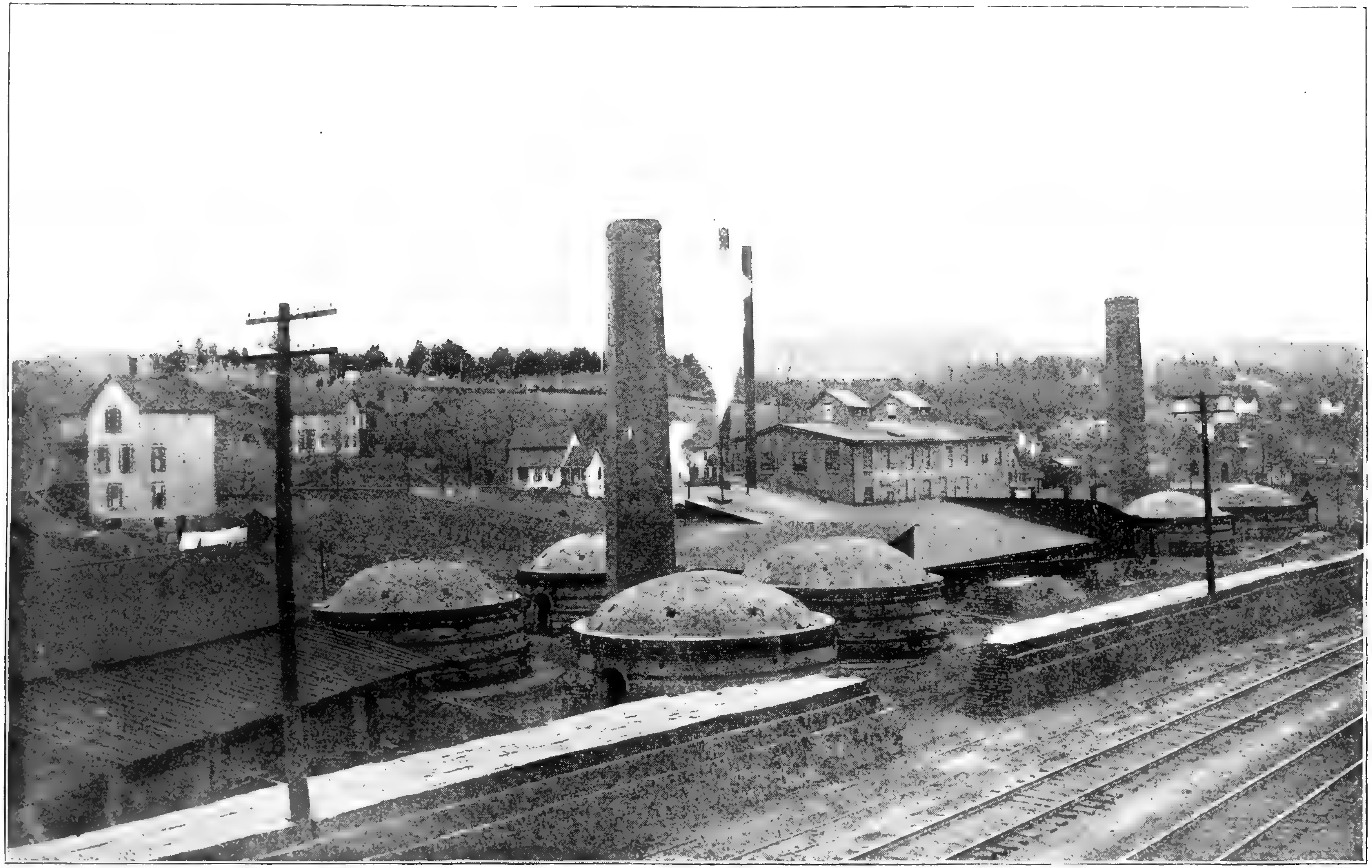
Newfield. The description of this plant is given on p. 728. The paving brick are auger side-cut ones, and are repressed either in hand or steam power represses.

Jamestown. The Jamestown shale paving brick company at this place makes both end-cut and side-cut paving brick. The product is usually repressed, dried in tunnels and burned in down-draft kilns. One form used at this works is divided longitudinally by a brick wall into two compartments. A view of the works is shown in pl. 63.

Syracuse. The New York paving brick company at Geddes, near Syracuse, is the only one in the state that uses clay alone. The material is brought by canal from Threeriver Point on the Oswego river, 10 miles northeast of Syracuse. The clay deposit is said to be 35 feet thick. It is a soft gritty clay of moderate plasticity and great stickiness.

Plate 63

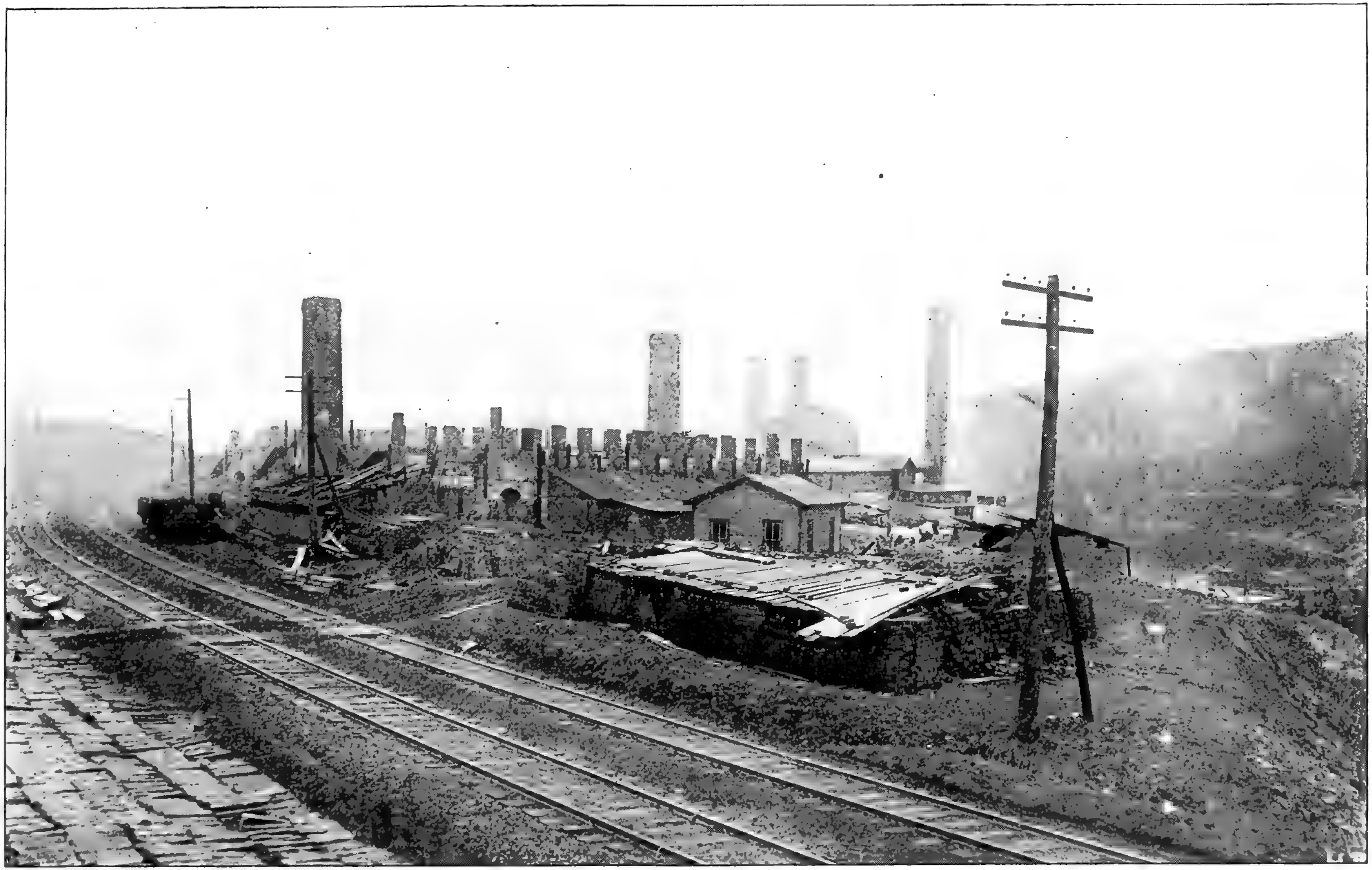
To face page 756



H. Ries photo.

General view of Preston brick co., Hornellsville.

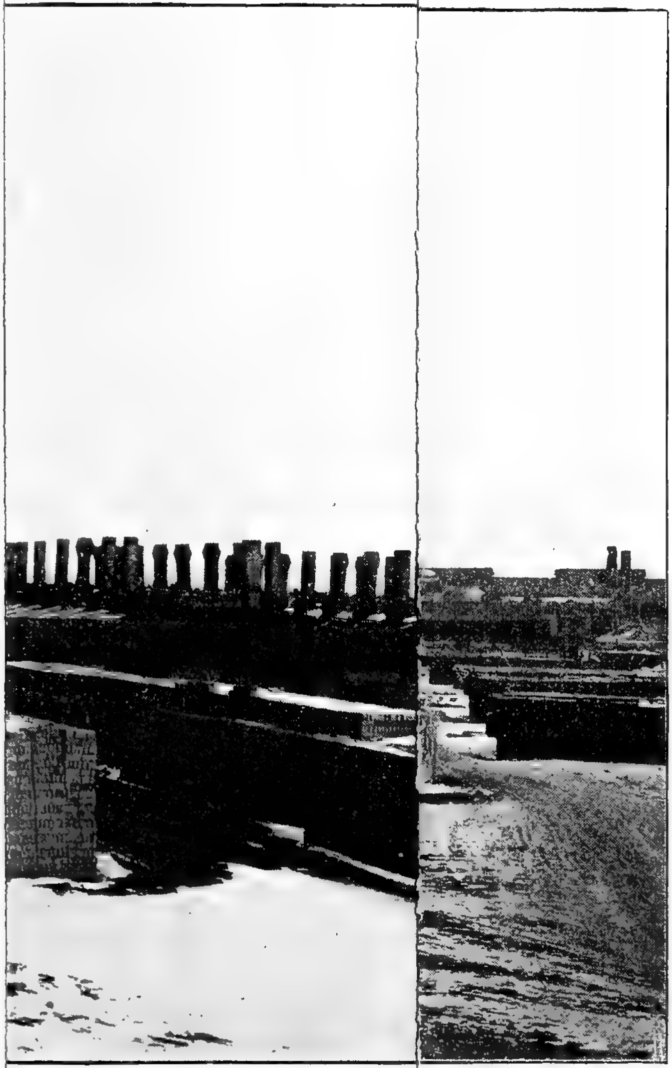
Plate 64



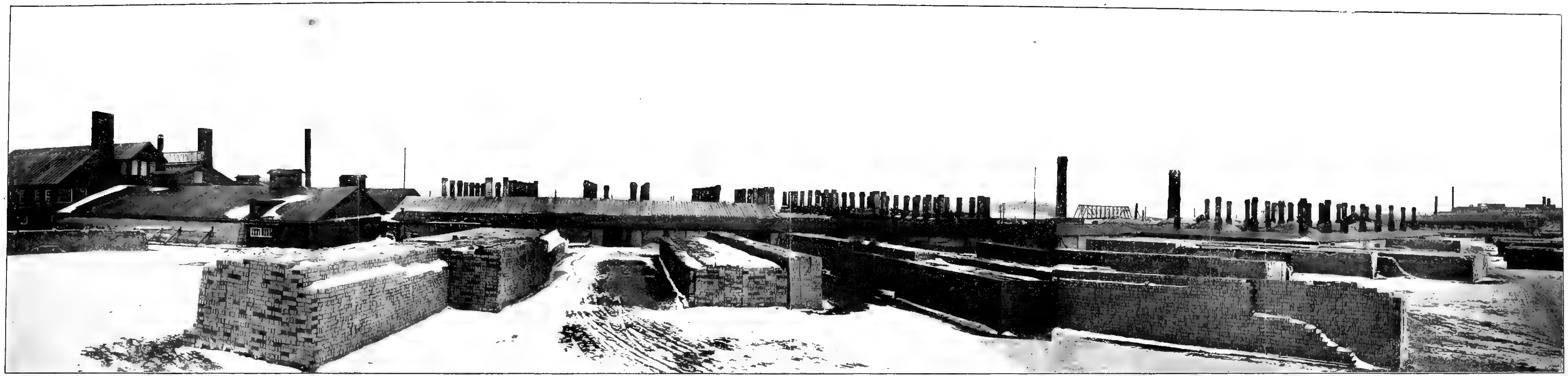
H. Ries photo.

General view of Jamestown shale paving brick co., Jamestown.

Plate 65) face page 757.



brick & paving co., Syracuse.



H. Ries photo

View of works and yard N. Y. brick & paving co., Syracuse

Experiments made with a sample of it showed that 28% of water was needed to work up the air-dried material, but in actual practice the clay is so moist when it reaches the factory that little water has to be mixed with it. The air shrinkage is 5%. At incipient fusion, which occurs at cone .05, the total shrinkage is 7%. Vitrification occurs at cone 1 with 11% shrinkage; this agreeing quite closely with the amount that takes place in the manufacture of the brick. At cone 3 the clay became viscous.

The tensile strength of the air-dried briquettes ranges from 60 to 70 pounds a square inch. The clay contains .55% of soluble salts. As the bricks are burned to vitrification these do not produce any harmful results.

The bricks are molded either in a Penfield soft mud machine or in a stiff mud plunger machine, in which case they are repressed. The works are equipped with a large number of drying tunnels, and both rectangular and circular kilns of the down-draft type.

Samples of the product tested from time to time show a high crushing strength and very low absorption.

Many of the streets in Syracuse are paved with brick from this factory. They have also been used at other places.

TERRA COTTA

General properties

The increasing tendency of architects to place considerable adornment on the exterior of buildings has led to the extensive adoption of terra cotta as a cheap substitute for stone.

The advantages ascribed to it are

Durability
Cheapness
Permanent color
Resistance to fire
Lightness and strength.

The term terra cotta is usually applied to those ornamental clay products for structural work which are more than 8 inches square. If the pieces are under this size they are called ornamental brick.

Terra cotta objects should be burned to an even color, the pieces should be of regular outline and not show signs of warping, neither should they discolor superficially. The hardness should be above 6 in the scale, that is, it should resist scratching with a knife.

Terra cotta is seldom vitrified, but the slip covering the surface generally forms an impervious coating, and also serves to give the desired color to the ware.

At first the forms produced in terra cotta were comparatively simple, but improvements in methods and experience have greatly extended the possibilities of the material. Among the more recent uses is to be mentioned its employment in columns and balustrades.

In the manufacture of balustrades the solids and voids should be made in the proper proportions to prevent warping and cracking of the ware in burning.

The strength of terra cotta brackets has been well shown by the following experiments:[1]

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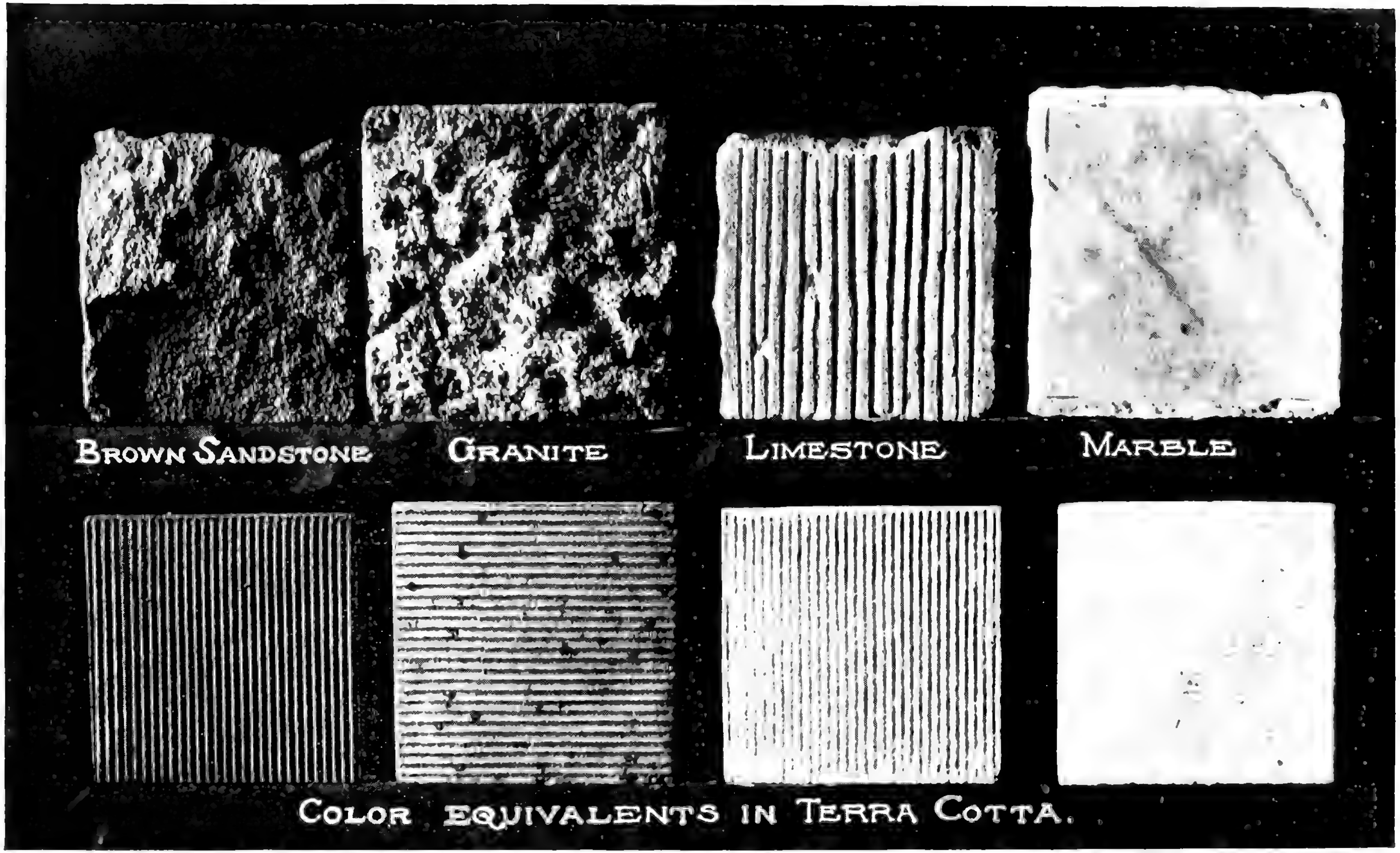
[1] **An important and instructive series of articles on "Terra cotta in architecture", by T. Cusack, has appeared in the *Brickbuilder*. 1898. p. 7, 55, 98, 142, 185, 230.**

Plate 66

To face page 759

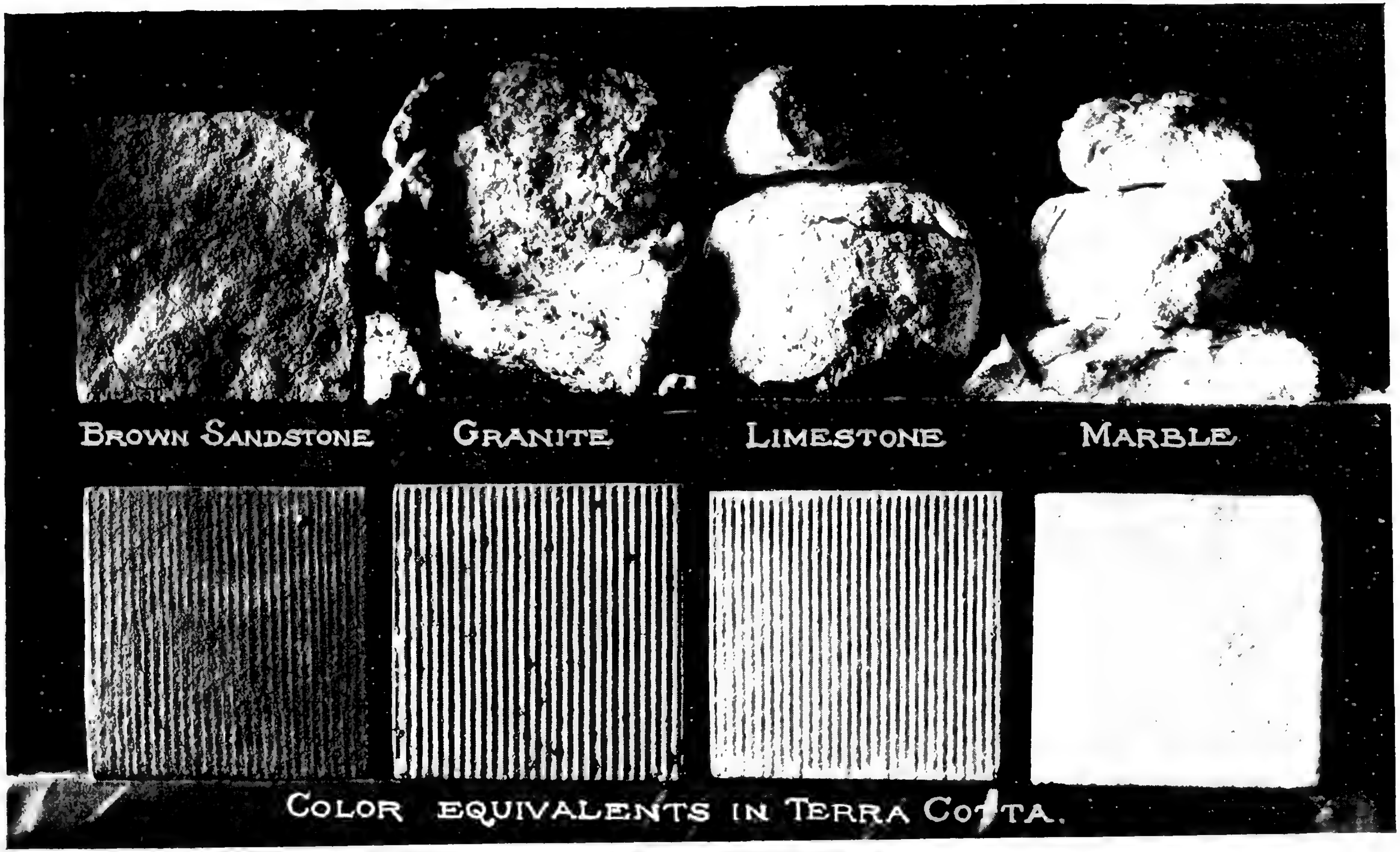


T. Cusack photo.

Cubes of building stone and their color equivalents in terra cotta, taken before they were subjected to a fire test and cooling test.

Plate 67

To face page 759



T. Cusack photo.

Cubes of building stone and their color equivalents in terra cotta, taken after they had been subjected to bright redness in the kiln, and then put into the cold water; the terra cotta at once and the stone after, first cooling a few minutes in the air.

Plate 68

H. Ries photo.

Dry pan for grinding grog and clays used in the manufacture of terra cotta. N. Y. architectural terra cotta co.

A cornice modillion made by the Northwestern terra cotta co. was braced on a firm support, in a horizontal position, the portion which would project beyond the wall being free of course. At the wall line this modillion was 11½ inches high, 8 inches wide on its face, and projected 2 feet. It carried a weight of more than 2 tons without breaking.

A smaller modillion made by the New York architectural terra cotta company was similarly tested. It was 5½ inches high, 6 inches wide at wall line and had a projection of 14 inches. Allowing the same thickness of shell (for these modillions are hollow), the second would have about half the sectional area, but more than half the projection of the first. It was loaded in a similar manner, and finally broke at the wall line under a weight of 2650 pounds. Another bracket made in the same mold was loaded with 2400 pounds and sustained this weight without breaking. A slightly larger bracket made from a different clay was loaded with 3200 pounds of pig iron without yielding.

The relative resistance of terra cotta and stone to fire was recently tested in an interesting manner. Cubes of granite, sandstone, limestone and marble, and terra cotta cubes of corresponding color were taken; all eight were placed in the hottest portion of the kiln. When thoroughly heated they were withdrawn, and the stone cubes allowed to cool slightly and then immersed in water, while those of terra cotta were plunged directly into water.[1] The result is here given.

Granite	Cracked, and melted superficially
Sandstone	Crumbled
Limestone and marble	Calcined
Terra cotta	Intact; two very slightly cracked

Terra cotta clays

Staten Island. The clays mined for this purpose in the pits of B. Kreischer's Sons have been mentioned under fire clays.

In addition to that clay, much is also quarried by T. Ryan near Roseville. This is a sandy, somewhat ferruginous clay, and is

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[1] T. Cusack, *Brickbuilder*, Jan. 1899. p. 14.

one of those used by the New York architectural terra cotta co. It possesses the advantages of being very plastic, burning to a deep red, with a very dense body at a comparatively low temperature. It took 33.70% of water to work it up. The air shrinkage was 6%, and at .06, 9.5%. Incipient vitrification began at .03, with 12% shrinkage; complete vitrification was reached at 4. Viscosity at 6. The percentage of soluble salts contained in the clay was .25%. The tensile strength showed a minimum of 75 pounds and a maximum of 90 to the square inch. The clay slakes quite rapidly in water.

Its composition is

Silica	57.00
Alumina	29.20
Ferric oxid	4.80
Lime	.65
Magnesia	.31
Alkalis	1.80
Water	6.10
Total	....

Glens Falls. Two varieties of clay occur here in the pits of the Glens Falls terra cotta co., the upper being red, and the lower bluish gray. The composition is indicated by the following analyses.

	Bluish gray	Red.
Silica	48.35	57.46
Alumina	11.33	21.15
Oxid of iron	4.02	5.52
Lime	15.38	3.65
Magnesia	3.17	1.50
Organic matter	1.18	....
Alkalis	6.05	4.72
	89.48	94.00

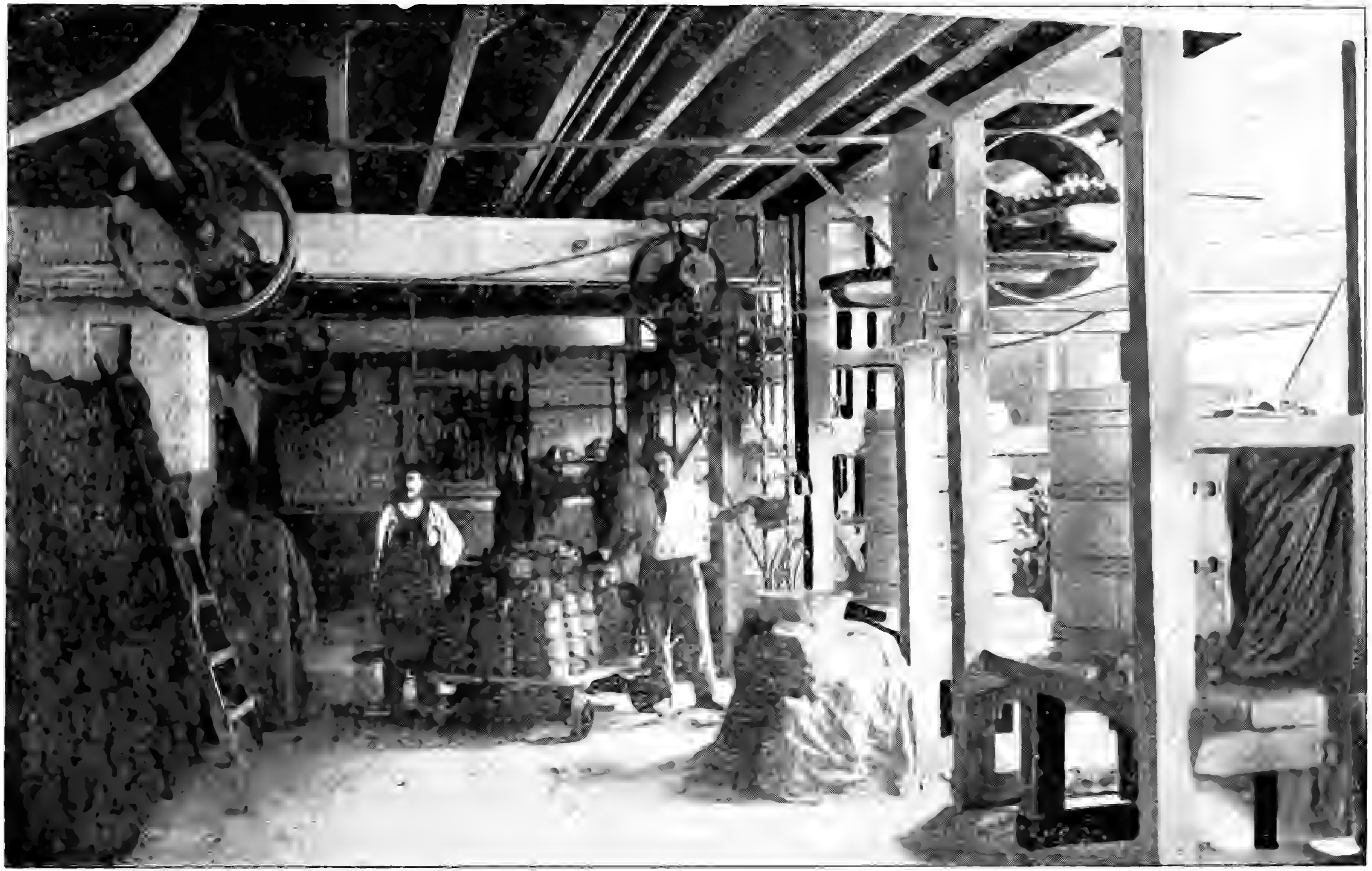
Plate 69

To face page 761

H. Ries photo.

Kiln room of a terra cotta works, showing clay stacked up around the kiln and spread out on the floor to dry.

Plate 70



H. Ries photo.

View in mixing department, N. Y. architectural terra cotta co. (a) Pug mills; (b) pugged clay which is being placed on the conveyor to be taken up to the molding department.

The red owes its color to the higher state of oxidation of the iron; the lower percentage of lime is due probably to its having been leached out of the red clay by percolating surface waters.

Elm Point, L. I. This clay was used for a time by the New York architectural terra cotta co., and also for stoneware, under which head it is described.

Terra cotta manufacture

It rarely happens that terra cotta is made from one clay, it being usually found necessary to mix several different ones to get the best results. In addition to this a certain amount of sand or ground brick is added to prevent excessive shrinkage.

The clay and fire brick are ground in a dry pan; and the mixing is done in a pug mill. The clay is then stored in bins till used; and before the clay is sent up to the molding room it is put through another pugging.

A model is first made of every object to be constructed. For simple forms of straight outline this can be done with the aid of a templet. Thus, if a cornice is to be modeled, the ground form of the piece is constructed by putting together several slabs of plaster of paris; over these a mass of soft plaster is poured and the templet is then run along the surface, the pattern of it being the same as the profile of the cornice. In the case of complicated or elaborate forms, the model has to be molded entirely or in part by hand, requiring the services of a skilled modeler. When the straight edge and elaborated center of a panel or similar piece are desired, the latter is modeled, while the former is obtained by means of a templet.

The model completed, a mold of plaster is next made from it. This is made of several parts, which are held together by an iron band, tightened with a wooden wedge. In filling the mold the soft, plastic clay is forced into all the corners, till it forms a layer about 2 inches thick all over the interior. The mold is allowed to stand for a short time, while the clay dries sufficiently to permit the parts of the mold to be lifted off, when the edges of the object are trimmed off by means of a knife. Large objects such as a statue or column have to be molded in several pieces, a separate mold being required for each. Indeed extreme care has to be exercised not to make single pieces which are too large or too complicated, otherwise they would warp and crack in drying and burning.

Drying of the wares needs to proceed with great slowness, and in the case of larger pieces has even to be retarded by keeping them covered with a damp cloth. The drying process is carried on in warm rooms; where, in some terra cotta factories, coils of steam pipe are laid under the floor. The shrinkage of terra cotta in burning and drying is commonly about $\frac{1}{12}$.

Much terra cotta is covered either with a soft dull enamel, or glaze. This is commonly applied by dipping the green ware into the glazing liquid, or it is put on by spraying. (pl. 77.)

In the burning of the ware, simple forms can be piled on one another in the kiln, but larger and more complicated pieces have to be set in between slabs of firebrick, to shield them from any pressure during the burning. Both coal and oil are used as fuel, the latter having met with success at the works of the New York architectural terra cotta co.

The color of terra cotta is either that of the body or is imparted by a thin coating of slip. The slipping of terra cotta is extensively practised, the advantages being that it makes the color of the clay when burned immaterial, since the color of the object is given by the slip coating.

According to the composition of the slip, the surface is dull, enameled or glazed. The composition of the coating must be such of course that the coefficient of expansion of the body and of the coating is the same, otherwise a crazing of the surface is sure to ensue.

The temperature reached in the burning of terra cotta depends on the refractoriness of the clay. For calcareous clays the temperature seldom exceeds 2000° F., but when semi-fire clays are

Plate 71

To face page 762

H. Ries photo.

Molding terra cotta, showing the green clay being pressed into the mold (a); the mold inverted and ready to be taken off of the object (b); molded piece with a plaster mold removed (c), and (d) the tempered clay ready for molding.

H. Ries photo.

Molding room, N. Y. architectural terra cotta co. On the floor are freshly molded pieces of terra cotta from which the plaster mold has been removed.

Plate 73

H. Ries photo.

Modeling clay for terra cotta. N. Y. architectural terra cotta co.

Plate 74

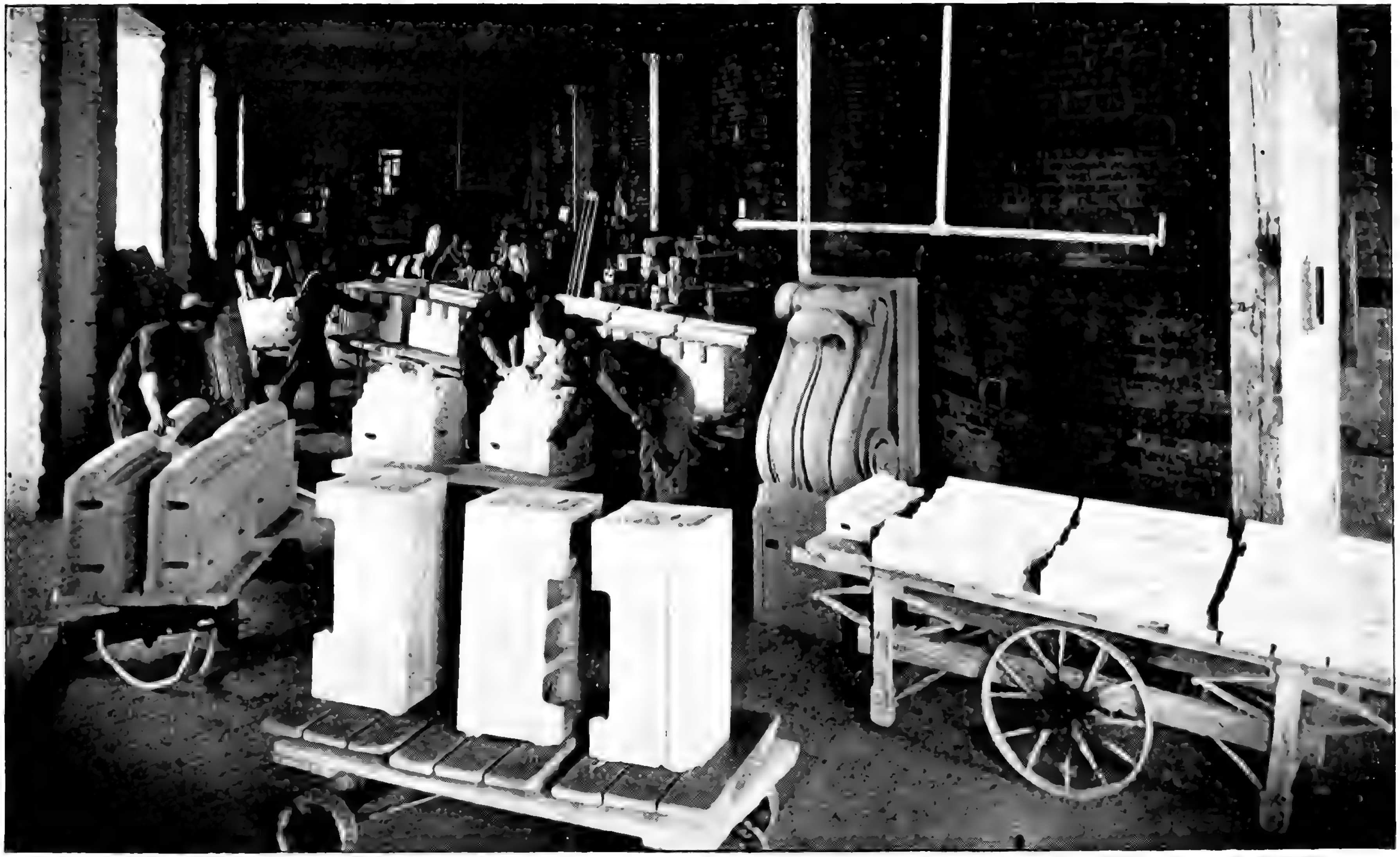
To face page 763

H. Ries photo.

Spraying the enamel mixture on the green terra cotta before placing it in the kiln. N. Y. architectural terra cotta co.

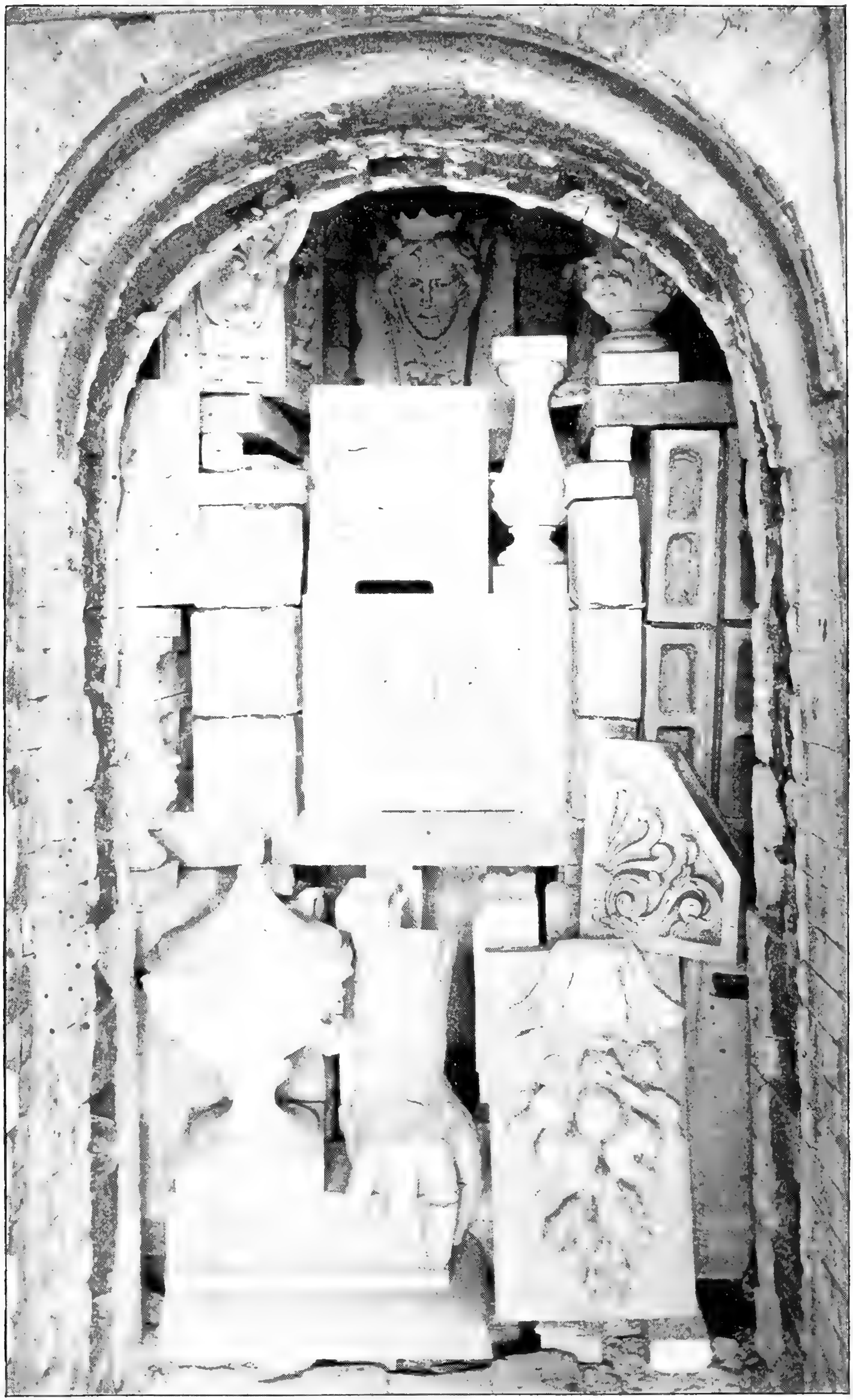
Plate 75

To face page 763



T. Cusack photo.

Kiln room, N. Y. architectural terra cotta co. Loading unburned ware into the kilns.



T. Cusack photo.

Interior view of terra cotta kiln with burned ware ready to be removed. The slabs and blocks which form a scaffolding around many of the objects are to protect them against the weight of the pieces above. N. Y. architectural terra cotta co.

Plate 77

T. Cusack photo.

View in the modeling department of the N. Y. architectural terra cotta co. The ornamentation seen on the various objects has been molded by hand.

Plate 78

H. Ries photo.

Barnard college, New York. The bricks are overburned ones from the Hudson river district and the terra cotta was supplied by B. Kreischer's Sons, Kreischerville.

employed, 2200° or 2300° F. are not infrequently attained. Even in such cases, not all the clays of the mixture are able to resist the latter temperature; in such cases those whose fusibility is below this point serve as the bond for the body, while the more refractory ingredients tend to preserve the form of the ware.

At the present day the manufacture of terra cotta has reached so high a degree of perfection that the manufacturer who is thoroughly familiar with the behavior of his clays in burning is able to produce pieces of exactly the desired size, and of regular shape, which in their complete condition fit more or less perfectly together. At the same time however a little trimming of the edges has to be done at times; therefore the burned ware is taken from the kiln to the fitting room, where the different portions of th design are placed together in their proper relation, in order t make sure that they fit as perfectly as possible.

Terra cotta manufacturers are constantly endeavoring to produce new designs and colors; while the handsome buildings of many cities attest their success. It is a common custom now to construct the first and perhaps the second story of a building of stone, and the succeeding stories of brick with terra cotta decoration; it therefore becomes necessary to see that the color of the terra cotta harmonizes with that of the other materials used. Terra cotta has thus come to be one of the most useful and durable of modern building materials; yet its use has become so wide spread that at times there seems to be danger of its being carried to an excess by some of its more enthusiastic advocates. In its place terra cotta has no equal, and if properly used will steadily grow in public favor.

New York terra cotta industry

The firms at present engaged in the manufacture of terra cotta in New York are

The New York architectural terra cotta co., Ravenswood, L. I
B. Kreischer's Sons, Kreischerville
Glens Falls terra cotta co., Glens Falls
Corning brick and terra cotta co., Corning

The clays used are obtained wholly or in part from this state.

The New York architectural terra cotta co. The factory is located at Ravenswood, borough of Brooklyn, and is the largest in the state. There are eight kilns. The product includes all kinds of architectural terra cotta, made in many different colors, either with plain or speckled surface.

The clays are obtained in part from Staten Island, the balance from New Jersey.

Among the many specimens of the company's work may be mentioned the new Delmonico building at 44 st. and 5 av., Colonial club, Fifth Avenue theater, all in New York city.

B. Kreischer's Sons' factory is at Kreischerville, on Staten Island. The clays used by them come largely from Staten Island, while the product includes various colors of terra cotta. Much gray and white ware has been made. The terra cotta decoration on Barnard college, at 120 st. and the boulevard, is one of the products of this factory. (pl. 78)

Glens Falls terra cotta co. at Glens Falls, N. Y. The factory of this firm has already been mentioned under the head of pressed brick. The same clays are used. The ware is either red or buff.

Corning brick and terra cotta co. While the chief products of this factory are paving and building brick, some terra cotta is produced.

H. Ries photo.

Molding room, B. Kreischer's Sons, Kreischerville.

Plate 80 To face page 764

H. Ries photo

Plaster room, B. Kreischer's Sons, Kreischerville

C. Kreischer photo.

Terra cotta vase made at the factory of B. Kreischer's Sons, Kreischerville. Side view.

Plate 82

To face page 764

Works of the Brick, terra cotta and supply co., Corning.

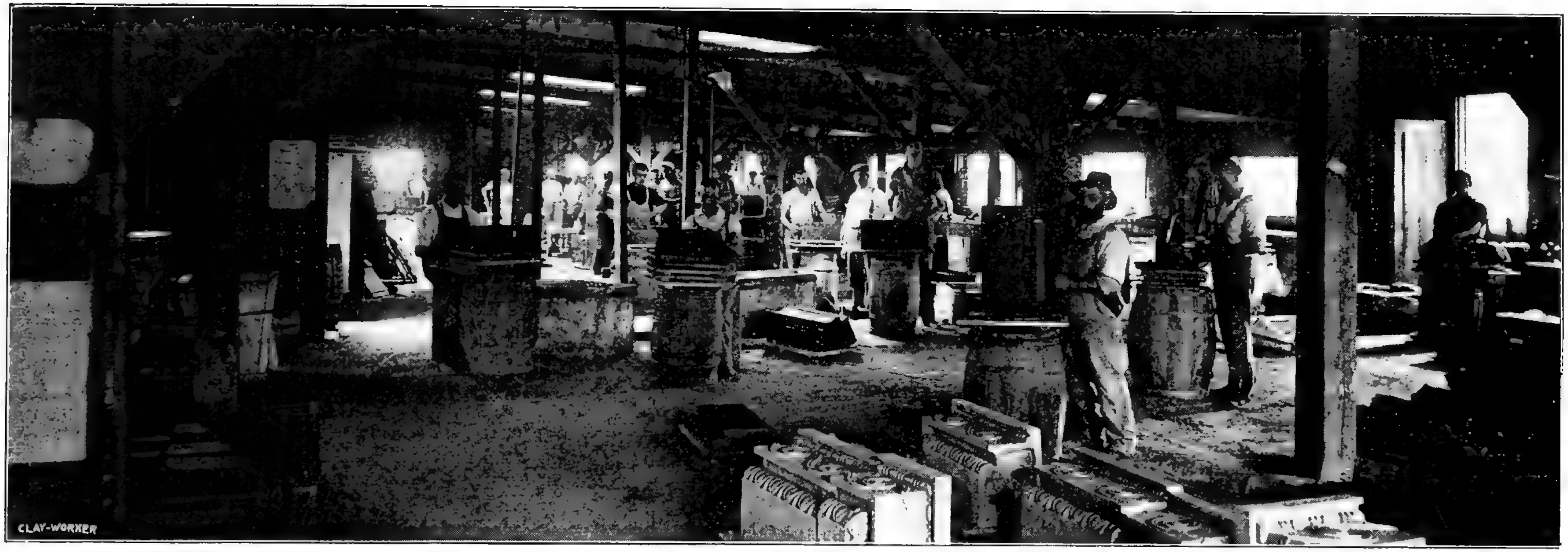
Plate 83

To face page 164

Modeling department of the Brick, terra cotta and supply co., Corning.

Plate 84

To face page 764



Pressing and finishing department, Brick, terra cotta and supply co., Corning.

Plate 85

To face page 764

T. Cusack photo.

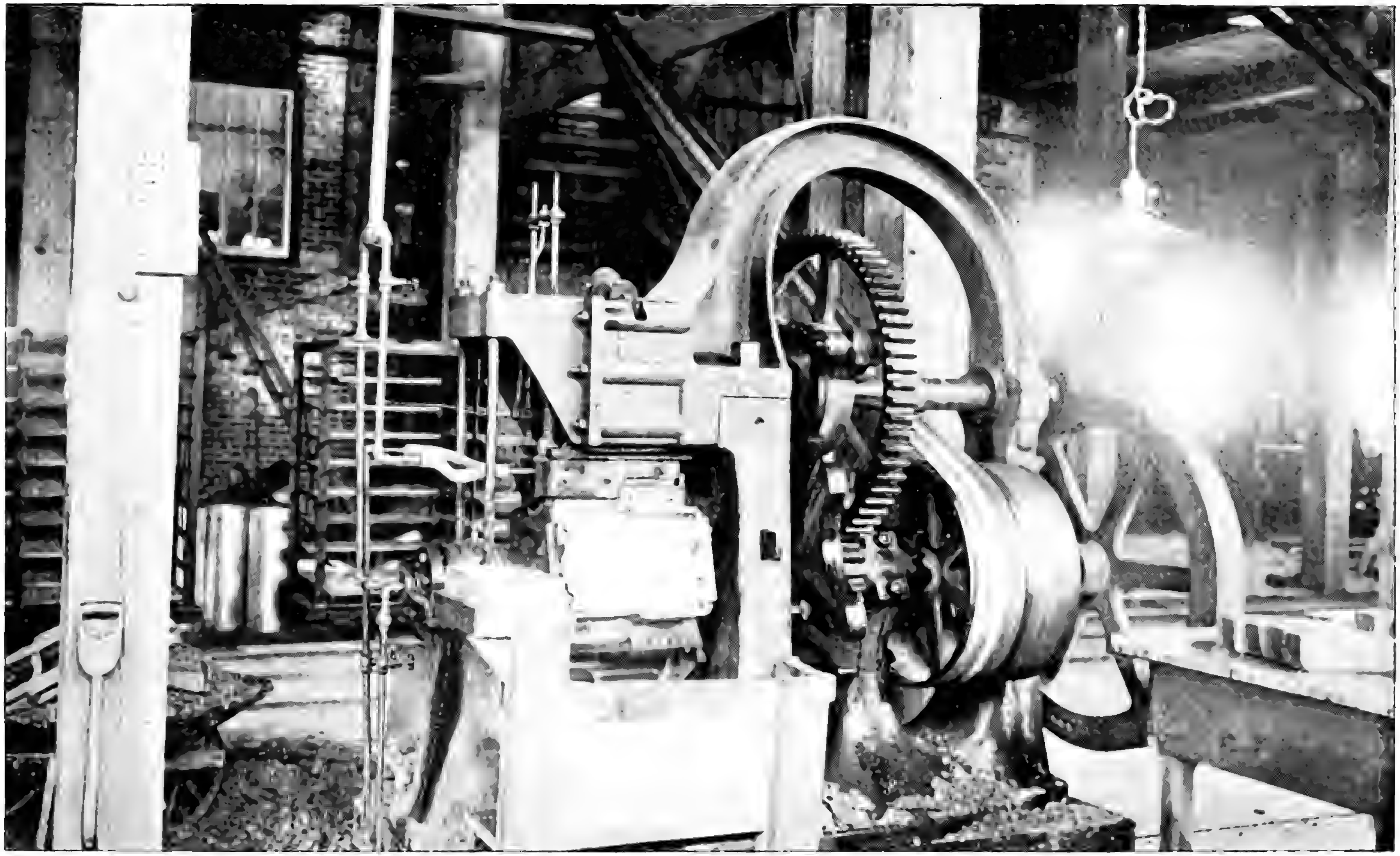
Drying room in a terra cotta works.

Plate 86

H. Ries photo. Rear view of roofing tile press, showing the green tile (a) which have just been received from it.

Plate 87

To face page 765

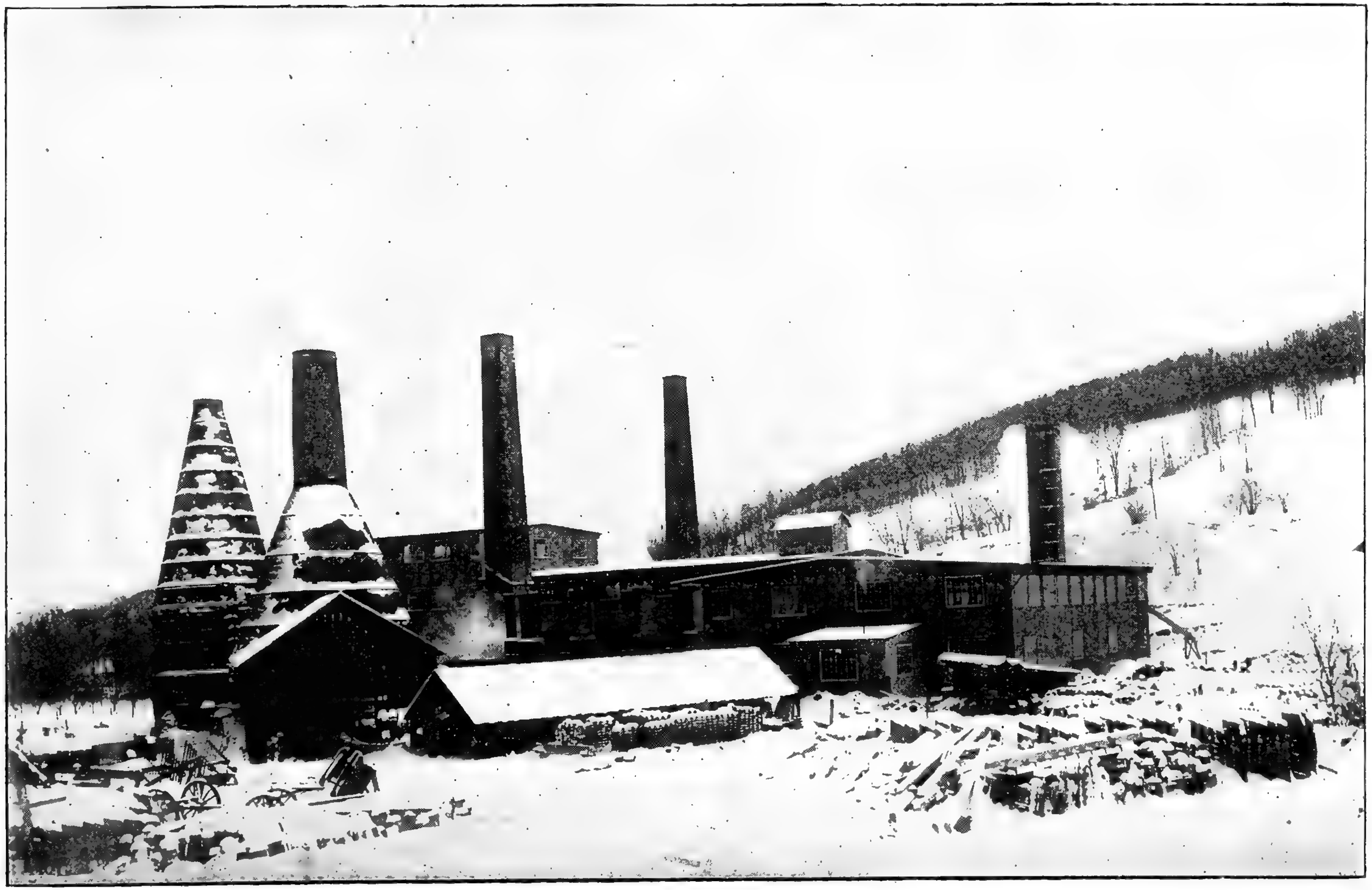


H. Ries photo.

Roofing tile press, Celadon terra cotta co., Alfred Center.

Plate 88

To face page 765



H. Ries photo.

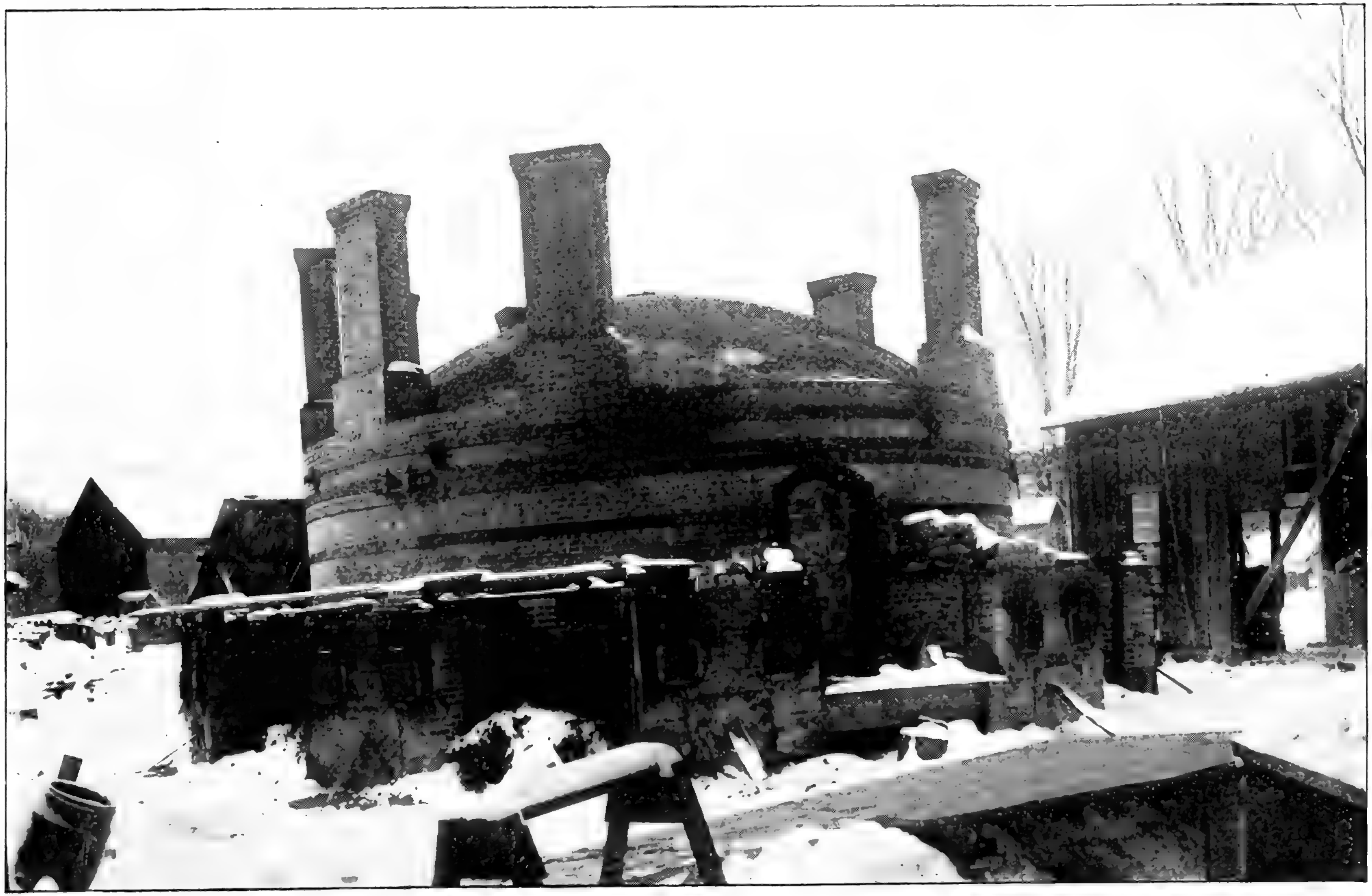
General view of Celadon terra cotta co.'s roofing tile plant.

Plate 89

H. Ries photo.

Tile roof. Celadon terra cotta co., Alfred Center

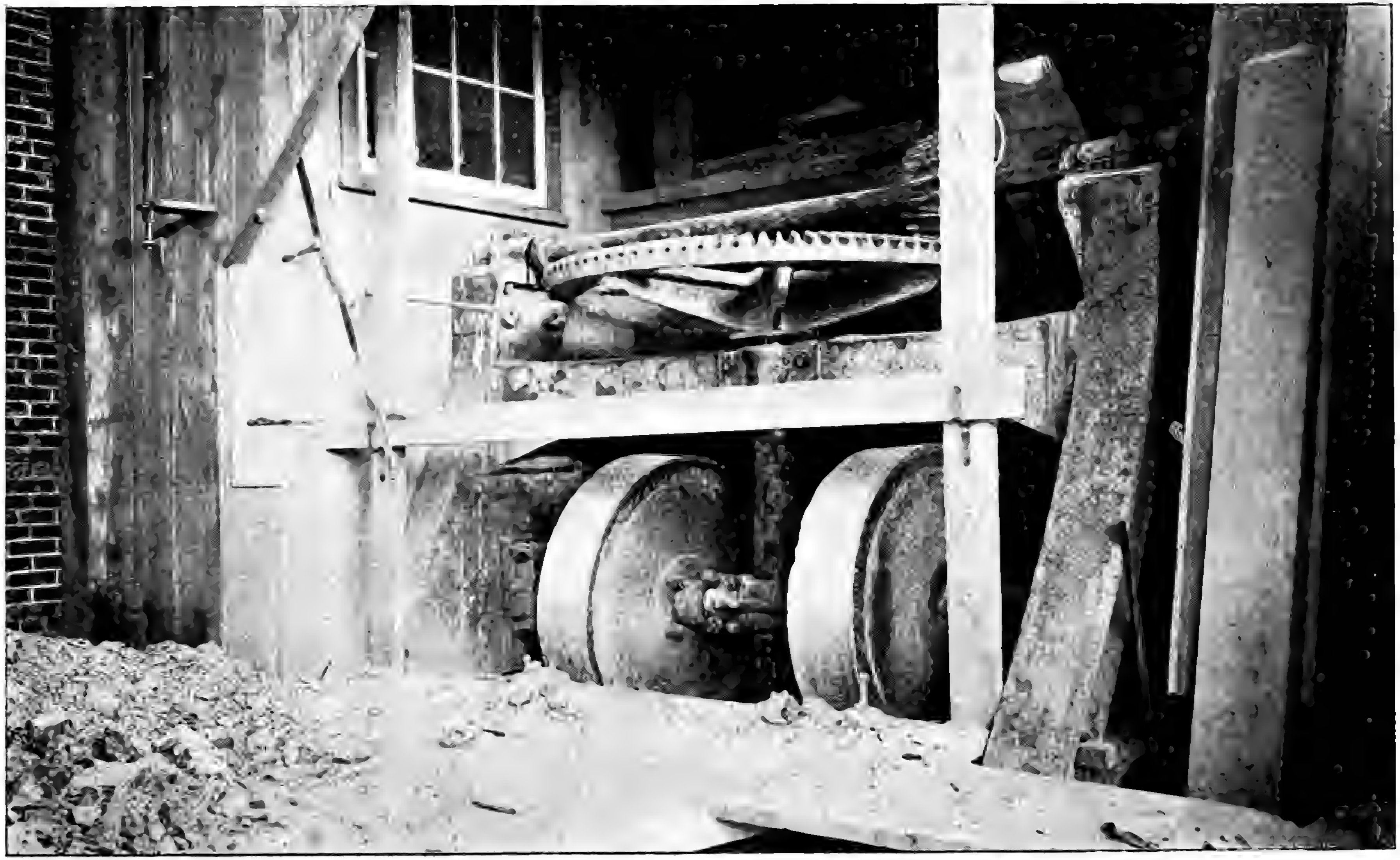
Plate 90



H. Ries photo. Grath coking furnace used for burning roofing tile. Celadon terra cotta co., Alfred Center.

Plate 91

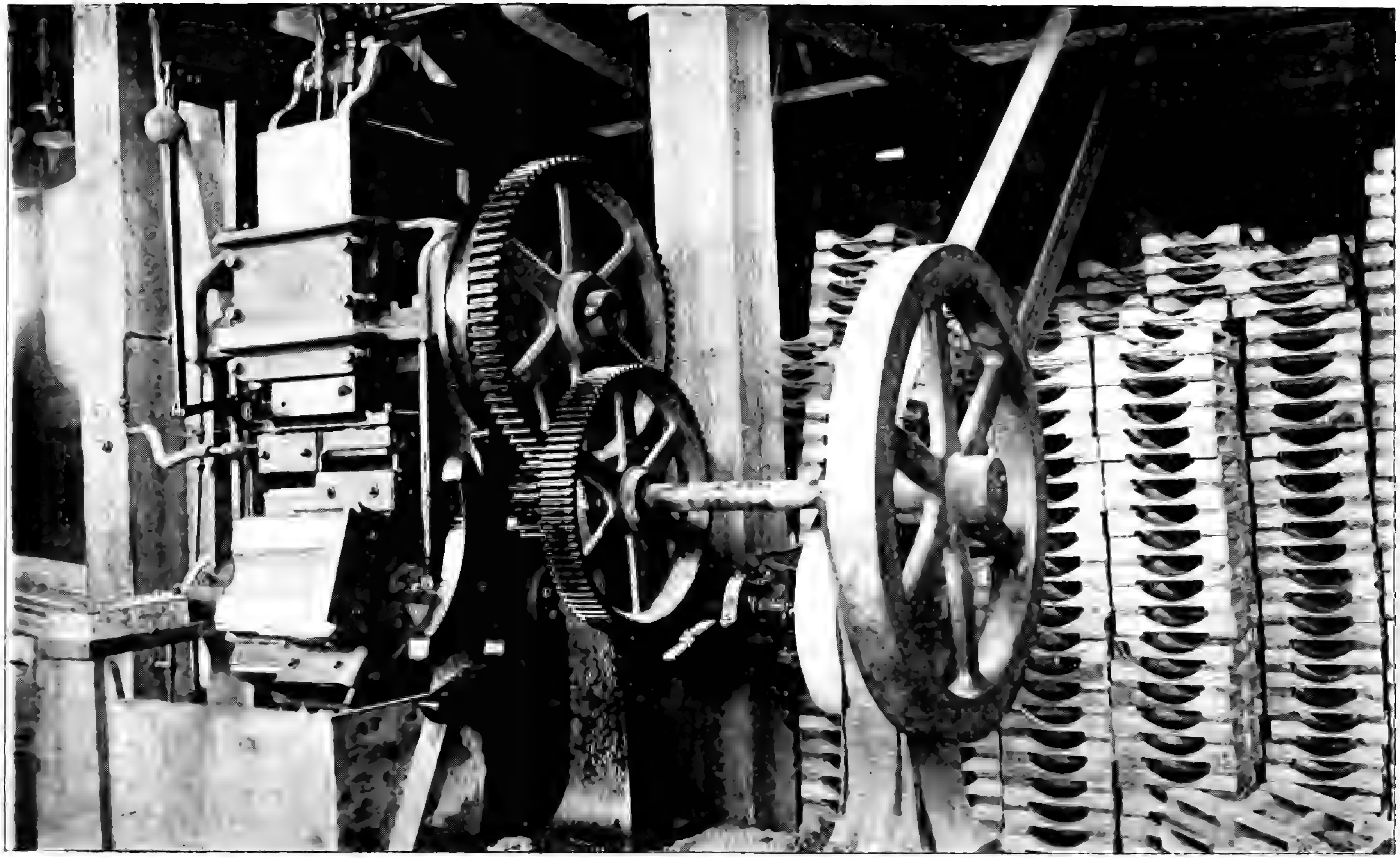
To face page 465



H. Ries photo.

Dry pan for grinding shale, Celadon terra cotta co., Alfred Center

Plate 92



H. Ries photo.

Large roofing tile press, Celadon terra cotta co., Alfred Center.

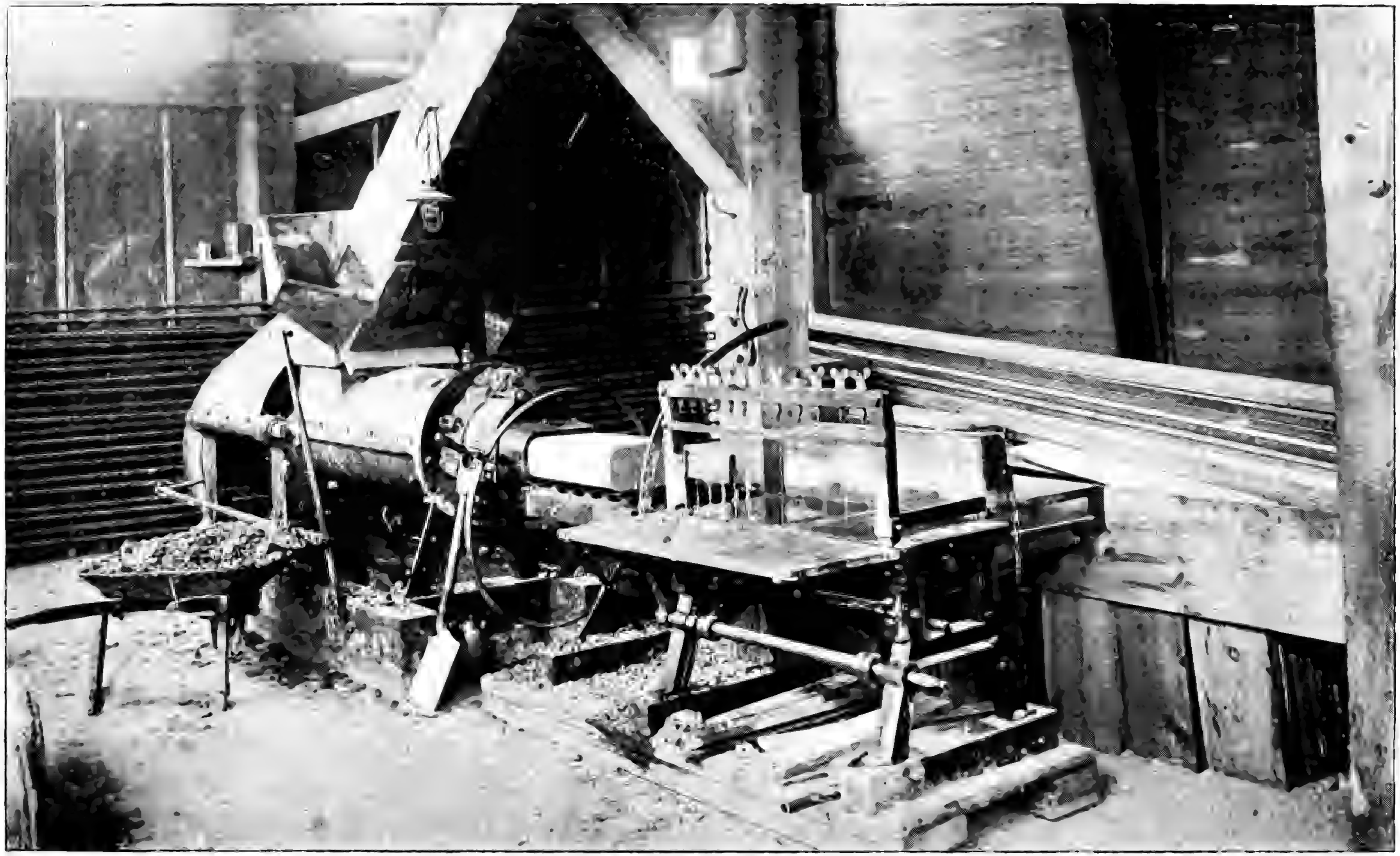
Plate 93

H. Ries photo.

Tunnels for drying roofing tile. On left is car with green tile entering tunnels; in center, alongside of tunnels are empty cars showing pallets which carry the green tile.

Plate 94

To face page 765



H. Ries photo.

Stiff mud machine for molding slabs to be repressed in roofing tile machine.

ROOFING TILE

Comparatively few roofing tile are made in New York state, nevertheless most of the product is of superior quality, and bears a national reputation.

Alfred center, New York. The works of the Celadon terra cotta co. are established at this point 2 miles from Alfred Station. The material used is a Chemung shale which is quarried along the highway, about 1 mile from the works. The quarry is located in a spur of the hill, and a practically inexhaustible supply of material is in sight.

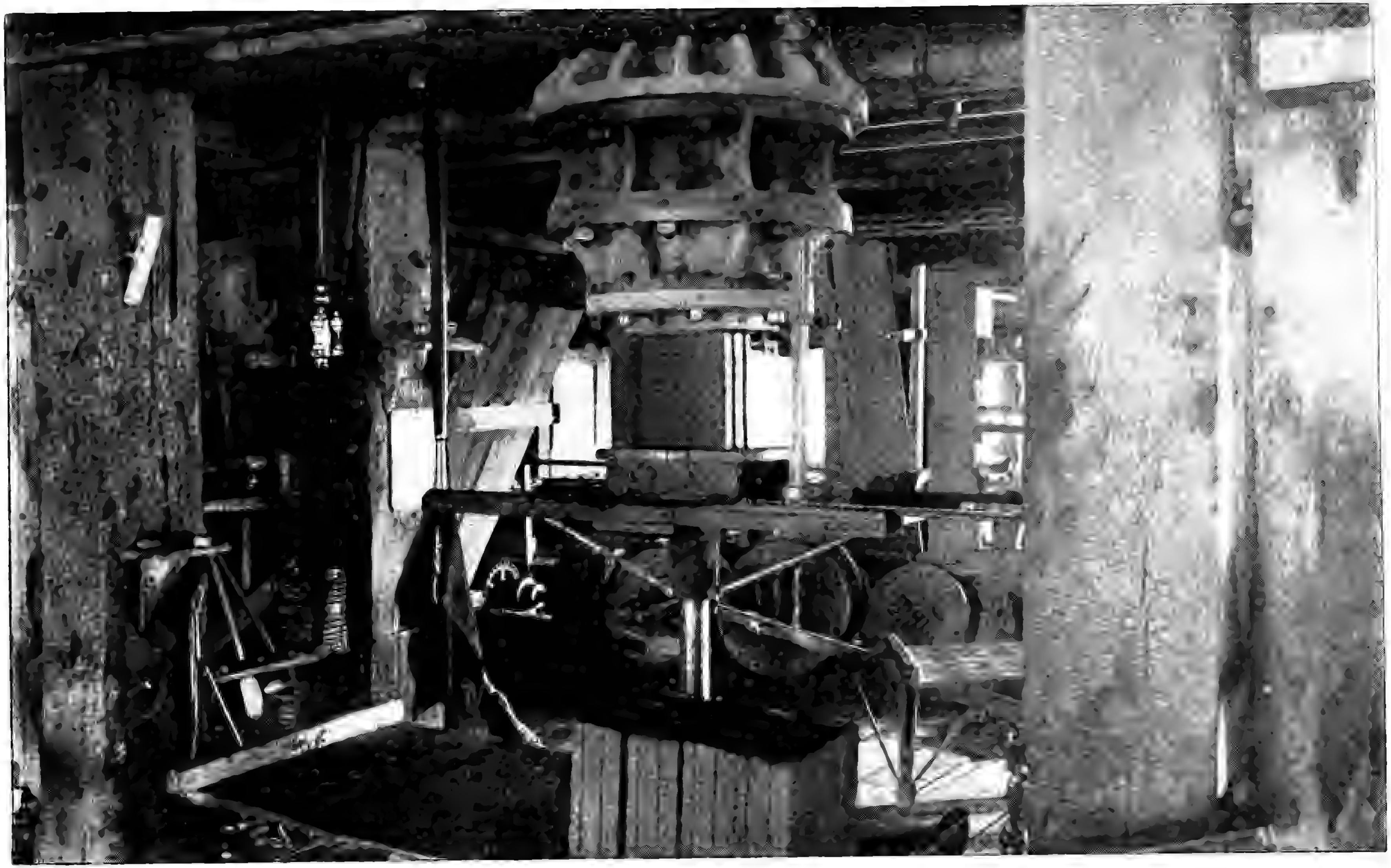
The roofing tile manufactured at this factory are of the interlocking type, and are made in a number of different shapes. The color of the product is usually a rich shade of red; the body is vitrified. The works of this company began active operations about 1890; and since that time they have been gradually enlarging.

The clay as it comes from the bank is first thoroughly crushed, in the dry pan, and passes from there to the pug mill, where it is perfectly mixed with water, producing a homogeneous, well tempered mass. This tempered clay is charged into an auger machine; and the bar of clay as it issues from the die is cut up into a number of slabs. The slabs are put into the tile-pressing machine, where they are repressed in the form of roofing tile. The green tile are loaded on the cars and run to the drying tunnel, after leaving which they are set up in a kiln and burned. In placing them in the kiln, they are set on edge, and protected from pressure by means of fire brick slabs. The company has six kilns.

These tile weigh from 750 to 1300 or 1500 pounds a square, the amount of tile required to cover a space 30 feet square, including overlaps.

The product of this factory is to be seen on a number of buildings in various states, but, as examples of their work in New York state may be mentioned the episcopal church at Ithaca, the high school at Tarrytown, the Erie railroad depot at Jamestown, and the Dairy building, Cornell university.

The Alfred clay co. While the chief product of this company is dry pressed brick, it has recently gone into the manufacture of roofing tile, but the only style thus far produced by them is a shingle tile, one of the peculiarities of which is that it is made by the dry press process. The tile is also of the interlocking type, but differs in many respects from that made at Alfred center.



H. Ries photo.

Clay cylinder of sewer pipe press. Shows hollow brick issuing from the press and being received on the table. In foreground molded hollow brick on trucks. J. Lyth & Sons, Angola.

SEWER PIPE

Clays used

The qualities of clay required for this purpose are in general the same as those demanded for any ware with a vitrified body. They should therefore be sufficiently plastic to permit molding without cracking; a high tensile strength, while desirable, is not absolutely necessary. Many clays used in the manufacture of sewer pipe have a tensile strength as high as 125 or even 150 pounds a square inch, while on the other hand shales are used whose tensile strength when ground to 30 mesh is not over 90 pounds a square inch. The clay should burn to a hard, dense, impervious body; the amount of iron in such clays or shales is usually sufficient to color it a red, or deep red. The drying should be rapid, and the ware should not warp or crack in drying. Owing to the thinness of the body, sewer pipe may be burned more rapidly than paving brick.

An excess of fluxing impurities may render a clay so fusible that in burning it softens and loses shape. It is a very common practice to use a mixture of clays, the one being fusible to form a bond in burning, the other more refractory to preserve the shape of the ware.

Sewer pipe are usually glazed by means of salt, thrown into the fireplaces when the temperature of the kiln is at its highest, the vapors, passing through the kiln and uniting with the silica and the alumina of the clay, forming a glaze over the surface of the ware. The following is the reaction which occurs:

$NaCl+H_2O=HCl+Na\,OH.$

$Na\,OH+nSiO=NaO+nSiO_2H_2O.$

Glazing requires one to two hours; some manufacturers add manganese to the salt in order to produce a glaze of the proper color. An excess of silica in the clay seems to be detrimental to the formation of a good glaze.

Manufacture of sewer pipe

If a shale or very hard clay is used the material is first ground in a dry pan, after which, or directly, if soft clay is used, the material is put into the wet pan, or chaser mill, either of which in a few minutes tempers a charge of clay in a thorough manner. This method of tempering is far more thorough and quicker than the work of a pug mill, though requiring more power.

The tempered clay is usually conveyed to the upper floor of the factory by means of bucket elevators, where it is delivered to the sewer pipe press. This press consists of two cylinders, an upper steam cylinder and a lower clay cylinder, the ratio of their diameters being most often as 3 to 1. The steam cylinder has a diameter of about 40 inches; the piston of the steam cylinder is moved both upward and downward.

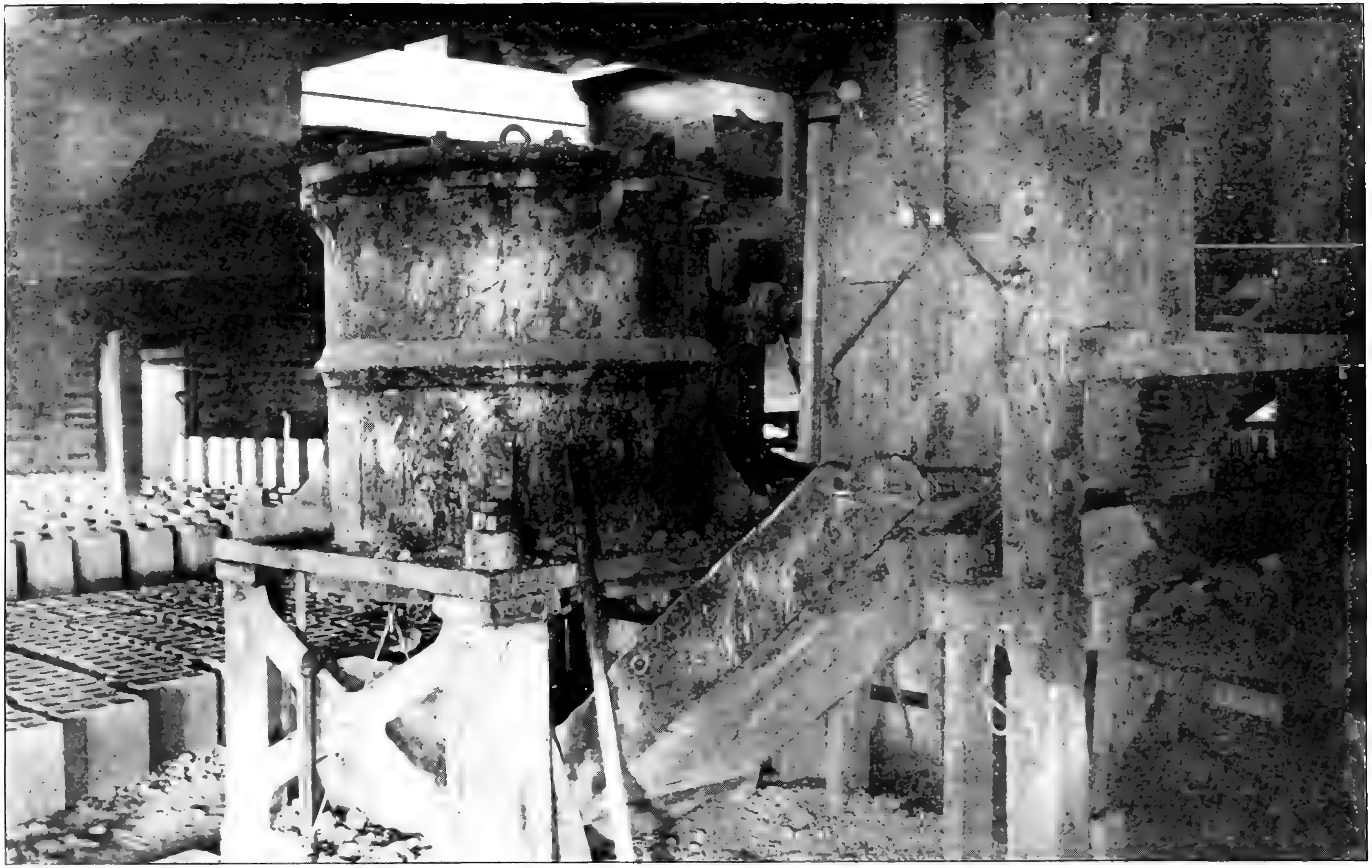
The clay cylinder is filled with clay; and the piston then forced downward by the piston of the steam cylinder above, the piston rod of the two being continuous. This forces the clay out through a specially constructed die at the lower end of the clay cylinder. Inside of the cylinder at its lower end is the bell, which regulates the internal dimension of the pipe. The clay pipe issues from the press till of sufficient length, when the machine is stopped, and the pipe cut off, and removed to the drying floor. The cutting off of the clay pipe takes place close to the mouth of the die either by means of a wire or an automatic knife edge set within the die.

The drying of the pipe is often done on slatted floors, or at other times on solid ones, in steam-heated rooms. The small diameter pipe can be dried comparatively fast, but the large ones must be dried very slowly.

Sewer pipe are usually burned in down-draft kilns, from 16 to 25 feet in diameter. (pl. 97) The pipes are set on one another, and when they are of several sizes can be nested.

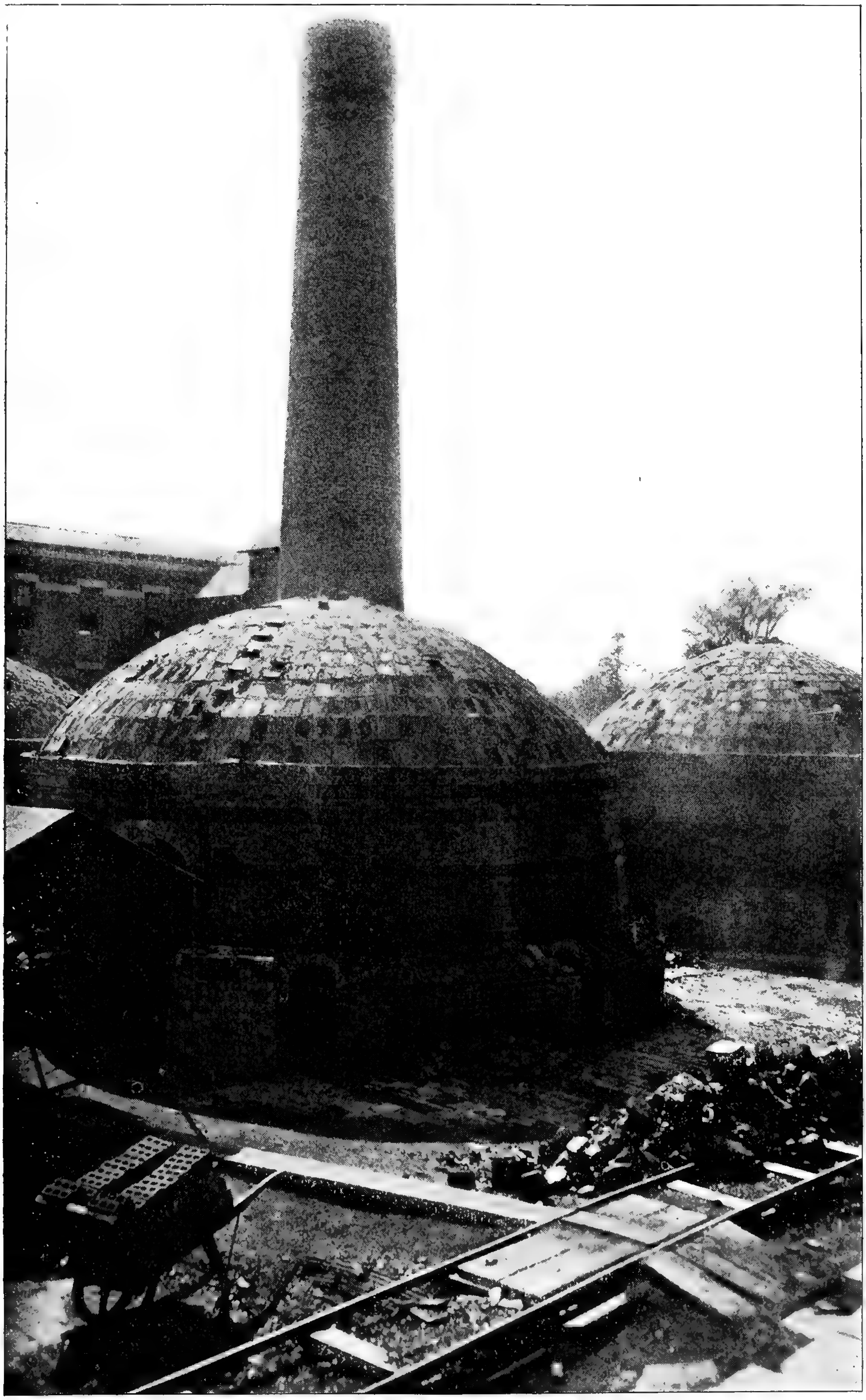
Sewer pipe should be free from blisters, cracks and other defects, and should be straight.

Plate 96



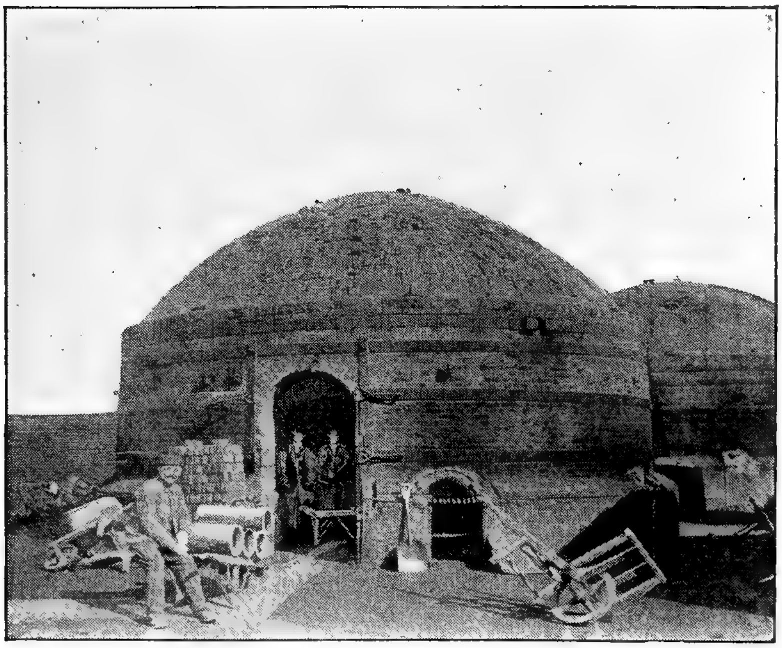
H. Ries photo.

Steam cylinder of sewer pipe press. J. Lyth & Sons, Angola.



H. Ries photo.

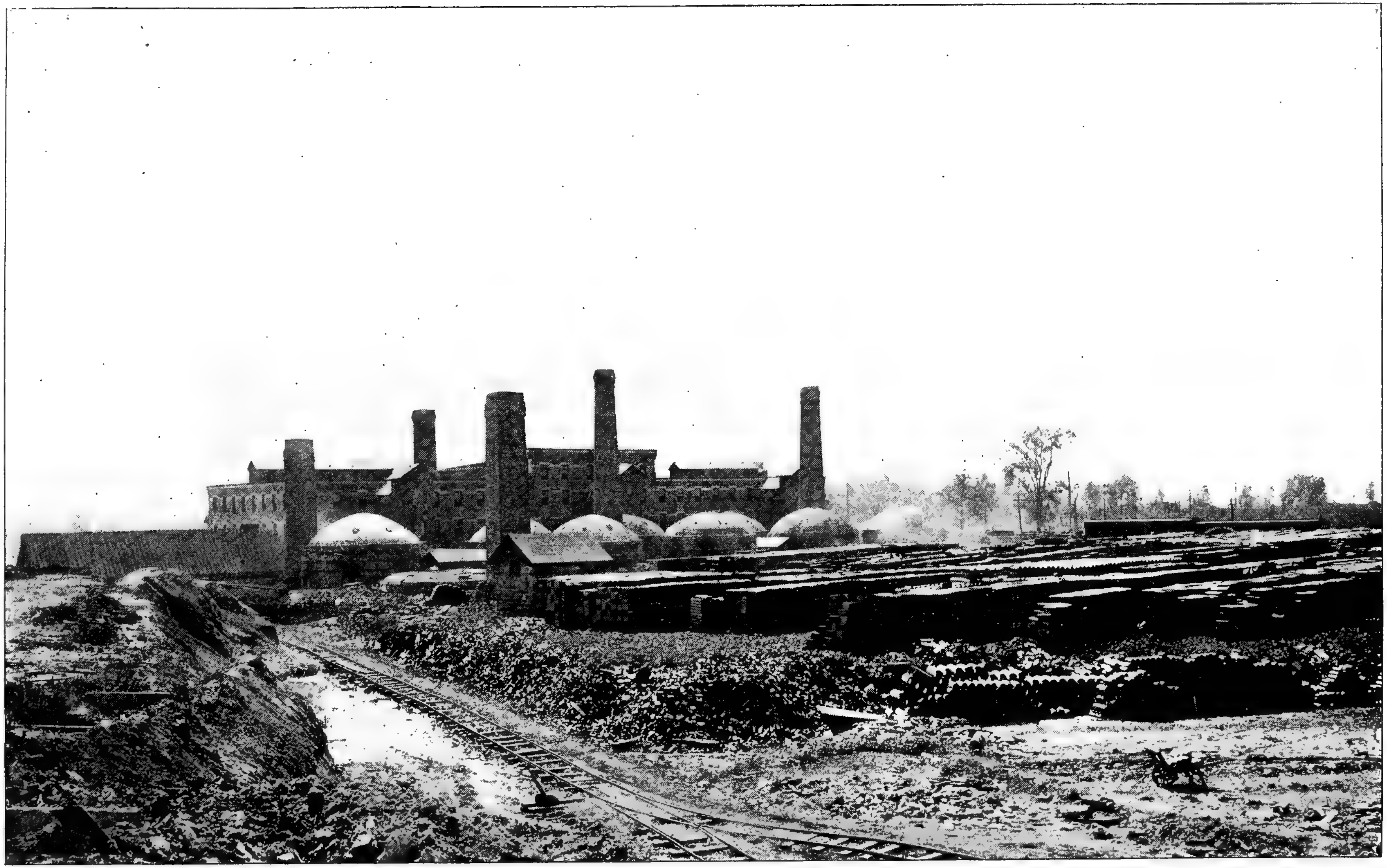
Circular down draft kiln, J. Lyth & Sons, Angola.



Circular down draft kiln for burning sewer pipe and drain tiles. J. Lyth & Sons, Angola.

Plate 99

To face page 769



H. Ries photo.

General view of sewer pipe and hollow brick works. J. Lyth & Sons, Angola.

Plate 100

H. Ries photo.

Shale bank, J. Lyth & Sons, Angola. The roofed over portion is worked in winter.

Elbows and Y's are made by molding the clays in plaster molds; or in the case of Y's and T's, straight pieces of pipe are sometimes trimmed to fit together in the desired shape and the parts cemented by slip. Such complicated pieces need to be dried more slowly.

Sewer pipe are made from 2 to 2½ feet in length; the diameter ranges from 3 to 30 inches.

New York sewer pipe industry

Angola. John Lyth & Sons. The works are situated along the Lake Shore railroad some few hundred feet southwest of the station. The material used is the Portage shale, of a gray color and containing streaks of bituminous matter. It is mined about 200 feet east of the factory. A small blast serves to loosen a large quantity of it. A part of the bank is roofed over to protect the workmen in winter. Cars drawn by horses convey the shale to the dry pans, where it is ground to a fine powder and then farther ground with the addition of water in a wet pan. The tempered material is carried in a bucket ladder to the upper floor of the building, where it is fed into the sewer pipe press.

The composition of the shale used at Angola is

Silica	65.15
Alumina	15.29
Oxid of iron	6.16
Lime	3.50
Magnesia	1.57
Alkalis	5.71
	97.38

At the present time hollow brick and terra cotta lumber form the chief product of the factory.

Rochester. Otis & Gorsline use a mixture of New Jersey fire clay and Quaternary clay obtained from Chili, near Rochester. The method of manufacture followed by them is very similar to that at Angola. Rectangular kilns are however used for burning, which takes about one week.

Sewer pipe are also manufactured at Albany and Troy but from New Jersey clays.

Drain tile

A clay that is capable of making good building brick will usually make a good drain tile. That is to say, a plastic clay and one that will burn to a tough product. Unlike bricks, tile may be somewhat porous in its character. It is of importance that the clay should be thoroughly tempered before molding. The latter is, in most instances, done with some form of stiff mud machine, the clay being forced out through a die of desired pattern; the cylinder of clay as it issues from the machine is cut up into desired lengths. Drying is sometimes done on pallets such as are used for common brick, or it may be done under inclosed sheds. The drain tile should be thoroughly dry before being set in the kiln. Burning is done in ordinary scove-kilns, clamps or down-draft kilns. The smaller tile are set in the lower portions of the kiln and around the sides, while the larger ones are set in the center. Very often when several sizes are burned at the same time they are nested, the smaller ones being set within the larger.

The dimensions of cylindric tile usually run:

Diameter	Length	Weight by piece
2 inches	13 inches	3¾ pounds
3 "	" "	6 "
4 "	" "	9 "
5 "	24 "	18 "
6 "	" "	24 "
8 "	" "	30 "

The styles of drain tile made are as follows:

Horseshoe tile, having cross-section shape of a horseshoe

Sole tile, cylindrical with a flat base

Pipe tile, plain cylinder

Flange tile, like the preceding but with the flange at one end

It is considered by many that the best form of tile is the sole tile with an egg-shaped section having the smallest diameter across the bottom, which keeps the water collected in the smallest possible space and secures a good current to carry off the sediment. The horseshoe tile is objected to, as it is liable to break from the lateral pressure of the soil. In Westchester co. glazed sewer pipe are generally used for draining the soil, but it is doubtful if there is any special advantage to warrant the use of this more expensive material. In size the tiles range from 2 to 12 inches in diameter and 1 to 2 feet in length. They are laid at varying distances below the surface, according to the depth the ground is to be drained. A drain is said to draw water from the soil on either side for a distance of from 30 to 100 feet, according to depth of drain and character of soil.

The following firms in this state are making drain tile.

Albany, Albany co. The New York state drain tile works are large producers. The drain tile are made in numerous sizes. Hudson river clay is used. Front brick are manufactured.

Chittenango, Madison co. Central N. Y. drain tile and brick co. Only tile manufactured at present. The plant is situated about 1 mile from the New York Central railroad, and three quarters of a mile from the West Shore railroad, a few rods south of the Erie canal. The clay bed lies at the foot of the hill. There is no stripping, and sand underlies the clay. The tiles are made with horse power machinery, dried under sheds and burned in down-draft kilns.

Allenshill, Ontario co. B. G. Abbey's are the only works here. Few brick have been manufactured for several years, as drain tile is the chief production. After stripping a few inches of soil the clay is mixed from top to bottom of the bank for use. The bank is 20 to 25 feet in hight, and the clay is blue in color, becoming reddish gray near the surface. A small amount of coal dust is added to the clay. The tiles are made of various sizes.

East Bethany, Genesee co. B. F. Peck manufactures brick and drain tile. The clay deposit worked is a portion of a strip 1 to

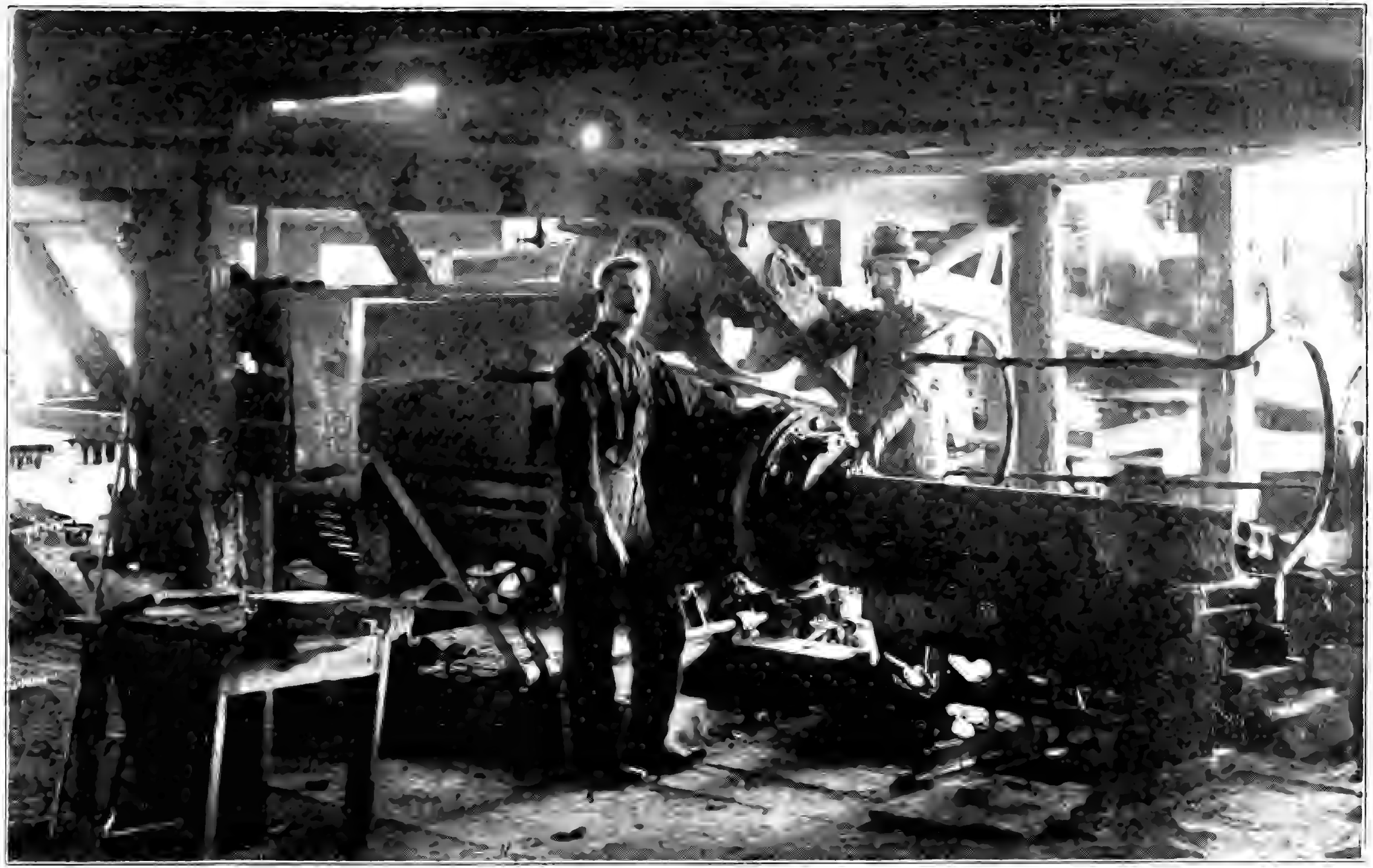
2 miles in width, extending east and west across Genesee co., a few miles north of its southern boundary. The clay is usually covered with a thin layer of clayey loam. Mr Peck has about 50 acres of clay of sufficient quality for making bricks and tile. It averages about 4 feet in thickness. The upper portion when dry is nearly white, but becomes blue with the depth, and below 4 feet is very much so. It is also tough, coming up in hard flakes of a stony nature. Below this it passes into the shale, hard enough to resist the pick but crumbling on exposure. The last-mentioned rock is said to contain calcareous layers, varying in thickness from 1 to 6 inches. About 250,000 feet of drain-tile is annually made for local use. The clay burns to a nice red in the drain tile, deepening to brown when burned harder. The machinery is run by steam power.

Owasco, Cayuga co. A. Lester's clay bank and brick yard are located in the north end of Owasco village on the bank of Owasco creek. The clay deposit has an area of about 9 acres and is from 10 to 15 feet in thickness. Gravel overlies the clay in places. Soak pits are used for tempering, and a Penfield plunger machine for molding. The tiles are dried in an open shed and burnt in scove-kilns. Drain tile is the chief production but a few bricks are made. The color of the product is white.

Other manufacturers of drain tile, whose works have been already mentioned in the detailed account of brick yards, are:

William Davenport, Fonda
C. Stephens, South Bay
Rochester brick and tile manufacturing co., Rochester
A. Mosell, Lockport
James Sigler, Clarkson
J. E. Mecusker & Son, Jamestown
B. G. Abbey, Allenshill
J. B. Lowe, Bigflats
P. Hayne, Goshen
Clark & Sons, Union Springs

Plate 101

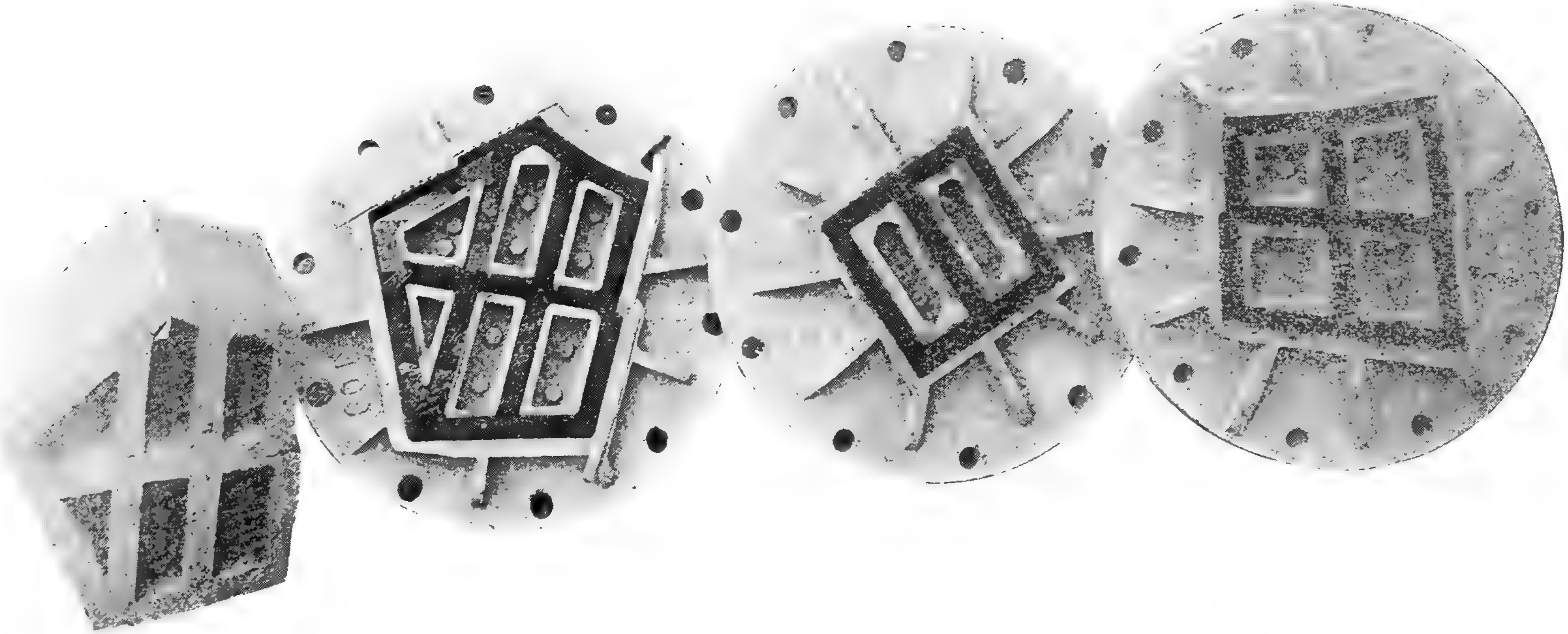


H. Ries photo.

Auger machine molding hollow brick. Rochester brick and tile co.

Plate 102

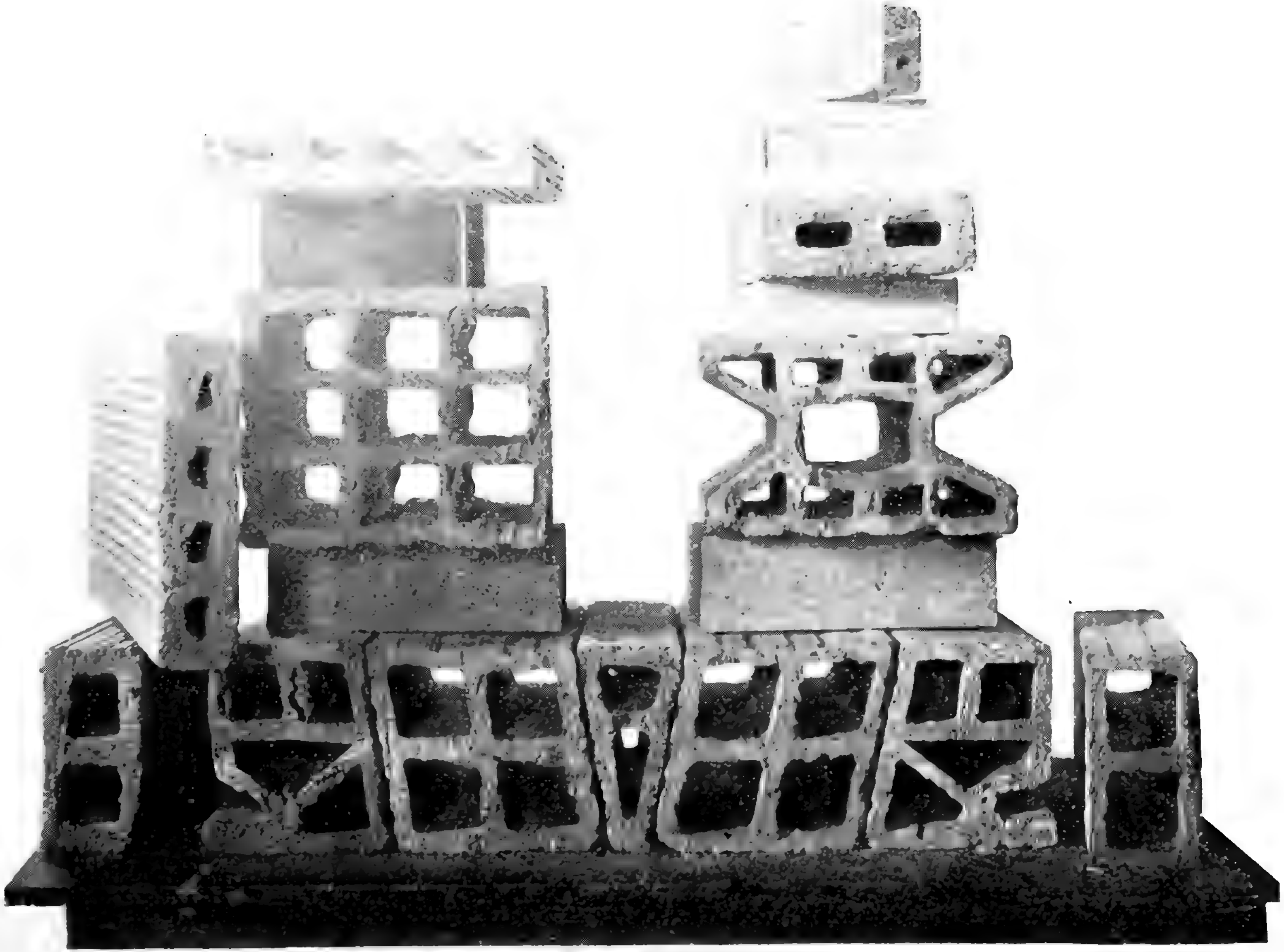
To face page 773



Three styles of die used for making hollow brick. On the extreme left is a brick produced from one of them. Onondaga vitrified brick co., Warners.

Plate 103

To face page 773



C. M. Doyle photo.

Some forms of fireproofing made in pipe press or auger machine. At the bottom of the pile is a flat arch.

HOLLOW BRICK, TERRA COTTA LUMBER, FIRE-PROOFING.

The first term is generally applied to large hollow bricks of more or less rectangular shape, having cross partitions. They are made either of brick clay or semi-fire clay, the latter being the better if protection against fire is desired. The term terra cotta lumber is specially applied to bricks of this class made of a mixture of clay and sawdust, so that in burning the sawdust burns out, leaving the body of the ware porous.

The shape of these bricks is quite variable, and can best be judged by reference to plate 103. They are used for the construction of floor arches, partitions, flue linings, and for wrapping around steel beams and girders. They are also used at times as foundation blocks in buildings, in which case, the brick are salt glazed to prevent absorption, if the body of it is not vitrified. One of the purposes of these bricks is to combine lightness and strength, in addition the hollow spaces serve as nonconductors of heat.

When used for fireproofing purposes, the product should be such that it will resist any heat to which it might be exposed in case of fire, and when heated it should be able to withstand a stream of cold water without splitting off or cracking. It is for the latter reason that hollow bricks used for fireproofing should be made from a semi-fire clay, and should not be vitrified.

Hollow brick are manufactured at a number of places in New York state; the material used is in some cases shale, in other cases clay. They are molded in the same kind of press as sewer pipe. Reference to plate 102 will show the style of die employed.

FLOOR TILE

Tiles made of burned clay are now used to a large extent for flooring as a substitute for marble and slate, for the reason that they are often more durable, wear more evenly, are harder, and can be made in a greater variety of colors and shapes.

While floor tiles are made in this state, in the city of Brooklyn, yet most of the materials used in their manufacture are obtained from other states.

In floor tile of a solid color, the tint extends through the tile from the face to the back. In "encaustic tile" the pattern or face color is only about $\frac{3}{16}$ of an inch thick, while the rest of the tile is made of a different kind of clay.

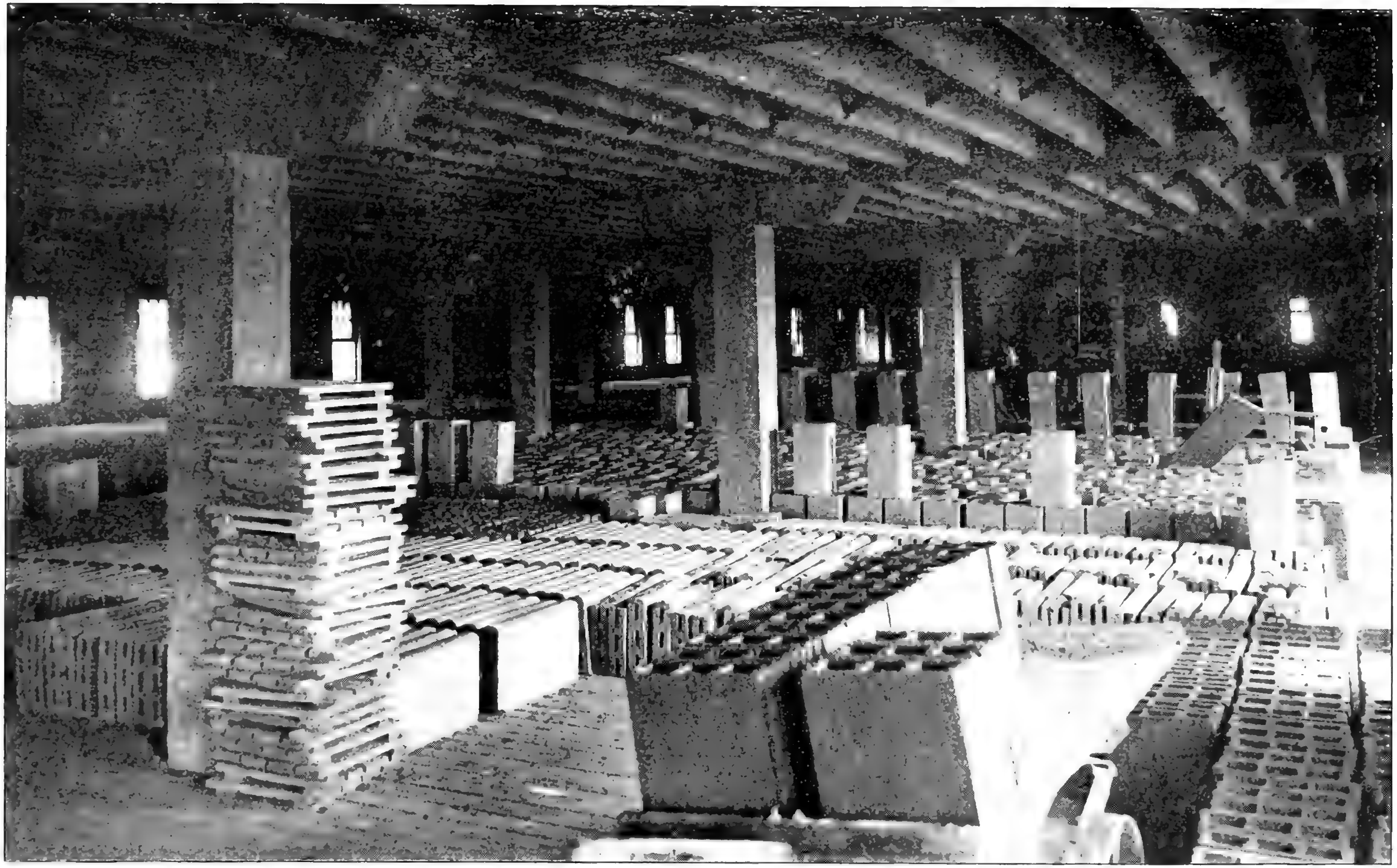
Floor tile are made by the dry press process, and, like dry press brick, are exposed at times to the danger which accompanies this method of molding, viz cracking of the green tile with the expansion of the imprisoned air. When properly pressed, this does not happen.

It is highly essential that the composition of the body should be such that the ware will both dry and burn without cracking or warping. The temperature attained in the burning of these tile depends naturally on the nature of the clay, but it often reaches the melting point of feldspar, as this material is used to a large extent to aid in the vitrification of the body.

Tiles are open to the same trouble from efflorescence, due to the presence of soluble salts in the clay, as other clay products, and the trouble has to be corrected in the customary manner with barium.

Another method of preventing the formation of these coatings on the surface, is to coat the face of the tile with petroleum or tar so that the evaporation in drying can take place only from the back of the tile. (Langenbeck's *Chemistry of pottery*, p. 154) In the firing, this coating of oil or other material burns off, without having

Plate 104



H. Ries photo.

Drying floor for sewer pipe and hollow brick. J. Lyth & Sons, Angola.

done any harm. The soluble salts may also get into the clay from some of the materials used to color the tile artificially, umber, for example, being seldom free from sulfate of lime.

Floor tile should be burned to a condition of great density, in order that they may not absorb water, nor permit the entrance of dirt into their pores, rendering their cleaning more difficult.

Langenbeck (*Chemistry of pottery*, p. 156) gives the following percentages of water absorbed by floor tile of different colors.

Water absorption of floor tile

Color of the clay	Extremes	Averages
Salmon	1.5 — 9.1	5.8
Buff	1.9 — 7.2	4.6
Light gray	1.9 — 8.5	5.8
Dark gray	2.0 — 5.8	4.4
Chocolate	0.0 — 7.4	4.8
Red	1.5 — 8.4	6.0
Black	4.4 — 10.3	7.5
Fawn	....	8.3

In the manufacture of encaustic tile, the clay that is to form the surface of the tile and give the pattern is charged into the mold first, while the clay that makes up the body is then put in on top and the whole subjected to pressure in the machine. The molds can be filled by machinery when the color of the tile is solid.

With encaustic tile the molds have to be filled by hand. Where the pattern is made up of clays of several different colors, a framework of brass strips, so arranged as to mark the boundaries of each color is first set into the mold, thus dividing it up into cells. Into each of these the color is charged by means of a small hand scoop, till every cell is filled with the color whose boundaries it incloses. The framework is then withdrawn from the mold, and the latter filled up to the top with the clay that forms the body of the tile.

It is essential that the clay forming the face and that which serves as the backing should have the same expansion, otherwise they would separate in burning; furthermore the density in the burned condition should be the same.

Both solid and encaustic tiles are made in many different shapes and colors, and the former specially are capable of being laid in a great variety of patterns.

DECORATIVE TILE

While many of the tile mentioned under the previous head could be classed under this one, at the same time it applies more directly to those tile which are not only glazed, but also often ornamented with raised designs. They are used to a large degree for wainscotting, mantels, soda water fountains, etc.

There is but one factory in this state engaged in the manufacture of glazed tile; that is the Tarrytown porcelain tile co.'s at Tarrytown.

Glazed tile are made by the dry press process. The color of the body is generally white. The relief of the surface is often very prominent, and over this there is usually a heavy coating of colored glaze, the variation of the glaze in depth being depended on to bring out the decorative effect, as those portions over which the glaze is thickest appear the darkest. Glazed tile should show the same freedom from warping in drying and burning as those previously described; and in addition the glaze should be free from cracks or crazes, pin holes and bubbles.

Sometimes colorless glazes are used, at others a tin glaze imparts a white opaque covering to the tile. For other colors the oxids of cobalt, nickel, copper, chromium, manganese, iron or uranium are used according to the colors desired.

Methods of decoration.

These have already been referred to in part under the description of the methods of manufacture.

While the use of natural clays permits the production of a considerable range of colors, nevertheless these fall far short of the ambition of the ceramic chemist and the demands of the architect.

As the use of artificial coloring materials is often expensive, the color decoration is applied to the surface of the ware only, instead of allowing the design to extend through the body.

Slip decoration. A slip of coloring material is sometimes applied to the tile either in its burned or unburned condition. The latter can be done in all cases but the former only in certain ones; its use on dry pressed green tiles being among the impossibilities. Before slipping the surface of the tile, it is cleaned with a brush or blower; then it is dipped into the slip. The water of the latter is absorbed, while the insoluble constituents remain as a thin coating on the surface of the tile. If the glaze is to be extremely thin, it is sometimes sprayed on, as is done in the case of terra cotta. The slip is best applied with a brush in the case of raised surfaces or where each color occupies only a portion of the surface of the tile.

The usual method of decorating encaustic tile has already been mentioned in connection with the molding process. A second method is to pour the powdered clay for the different colors into depressions stamped in the face of the tile; while a third consists in painting the design by hand on the surface, or printing it on. The painting can be done on either the glazed or unglazed tile, while the printing can be impressed only on the burned material, either under or over the glaze.

Painting can be done either on the green tile or on the burned ware either before or after glazing.

Painting the green tile. The color is applied by means of a brush, the portion to be colored being outlined by means of a lead pencil if the tile is flat, but with a relief surface this is not necessary. The design may also sometimes be painted by means of a stencil.

If several colors are to be applied, great care should be taken that the different ones shall not overlap. The color, instead of being applied with a brush, is sometimes poured on. The painting on the unburned glazed tile is done in a similar way.

If the design which is being painted on the tiles is very large, it is essential that the tiles shall be placed together in order that the lines of color on adjoining tiles may fit together.

Painting on the burned tile. This can be either over or under glaze. In the latter case of course the glaze must be transparent;

for this purpose, only hard fire or underglazed colors can be used (Dümmler *Ziegel Fabrikation.* p. 95). In producing definite and distinct colors the composition of the glaze exerts as much effect as the character of the coloring material. It is therefore highly essential that the colors used shall always be of the same composition, be ground to the same degree of fineness, and burned at the same temperature. If new glazes or colors are used, they should first be tried experimentally. In the process of burning, the glaze may or may not exert action on the underlying coloring material. In some cases the color will dissolve in the glaze, in others it will only become suspended in it, but in the latter cases the shades are not often soft, and the change from one color to another will be sudden. If on the other hand a color is easily soluble in the glaze, there is the danger that it may run, causing the design to be blurred. In order to prevent this, the coloring materials are generally combined with others, so that compounds of the spinel type are obtained.

To prevent hard colors several devices are employed, such as substituting for a portion of the coloring material a slight amount of arsenic, or placing a little arsenic in the kiln. This method is most advantageously employed when cobalt colors are used.

In addition to underglazed painting, slip or engobe decoration is used. This consists in applying white or colored clay paste to the white or colored tile.

The body can also be colored by dipping it into hydrochloric or acetic acid solution of the coloring metallic oxids. In this case the product is to be once more subjected to a slight ignition.

In slip painting the slip is made of a mixture of the powdered tile glaze and metallic oxid or underglaze colors. These decorated pieces are dried and burned at the temperature of the melting of the glaze. The whole is then covered with a thin coating of glaze and burned once more. If the slip contains 50% or more of glazing material, the second glazing operation is not necessary.

Overglaze decoration requires strongly coloring oxids which are mixed with some easily fused material, and rubbed together with oil. Such colors are very susceptible and hence have to be burned in muffles. They are also strongly influenced by the degree of temperature to which they are subjected, and hence the different colors are often burned separately, those standing the highest temperature being applied and burned first, and those most affected, last. This method of decoration requires repeated burning, but it permits a variety and richness of color not attainable in underglazed work.

In preparing these colors, it is highly essential that they be ground as finely as possible, and underglaze colors are generally mixed with water before being applied, the porous body of the tile absorbing the moisture and causing the color to cling to it. If this does not happen, the color must be mixed with oil, in which case the ware must be fired lightly at first, to burn it off.

At the present day, where a number of tile with the same design are made, the design is applied mechanically. This is effected by a process of printing, the pattern being printed on paper from a plate and this transferred to the tile. Usually but one color at a time can be printed on the paper. But in more recent years it has been found possible by a process of chromolithography to print several colors on the ware at once.

Plate 105

To face page 781

H. Ries photo.

Bank of Cretaceous fire clay, Kreischerville.

FIRE CLAYS

Definition. Strictly speaking the term fire clay can be said to include those clays which are able to withstand a high temperature. Regarding the condition of the plasticity, the shrinkage in drying and burning, the texture, and color, no fixed rules can be laid down; for, except in refractoriness, fire clays show a wide variation in physical characters.

Refractoriness. The degree of temperature which a fire clay should be able to withstand without fusing has not been entirely settled in this country, but in Europe, specially in Germany, a clay is not considered refractory unless its fusing point lies above 2700° F.

Nevertheless many of the clays denominated fire clays which are marketed in this country are not up to this standard, while others are far above it. The color of fire clays varies, but they are not infrequently colored bluish gray, gray or black by organic matter. Some of those mined on Staten Island are pure white or yellowish white, but at the same time they are highly refractory.

Fire clays are divisible into two groups, the plastic, and the non-plastic or flint clays. The former sometimes occur in the form of hard shales which become plastic on grinding and mixing with water, whereas no amount of grinding renders the flint clays more than very slightly plastic. The latter are not found in New York state, but occur abundantly in Pennsylvania, Ohio, Kentucky, Missouri and one or two other states.

In chemical composition the flint clays stand close to kaolinite, and at times even exceed it in the percentage of alumina which they contain. (See Kaolin, p. 503.) Flint clays vary in color, being gray, black, brown or even yellowish. The iron contents of the bed are generally collected in concretionary masses. In many Pennsylvania mines there often occurs considerable iron oxid, and iron carbonate, which are known as ore-balls.[1] The iron oxid concretions are generally near the surface, while the iron carbonate is confined to the interior of the bank. In the mining of the clay, these concretions have to be picked out. This collecting of the iron by natural processes has therefore served to purify the clay mass; where it has not taken place the material loses its value as a refractory clay. Flint clays are hard, they lack plasticity, have a conchoidal or shell-like fracture, and sometimes a very faint luster. At times they occur in beds interstratified with other rocks, or again they may occur as basin-shaped deposits, in which case they seem to have been formed by chemical precipitation.

The color of a fire clay is an indication of its refractoriness only to a limited extent. Many fire clays are bluish in color, while others are light gray or yellowish white. A given amount of iron will color a sandy clay more strongly than a less silicious one; the same is true of organic matter. The latter might even mask the color of iron. The condition of oxidation of the iron would also cause a difference in color, ferric compounds being red or yellow, while ferrous ones may be blue or gray.

Whatever the color of the fire clay in its unburned condition, in the fired state it is always buff, unless vitrified, when it may become red.

The refractoriness of a fire clay is dependent almost entirely on its chemical composition. It can be said in general that the more powerful fluxing impurities, such as ferric oxid, lime, alkalis, and magnesia should not exceed 1% if possible. Many fire brick manufacturers do not seem to recognize the fact that silica acts as a flux at high temperatures.

The recent experiments of H. O. Hofman tend to indicate that in the case of fire clays at least the size of grain has no effect on the fusibility of the mass. The tests which he carried out are described under "Fusibility of clays" p. 563.

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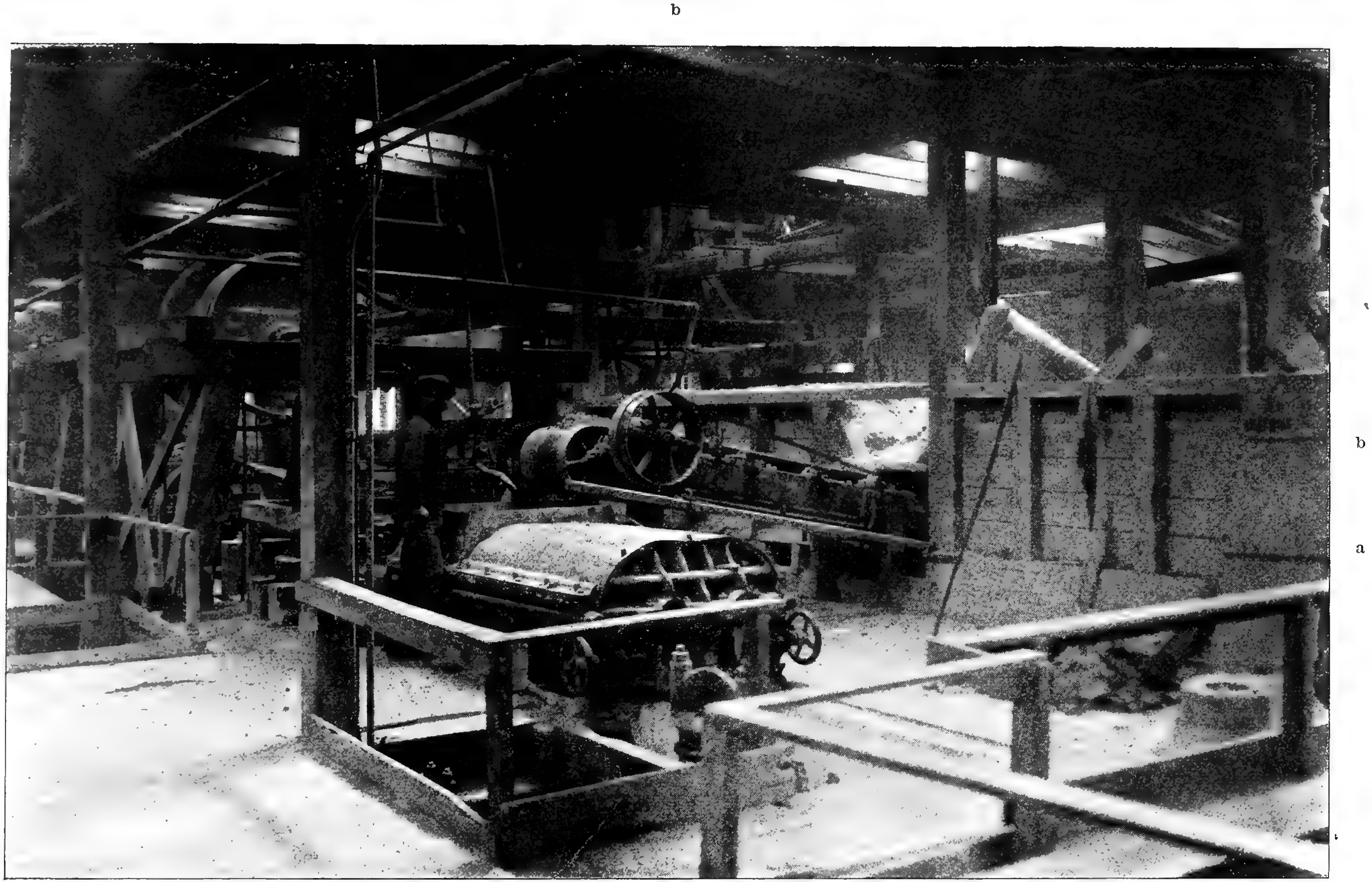
[1] *Annual report Pa. state college.* 1897. p. 52.

Plate 106

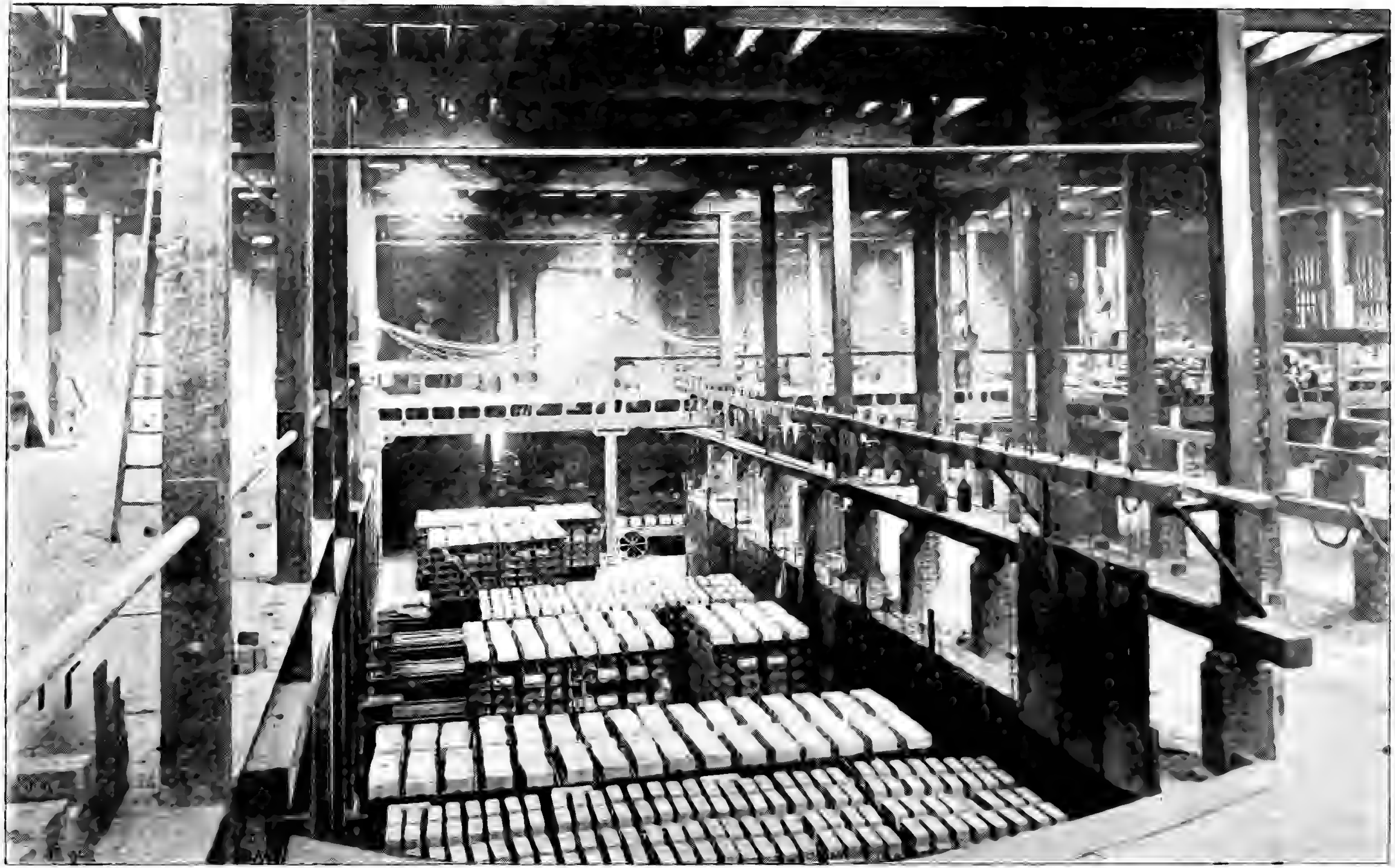
To face page 782



H. Ries photo.

Double pug mill (a) with belt (b) for feeding clay at the rear of it. B. Kreischer's Sons, Kreischerville.

Plate 107



H. Ries photo. Drying tunnels with cars of green brick ready to enter them. B. Kreischer's Sons. Kreischerville.

The following figures indicate the fusibility of several well known American fire clays, the fusion points being expressed in terms of Seger's cones. For comparative purposes the refractoriness of several standard European clays are given.[1]

1	Kreischerville, N. Y. white clay	35+
2	St Louis, Mo. Christie raw clay	31–30
3	Golden, Col.	32–31
4	Mineralpoint, O.	33
5	Mt Savage, Md. (hard)	34–35
6	Sayreville, N. J.	35

Refractory clay products

Fire bricks. These are the commonest fire clay products, since most of the refractory clay mined is used for this purpose. They are utilized in many different ways; consequently not only the shape but also the quality varies. In certain cases the brick has to withstand high temperature, in others corrosion by molten materials, while again in other situations resistance to abrasion is required.

The bricks set in the upper part of a blast furnace must resist abrasion, those in the boshes must resist corrosion, and the same condition must be complied with in glass pots.

An idea of the number of shapes and sizes of fire brick manufactured can be gained from the statement that one large steel company in this country uses 200 different ones.

Many fire bricks are used for lining coke ovens. For such service it is highly essential that they be able to withstand sudden changes of temperature and not crack when the coke oven is watered down after burning. The degree of heat which such brick are subjected to is not very high. None are made in New York state.

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[1] No. 1 tested by the writer. The others by H. O. Hofman, *Trans. Amer. inst. min. eng.* 25: 14.

Other refractory articles are locomotive and steamboat tile, steel runners, sleeves, nozzles, crucibles, stove linings, glass pots, gas retorts, tuyeres, rolling-mill tiles, hexagon stove shapes, grate backs and stove linings.

In addition to fire bricks made from clay alone, several other types of refractory bricks are recognized.

Dinas brick are made of about 97% silica and 3% of some material such as lime to bind the grains together.

Silica brick is practically another name for the above mentioned.

Ganister is a refractory silicious rock which has about enough clayey matter to hold it together when wet.

Magnesite bricks are made of magnesite, the carbonate of magnesia.

Manufacture of fire brick

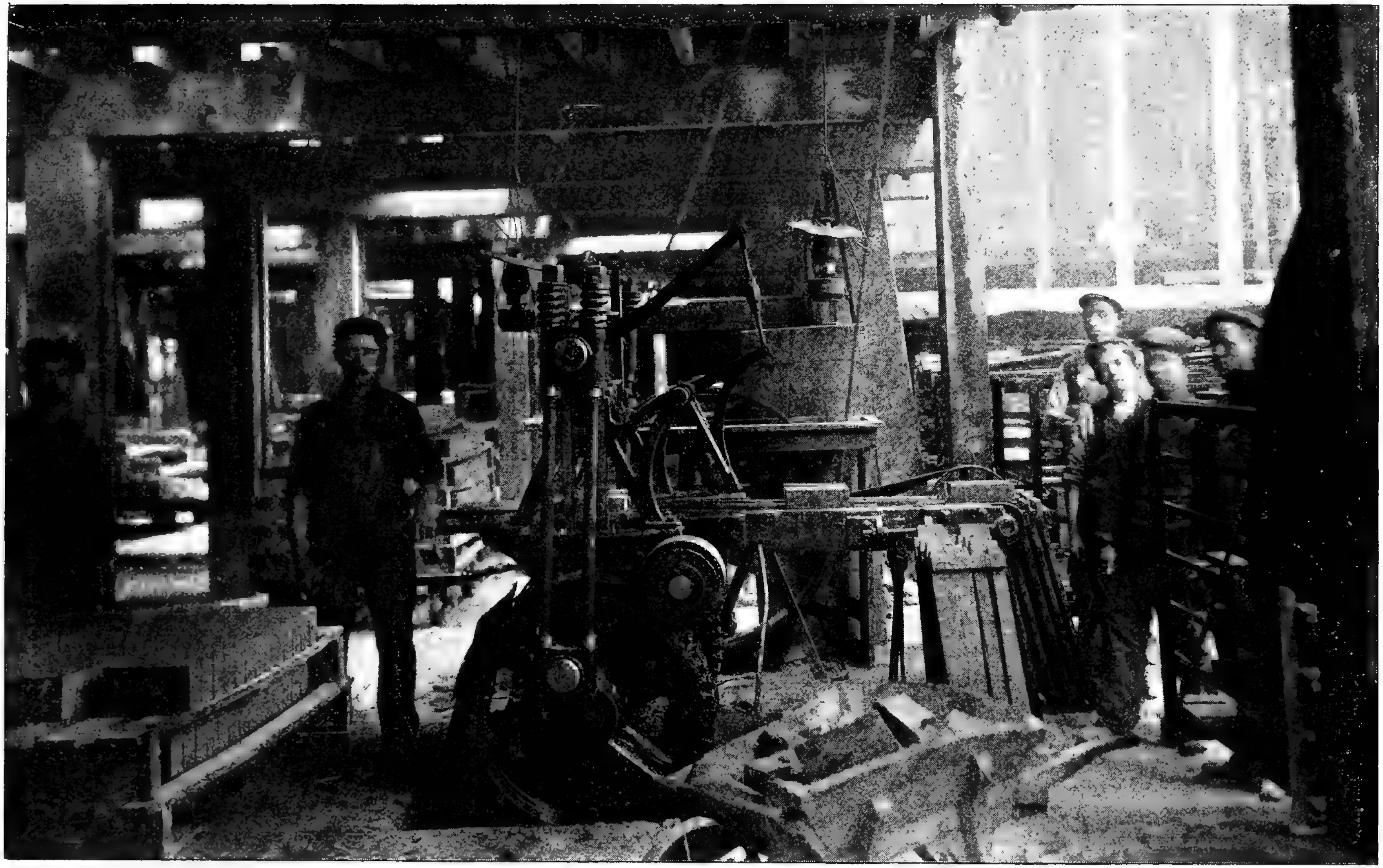
Fire brick are commonly made of a mixture of clays, to which is added a certain percentage of ground fire brick or burned clay, and sometimes sand. If the clay is in the form of shale, it is commonly ground in a dry pan, and the old brick which serve as grog are treated in the same machine.

The different ingredients are often charged into a large pit, one layer over another, and the whole mass thoroughly soaked with water. When sufficiently soaked the mixture goes to some form of pug mill, in which it becomes more thoroughly mixed.

In some works the clay is tempered in a wet pan, which for flint clays has to be of more powerful construction than for shales.

The molding of fire brick is ordinarily done by hand in wooden molds, though a minority of fire-brick manufacturers use stiff mud or soft mud machines.

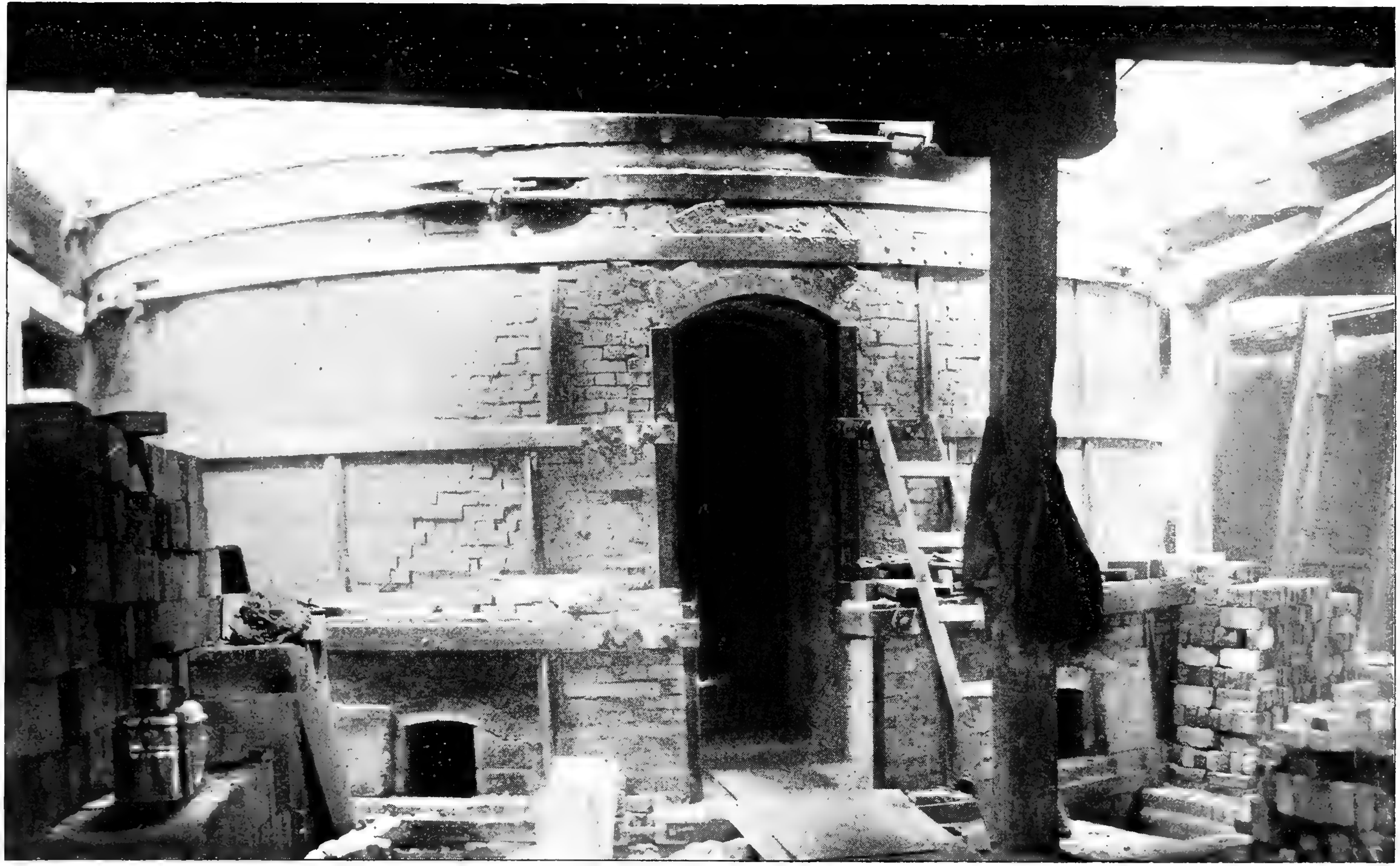
The machine-made fire brick meet objectors who say that their density reduces too much their resistance to alternations of temperature, and the lamination imparted by stiff mud machines is also brought forward as an objection; but, as fire brick clays are often less plastic than many used for common or front brick, the laminations are less pronounced.



H. Ries photo.

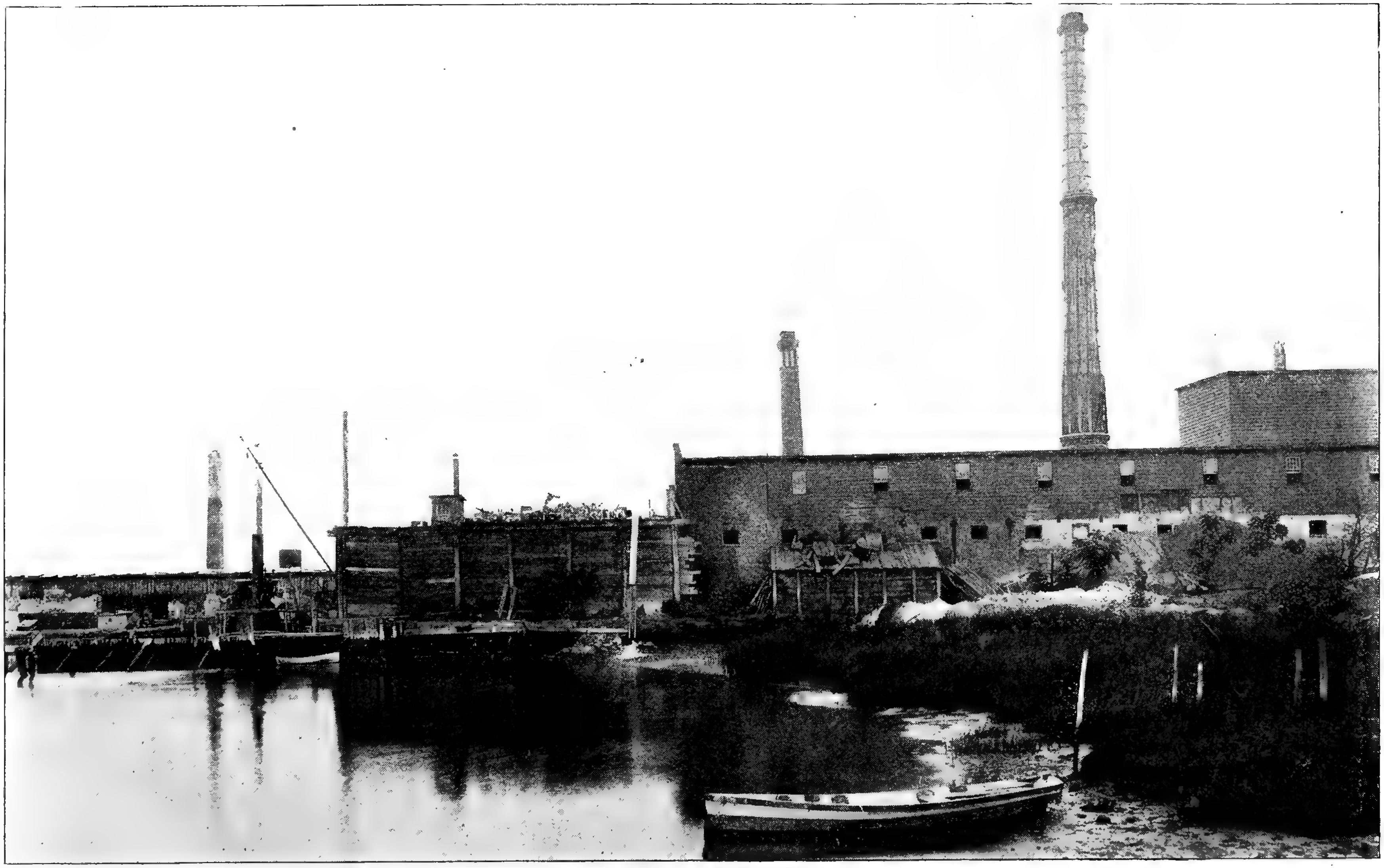
Side view steam power repressing machine. B. Kreischer's Sons, Kreischerville. Bricks are put in at left hand side and removed from discharge belt on right of machine.

Plate 109 To face page 784



H. Ries photo. Circular down draft kiln used for burning fire brick. B. Kreischer's Sons, Kreischerville.

Plate 110 To face page 785



H. Ries photo. Fire brick works, B. Kreischer's Sons, Kriescherville.

Fire brick when molded are commonly set on the floor to dry for a few hours, after which they are repressed.

They are then loaded on cars and sent to the drying tunnels. (See description under Drying of bricks, p. 668) The rapidity with which the drying can be carried on depends on the porosity of the clay, its plasticity and the size of the molded object.

The burning of fire brick is done either in up or down-draft kilns, of either circular or rectangular form.

Behavior of refractory brick when heated

In some experiments recently made by J. D. Pennock[1] to determine the heat conductivity, expansion, and fusibility of refractory brick, bricks made of Grecian magnesite, American magnesite, silica brick, and coke oven tiling made in Belgium, were used.

In the charts and detailed figures given by Mr Pennock it is shown that the Grecian magnesite conducts heat the most readily, the American next, then the silica brick, while the coke oven brick is the poorest conductor. The poor conductivity of the coke oven brick is thought to lie in its purity and density.

Expansion tests of fire brick

	Expansion of core	Expansion per 12 inch brick
	Inch	*Inch*
Grecian magnesite	0.07	0.11
"	.07	.11
American magnesite	.067	.10
"	.057	.088
Coke oven tiling	.05	.076
"	.05	.076

The expansion test was made by supporting a core of the brick in a horizontal position. One end was against a support and the other against a movable lever. The core was heated by means of burners placed underneath.

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[1] *Trans. Amer. inst. min. eng.*, September, 1896. p. 263.

Analyses of fire brick used in above tests

	Grecian magnesite	American magnesite	Silica brick	Coke oven tiling
SiO	2.16	3.10	94.07	69.89
$Fe_2O_3+Al_2O_3$	.72	6.64	3.66	27.75
CaO	4.20	3.76	1.39	.27
MgO	93.03	86.50	.19	.17

The specific gravities and weight to the cubic foot were:

Specific gravity of fire brick

	Specific gravity	Weight a cubic foot *Pounds*
Grecian	3.54	170.2
American	3.44	160.9
Coke oven tiling	2.56	109.9
Silica brick	2.54	111.4

Glass pot clays

Glass pots are made of a special grade of refractory clay, whose necessary qualities are given below. While no glass pot clays are found in this state, still many of the glass factories in New York obtain the raw clays elsewhere and make the pots at their works. Great care has to be exercised in their manufacture; not only must the clay be thoroughly weathered, but the molded pot must be free from the slightest cracks and exhibit a homogeneous structure throughout.

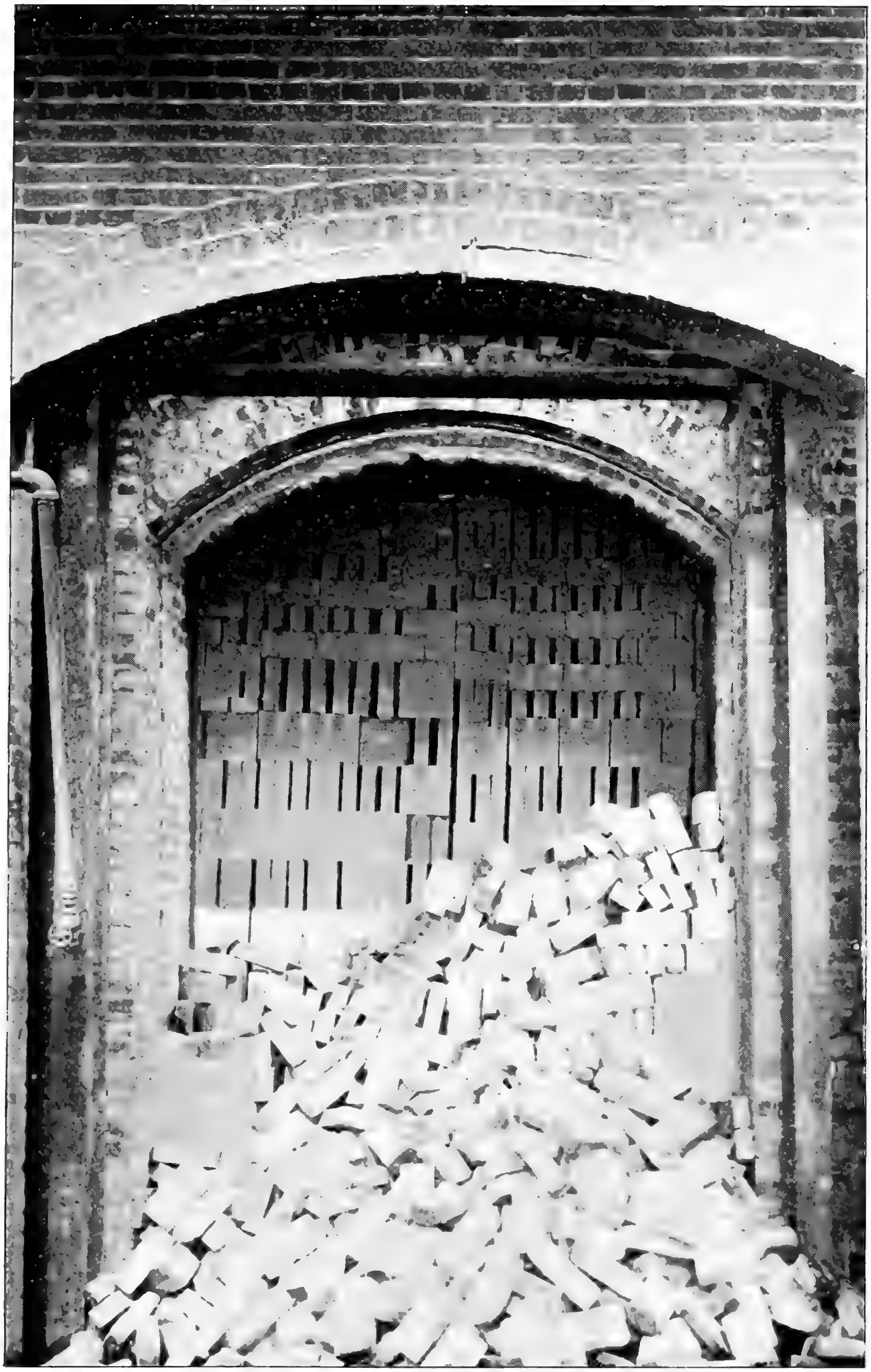
Requisite characters. A clay, in order to be suitable for the manufacture of glass pots or blocks for tank furnaces should conform to the following requirements:

1 Sufficient refractoriness to withstand the highest heat used without changing form

2 Great plasticity, such that the addition of 50%–60% of grog will not affect it appreciably

3 In burning, density at as low a temperature as possible

A clay is generally considered sufficiently refractory for making glass pots if its fusion point is the same as that of cone 30. It



H. Ries photo.

Entrance to fire brick kiln which has been opened up at the end of the burning. B. Kreischer's Sons, Kreischerville.

should also burn dense at so low a temperature that when grog is added the heat will not need to be raised too much in getting the required density. The addition of grog will raise this point to an extent depending on the amount added. Thus the temperature of densification of a mixture given below is the same as cone 5, while that of the clay is cone 1. If now a clay is used as binding material which sinters at high temperature, the temperature at which the mixture becomes dense will be so high as to make its burning difficult.

In judging the tensile strength, the size of the grain of grog must be considered, as also the relation in which the different sized grains are mixed, but no fixed rule can be laid down for the last point. In the grinding of grog both a powdery product and angular grains are obtained, and practice has shown that it is desirable to add both of these to the clay, since, if the grains alone were added, the mixture would show a tendency to crack.

The following mixture is one given by E. Cramer (*Thonindustrie zeitung.* 1897. p. 47): 100 parts by weight of clay and 120 parts grog. On a sieve of 10 meshes to the square cm the grog left no residue, but 20% remained on a 60 mesh sieve, and 12% on one of 120 mesh, 24% on a 900 mesh, 30% on a 5000 mesh, and 14% went through.

The investigation of glass-pot clay is confined to a determination of plasticity, shrinkage, temperature at which the clay becomes dense, fusion point, and chemical composition.

Clays fulfilling all these conditions satisfactorily are rare in the United States. They are thus far known in only a few regions, being found in Missouri and in small quantities in Ohio and Pennsylvania. In Europe they occur at several localities, in Germany, Belgium, Bohemia, Russia, England, France, and Scotland.

Large quantities of the German and Belgian glass pot clays are annually exported to the United States[1].

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[1] For information concerning the properties of some of these European glass pot clays, see *Report on kaolins and fire clays of Europe.* 19*th ann. rep't U. S. geol. sur.* pt 6.

New York fire clays

Though there are several fire brick factories in the state, all with one exception obtain their clay from New Jersey. The New Jersey fire clays, which are of Cretaceous age, extend in a belt across New Jersey and over on Staten Island, and it is at the latter locality that the refractory clays of New York state occur. The fire brick factory of B. Kreischer's Sons is located on the southwestern shore of Staten Island at Kreischerville. They manufacture fire brick, cupola brick and gas retorts. Most of the clay used is obtained from Staten Island, and the rest from New Jersey. Many openings have been made in the vicinity of Kreischerville. The deepest one made was opposite Kilmeyer's hotel. The clay from it was used for fire brick. It is tough, of a whitish color and mottled with yellow, but its thickness is not very great and there is 15 or 20 feet of stripping. This pit has been abandoned. Southwest of it is another pit, but in this the clay, as first exposed, is of a more sandy nature and overlain by about 4 feet of sand. It was bluish in color and was chiefly used for mortar. In recent years, however, this bank has been strongly drawn on and is now of considerable size (pl. 105). The clay consists of an upper 4 feet of bluish clay, stained here and there with iron, while under it is a less sandy variety. Another opening was made near the shore some years ago, known as the "Wier bank". The material obtained from it was a stoneware clay, and in this pit the clay as exposed in 1892 was 10 feet thick, and is overlain by horizontally stratified fine sand. Since then the bed has been worked out.

In the spring of 1897 a small pit was opened just north of the old one opposite Kilmeyer's hotel. The clay found in this opening is white and extremely refractory. It is also sandy in places, so that two grades are obtained known as no. 1 white, and sandy white.

The white clay when mixed with water gave a moderately plastic and somewhat tough mass. 38% of water was necessary to temper it. The air shrinkage was 10%; the air-dried briquettes had an average tensile strength of only 11 pounds to the square inch, with a maximum of 14 pounds. In burning the total shrinkage up to cone 12 amounted to 18.7%; the color was whitish. At cone 34 in the Deville furnace the clay showed no sign of fusion whatever, and is therefore highly refractory.

A mechanical analysis yielded:

Clay substance	97.66
Silt, very fine sand, fine sand	2.00
	99.66

The composition is:

Silica	47.40
Alumina	39.01
Ferric oxid	.15
Lime	tr
Magnesia	tr
Alkalis	tr
Water	14.10
Total	100.66

The rational composition is:

Clay substance	97.50
Feldspar Quartz	1.50

The sandy clay was more plastic, and required only 31% of water to mix it up. The air shrinkage was less, being only 6.5%, and the tensile strength was 20 pounds a square inch. At cone 9 the total shrinkage was 15% and the color whitish. In the Deville furnace at cone 34 the clay remained unaffected.

The mechanical analysis is:

Clay substance	92.50
Silt	2.30
Very fine sand	.80
Fine sand	4.60
	100.20

A sample of the better grade fire clay from the present large opening was likewise tested, as it represents a common type of clay found on Staten Island.

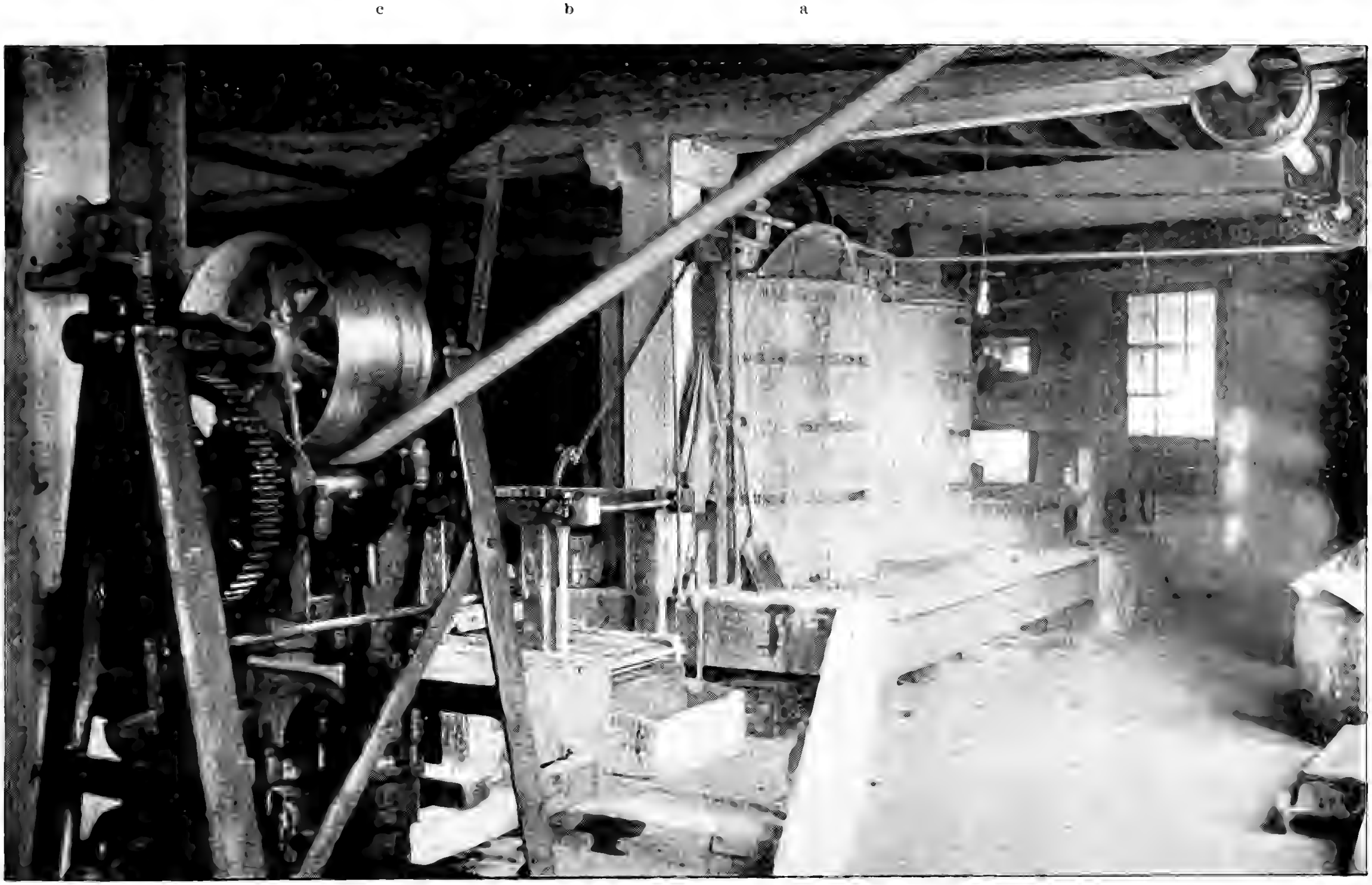
This was far more plastic than the other two; it had a tensile strength of 45 pounds a square inch. 30% of water gave a workable mass, whose air shrinkage was 8.25%. When burned to cone 12 the color was yellowish white and the total shrinkage 17%.

The clay did not fuse at cone 30 in the Deville furnace; so that it can be properly classed as a fire clay.

The mechanical analysis gave:

Clay substance	70
Silt	7
Very fine sand	7
Fine sand	14
	98

Plate 112



Ries photo.

Machinery for preparing porcelain and white earthenware mixtures. The ingredients are mixed to a slip with water in the blungers (a); the slip passes over the lawn sieves (b), and is then forced into the filter presses by the slip pump (c). Pass & Seymour, Syracuse.

POTTERY

The term pottery is properly applied to such articles for domestic or ornamental use as can be turned on a potter's wheel. While this was the original method of forming such wares, in the progress of the art many other methods have been devised, which, in some cases, have superseded the potter's wheel, though this useful machine is still employed to a large extent.

Description of different grades

The more important grades of pottery which are recognized are quite numerous.

Earthenware. This is the lowest grade of pottery, and is usually made from medium or poorer grades of clay. The body is either red or buff, and more or less porous. Earthenware vessels will not hold liquids unless glazed, owing to their porous nature. The common forms of earthenware are flower pots, crocks and jugs.

In recent years glazed or slipped earthenware for ornamental application has found an extensive use.

Stoneware differs from earthenware only in degree, the former being burned to vitrification, with the result that the body is impervious to moisture. The color of the body is either red, buff or bluish black, but this is frequently masked by a coating of salt glaze or slip.

The burning and glazing are done in one operation; and if the ware is coated with slip the latter is applied to the unburned clay.

The uses of stoneware are chiefly domestic, though much ornamental pottery has a stoneware body; the Flemish ware so extensively imported to this country belongs to this class.

Stoneware is commonly made from refractory or semi-refractory clays; the best results are often obtained by using a mixture of them. The clays used should have sufficient plasticity to permit their being molded without cracking. The tensile strength should not be less than 125 pounds a square inch, though 150 is preferable. The clay should not shrink excessively in burning, and should give a vitrified body at not over 2100° F. if possible, for the lower the temperature of vitrification the greater economy in fuel. The clay should however be sufficiently refractory to hold its form at the temperature required to melt the glaze, and not do more itself than vitrify at that temperature. The fusible impurities in a stoneware clay should be sufficiently high to cause vitrification. Ferric oxid forms a desirable coloring ingredient, the same being true of lime if not in excess of 2%–3%. Sulfur in any combination is undesirable, as its escape at high temperatures causes blistering of the ware.

In mixing two clays, the one is generally used for supplying stiffness to the body in burning, and the other, fluxing qualities.

For common earthenware, almost any plastic clay, one which is not too coarse, suffices.

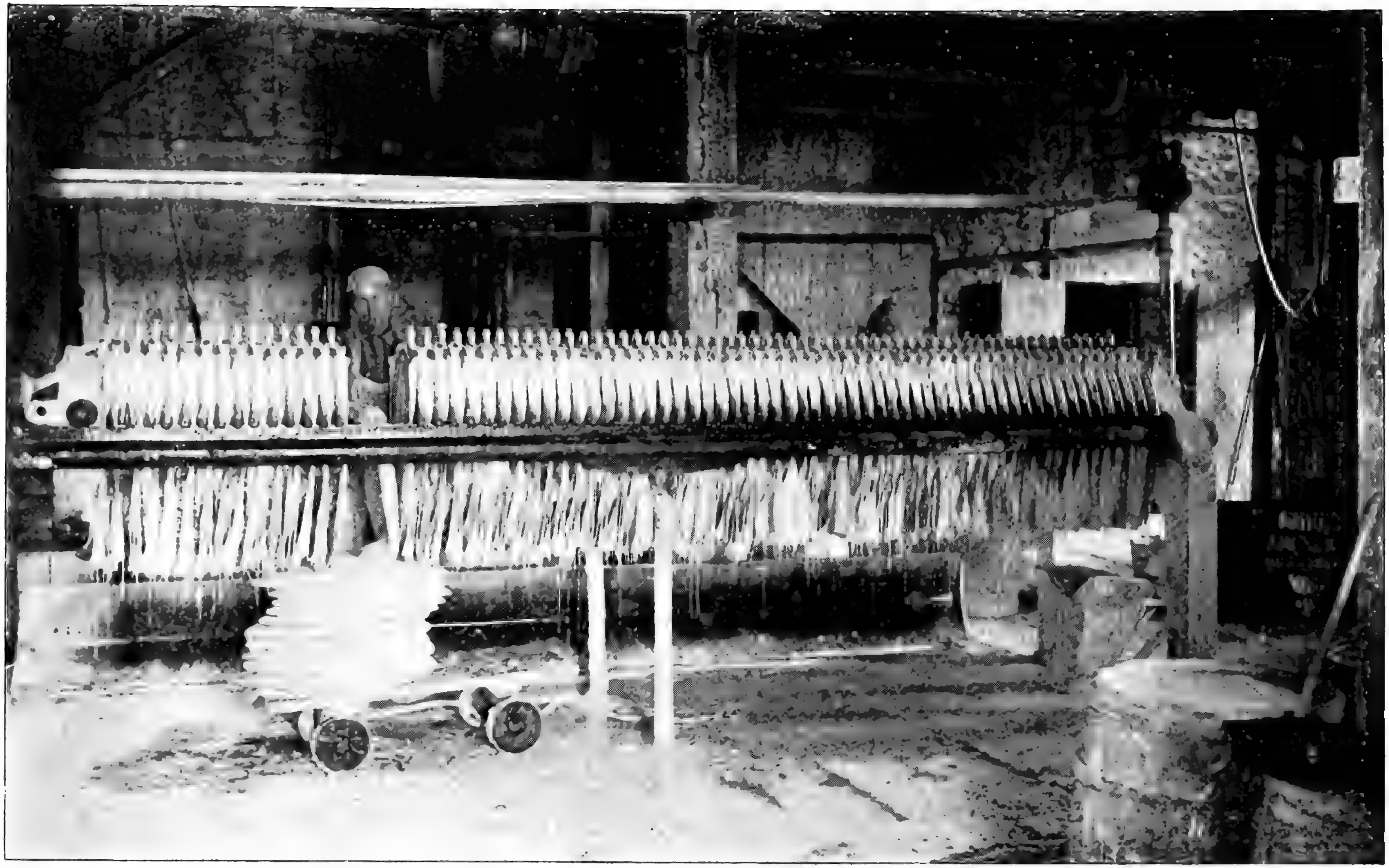
If the ware is to be glazed, the clay should be sufficiently refractory, so that at the temperature required to melt the glaze, it will not burn to more than incipient fusion.

Analyses of stoneware clays are given in the table at the end of this report. In addition, are given here the average of 10 stoneware clays now in use. (E. Orton jr. *Clays of Ohio, Ohio geol. sur.* v. 7, pt 1, p. 95)

Clay base	56.65
Sand	37.45
Fluxes	4.44
Moisture	1.57
	100.11
Total silica	65.09

Plate 113

To face page 792

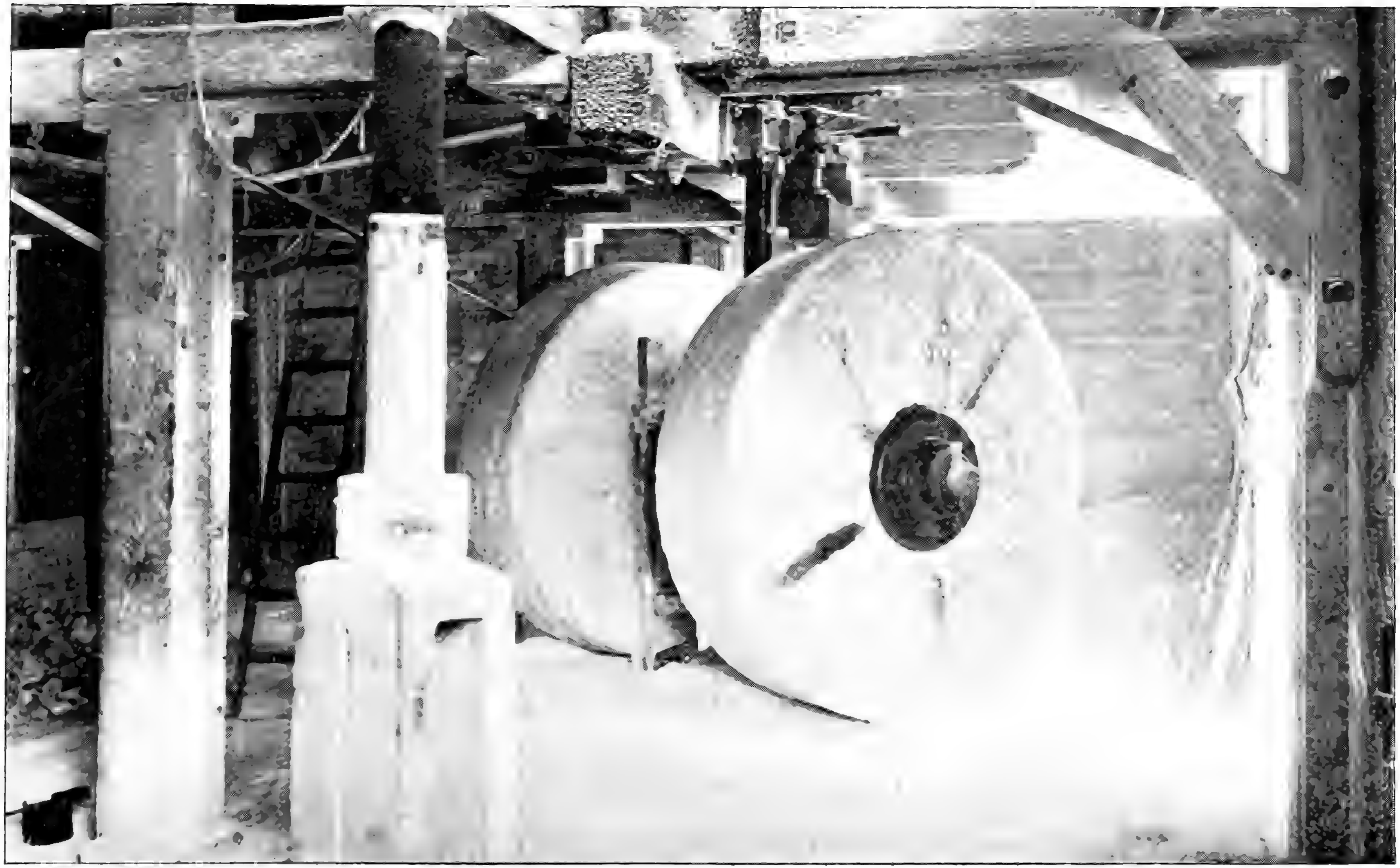


H. Ries photo.

Filter press for pressing the water out of the blunged porcelain or white earthenware mixture. The portion at the left end has been emptied and the leaves of clay taken from it are on the car. The workman is just removing a leaf of clay from the press. Onondaga pottery co.

Plate 114

To face page 793



H. Ries photo.

Buhrstone mill for grinding quartz and feldspar. Union porcelain works, Brooklyn.

Yellow ware and Rockingham ware. These differ from stoneware in that the body is burned first, then glazed and burned again. It agrees with stoneware in being made from natural clays, and with white earthenware, or porcelain, in being burned twice.

In yellow ware the body is covered with a transparent, easily fusible glaze, while in Rockingham ware the glaze is colored brown or black by the addition of manganese.

C. C. ware, white granite. These are made of high grade clays, but not the best obtainable, with other materials. The mixture usually consists of kaolin to form the body, ball clay for plasticity, silica to prevent excessive shrinkage, and feldspar to serve as a flux.

C. C. ware differs from china or porcelain in the quality of the materials used, the clays employed having enough iron to give a slight off color to the ware. Attempts are made to counteract this by introducing coloring material into the glaze.

In white granite or ironstone china the best materials obtainable are used, but the body is not burned to vitrification, and differs in that respect from porcelain. In fact white granite bears the same relation to porcelain that earthenware does to stoneware. A very slight amount of iron will tend to produce a yellowish tint, which is neutralized by adding a small amount of cobalt oxid, that produces a greenish hue far less noticeable.

The kaolins and sometimes the ball clays have to be purified by a washing process; for the percentage of iron oxid which a kaolin contains should be less than 1%. Even though the clay alone may not show any off tint when burned, the presence of a coating of glaze is sure to bring it out, if the iron is present. The kaolins used in this country are obtained mostly from England, North Carolina, and Georgia, while the ball clays come from New Jersey, Florida, Kentucky and Missouri.

Quartz and feldspar are obtained from a number of localities, some of them in New York.

Porcelain

The same materials are used as in the manufacture of white granite, but the proportions are usually different; the ware is burned to vitrification, so that the body is transparent, and the fracture of it would show a vitreous luster.

Porcelain which is fluxed by feldspar is spoken of as spar china. It shows a slightly yellowish color by transmitted light, while porcelain fluxed by calcined bones in part replacing the feldspar is spoken of as bone china. It shows a bluish white color by transmitted light.

The proportion of fluxes is greater in porcelain than in white earthenware; but still, taking porcelains as a whole, there is a wide range in their composition, as will be seen from the following figures representing the range of the ingredients used in the manufacture of hard porcelains. (Hecht. *Dammer, Chem. Tech.* 1 :773 and following)

	Per cent
Clay substance	40–66
Quartz	12–40
Feldspar	15–30
Carbonate of lime (at times)	6

The variation outside of these limits should be very small, for if the clay substance gets below 40%, the refractoriness decreases considerably, as does also the ability of the ware to withstand sudden changes of temperature.

As excessive shrinkage in burning tends to cause cracking and warping, one aim of ceramic chemists has been to produce bodies of low shrinkage; and experiments have indicated that the use of porcelain *sherds* ground up gives a much more homogeneous mass than can be obtained by the use of quartz. (*Chemiker zeitung.* 1895. p. 89)

Plate 115

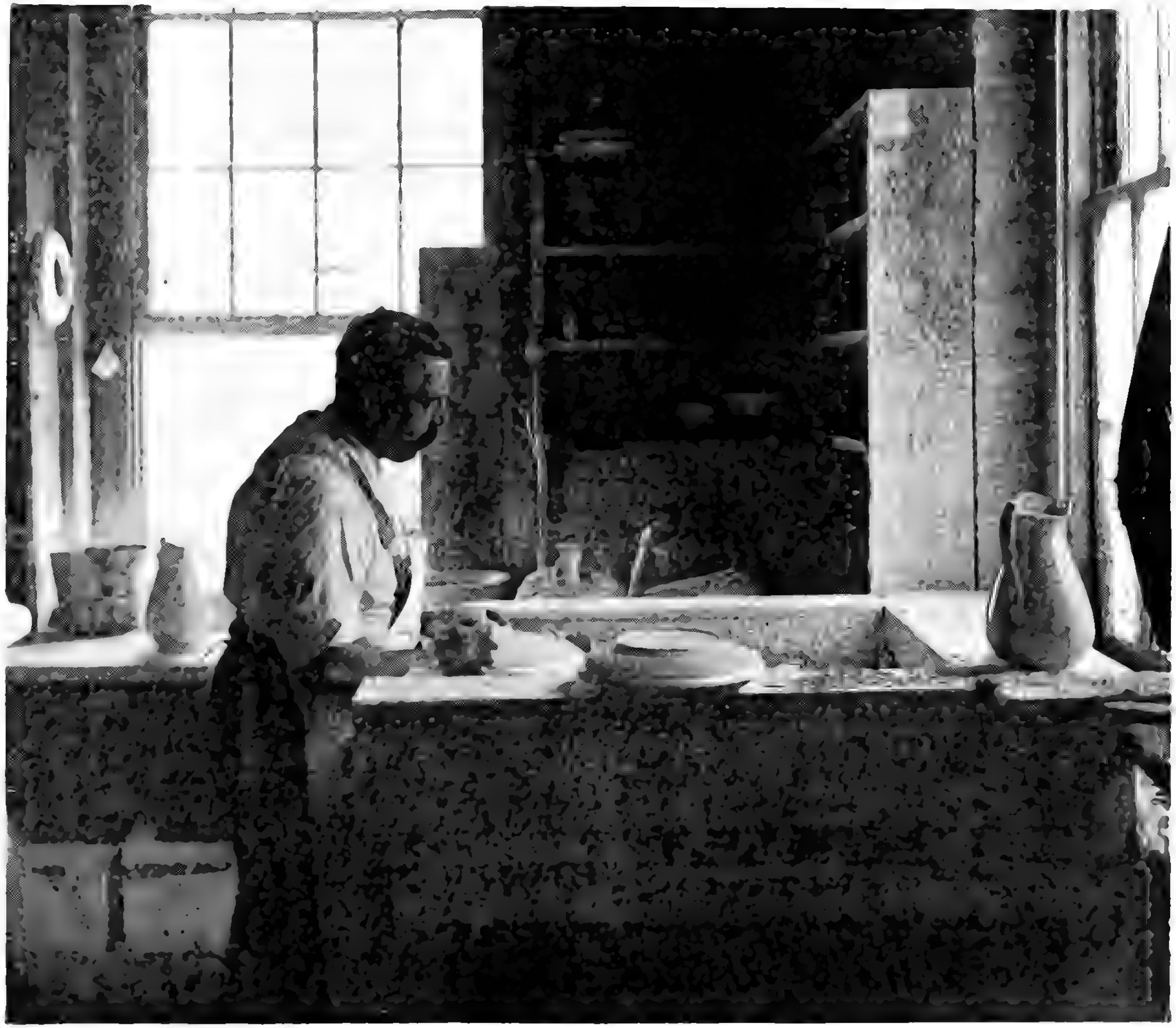
To face page 791

H. Ries photo.

Machine for kneading porcelain mixture. The ring shaped mass is the white clay mixture being worked over by the corrugated rolls. Union porcelain works, Brooklyn.

Plate 116

To face page 795



H. Ries photo.

Pressing plates on potters wheel. A formed plate still on the mold is on the front edge of the table. Onondaga pottery co., Syracuse.

One mixture of this type is as follows:

Composition of porcelain mixture for the production of bodies of low shrinkage

	Parts by weight
Quartz sand	120
Feldspar (Norwegian)	85
Marble	3
Zettlitz kaolin	60 to 70
Porcelain sherds	20 to 60

It has also been found that porcelains rich in fluxes are soft, while those poor in these ingredients are hard; neither do the most plastic masses always show the greatest shrinkage. The shrinkage of Seger's porcelain, which is rich in fluxes, occurs mostly in drying, and the total linear shrinkage is 10%; it expands in firing when a certain temperature is reached, owing to the high percentage (45%) of quartz which it contains. Plastic clays give a very smooth surface and are difficult to dry, and are not adapted to the manufacture of large pieces. A mixture poor in fluxes, with a high shrinkage, can be very lean when it contains no sedimentary clay but kaolin as the plastic element. Bodies of good plasticity, but low in fluxes, are of comparatively recent introduction, and are specially adapted to large objects and chemical stoneware.[1] Owing to its high percentage of clay substance and low fluxes, the mass acquires little translucency when burned at high temperatures, but stands temperature changes very well.

Hecht has recently published the results of some rather detailed investigations on the composition of porcelains and white earthenware bodies poor in lime. It has generally been considered that these two classes of ware vary in composition only between fixed limits, and that the predominance of feldspar in the mixture was generally confined to porcelain. This, however, has proved to be an error, and Hecht finds porcelains which are low in feldspar, and earthenware bodies rich in it. The following examples are given.[2]

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[1] *Chemiker zeitung.* 1894. p. 821.

[2] *Thonindustrie zeitung.* 1897. no. 21, p. 714.

Comparative compositions of porcelain and white earthenware

	Japanese porcelain mixture	Wegeli porcelain mixture	Belgian white earthenware mixture
	Per cent	*Per cent*	*Per cent*
Clay substance	49.44	81.37	58.56
Quartz	45.36	5.53	30.36
Feldspar	5.20	13.10	11.08
Total	100.00	100.00	100.00

The conclusions are that the difference between porcelain and white earthenware depends on the temperature at which the material is burned, viz, to vitrification or incipient sintering, and not on the composition.

Some porcelains are vitrified at a temperature of only 2400° F. (Seger's cone 9). Examples of this are Seger's porcelain and Copenhagen biscuit ware, whose rational compositions are as follows:

Compositions of Seger's porcelain and of Copenhagen biscuit ware vitrifying at 2400° F.

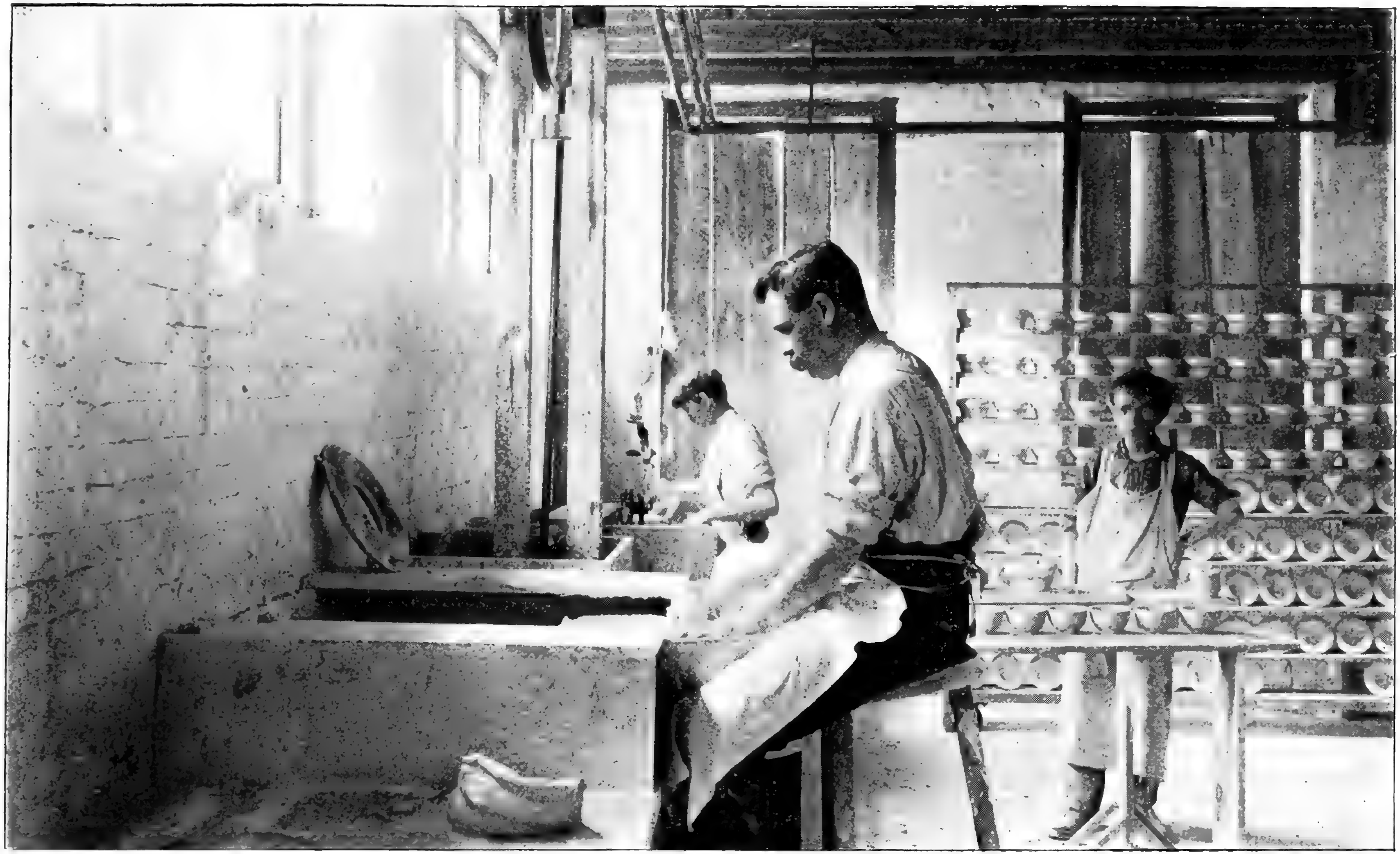
	Seger	Copenhagen
	Per cent	*Per cent*
Clay substance	25	32
Quartz	45	..
Feldspar	30	68

These bodies when burned show a glassy, conchoidal fracture. As the feldspar is that part of the porcelain which brings about the vitrification, we must assume from the Japanese and Wegeli porcelain mixtures, given above, that a much higher temperature is required to sinter them than the Seger and Copenhagen mixtures.

It is possible to find mixtures showing all grades of transition in composition between white earthenware and porcelain.

As to the behavior of easily fusible white earthenware glazes and porcelain glazes on these transitional members, Hecht finds

Plate 117



H. Ries photo.

Making cups. Onondaga pottery co. In foreground potter is turning the lining on his wheel; while his helper in the distance is shaping the same on a jolly in plaster mold; on the shelves are the cups drying in the mold, and molded cups ready to be carried to the drying closets are on the table.

Plate 118

To face page 797

H. Ries photo.

Machine for turning oval plates. (d) Plaster form for pounding out sheet of clay on plaster slab (c), (b) sheet of clay laid on the plaster form: (a) the machine with plaster form on it. Onondaga pottery co., Syracuse.

that a great number hold, without crazing, on bodies having the following composition, whether burned in a hard porcelain fire or moderate white earthenware fire:

Composition of bodies on which many earthenware and porcelain glazes do not craze

Per cent		
80	Clay substance	30
20	Quartz and feldspar	70

The degree of tenacity with which the glazes hold depends on the temperature at which the biscuit and glazed ware are burned, and to a greater or less extent on the relative amounts of kaolin and plastic stoneware clay in the body.

The practical value of the above observations is that it points toward much greater possibilities in underglaze decoration, for while in the past such work could only be done under hard fire glazes, we can now paint the porcelain with underglaze colors hitherto used only for white earthenware and cover them with easily fusible muffle glazes.

The effect of excessive grinding on the ingredients of a porcelain mixture has recently been shown to be serious. (*Sprechsaal.* 1896. no. 29. p. 812) It was found that, when a mixture of kaolin, quartz and feldspar was ground in a ball mill for 120 hours, the ware in burning became blistered and showed a finely vesicular structure throughout. If on the other hand only the quartz and feldspar were ground for 96 hours, and the kaolin then added, the result was a strong, translucent porcelain of normal color, free from blisters. The experiments suggest how porcelains which are only slightly transparent can be made more so.

Delft ware. This name was originally applied to a white ware made at Delft in Holland, which was ornamented with blue designs representing Dutch scenery. It is extensively manufactured at many localities at the present day, the body of the ware being porcelain or white earthenware. The articles which are usually decorated under the glaze include clocks, vases, jardinieres, toilet articles, etc.

Belleek, or eggshell ware, is a high grade of porcelain of unusual thinness and delicacy. It was originally manufactured at Belleek, Ireland, but its production there has nearly died out. The manufacture of it in this country has been attended with more or less success. The dull cream enamel of the surface bears some resemblance to the Royal Worcester porcelain. Sometimes the ware is finished with a transparent glaze showing the white color of the body, the decoration being over the glaze. Belleek wares are often formed by casting.

Electric supplies. This branch of the clay-working industry is rapidly growing, and gives every indication of being permanently successful. The supplies which have a vitrified body include insulators, cut-outs, fuse-boxes, push-buttons, etc. They are manufactured in this state at Brooklyn and Syracuse and Victor.

Majolica. This is an earthenware decorated in many colors, which are applied to the ware in the glaze either by slipping or with a brush. The ware is fired at a low heat, thereby permitting the use of softer tints. The clays used for the body are often of a low grade; the glaze is used to cover up a multitude of imperfections, but the ware is cheap and the bright tints of the decoration are usually catching. On account of its cheapness combined with its rather bright and attractive appearance it is frequently used by merchants to give away with samples of their ware.

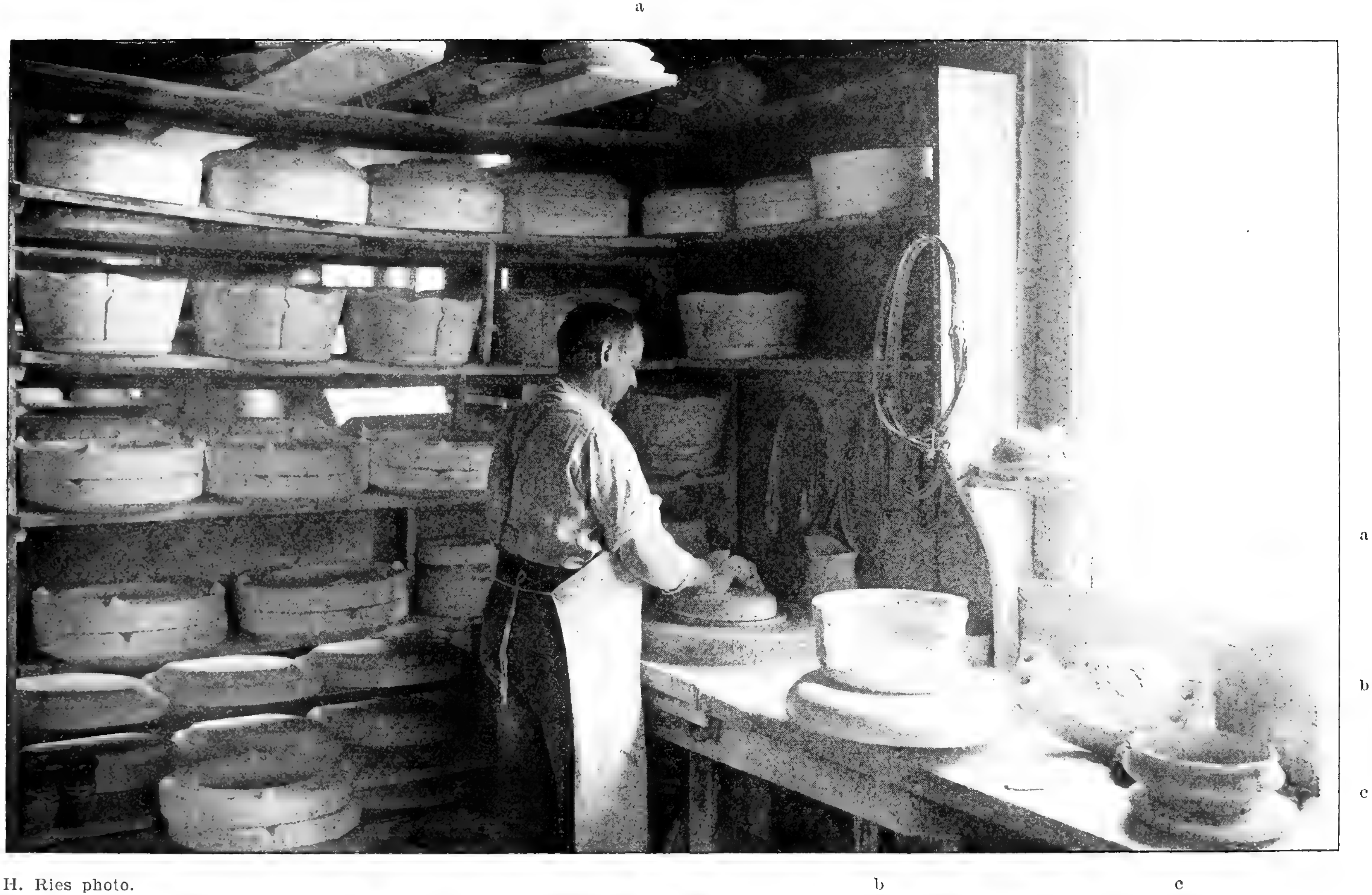
Majolica was formerly manufactured in New York state, but the factory has turned its attention to other and more profitable lines of ware.

Parian ware is a term applied to white, unglazed porcelain, with a dense body, which is considered to resemble closely Parian marble. This class of ware is used somewhat for the manufacture of ornaments and busts, but has comparatively little sale in this country. It was for a time made in Brooklyn.

Methods of manufacture

Certain steps in the manufacture of pottery are common to the production of all grades of ware, but the higher the quality of the product the more complicated usually the process.

Plate 119 To face page 798



H. Ries photo.

Pressing white ware. (a) Potter pressing out bat of clay; (b) pieces of plaster mold; (c) green ware just removed from mold. On the shelves are molds from which the ware has not yet been removed.

Plate 120

To face page 499

H. Ries photo.

Casting clay wares. Union porcelain works. The slip is poured into the molds from the tube which the workman is holding.

The different stages in the manufacture of pottery may be grouped as follows:

Preparation	Washing
	Weathering
Tempering	In chaser mills
	Wet pans
	Pug mills
	Tables
Molding	Turning
	Jollying
	Casting
	Pressing
Drying	
Burning	
Glazing	
Decorating	
Burning	

Preparation

In some regions the clay is prepared in a preliminary way by weathering, but this is not a very widespread custom.

Clays for common earthenware are seldom washed, but those used in the manufacture of stoneware, specially of the higher grades, are frequently prepared in this manner; those clays which are used for white earthenware and porcelain are nearly always washed.

Clays are washed by one of two methods. With the first method, the clay is thrown into large circular tubs filled with water, in which it is stirred up by revolving arms and the clay lumps thereby disintegrated. By this treatment the fine kaolinite particles, as well as very fine grains of mica, feldspar and quartz remain suspended in the liquid, while the coarser grains settle on the bottom of the tank. The water with the suspended clay is then drawn off to the settling tanks.

A modification of this consists in the use of a large cylinder, closed at both ends, which is set in a horizontal position, and contains an axis with iron arms, their revolution serving to break up the clay, which is charged through a hopper at the top. A current of water passes through the cylinder and carries the fine clay particles with it, while the coarse ones are left behind in the machine. The speed of the current has to be regulated by experiment, for if too much water is used coarse material will be washed out of the cylinder, and conversely if the current is too slow the clay will not yield a sufficient percentage of washed product. One objection to this apparatus is that it has to be stopped from time to time to remove the coarse sand from the machine.

The method most commonly used at the present day for washing kaolin is in its general detail as follows:

As the kaolin comes from the mine it is generally discharged into a log washer, a semicylindric trough, in which revolves a horizontal axis, bearing short arms. The action of the arms breaks up the kaolin more or less thoroughly, according to its density, and facilitates the subsequent washing. The stream of water directed into the log washer, sweeps the kaolin and most of the sand into the washing trough, which is about 15 inches wide and 12 inches deep, but should be wider and deeper if the kaolin is very sandy. The troughing is about 700 feet long, and to utilize the space thoroughly it is broken up into sections (50 feet each is a good length) these being arranged parallel, and connecting at the ends, so that the water, with suspended clay, follows a zigzag course.

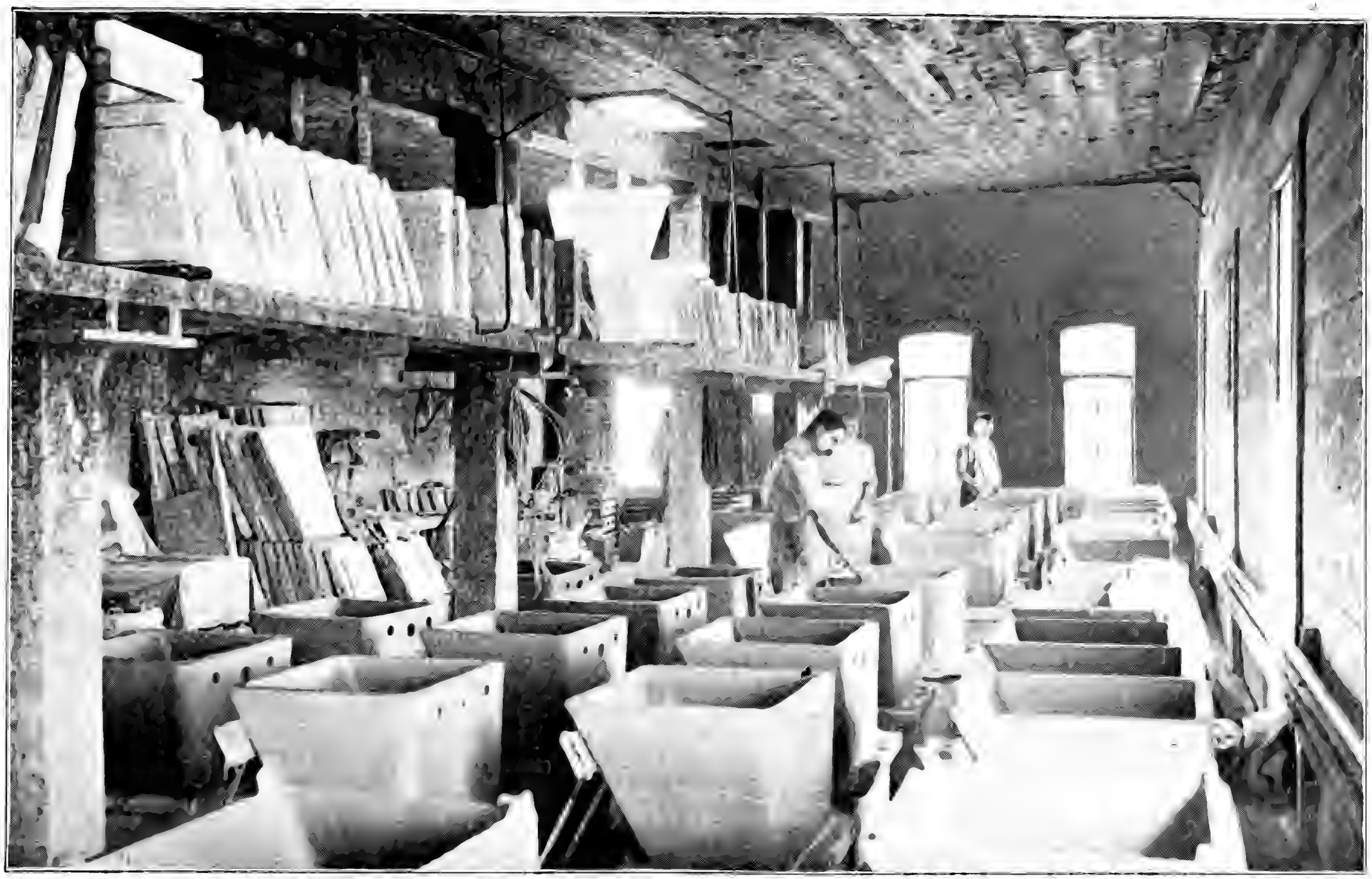
The troughing has a slight pitch, commonly about one inch in 20 feet, but the amount depends on the kaolin, and whether the contained sand is fine or coarse. If the kaolin is very fine, and settles slowly, the pitch need not be so great, and vice versa. A large quantity of very coarse sand in the kaolin is a nuisance, as it clogs up the log washer and the upper end of the trough more quickly, causing much labor to keep them clean. As it is, considerable sand settles there, and, to keep the trough clear, sand wheels are used. The wheels are wooden, bearing a number of

H. Ries photo.

Molding acid receivers, Graham chemical stoneware works. On the table at the right is a slab of clay for spreading on one half of the interior of the mold. On the extreme left is the mold, with upper portion removed, with the workman bending over into it in order to smooth the seams in the bottom and along the sides where the sheets of clay join. In the center is a finished jar from which the plaster parts of the mold have been removed.

Plate 122

To face page 801



H. Ries photo.

Molding washtubs. On the shelves on the left are the different parts of the plaster molds used. Graham's chemical stoneware works, Brooklyn.

iron scoops on their periphery. As the wheels revolve the scoops catch up a portion of the sand which has settled in the trough, and, as each scoop reaches the upper limit of its turn on the wheel, it, by its inverted position, drops the sand outside the trough. These sand wheels are a help, but it is often necessary in addition to keep a man shoveling the sand from the trough.

If the sand is finer it is not dropped so quickly, and, distributed more evenly along the trough, does not clog it up so fast.

The zigzag arrangement of the troughing has been objected to by some, as it produces irregularities in the current, causing the sand to bank up in the corners, at the bends and at certain points along the sides of the troughing. (E. Hotop. *Thonindustrie zeitung.* 1893) The effect is to narrow the channel, and consequently increase the velocity of the current, thereby causing the fine sand to be carried still farther toward the settling tank. This difficulty, which is not often serious, has been obviated either by having the troughing straight or by allowing the water and suspended clay as they come from the log washer to pass through a section of straight trough, and from this into another, of the same depth but 5 or 6 times the width, and divided by several longitudinal partitions. The water and the clay then pass into a third section, twice as wide as the second, and divided by twice the number of longitudinal divisions. By this means the water moves only in a straight course, but as it is being continually spread out over a wider space it flows with an ever decreasing velocity.

By the time the water has reached the end of the troughing nearly all the coarse grains have been dropped and the water is ready to be led into the settling vats, but as a farther and necessary precaution it is discharged on a screen of 100 meshes to the linear inch, with the object of removing any coarse particles that might remain, and also eliminating sticks and other bits of floating dirt.

Two kinds of screens can be used, the first stationary, the second revolving. The stationary screen is simply a frame covered with a copper cloth and set at a slight angle. The water and suspended kaolin fall on the screen, and pass through, otherwise they run off and are lost. A slight improvement is, to have two or three screens overlapping one another, so that whatever does not get through the first will fall on the second. If the vegetable matter and sticks are allowed to accumulate, they clog the screen, and prevent the kaolin from running through; consequently stationary screens must be closely watched.

The revolving screens are far better; for they are self-cleansing. Such screens are barrel-shaped, and the water, with the kaolin in suspension, is discharged into the interior and passes outward through the screen cloth. As the screen revolves the dirt caught is carried upward and finally drops; but, instead of falling down on the other side of the screen, it falls on a board, which diverts it out to the ground.

The settling tanks, into which the kaolin and the water are discharged, may be and often are about 8 feet wide by 4 feet deep and 50 or more feet long. As soon as one is filled the water is diverted into another. The larger a tank the longer it will take to fill it, and allow the kaolin to settle. Clays obtained in this manner are expensive, particularly when the market takes the output of washed kaolin as soon as it is ready. Small tanks have the advantage of permitting the slip to dry more quickly, specially when the layer of clay is not very thick; furthermore a small pit takes less time to fill and empty. But one disadvantage urged against a number of small tanks is that a thoroughly average product is not obtained, owing to the thinness of the layer of settlings and the small amount in each. In addition a series of small tanks require considerable room. The advantages asserted in the case of large tanks are that the clay can be discharged into any one for a considerable period, and, if the clay deposit varies in character, the different grades get into one tank and a better average is thereby obtained.

If the kaolin settles too slowly, alum is sometimes added to the water to hasten the deposition. When the kaolin has settled,

Plate 123

H. Ries photo.

Turning cups smooth on the lathe after they have been molded and dried, but before they are burned. Onondaga pottery co., Syracuse.

most of the clear water is drawn off; the cream-like mass of kaolin and water in the bottom of the vat is drawn off by means of slip pumps and forced by these into the presses.

The presses consist simply of flat, iron or wooden frames between which are flat canvas bags. These bags are connected by nipples with a supply tube from the slip pumps, and by means of the pressure from the pumps nearly all of the water is forced out of the kaolin and through the canvas. When as much water as possible is squeezed out, the press is opened and the sheets of semi-dry kaolin are taken out. It is then dried either on racks in the open air or in a steam-heated room.

As for every ton of crude kaolin usually only about $\frac{2}{5}$ or $\frac{1}{4}$ of a ton of washed kaolin is obtained, it is desirable to have the washing plant at the mines, to avoid the hauling of 60% to 70% of useless sand which has to be washed out before the kaolin can be used or even placed on the market.

Tempering

Chaser mill. This consists of a circular iron pan in which revolves a frame bearing two heavy iron wheels, about 30 to 36 inches in diameter. As this frame revolves, the wheels, by means of a gearing, travel from the center to the circumference of the pan and then back. The clay is dumped into the pan, water added, and by the action of the wheels, grinding and cutting it up, it is ground and mixed in from one to two hours. The action of such a machine is quite thorough, but requires considerable power to operate it. It is sometimes used for stoneware clays.

Wet pans. The action of these has already been described, under bricks. This machine is occasionally used in the preparation of pottery clays, and is fully as efficient in its action as the preceding one, while it has the advantage of operating continuously and also of requiring less power. The clay is also ground and mixed much more quickly in a wet pan than in a chasing mill; and the greater width of the wheels, and the presence of scrapers to throw the clay under them, insures the thorough grinding of any lumps which may be present. A wet pan will grind a charge of clay in about 10 minutes.

Pug mills. Those used in pottery manufacture consist of an upright rectangular box, in which revolves a vertical shaft, bearing iron blades. The clay is charged at the top, and is slowly forced downward to the opening at the bottom of the box, at the same time going through a thorough mixing action.

Molding

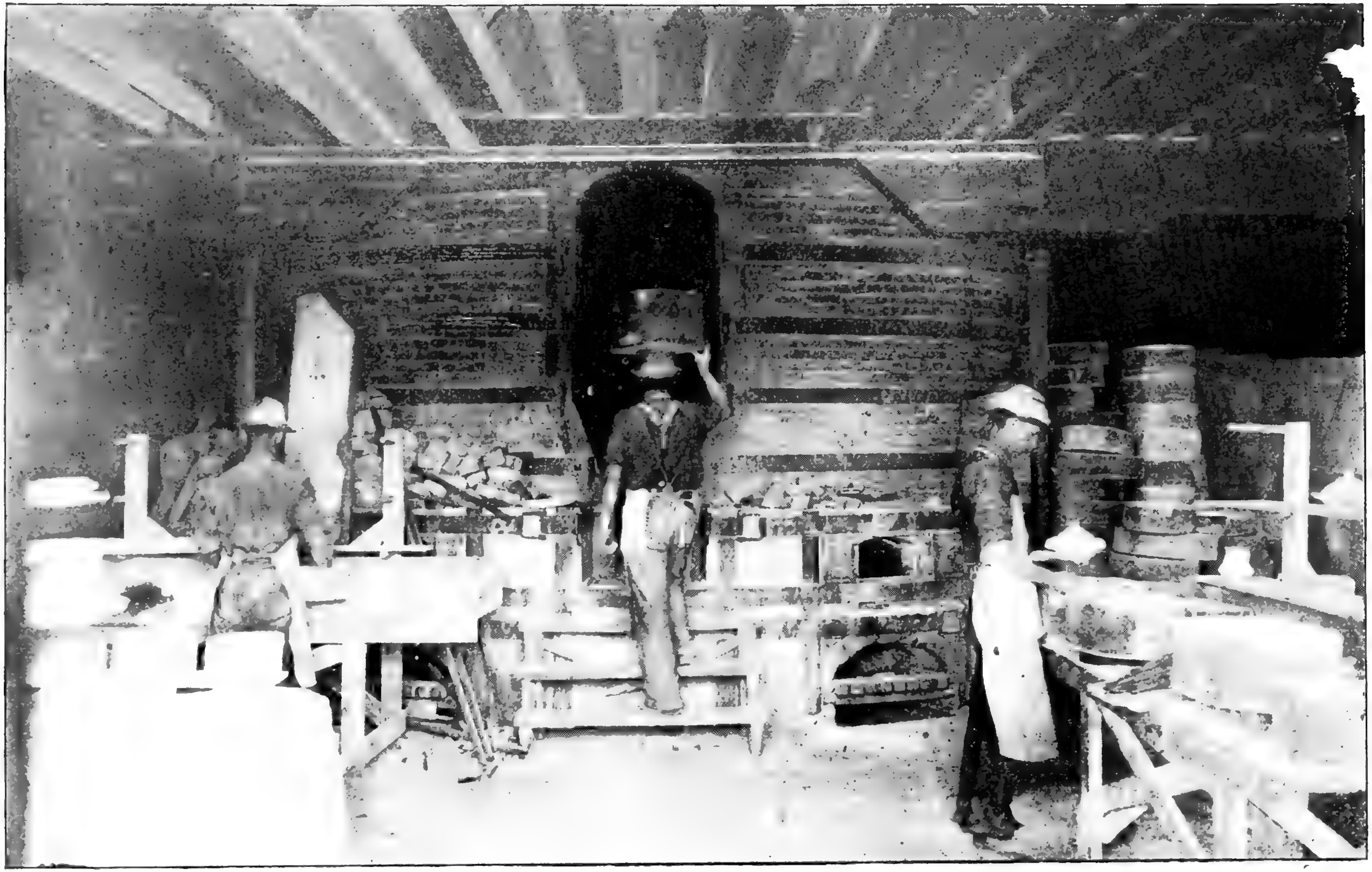
Pottery is molded in four different ways, turning, jollying, casting, and pressing.

The clay after coming from the presses, is first wedged, that is a lump of the desired size is cut in two by a wire, the two halves united by bringing them down on the table with much force, the piece cut again, the two halves once more united, and so on, the object being to subject the clay to a kneading action, whereby all the air bubbles are eliminated.

This operation is accomplished in many European factories by a kneading machine, which consists of a circular table about 6 feet in diameter, whose upper surface slopes outward. On this are two conical rolls, 20 to 30 inches in diameter and about 8 inches wide. These rolls have corrugated rims, and are attached to opposite ends on a horizontal axis, having a slight vertical play. The clay is laid on the table and as the rolls travel around on it the clay is spread out into a broad band. A second axle carries two other pairs of rolls of the same shape but smaller size, which travel around in a horizontal plane. These rolls press the band of clay together again. In this way the clay is subjected to alternating vertical and lateral pressure and all air spaces are thus thoroughly closed. The rolls make 10 to 12 revolutions a minute, and a machine kneads two to three charges of 350 pounds each in an hour.

Turning. This is done on a rapidly revolving horizontal wheel. The potter takes the lump of clay, places it on the revolving disk, and, after wetting the surface with a slip of clay and water, gradu-

Plate 124



H. Ries photo.

Kiln room, Onondaga pottery co. The green ware is being placed in saggers which are being carried into the biscuit kiln.

Plate 125

To face page 805

H. Ries photo.

Corner of decorating room, Onondaga pottery co., Syracuse. The girls are painting the decoration on the burned ware, while the man at printing machine in the rear is preparing transfer prints.

ally works the mass up into the desired form. After being shaped, the object is then detached from the wheel by running a thin wire underneath it, and it is set aside to dry. Crocks, jugs, and similar articles are turned. This is the method almost invariably employed for molding earthenware and frequently employed in forming stoneware articles. An expert potter is able to turn jars of very large size.

Jollying or jigging. This is a more rapid method than turning. The clay to be used for this purpose is tempered to a much softer consistency. The jolly is a wheel fitted with a hollow head to receive the plaster mold, whose interior is of the same shape as the exterior of the object to be molded. A lump of clay is placed in the revolving mold and is gradually forced up around the sides of the latter by means of the fingers. A metallic arm, or templet, as it is called, is then brought down into the mold and severs to shape the interior of the object. Cups, crocks, jugs, pitchers and even wash basins can be molded in this manner. Articles with tapering necks are generally jollied in two parts, which are subsequently cemented together with slip. Handles are generally stamped out separately and subsequently fastened on the article.

A modification of jollying, used for making plates and saucers, consists in having a plaster mold whose surface has the same shape as the interior of the object to be molded. The potter's assistant takes a piece of clay of the desired size, and pounds it into a flat cake, called a " bat ", which is laid on the mold, he then shapes the other side or bottom of the plate by pressing a wooden templet of the proper profile against it as it revolves.

Ewers and vessels of oval or elliptic section are usually made by means of sectional molds, consisting of two or three pieces whose inner surface conforms to the outer surface of the object to be molded. A slab of clay is laid in each section and carefully pressed in. The mold is then put together and the seams carefully smoothed with a wet sponge. After drying for a few hours the parts of the mold are lifted off. Clocks, lamps, picture frames, water pitchers and many other articles of a hollow nature are molded in this manner.

Casting. Casting consists in pouring a slip of clay into a porous mold, which absorbs some of the water, and causes a thin layer of the clay to adhere to the interior surface of the mold. When this layer is sufficiently thick, the mold is inverted and the remaining slip is poured out. After a few hours the mold can be removed. This method is extensively used in making thin porcelain ornaments; many white earthenware objects can be formed by the same process. Much of the success of molding depends on the proper consistency and composition of the plaster mold.

Drying

The ware after it has been molded is usually set aside on shelves in steam-heated rooms to dry.

From this point on, the method of manufacture varies somewhat, depending on the kind of ware that is to be produced.

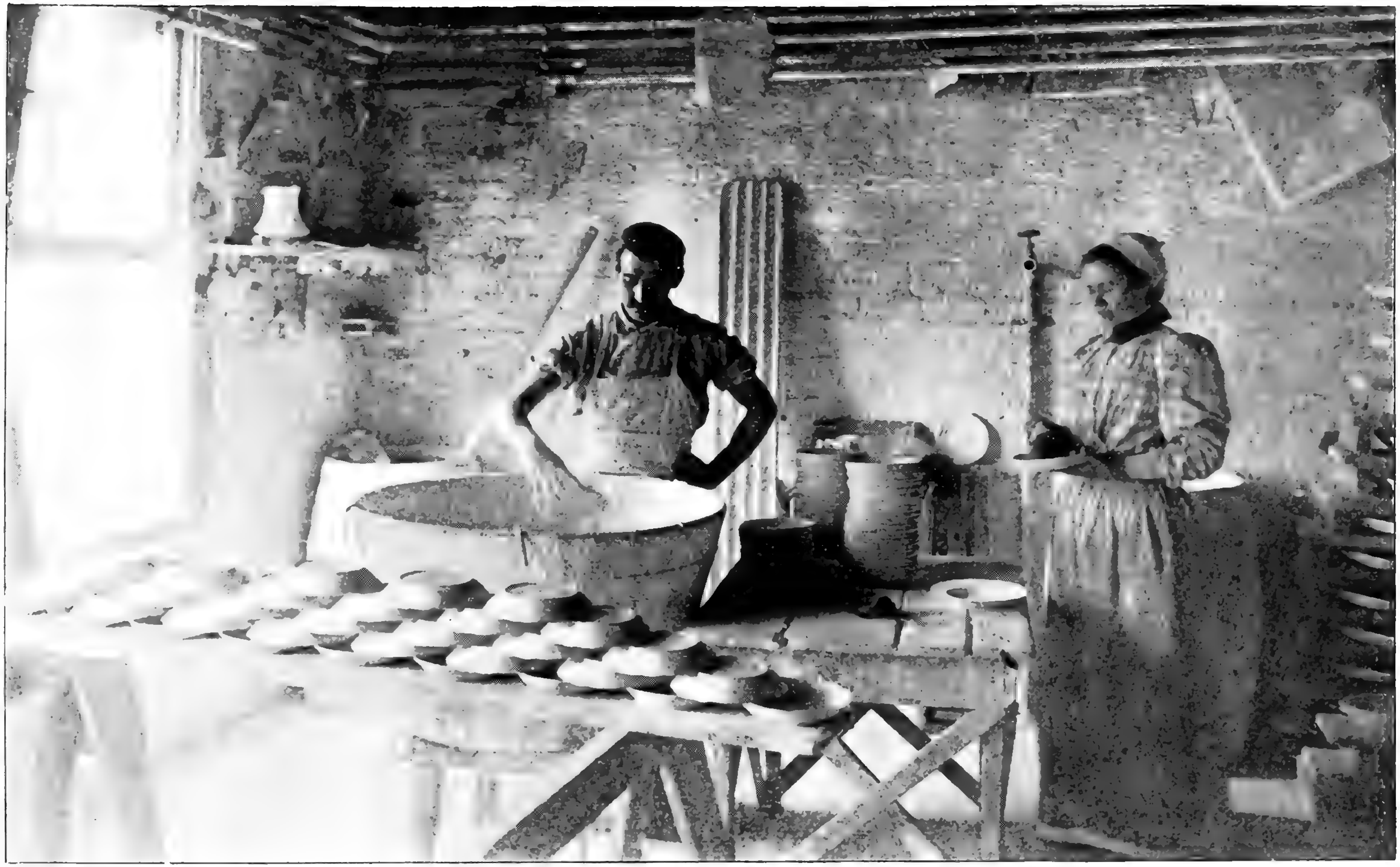
Glazing stoneware

Stoneware is most commonly glazed either with salt, or by means of slip clays. Slip clays, which are really natural glazes, are very impure, easily fusible clays. The clay is mixed with water to the consistency of cream, and the ware before burning is either dipped into this slip, or the slip is put on the ware by a brush.

The most desirable thing in a slip clay is that it shall fuse at a low temperature, form a glaze of a uniform color, and this glaze shall not crack or craze. Many fine-grained impure clays fulfil the first requirement but are seldom able to comply with the second and the third condition.

Slip clays have been supplied to a considerable extent by several different states, but the most important and the best thus far used is obtained from the Champlain deposit at Albany, N. Y. This Albany slip makes a splendid, even colored, natural glaze, and one which does not crack. It not only works well by itself but gives

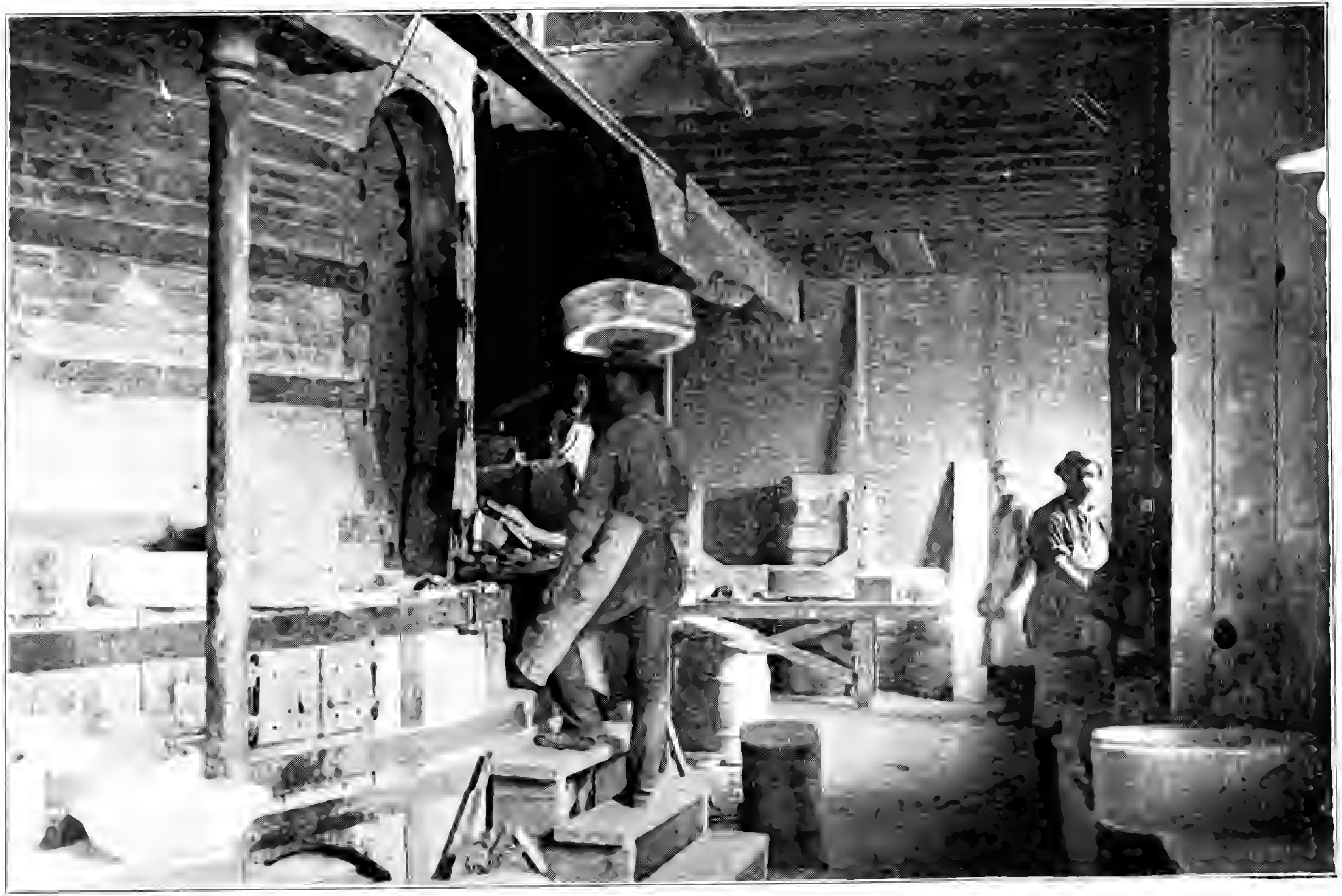
Plate 126



H. Ries photo.

Dipping the biscuit ware into the glazing mixture. The plates on the table in front of the tub have already been dipped. Onondaga pottery co., Syracuse.

Plate 127



H. Ries photo.

Workman carrying sagger of ware into glost kiln. Onondaga pottery co.

good results when mixed with other clays or with artificial fluxes. Analyses of this material are given beyond.

The following analyses made by the Missouri geological survey gives the composition of the clay.

Silica	56.75
Alumina	15.47
Combined water	8.87
Moisture	.37
Protoxid of iron	5.73
Protoxid of manganese	tr.
Lime	5.78
Magnesia	3.32
Alkalis	3.25
Total	99.54

Another analysis made by H. H. Griffen (*Clay worker*, 28: 178) gives:

Silica	17.02
Alumina	14.80
Ferric oxid	5.85
Manganic oxid	.14
Lime	5.70
Magnesia	2.48
Potash	3.23
Soda	1.07
Phosphoric acid	.15
Water	5.18
Moisture and carbonic acid	4.94
Sand	38.58
Total	99.14

Tests made by the Missouri geological survey showed that this clay shrunk 6% when air dried and 8% when vitrified, giving a total shrinkage of 14%. Incipient vitrification occurred at 1700° F., complete at 1850° F., and viscosity above 2000° F.

From the analysis made by H. H. Griffen it is seen that the clay approaches closely to the formula:

$$1RO, .7R_2O_3, 4SiO_2,$$

which is similar to that of an alkaline glaze, but with an excess of R_2O_3. The addition of lead increases this excess of bases, and it is necessary to add silica also.

For many years the slip has been used as a glaze without the addition of any artificial fluxes, for attempts in this direction had always been without success. A number of experiments were made by Mr Griffen, to determine in what manner it was possible to lower the fusibility of the slip clay, and make it run more easily without destroying its richness of color. The addition of lead alone gave a transparent and greenish colored glaze, which showed a tendency to blister; alkalis added alone gave the same result. It is, therefore, necessary to add other materials with the lead. Good results were obtained by adding iron alone, but the combination of chromium, manganese and iron produced the best effect. The chromium, Mr Griffen finds, takes from the iron its tendency to run into greenish and yellowish tints. The best form in which to introduce the chromium is as chromate of lead, this giving the finest color effect; but, as an excess of this sort also has a tendency to cause blistering, it is well to add some of the chromium in the form of chromate of iron.

The following recipe is for a moderately low heat glaze, the variation being for different conditions.

Albany slip clay	63.30	to	70
White lead	25.30	to	17
Flint	6.30	to	7
Oxid of iron	.72	to	.79
Oxid of manganese	.56	to	.61
Chromate of lead	1.27	to	1.40
Chromate of iron	.67	to	.73
Oxid of zinc	1.88	to	2.07

H. Ries photo. View in one of the decorating rooms. Union porcelain works, Brooklyn.

Plate 129 To face page 809

H. Ries photo.

Making electrical supplies on dry presses, Pass & Seymour, Syracuse. Behind the workmen are the molded goods, air drying on the racks.

Artificial glazes are used to some extent on the better grade of stoneware made at the present day.

Stoneware is sometimes coated with a slip of white clay.

Burning stoneware

Stoneware is commonly burned in round kilns. The articles are piled one on top of the other till the kiln is filled, but they are set in such a way as not to interfere with an even draft throughout the kiln, and the larger pieces are placed in the center. If both salt glazed and slip glazed wares are burned in the kiln at the same time, the latter have to be protected from the salt vapor in some way.

The time of burning depends partly on the size of the kiln, and partly on the clay. It may be as short as 30 hours or as long as 90.

The temperature attained in burning stoneware also depends on the clay. Experiments made in Ohio show that the temperature ranges from about 1850° to 2000° F. Other experiments made by the writer indicate that in the case of the New Jersey semi-fire clays the temperature in stoneware kilns reached 2300° F. at times.

The kilns used in burning stoneware are either up-draft or down-draft, both round and rectangular.

Glazing white earthenware and porcelain

In this grade of ware, the glazing and burning are not done in one operation, as in the case of the stoneware, but, on the contrary, the ware after molding is first burned to a comparatively low temperature, after which it is dipped in the glaze and burned a second time. In the case of white earthenware the temperature of the second burning is lower than that of the first, while in the case of the porcelain it is higher.

The production of a glaze on the surface of either porcelain or earthenware, free from the numerous defects to which such materials are very liable, is often attended by considerable difficulty.

The glaze on pottery consists of a fusible mixture which is applied to the surface of the ware, either when it is still in a green state or after burning. In the burning the ingredients of this mixture unite during fusion and cover the surface with an impervious glassy coat.

Pottery glazes are generally of two kinds, raw or fritted. The former consists usually of some mixture of metallic oxids, which is sprayed on the surface of the raw clay. In the case of the latter, the ingredients of the glaze are first fused together, forming what is known as a frit, the frit is then ground very fine, and mixed with water, this mixture being applied to the surface of the green ware. It is specially necessary to prepare such a frit when the glaze contains any soluble salts, the object of the fritting being to render these salts insoluble. The fritting is usually done in a special furnace, which has the bottom sloping toward one point, so that the melted material can be run out into a tank of water, at the proper time. Certain frits, either on account of the difficulty with which they flow on melting or owing to the corrosive action they exert when fused, can not be melted in the furnace, but are fused in a special crucible or sagger.

The proper preparation of the glaze often requires much skill and experience; for the production of a uniform coating of glaze on the surface of the ware is influenced by many different things, such as the degree of porosity of the ware when glazed, the cleanliness of the surface to be coated, the consistency of the glaze, etc.

If the density of the body is too great, or there happens to be a film of dust or fat on the surface, the glaze is apt to contract into drops during the burning. If the glaze is too refractory, or the kiln fire is not hot enough, the glaze will not be homogeneous, but show little dots and pin holes. A frequent fault is the tearing or springing off of glaze, which is due to the glaze and the body having a different coefficient of expansion. If that of the glaze is greater, the body is apt to tear, whereas, if the reverse is true, the glaze spalls off. It may be said in general that with an increase in the amount of fluxes the coefficient of expansion of a glaze increases, while it decreases with the amount of acids. The coefficient of expansion may also be diminished if the percentage of boracic acid in the clay is increased at the expense of the silica. The amount of alumina exerts but little influence on the expansion or contraction of the glaze, but a small percentage of alumina prevents glazes which are poor in alkalis from becoming opaque.

The tenacity of adherence of the glaze to the body depends on the composition of both and also on the temperature of the kiln.

We can say that the power of the body to carry a glaze without causing it to crack is influenced by its rational composition, its degree of plasticity, the fineness of the quartz grains which it contains, and the temperature at which it is burned.

Burning white earthenware and china

This is done in saggers, which are oval or cylindric receptacles about 20 inches in diameter, 8 inches in hight, with a flat bottom. The saggers are filled with the pieces of the unburned ware and are set one on top of the other, so that the bottom of one forms a cover for the one below it, the joint between them being closed by means of a strip of soft clay. The use of these saggers is to protect the ware from the smoke and gases of the kiln fire, which would tend to discolor it.

The requisite of a sagger clay is that it stand slightly more heat than the ware placed in it. Saggers are generally made from a plastic, refractory clay, with as great an admixture of grog (ground up fire brick or old pottery) as possible, but an excess of the latter is deleterious. The color burning properties of a sagger clay are of little importance. Saggers are made in various ways, sometimes being turned on a wheel, or again being formed in plaster molds, or around wooden forms. In Germany metal forms are now mostly used, because they permit the working of a stiffer mass, and, the clay containing less water, the saggers after molding shrink and tear less, while in addition they dry more quickly. The interior of the sagger is frequently coated with a slip of kaolin and quartz, in order that the ware may not receive any discoloration from this source. When complicated forms are placed in the sagger the overhanging or greatly projecting portions are supported by pieces which have the same composition as the ware itself, so that in burning the shrinkage of both will be the same.

The proper placing of the ware in the kiln as well as in the saggers is a matter of great importance.

The condition of the fires in the burning of porcelain or earthenware has to be taken into consideration. In the burning of spar china from redness up to the point of vitrification, it is desirable to have the fire reducing in its action, while above that point it should be neutral or weakly oxidizing. In using coal which contains pyrite, if the fire is oxidizing, sulfuric acid is set free; and this tends to unite with any lime carbonate or alkalis which the glaze may contain, the lower the temperature of the kiln the more rapid this union, for the lime and alkalis will unite with the sulfuric acid, as long as they have not entered in combination with the silica of the glaze. When the glaze has once melted, the danger that this will take place is far less. If the gases are reducing, any sulfate salts formed are broken up and sulfurous acid gas escapes. If the glaze particles have not yet been thoroughly fused the gas just mentioned escapes without causing any trouble; but, if the fusion has already occurred, blistering or scaling of the glazed surface results.

Both the body and the glaze may sometimes have a small amount of gypsum, which may come from an Alsing cylinder, if such a machine is used for grinding the clay. The reducing action of the fire must, however, not be too strong, otherwise any organic matter which the clay contains will not burn off at the proper time, and will subsequently be liable to cause bursting in the ware during burning. A reducing fire tends to insure a whiter color in the ware by reducing any ferric combination of iron, thus carrying the color from reddish over into whitish gray, or the pale green of complex ferrous silicates. The latter are hardly noticeable so that the whole body appears white. It sometimes happens that during the slow cooling of porcelain in a muffle kiln the iron is changed back to the ferric condition with its accompanying yellow.

When a kiln full of ware is finished, the material at times has to be sorted, as it seldom happens that all the ware drawn from the kiln is perfect. The sources of flaws in the burned ware may be either faults in the body or bad firing.

In connection with body faults: the more plastic and finer grained the clay mixture used, the quicker it shrinks in drying; masses which are fat shrink more than those which are rich in fluxes, such as feldspar, or are very lean. The size of the quartz and feldspar grains is of importance, for, if they are in the form of fine powder, they are not very plastic, but if ground extremely fine they develop a certain amount of pastiness, and this is accompanied by an increased shrinkage. If the clay mixture was not properly worked, or was too soft, or the thickness of the molded object is not the same throughout, or the mechanically combined water is not evenly distributed through the material, the ware is very likely to warp in burning. The shrinkage may also be uneven if the pressure exerted by the molder is not uniform, and cracks occur when the molded piece is stronger on one side than on the other. Flaws, such as air bubbles, appear only when the ware is burned.

Firing errors are usually due to too quick heating or cooling. If cracks are caused in the early part of the burning, they increase as the firing proceeds. Cracks formed in the body as a result of too rapid cooling are not generally seen with the naked eye, but the ware produces no ring when struck. Another cause of cracking is an uneven temperature on the two sides of the object. Over burning as well as under burning of porcelain tends to produce fine cracks in the body.

The glaze is also a source of much worriment to the manufacturer. It should of course have the same coefficient of expansion as the body to which it is applied. If under burned the glaze will not appear thoroughly glassy and develops fine cracks, but, if over burned, a chemical action is apt to take place between the glaze and the body and the former absorbs elements of the latter, altering its composition and consequently its properties. This over burning of the glaze is the principle used by the Chinese to produce their celebrated crackle ware.

Kilns. The type of kiln used depends on the ware, the temperature to be obtained, and the fuel.

In this country a round vertical kiln is generally used for both the first and the second burning. The first burning, which is known as the biscuit burn, is done at a lower temperature. The second firing is done in a similar kiln, known as the Glost kiln. After the ware has been burned with a glaze on it, it is sometimes decorated and then fired a third time in what is known as a muffle kiln.

The two points necessary in a kiln are first equal distribution of heat, and secondly economy of fuel, with a development of the maximum heat.

Most of the kilns used are down-draft, and in these we get a more complete combustion, for the reason that the air and gases must follow a longer path, and consequently, get a better chance to mix. The continuous type of kiln is little used in this country, though it has been used with marked success abroad for the burning of both white earthenware and porcelain.

Methods of decoration

These seem to deserve special mention, as in many cases they form an important and distinct branch of the pottery industry.

Decoration may be imparted to a ware in three ways: 1) by the production of a raised design; 2) by covering the ware with a solid color; 3) by the decoration of the surface with various designs, applied to the ware in one way or another. Common red earthenware seldom receives any decoration, though this has been decorated more within the last year or two. Stoneware, yellow ware and Rockingham ware often have the surface ornamented with a raised design, which is imparted to the article in molding it. Stoneware is often decorated under the glaze with crude designs made by

H. Ries photo. Girls attaching brass work to porcelain electrical goods. Pass & Seymour, Syracuse.

H. Ries photo.

Room where the brass work for the porcelain electrical supplies is prepared. Pass & Seymour, Syracuse.

tracing the figure with a dull point and some coloring matter, which remains in the depressions of the design. Yellow ware is frequently ornamented with bands of various colors.

In majolica the coloring materials are mixed directly with the glaze.

It is the decoration of white earthenware and china, however, that calls forth the ingenuity and skill of the potter. White wares may be decorated either over the glaze or under it. In the former the decoration is applied after the glaze has been put on and fired; in the latter the decoration is put on the biscuit ware, then fired, then the glaze applied and the ware fired again.

The advantage of underglaze decoration is that it is more durable, the decoration being protected by the glaze, and oftentimes the effect produced is prettier than when the colors are applied on the glaze. The number of colors which can be used in underglaze decoration is limited, as they have to withstand the effect of the heat required to fuse the glaze. The colors which can thus be used are blue, brown, green, yellow. It is on this account that hard fired porcelains have their delicately tinted decorations applied over the glaze. Pink, for instance, has to be applied in this way, and so does gold.

An imitation of underglaze work is sometimes made by applying the decoration on the glaze and then firing until the glaze softens and the colors sink into it.

Underglaze work was the prevalent method of decoration in this country from 1845 to 1850. It was then abandoned for a time, and in the last 10 years the method has been steadily regaining favor.

All designs and colors were formerly applied by a brush, but the prevalent method now is by printing. The design is engraved or etched on a copper plate; the reversed print is then made on specially prepared fine paper. This is applied to the piece of pottery to be decorated, either on the glaze or on the biscuit ware. The paper is carefully rubbed so that every portion of it shall come in contact with the surface of the ware, and it is then allowed to stand for a while, when the paper is removed, leaving the design on the ware. This is then gone over with colors and the design filled in. The decoration is then called a "filled print". The amount of "printed" ware turned out annually is very great.

Raised gold work, often seen on wares, is made by painting the design with a yellow paste overglaze, firing in the decorating kiln, and then covering with gold and firing again.

Underglaze colors are fired at a sufficient temperature to drive off the oil. The overglaze colors are usually fixed in a muffle kiln in which the temperature reaches between 900° and 1000° F.

A rather ingenious method of making border decorations on plates and cups consists in having a design, such as a flower or cluster of leaves, stamped on a flat surface of fine-grained sponge. The plate, for instance, is then placed on a wheel, and while slowly revolving it receives a number of successive touches with the inked surface of the sponge. In this way a continuous design is stamped on the ware. The method is quick, cheap and well adapted to the cheaper grades of white ware, for which it is used.

Chromolithographic decoration[1]

The adaptation of chromolithographic printing to ceramics has been quite recently successfully attempted, and may very possibly supersede line engraving. The great advantage of the chromolithographic decoration lies in the high excellence of the ornament that may be used and the purity of the color that may be obtained. By this means the design of a first-class artist may be reproduced with all its original delicacy and softness. This new method does away with the filling in of prints, which is often of unequal quality. Up to the present time chromolithographic work has been used only for overglaze decoration, but experiments are being made with it in underglaze ornamentation. The difficulties in the latter case are porosity of the rough surface of the "biscuit" ware. The greatest difficulty is said to be this. In printing from engravings, the

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[1] *Jour. soc. arts*, 18 Sep. 1896. p. 322.

Plate 132

To face page 815

H. Ries photo.

Molding doorknobs and insulators in hand power dry press machine. Union porcelain works.

" print " is really a relatively thick line of color ; just in proportion as the engraver cuts deeply into the plate, so is the quantity of color " taken up ". Now " underglaze plates " are cut much more deeply than " enamels ", and if the " transfer " or printed paper is examined under a microscope the underglaze prints are seen to consist of raised (as we have previously said), relatively thick ridges of color, laid with the point of the ridge uppermost. It is this depth or strength of cutting that enables the underglaze prints to produce their strong patterns, for, owing to the action of the glaze, if only a thin film of color, as in chromolithography, were applied to the ware, the decoration would be so faint as scarcely to be visible. The number of colors which have a strong staining power when applied only in a thin coat is small. This is the chief difficulty. At present the best chromolithographic work is done by the French, and by some Staffordshire potters.

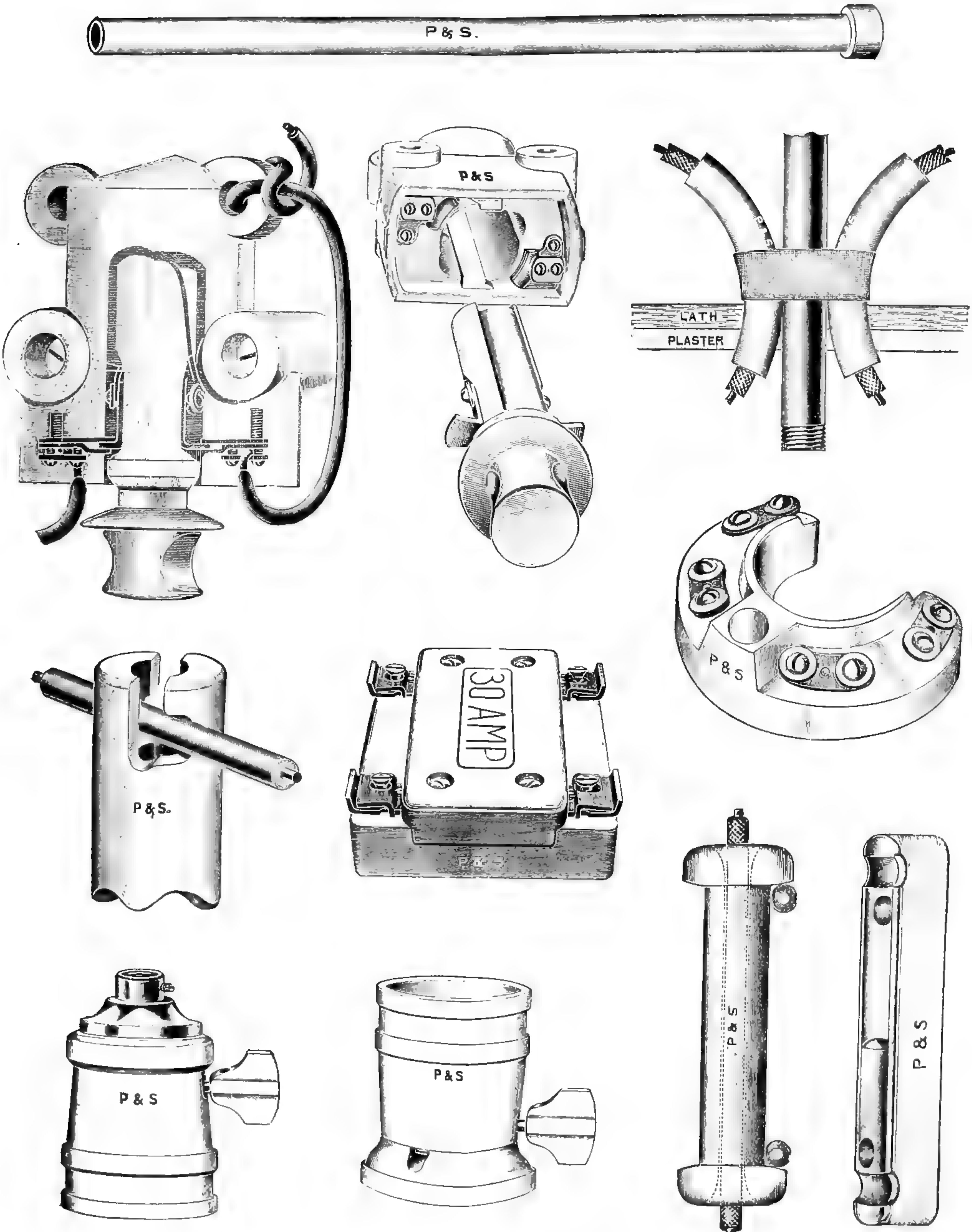
New York stoneware clays

Deposits of clay suitable for the manufacture of stoneware are found on Staten Island and Long Island. Those of Staten Island are at Kreischerville. The Long Island clays are found at Elm point, on Greatneck, at Glencove, and Littleneck, near Northport. They have been shipped to a number of points, including Poughkeepsie, Rochester, Utica, in New York; also to New Haven, Stamford, Norwalk and Hartford, Ct., Newark, N. J., and Pittston, Pa.

Most of the Long Island clays are rather sandy in their nature; consequently they have been found well adapted to mix with the New Jersey clays in order to prevent the latter from cracking in burning. The sandy nature of the Long Island clays makes it difficult to turn many of them alone on the potter's wheel.

Elm point. A deposit has been worked for many years at a point about one and a half miles north west of Great neck, but the pit is no longer in operation, though the supply of clay does not appear to have given out, as a considerable amount of it is still to be seen outcropping along the shore at several points to both north

Plate 133 To face page 517



Porcelain electrical supplies made at works of Pass & Seymour, Syracuse.

and south of the pit. The one objection to the deposit is that the clay is overlain by about 20 feet of yellow gravel and drift, which has caused much trouble at times by caving. It would seem that underground workings could be established, which would be more permanent. A number of pits have been sunk in the clay, many 30 feet in depth, the usual diameter being 10 feet. This clay has been used for a variety of products, such as architectural terra cotta, common stoneware, chemical stoneware and clay pipes.

The clay, which was of a dark gray color, was very plastic and often quite smooth. At the time the samples for physical work were collected the bank had caved in and no specimens were obtainable, but the following is an analysis of it made by Dr H. C. Bowen on a sample collected some years ago.

Silica	76.50
Alumina	15.17
Ferrous oxid	1.34
Lime	.59
Magnesia	.11
Soda	.81
Potash	.127
Phosphoric acid	.07
Moisture	.12
Water (combined)	4.27

Glencove. Carpenter Bros. have a bed of stoneware clay, fire sand and kaolin on the east side of Hempstead harbor. The clay is of a white and pink color, the layers being 4 inches to 1 foot thick, interstratified with layers of quartz pebbles. Nearer the shore this dips under a bed of the clay free from pebbles. Associated with the clay is a deposit of kaolin and fire sand. The clay burns a cream color. The quartz pebbles, which contain small cracks, crumble easily and seem to have been subjected to the action of some alkaline solution.[1] When ground they can be used for the finest grades of pottery and stoneware. The fire sand and kaolin are screened and sold according to grade.

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[1] F. J. H. Merrill. "Geology of Long Island," *Ann. N. Y. acad. sci.* 1884.

Plate 134

H. Ries photo.

View looking north from head of Northport harbor, Long Island. Little Neck, which is underlain by cretaceous clay, is seen on the left.

This clay is used chiefly for the manufacture of stoneware, being shipped to various cities in Connecticut and New York states. It is also used by Perkins & Pit of Stamford, Ct., for the manufacture of stove linings. In the latter case about 15% of it is mixed with New Jersey clay. Under an ordinary fire this clay burns to a light color, but with a hard fire it is said to blacken. The fire sand found associated with this clay bears a most excellent reputation as regards its refractory qualities.

Owing to litigation the clay deposit of Carpenter Bros. has been inactive for several years, but work on it will be resumed again this summer. An analysis of the material is given in the table of analyses below.

In the spring of 1898 a new deposit was opened on the north shore of Mosquito inlet almost directly opposite Carpenter's pit. It is said that this deposit is fully 30 feet deep. It is on the property of Mrs Helen McKenzie. A sample of this clay was collected for physical examination. It is sandy and grayish, quite different in appearance from that found in Carpenter's pit. When mixed with 32.40% of water it gave a very plastic mass, but owing to the large amount of organic matter which it contained it was impossible to form briquettes not free from flaws, so that the tensile strength was only 42 pounds a square inch as a minimum, with 50 pounds maximum, which is undoubtedly low.

The air shrinkage of the bricklets was 8%. At 2200 degrees F. the total shrinkage was 13%, and the clay had become thoroughly dense. Viscosity occurred at cone 27 in the Deville furnace. The color when burned to vitrification is buff, but at viscosity the clay burns reddish. The mechanical analysis of the clay showed:

Clay substance	85
Silt	3
Very fine sand	3
Fine sand	6
	97

Balance mostly organic matter

An analysis made by the writer gave:

Silica	55.39
Alumina	29.90
Ferric oxid	1.10
Lime	tr.
Magnesia	.65
Alkalis	2.50
Water	9.75
Total	99.29

Northport. The Northport clay and fire sand co. has an extensive series of pits on Littleneck near Northport. Both fire sand and clay are obtained. The clay bank has a hight of about 40 feet, the clay is of a bluish black and yellowish white color. The darker clay is the lower, and contains much carbonaceous matter. The deposit is stratified, the layers of clay being separated by thin sheets of a rather coarse sand. It is shipped chiefly to New England.

At the eastern side of the bank a bed of white clay underlies the fire sand, but little of this has been mined.

The following are analyses of New York stoneware clays and kaolin.

	Elm point	Glencove	Littleneck	Kreischervil'e	Kaolin Kreischerville
Silica	62.06	70.45	62.66	64.26	82.51
Alumina	18.09	21.74	18.09	24.76	11.57
Oxid of iron	5.40	1.72	0.97	0.83	0.63
Lime	1.05	0.24	0.79	0.73	0.29
Magnesia	tr.	0.30	.....	tr.	0.78
Alkalis	6.11	5.00	2.23	2.35	2.66
	92.71	99.45	84.74	92.93	98.44

Plate 135

To face page 820

H. Ries photo.

Stoneware clay of Cretaceous age in pits of Northport fire clay co., Little Neck near Northport L. I. Cretaceous leaves are found at the level (a)

The following are analyses of Long Island stoneware clays made by C. H. Joüet. (*School of mines quart.* Jan. 1895)

	White clay from Northport	Black clay from Northport	White clay from Seacliff
Silica	68.34	58.84	62.35
Alumina	19.89	23.40	23.14
Ferrous oxid	.90	1.18	1.12
Lime	.35	.....	.....
Magnesia	tr.	.....	.....
Carbonic acid	.....	.....	.....
Sulfuric acid	.....	1.03	1.09
Potash	3.55	5.04	3.17
Soda	.84	.34	1.76
Combined water	6.03	9.20	6.77
	99.90	99.03	99.40

A physical test of the yellow clay from the pits of the Northport clay and fire sand co. gave the following results. It took 25% of water to mix the clay up to a workable mass, that was very gritty, but possessed good plasticity. The tensile strength of the clay does not stand in direct relation to the plasticity, as the average is only 25 pounds a square inch with a maximum of 30 pounds. The air shrinkage of the bricklet was 5½%, and at 2300° F. the total shrinkage was 12%. At this temperature the clay had burned buff, and was nearly vitrified. Viscosity occurred in the Deville furnace at cone 27.

The mechanical analysis of the clay shows the high percentage of sand contained, which is evidently responsible for its low refractory quality.

Clay substance Silt	30
Very fine sand	60
Fine sand	9
	99

It is probable that the washing of this clay and the consequent elimination of the grit would greatly increase its refractory power.

The black clay which underlies the lower is somewhat less sandy, running thus:

Clay substance and silt	81.00
Finest sand	3.30
Fine sand	16.20
	100.50

Like the preceding, it is not a highly refractory clay, fusing completely at cone 27 in the Deville furnace. It does, however, burn to a dense body of cream white color and its chief use is for stoneware. There is apparently no reason why it should not work for the manufacture of white or very light buff brick. The shrinkage at cone 3 is 8%, and at cone 6, 12%, at which temperature it is nearly non-absorbent, and begins to deepen in color.

The following is an analysis of the Eaton's neck clay, made by Dr H. C. Bowen.

Silica	66.46
Alumina	22.33
Ferrous oxid	1.38
Lime	.67
Magnesia	.07
Potash	1.52
Soda	.58
Phosphoric acid	.10
Moisture	.31
Water	6.21
	99.63

Pottery industry of New York

The products of this class made in New York include common earthenware, stoneware, both common and chemical, white earthenware, porcelain.

Greater New York. The works situated within its boundaries are:

D. Robitzels's Sons, Morrisania. White earthenware and hard porcelain

Capital pottery, Brooklyn. Stoneware

A. Benkert, Brooklyn. Stoneware

Joseph Newbrand pottery, Long Island City. Earthenware

Chemical pottery works, C. Graham, Brooklyn. Chemical stoneware

The clays used are mostly from New Jersey, but at times some Long Island clays are used. The product includes acid receivers, vats, jars, stop-cocks, sinks, pumps and other articles for chemical works.

W. T. Dufek, Brooklyn. Stoneware

Empire china works, Brooklyn. White earthenware

Green point porcelain works, Brooklyn. White earthenware

Union porcelain works, Brooklyn. White earthenware

The last factory makes a true hard porcelain, but it was originally established in 1854 as a bone china factory. The chief product of the works is both plain and decorated table ware, though the factory under the guidance of C. H. L. Smith has turned out a number of high grade ornamental objects, specially vases.

Syracuse. The Onondaga pottery, situated here, was organized in 1871, the product at first being white granite. Subsequently (1886) the manufacture of porcelain was begun; this forms the output at present. The ware bears a high reputation for its strength and toughness, with which is combined lightness.

Many of the plates illustrating the manufacture of pottery were taken at these works through the courtesy of Mr Pass, the president of the company. So successful have been the operations of this company, that the capacity of the plant has been doubled.

The factory of Pass & Seymour is located at the western edge of the town. The product consists entirely of porcelain electric supplies, many being quite complicated and their manufacture (which is by the dry press method) requiring considerable ingenuity.

The Syracuse pottery company on N. Salina street, produces stoneware.

Victor. Close to the New York Central railroad station is the factory of F. Locke, manufacturer of porcelain electric supplies. Mr Locke's products are made from a mixture of clays, obtained in part from New York state and in part from other states. The body is vitrified, and well fitted for the insulation of high currents. It is either white or colored. In some cases the ware is glazed with a Quaternary clay that is obtained in the vicinity of Victor. Among the large pieces of work turned out by this factory is a series of 600,000 insulators for a 40 mile line in California.

Rochester. The Flower city pottery. Stoneware

Utica. Central New York pottery

Lyons. Lyons pottery co. Stoneware

Fort Edward. Hilfinger Bros. Earthenware and stoneware

Chittenango. Chittenango pottery co. Ornamental and common stoneware.

Plate 136

H. Ries photo.

Stock yard, Graham's chemical stoneware works, Brooklyn. Shows different types of ware produced.

SHALES OF NEW YORK

These form an enormous series of deposits in the southern region of the state, as well as some of the central portions.

The origin of shale has already been mentioned (p. 502). From the fact that they were deposited in the sea they are usually much more extensive than the Quaternary clays immediately underlying the surface.

The shales found in New York state are in every case quite impure, and often silicious, indeed are at times interbedded with thin layers of sandstone. Owing to their consolidated nature the shales have to be first ground in order to develop their plasticity; the finer the grinding the more plastic the mass. It has also been found that in some cases the finer grinding of the shale produces a vitrified brick at a temperature that formerly did not allow this, the brick made from the coarser shale showing 6%–7% absorption.

Shales exhibit a great variation in hardness; this fact shows itself specially during the grinding process. As has been stated in another place, shale is only a consolidated clay. Sometimes this hardening or consolidation has occurred by the weight of the overlying beds alone, while at other times the clay particles have become more or less cemented together. It is obvious, therefore, that those shales hardened by the former circumstance will fall apart more readily in the grinding pan, and tend to yield a more plastic mass.

So far as the shales have been used and tested, the Devonian shales seem to work best for a vitrified product, as the points of incipient fusion lie from 250 to 300° F. apart.

The Salina shales make a good strong brick if thorough vitrification is not desired, for they are often calcareous.

The Medina shales, particularly the weathered portions, are utilized in Ontario for making pressed brick and give good results. The deposit continued across west central New York awaits development.

The physical and chemical characters of the shales can be judged from some of the tests given beyond under the locality descriptions.

The shale-bearing formations occurring in New York state, beginning with that geologically oldest, are as follows:

Lower Silurian	Hudson river
Upper Silurian	Medina
	Clinton
	Niagara
	Salina
Devonian	Hamilton
	Portage
	Chemung

A geological map will show the outline of the area underlain by the outcropping edges of each shale formation, and it will be noticed that they form bands of variable width extending across the state from east to west.

As the formations have a slight dip (40–60 feet a mile) to the south, the belts of shale encountered in crossing the state from south to north will be successively older.

Furthermore any one bed will of couse be higher above sea level to the north than to the south. The Chemung shales underlie the whole surface in the southern part of the state, but as we proceed northward they are found only on the ridges of the higher hills, the sides and bottom of the valleys being underlain by the Portage shale, which in turn succeeds the Chemung as the surface formation.

Distribution and properties

Hudson river. This formation is abundantly displayed in the counties of Lewis, Oneida, Montgomery, Schenectady and Columbia. Its tendency is to exhibit silicious or slaty phases, but in eastern Columbia co. it becomes at times argillaceous and at the same time contains considerable iron.

Medina. The Medina formation at times is shale-bearing, as along the Genesee river, where it is also marly, but the extent of the shaly layers is unimportant. (Hall. *Geology of the 4th district of New York.* p. 38)

The shale beds are, however, well developed at Lewiston, where they are exposed in the sides of the gorge on both the American and Canadian shore. From this point they extend eastward and are to be seen at a number of points in the terrace escarpment.

The shale is rather soft and crumbly, and in places contains abundant mica flakes. It is highly ferruginous and weathers to a red clay, which is more plastic than the mass produced by grinding the partially weathered shale and mixing it with water.

This material has not thus far been utilized in New York state, yet it is extensively employed at several localities in Ontario, notably Beamsville, for the manufacture of pressed brick.

A sample collected from the exposures at Lewiston was tested with the following results.

The partially weathered shale gave a lean mass when mixed with 16% of water. The air shrinkage of the bricks was 3%, and the tensile strength of the air-dried clay was 15 pounds a square inch.

The clay contains .6% of soluble salts. In burning it shrinks very slowly, and at 1 the shrinkage was only 6%. At this point the shale had vitrified and showed a deep red color. Incipient fusion occurred at .04, the clay burning bright red. It became viscous at above 4.

Its composition is:

Silica	59.50
Alumina	20.60
Ferric oxid	8.00
Lime	.80
Magnesia	.35
Alkalis	3.60
Water	5.50
Total	98.35

Owing to its highly ferruginous nature, it tends to blister when burned to vitrification unless heated very slowly.

Clinton. The Clinton group is shale-bearing in its lower members in eastern Wayne co. It is a bright green shale and is about 30 feet thick. At Sodus Point the shale is purplish. It occurs at other localities, but is very thin, not more than 2 to 4 feet. (Hall. *Geology of the 4th district of New York*, p. 59) The second green shale of the Clinton group is less brilliant in color and everywhere full of fossils. It is well exposed at Rochester and at Wolcott furnace, in the banks of the creek, where it is more than 24 feet thick. The shale is probably frequently calcareous.

Niagara. Though a prolific shale formation in New York state, the writer has not seen any exposures of it which were not either very silicious or calcareous, so that it would probably not work well for the manufacture of clay products. When ground and mixed with water it possesses no plasticity.

According to Prof. Hall (*Geology of the 4th district of New York*. p. 80), the Niagara shale forms a member of great development in the lower part of the Niagara group. It is a dark bluish shale which, on exposure, forms a bluish gray, marly clay. It is well shown at Lockport, in the sides of the gorge at Rochester, just below the railroad bridge, and at many localities in Wayne and Monroe co. The lower layers of the shale are less calcareous than the upper ones.

The following is a partial analysis of this shale, the sample taken from the gorge at Rochester (*16th ann. rep't U. S. geol. surv.* pt 4, p. 569).

Silica	28.35
Alumina	10.47
Ferric oxid	1.90
Lime	21.47
Magnesia	8.24
Alkalis	5.73
	76.16

H. T. Vulté, *analyst*

The shale is also to be found in many of the ravines and gorges, from Rochester to the Niagara river.

Salina. The shales of this formation are contained in a belt extending from Syracuse westward along the line of the New York central railroad to Buffalo. As a rule they are extremely impure and at times even marly. They are soft shales, which weather very easily, and are generally red or green in color and contain the beds of gypsum and salt.

The Salina shales are well exposed at Warner, near Syracuse, where they are utilized for making brick.

Prof. Hall says of the Salina or salt group (*Geology of the 4th district of New York.* p. 117), that it forms an immense development of shaly marls and limestones, with interbedded deposits of gypsum. The formation extends from Syracuse westward through southern Wayne co., and northern Ontario and Seneca co., northern Genesee and Erie co. and a small part of the southern portion of Niagara. This group contains important shale beds, though they are unfortunately very calcareous at times and consequently require careful manipulation.

The red shale forming the lower divisions of the group was not observed west of the Genesee river. It appears in eastern Wayne co., as indicated by the deep red color of the soil overlying it. At Lockville the greenish blue marl with bands of red has been quarried from the bed of the canal. West of the Genesee this is the lowest visible mass; the red shale has either thinned out or lost its color, becoming gradually a bluish green; while otherwise the lithologic character remains the same. On first exposure it is compact and brittle, presenting an earthy fracture, but a few days are sufficient to commence the work of destruction, which goes on till the whole is resolved into a clayey mass.

The green marl of the lower division appears near the canal at Fairport and again at Cartersville. The bed of the stream at Churchville shows the greenish blue marl.

" The prevailing features of the second division of this group," says Prof. Hall, " are a green and ashen marl, with seams of fibrous gypsum and red or transparent selenite. It occurs in the vicinity of Lyons and numerous points farther west ".

The third division contains large gypsum beds and is probably not suitable for use.

The Salina shale, as stated above, is worked at Warner, Onondaga co., by the Onondaga vitrified brick co. The shale as exposed in their bank consists of a green or red, soft, argillaceous shale, of considerable impurity, as the following analyses furnished by the company show.

	Calcareous layer in bank	Red shale	Blue shale
Silica	25.40	52.30	57.79
Alumina	9.46	18.85	16.15
Ferric oxid	2.24	6.55	5.20
Lime	22.81	3.36	2.73
Magnesia	10.39	4.49	4.67
Carbonic acid	20.96	3.04	3.42
Potash	.95	4.65	4.11
Soda	.....	1.35	1.22
Water and organic matter	7.60	5.30	4.50
	99.81	99.89	99.79
Total fluxing impurities	36.39	20.40	17.93

These shales must be quite fusible owing to their high percentage of fluxing impurities.

At the works of the Onondaga vitrified brick co., the shale crops out in considerable thickness near the yard, and is of various shades of red, green, and gray; it disintegrates very rapidly, and the whole bank is traversed by numerous cracks, so that a small blast brings down a large amount. The material is mixed with a surface clay in the proportion of 1 of clay to 3 of shale; it is ground in a dry pan, and molded in an auger machine; the green bricks are dried in tunnels and burned in circular kilns; the product is of a red color, and very hard.

Marcellus shale. This formation presents numerous undesirable features, so that its occurrence is of little importance to clay

H. Ries photo. Bank of Salina shale, Onondaga vitrified brick co., Warners N. Y.

workers. It is generally slaty, gritty, and contains not infrequently much iron pyrite and bituminous matter. The rock is well exposed in the bed of the river at Leroy.

As the Hamilton, Portage and Chemung are the most promising and most extensive of the shale formations occurring in this state, a series of physical tests was made on samples from several localities, to determine their characters as related to each other, also as compared with other deposits.

The samples were ground to pass through a 30 mesh sieve[1]. The determinations made on these samples were: 1) amount of water required to make a workable mass, 2) shrinkage in drying, 3) shrinkage in burning, 4) plasticity, 5) tensile strength of air-dried briquettes, 6) temperature of incipient fusion, 7) vitrification, 8) viscosity, 9) per cent of soluble salts.

The localities from which samples that were tested came are Jamestown, Angola, Hornellsville, Alfred center, Cairo and Corning.

Hamilton. The Hamilton is one of the great shale-bearing formations of New York state. It is also widely distributed, extending from the Hudson river to Lake Erie, and at these two points shows wide extremes in its lithologic character. In the east it is a true sandstone, in the west a clay shale. "The valleys of Seneca and Cayuga lakes are both excavated, for more than half their length, in the shales of this group". (Hall. *Geology of the 4th district of New York*, p. 187)

The Hamilton shales extend from Port Jervis northeastward along the edge of the Chemung area in a belt about 5 miles wide, and then swing westward from a point a few miles west of Albany to Buffalo. In the central part of the state the Hamilton belt is about 20 miles wide, and thins to about 12 miles in the western half. The Finger lakes are largely bounded on the north by the Hamilton shale area.

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[1] Of most of the shales ground up by disintegrators, about 60% of any sample will pass through a 30 mesh sieve, and the balance through a $\frac{1}{16}$ or ⅛ inch mesh.

Along the banks of Seneca and Cayuga lakes the full section of the Hamilton group may be seen. The lower members are the most northern, and dip to the south under the higher ones. Prof. Hall makes the following divisions:

1 Dark, slaty fossiliferous shale, resting on the Marcellus shale

2 A compact, calcareous blue shale, of little thickness

3 An olive or blue shale, which in its upper layers is stained by oxid of manganese. This is one of the best adapted for clay products

4 Ludlowville shales, often sandy in their nature

5 A limestone

6 Moscow shales, of grayish blue color, and slightly calcareous in places

These subdivisions can all be seen along the eastern shore of Cayuga lake from Springport to Ludlowville.

Cairo, Green co. This is one of two localities at which the Hamilton shale is mined. The material, which is shipped to the works of the Catskill shale paving brick co., at Catskill, is a reddish gritty shale possessing little plasticity. This material was at first used alone, but found difficult to work on account of its excessive leanness, and consequently is now mixed with 50% of common red clay also obtained from Cairo. Samples of this mixture were tested with the following results. The moderately plastic paste shrunk 4% in drying, and 9% in burning. Air-dried briquettes had an average tensile strength of 97 pounds a square inch, and a maximum of 100 pounds a square inch.

Incipient fusion occurred at cone .05, vitrification at cone .01, and viscosity at cone 2.

The mixture of clay and shale is ground in dry pans, then passes to the pug mill on the floor above, whence, after tempering, it is discharged to the auger side-cut machine. The bricks are repressed, dried in tunnels, and burned in down-draft kilns. The company has recently erected a large continuous kiln; in this kiln, most of the firing is done in temporary fireplaces built in the door-ways of the kiln, no grate bars being used; it is said that practically no fuel is charged through the small openings in the roof of the kiln.

The Hamilton shale is also utilized in the western part of the state at Jewettville, where dry pressed and also stiff mud brick are made from it. (See detailed account of brickyards, p. 724)

Several samples have been collected by Prof. I. P. Bishop in Erie co., and tested with the following results. The numbers preceding each locality refer to Prof. Bishop's notes.

No. 2. Hamilton shale from near Windom. Forms a bed 10–12 feet thick. When ground to 30 mesh, it took 22% of water to work it up. The mass was fairly plastic. The tensile strength was 40 pounds a square inch, and the air shrinkage 4½%.

At .03 the total shrinkage was 9%. The brick was deep red, hard and semi-vitrified. Vitrification occurs at cone 1, with a total shrinkage of 14% and viscosity at 4. The shale is slightly calcareous, and the soluble salts were noticeable on the surface of the dried bricklet. A determination of these showed 9%.

No. 3 of Bishop is a 5 foot bed above the preceding one, and took only 20% of water to work it up. The air shrinkage was 2%. At .06 the total shrinkage was 4%; the color of the bricklet deep red when incipient fusion had been reached. It vitrified at 1 with 8% shrinkage. Viscosity began at 4. The percentage of soluble salts was 6%. The analysis yielded:

Silica	57.30
Alumina	21.61
Ferric oxid	6.50
Lime	2.52
Magnesia	1.50
Alkalis	....
Water	7.80

No. 4 of Bishop is from the top of the Hamilton shale at bridge west of Websters Corners. The bed is 5 to 6 feet thick. This sample gave quite a plastic mass, with 21% of water. The air shrinkage was 3%. When heated to .06 the total was 4%, with incipient fusion, and the color deep red. The clay vitrifies at 1, with a total shrinkage of 7%. The shale has .2% soluble salts.

No. 5 of Bishop is also from near Windom. It is a fine-grained shale, which worked up to a lean mass with 19% water. Tensile strength, 35 pounds a square inch. The air shrinkage was 3%. At .03 the total shrinkage was 7%, and the bricklet was nearly vitrified. It was completely vitrified at 1 with 9% shrinkage. It became viscous at 5. The soluble salts were .35%. Its composition is:

Silica	61.15
Alumina	14.57
Ferric oxid	7.20
Lime	3.06
Magnesia	.20
Alkalis	1.90
Water	5.95
	94.03

Portage. (*See* Hall. *Geology of the 4th district of New York.* p. 224.) Another important shale occurs in this member of the Devonian formation. The group consists of a lower shaly member, the Cashaqua shale, a middle member of shales and sandstones, and an upper one of sandstones.

The Cashaqua shale is exposed along Cashaqua creek, where it is a soft green shale that weathers to a tough clay. It also occurs along Seneca lake and at Penn Yan, but east of this becomes very sandy. Good exposures are seen along Allen's creek and Tonawanda creek, and the branches of Seneca and Cayuga creeks. On Lake Erie at Eighteen Mile creek it is 33 feet thick, while along the Genesee river it is 150 feet thick.

Concerning the Gardeau shales, Prof. Hall states that they are exposed along the Genesee river, where the section involves alternating layers of shales and sandstones. Toward the east the sandstones become more prominent, but to the west the shales increase and predominate, so that along Lake Erie, "the Cashaqua shale is succeeded by a thick mass of black shale, and this again by alternations of green and black shales", which aggregate several hundred feet in thickness.

Angola, Erie co. The Portage shale is used by J. Lyth & Sons at this locality for the manufacture of sewer pipe, fireproofing, drain tile and terra cotta. The clay is somewhat less gritty than that at Jamestown. It is a grayish, moderately coarse-grained shale and contains scattered streaks of bituminous matter.

When ground to 30 mesh it required 21.4% of water to work it up, giving a moderately plastic mass. The air shrinkage was 4% and the fire shrinkage 10%. The air-dried briquets had an average tensile strength of 92 pounds a square inch, and a maximum of 95 pounds a square inch. Incipient fusion occurs at cone .06, vitrification at cone .01 and viscosity at cone 4.

The analysis of the clay is as follows:[1]

Silica	65.15
Alumina	15.29
Ferric oxid	6.16
Lime	3.50
Magnesia	1.57
Alkalis	5.71
	97.38
Total fluxing impurities	16.94

In general composition it resembles a Carboniferous shale used for paving brick at Kansas City, Mo.[2] This shows the following analysis:

Silica	64.37
Alumina	19.73

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[1] *Bulletin New York state museum.* no. 12, v. 3, p. 228.

[2] *Clay worker*, December 1893.

Ferric oxid	9.07
Lime	.82
Magnesia	2.32
Alkalis	3.78
Total impurities	16.97

The principal output of these works is fireproofing. On account of its softness the shale is easily mined and transported in cars to the dry pans, where it is first ground and then tempered in a wet pan. The tempered material is then conveyed to the upper floors and discharged into the usual form of sewer pipe press. The glazing of the sewer pipe is done by means of salt.

Chemung. The most southern shale formations of New York state are included under this head. As a whole, the group consists of interbedded shales and sandstones, the former prominent toward the west, the latter becoming predominant to the east. The shales vary in color, and are black, olive or green. The shales sometimes pass into shaly sandstones; these are often highly micaceous. The members of the group recognized by Prof. Hall, beginning at the top, are:

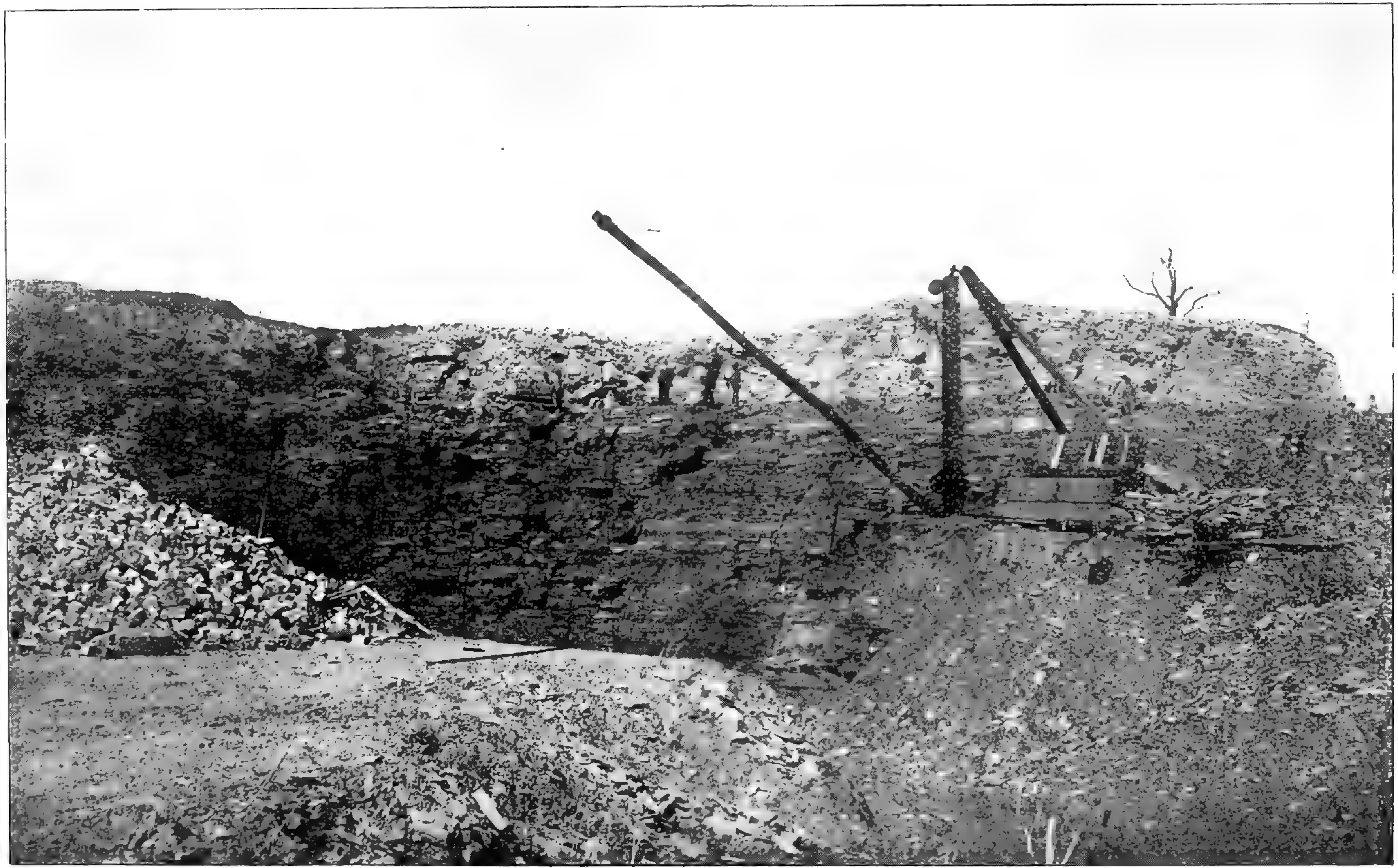
6 Sandstone and conglomerate
5 Old red sandstone
2 Black, slaty shale
3 Green shale with gray sandstones
4 Gray and olive shales and shaly sandstone
1 Olive, shaly sandstone
Portage sandstone

Of these members 2, 3 and 4 are the most important to clay workers; the beds of shale exposed are often 20 or 30 feet in thickness and free from sandstone.

"On the Genesee river the shale is often in thick beds of a bright green color and scarcely interrupted by sandy layers".

"Westward from the Genesee river there appears to be a constant augmentation in the quantity of the green shale, which is

Plate 138



H. Ries photo.

Shale quarry, Jamestown shale paving brick co., Jamestown.

often the predominating rock, though from weathering to an olive color it does not always appear as distinctly ".

" In the ravines in Chautauqua co., extending toward Lake Erie, the shale still retains its green color ".

Jamestown, Chautauqua co. This sample of shale came from the bank of the Jamestown shale paving brick co.

This was a rather gritty shale, which required 18.5% of water to make a workable paste; plasticity, lean. The paste shrunk 4.5% in drying, and an additional 7.5% in burning, making a total shrinkage of 12%. Air-dried briquettes made of this mud had an average tensile strength of 16 pounds a square inch, and a maximum of 20 pounds a square inch. This low tensile strength was due to the silicious character of the shale which, however, permitted rapid drying.

Incipient fusion occurred at cone .04, vitrification at cone .01 and viscosity at cone 3. The clay burns to a deep red and dense body.

A sample collected by the writer a year later, representing an average of the material used, gave: water required to mix up, 17%; tensile strength, 45-69 pounds; plasticity, lean; incipient fusion cone .06, with 5% shrinkage; vitrification .01, with 10% shrinkage; viscosity at cone 2. When vitrified the clay burns deep red. Soluble salts .55%.

Alfred center, Allegany co. Chemung shale is used at this locality for the manufacture of roofing tile. The shale is somewhat argillaceous, and moderately fine-grained.

It requires 20% of water to make a workable mass, which is slightly plastic. The shrinkage of this paste in drying is 4% and in burning 9%. The tensile strength of air-dried briquettes was, on the average, 61 pounds a square inch, with a maximum of 62 pounds a square inch.

Incipient fusion occurs at cone .06, vitrification at cone .01, and viscosity at cone 3.

The composition of the shale according to an analysis furnished by the Celadon terra cotta co., of Alfred center, is:

Silica	53.20
Alumina	23.25
Ferric oxid	10.90
Lime	1.01
Magnesia	.62
Alkalis	2.69
Sulfuric acid	.41
Titanic acid	.91
Water	6.39
Manganese oxid	.52
	99.90
Total fluxing impurities	15.74

This shale corresponds very closely in composition to that used at Kansas City, Mo.,[1] for the manufacture of paving brick, but there is a considerable difference in the fusibility, the Missouri shale being very fine and consequently more fusible.

When this factory was first started, both terra cotta and roofing tile were produced, but now the Celadon terra cotta co. confines itself entirely to the manufacture of vitrified roofing tile, which is of a superior quality, and bears an excellent and widespread reputation. At first a mixture of clay and shale was used, but now the latter material alone is found sufficient; the shale after grinding and careful tempering is molded either by hand or steam power machines, and set aside to dry slowly. The tile are no longer burned in saggers as was formerly done, but are placed in pockets in the kiln. The shale burns to a tough, cherry red body.

Alfred Station. A bed of shale is worked in a spur of the hill on the opposite side of the valley from the station. It is similar to

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[1] *Mo. geol. sur.* 11, 565.

Plate 139

To face page 839

H. Ries photo.

Shale bank, Corning brick and terra cotta co., Corning N. Y.

that from the quarry one mile north, and is used by the Alfred clay co. for the manufacture of roofing tile and dry press brick.

Hornellsville, Steuben co. The shale at this locality frequently contains interbedded layers of sandstone, which are separated in mining without much trouble. The shale is rather gritty, and on the addition of 20% of water gave a lean, workable paste, which shrunk 2.7% in drying and 5.3% in burning. The tensile strength of the air-dried mud to the square inch was on the average 34 pounds, with a maximum of 39.

Incipient fusion occurs at cone .06, vitrification at cone .01, viscosity at cone 4.

The shale burns to a dark red. It is used in the manufacture of paving brick.

The composition of the clay, from an analysis furnished by the Preston brick co., is as follows:

Silica	64.45
Alumina	17.77
Ferric oxid	7.04
Lime	.58
Magnesia	1.85
Potash	2.52
Soda	1.95
	96.16
Fluxes	13.94

The method of manufacture followed at these works consists of the usual dry pan for grinding the shale and wet pan for tempering it. The molding is done by a stiff mud, side-cut machine, and the green brick are repressed. The burning is in down-draft kilns.

Corning. A gray, gritty shale is quarried at this point for the manufacture of paving and building brick. The quarries are located along the Erie railroad, about half a mile west of town. The shale is argillaceous and contains occasional layers of sandstone, which are discarded in the quarrying. A siding runs into the quarry, so that the material can be easily loaded and then shifted over to the works.

A sample of this shale gave the following results: water required for mixing, 18%; plasticity somewhat lean; air shrinkage, 2%; shrinkage at cone .05, 3%, with clay incipiently fused; vitrification at cone 1; viscosity at 3–4. The soluble salts amounted to .3%.

An analysis of the shale made by H. Ries gave:

Silica	58.10
Alumina	17.50
Ferric oxid	6.00
Lime	4.50
Magnesia	2.88
Alkalis	4.15
Water	5.90
Total	99.03

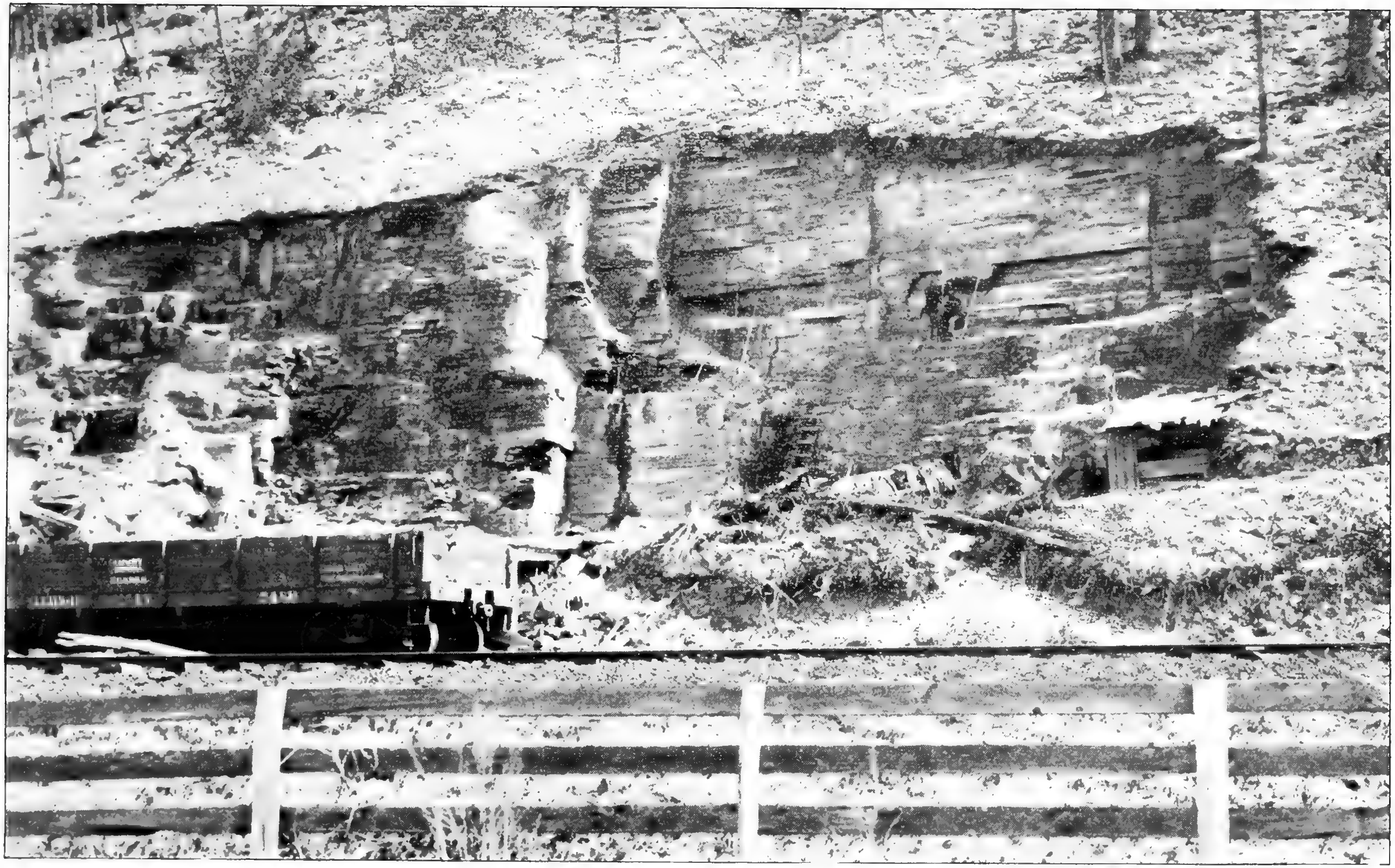
Horseheads. An opening has been made on the north side of the valley along the Elmira, Cortland and Northern railroad, to supply shale for the manufacture of common brick. The quarry face is about 20 feet high and shows the shale to be mostly gray, with occasional yellow layers due to weathering.

The shale deposits of New York are destined to play an important role in the future. They form an inexhaustible source of supply, easily located, adapted as present work shows, to a wide range of uses. The products now made from them are common and pressed brick, paving brick, roofing tile, terra cotta, sewer pipe and fireproofing.

From the tests cited above it will be seen that the shales used compare very favorably with the requirements of a paving brick material. Most of them are slightly more silicious than the average

Plate 140

To face page 840



H. Ries photo.

Shale bank (Chemung period), Empire brick works, Horseheads N. Y.

run of paving brick clays, but this is no serious objection. The lean character of many can be overcome by the addition of plastic clay, as in the case of the Cairo shale, in which instance the mixture, as already stated, had a tensile strength of 100 pounds a square inch. The amount of fluxes present permits their vitrifying at comparatively low temperature. But if necessary their refractoriness could be easily increased by the addition of a certain amount of fire clay.

Feldspar and quartz

Mineralogic characters. Feldspar, or "spar" as it is commercially called, is one of the commonest of rock-forming minerals, and yet, owing to its usual intimate association with other mineral species, commercially valuable deposits of it are comparatively rare. The deposit must be large and of sufficient purity. Its most common associate is quartz, but the two possess properties which render them easily distinguishable.

Feldspar is usually of a cream or red color, but at times may be white. It cleaves readily in two directions nearly at right angles to each other, so that fragments often show two smooth cleavage surfaces, the result of this property of splitting. Chemically, feldspar is a complex silicate of alumina and potash, soda or lime.

Quartz differs from feldspar in lacking cleavage, and being harder. Its hardness is 7 in the scale, and it easily scratches glass. It has also a bright glassy luster, and breaks with a conchoidal or shell-like fracture.

There are two well marked groups of feldspar minerals, the potash feldspars, of which orthoclase is the type, and the lime soda feldspars, or plagioclases.

It is the orthoclase feldspar that is usually mined, though there is undoubtedly some plagioclase in some of our commercial feldspars, but a systematic chemical investigation of the American materials has, however, never been carried out.

While there is but slight variation in the hardness of these feldspars, there is a variation in the chemical composition and fusibility.

The following table gives the composition and fusibility of the different feldspar species according to Dana.

	Name	Fusibility in scale	SiO_2	Al_2O_3	K_2	Na_2O	CaO	FeO
	Orthoclase . . .	5.0	64.7	18.4	16.9	. . .	. . .	. . .
Plagioclase	Anorthite	5.0	43.2	36.7	. . . .	. . .	20.1	. . .
	Albite	4.0	68.7	19.5	. . . .	11.8	. . .	. . .
	Oligoclase. . . .	3.5	64.0	24.0	2.0	9.0	3.0	. . .
	Labradorite . .	3.0	54.0	29.0	. . . .	5.0	11.0	1.0

Occurrence. Deposits of feldspar are found in the southeastern portion of the state, near the town of Bedford, about 40 miles north of New York city. In this region the feldspar together with quartz forms large pegmatite veins, in the augengneiss of that region. The width of some of these veins is over 50 feet. The spar at times forms large masses, at other times it is more or less intimately associated with the quartz, necessitating some sorting after it is quarried, and, when streaks of mica or black tourmaline are encountered in the veins, they are usually thrown out. The color of the feldspar varies from dark red to a creamy white, though most of it is a deep cream. The largest quarry is that operated by P. H. Kinkel & Son, where a large amount of quartz and feldspar has been taken out during the last 10 years. The feldspar in Mr Kinkel's quarry is orthoclase, as can be seen by the following analysis:

	No. 1	No. 2
SiO_2	64.97	65.85
Al_2O_3	20.85	19.32
Fe_3O_2	tr.	.24
K_2O (by loss)	13.72	14.10
Na_2O	. . . . .	. . . . .
H_2O (by loss)	.46	. . . . .
CaO	. . . . .	.56
MgO	. . . . .	.08
	100.00	100.15

No. 1 furnished by P. H. Kinkel.

No. 2 *Chemistry of pottery,* p. 38. C. Langenbeck *analyst.*

Other quarries occur in the vicinity of Bedford, on the farm of A. Hobby, and L. McDonald, but their output is not constant.

Though in New York the quartz and feldspar are found in the same veins, still at many localities they occur alone, but in every case the vein is found in metamorphic rocks.

Preparation. The quartz and feldspar are quarried in the usual way by blasting, and after sorting when this is necessary, they are ground in a buhr stone mill, similar to that shown in plate. This reduces the material to a condition of fine sand, after which it is put in a ball mill, with rolled flint pebbles, and ground for about six hours, the resulting product being a very fine powder, which is shipped.

Uses of feldspar. Feldspar is used to a large extent as a fluxing material in the manufacture of white earthenware, and porcelain bodies, and is also one of the ingredients of the glaze for hard porcelain. In addition it has also found some use as a constituent of glass, the feldspar furnishing the necessary amount of alumina for the purpose of hardening the product and as a wood-filler.

Uses of quartz. Quartz is also used as an ingredient of pottery for the purpose of counteracting fire shrinkage, and, in addition to its uses in this direction, powdered quartz finds application in a number of other branches of the industrial arts. Much of the quartz produced in this country is mixed with oil, and is used as a wood-filler in painting. That utilized for this purpose is ground as finely as the quartz consumed by the potters. It is also employed in the manufacture of sand paper, powders and scouring soaps and glass manufacture.

The entire output of the quarries at Bedford is hauled to Bedford Station, and shipped from there to the potteries at Trenton.

The prices obtained for both quartz and feldspar vary naturally with the grade of the material, and also the supply and demand. Ground spar at Trenton brings about $7 a ton, while ground quartz is sold for about $3 a ton. The percentage of ferric oxid in the material influences its commercial value to a large degree, as, in the manufacture of white earthenware or porcelain, it is highly essential that the iron percentage in the mixture shall be extremely low. For this reason many deposits of feldspar, which would otherwise be of commercial value, are left untouched.

MINOR USES OF CLAY

In the foregoing pages of this report attention has been given entirely to those uses of clay which depend on the presence of plasticity when wet and hardness when burned. There are, however, several other directions in which clay or shale can be used, in either the raw or the burned condition. At times the plasticity is of value in promoting the usefulness of the clay in some of the directions about to be discussed, at others it has no bearing on the matter, being entirely a question of proper chemical composition. The minor uses of clay may be classed under the following heads:

Portland cement
Mineral paint
Clarifying oils and fulling cloth
Filling paper
Food adulterants
Ultramarine manufacture
Polishing and abrasive uses
Road material
In engineering work for making puddle

Portland cement

As there is a state museum bulletin in preparation, discussing the lime and cement materials of the state, this question need not be gone into in any great detail in the present report.

Portland cement is made of a mixture of clay or shale, with limestone, marl or chalk. The essential ingredients of this cement are silica, alumina and lime, the first two being supplied by the argillaceous constituent, and the third by the calcareous one, the lime stone. As a rock containing these three ingredients mixed in exactly the right proportions is seldom found in nature, it is consequently necessary to mix them artificially. Both the materials are ground very fine in order that they be intimately mixed, and this mixture then burned in suitable kilns at a higher temperature than that arrived at in the manufacture of any except the most refractory grades of clay products proper, the object of the burning being to cause the component elements of the mass to unite — for which reason the material in burning has to be brought to a condition of sintering — the new compounds being calcic silicates and calcic aluminates. The burned mass is then finely ground, after which most of it will pass through a 100 mesh sieve, and a large percentage of it through 200 mesh as well. This ground material when mixed with water has excellent hydraulic properties, the mass setting into a stonelike condition. It has been found by Newberry that in the best cements the percentage of lime is equal to 2.8 times the silica plus 1.1 times the alumina.

New York, with her great series of Paleozoic limestone formations, her Quaternary marls, and her clays and shales ranging in age from the Silurian to the Quaternary, is liberally supplied with raw materials to support a flourishing portland cement industry, and indeed there are already seven factories in operation in the state, while an eighth one is nearly completed, and several more are in contemplation.

The characters of the different limestone formations are discussed in the bulletin already referred to, and an idea of the nature of the clays and shales can be gained from the analyses given in different portions of this bulletin. For farther reference there are given herewith some additional analyses of clays and shales used at different localities in the United States for the manufacture of portland cement.

Up to a few years ago most of the portland cement used in the United States was imported from foreign countries, but at the present time it is being found that it is possible to make just as good hydraulic cement in this country, and the local production, already large, is increasing annually, and prejudice against it, which has unfortunately existed, is slowly disappearing.

Clays and shales used in manufacture of portland cement

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	H_2O & Org
Glens Falls, N. Y.	55.27	23.15		5.84	2.25	.12	....
Warners, N. Y.	40.48	20.95		*a* 25.80	*a*.99	......	8.50
Sandusky, O.	64.70	11.90	9.90	.90	.70	......	11.90
Bronson, Mich.	62.10	20.09	7.81	.65	.90	.49	7.90
Yankton, S. D.	57.98	18.26	4.57	1.75	1.83	1.28	12.08
Arkansas	53.30	23.29	9.52	.36	1.49	......	5.16

a Determined as carbonate.

Mineral paint

By this term is meant a paint obtained by taking some earthy mineral or rock, which has the desired color, grinding it to a fine powder if it is not already in that condition, and then mixing it with oil.

One of the commonest forms of mineral paint is the well-known ocher which is simply a fine-grained ferruginous clay, of the proper color. Common ocher is not quarried in this state, but a variety of ocher known as sienna is found, forming a thin bed in the glacial drift south of Whitehall, and has been worked for a number of years.

In the southern part of the state near Randolph there occurs a series of shale beds which exhibit green, brown, bluish and olive colors, depending on the amount of iron oxid which they contain and its condition of oxidation. These are worked by the Elko mining and milling co., and ground for mineral paint.

Mineral paints made from clays and shales form a cheap and satisfactory form of color application for wooden surfaces. The value of the material depends to a large extent on the shade of the color, the amount of fineness which it naturally possesses and the percentage of oil which has to be mixed with it in order to give a mixture of the proper consistency.

Clarifying oils and fulling earth

Under this head is included the material known as fullers' earth. Properly speaking, fullers' earth is not a clay, because it lacks plasticity, but some of the material which is put on the market under this name and does the work required of it as well as true fullers' earth is ordinary plastic clay.

FULLERS' EARTH

Properties and uses. Fullers' earth is one of the most interesting materials with which the economic geologist has to deal. In appearance it resembles clay, in properties it differs from it very considerably, in that it usually lacks plasticity, and also has the power of absorbing large quantities of greasy substances. The ordinary quantitative analysis does not show it to differ much from ordinary clay, except that it usually has a relatively higher percentage of combined water. Fullers' earth when dried adheres strongly to the tongue, on account of its absorbent properties, but on the other hand some of the ordinary clays do the same. Fullers' earth was at first used for fulling cloth, that is cleansing it of grease, but at the present day its most important use is for bleaching cottonseed oil, and also for clarifying petroleum. Up to within the last two or three years, nearly all of the fullers' earth used in the United States was imported from England, where large deposits of this material exist. Since that time, however, the importance of these materials has become more or less widely known, and it is mined in this country also, deposits having been found in different states, and in time the importation of the English material may perhaps cease altogether.

The only reliable means of determining the quality of fullers' earth is to subject it to an actual test, which can be done in the laboratory.

This of course necessitates some careful manipulation and practice in order to insure the best and thoroughly reliable results.

Occurrence in New York. In New York, deposits of fullers' earth occur at a locality known as McConnellsville, 12 miles north of Rome on the Rome, Watertown & Ogdensburg railroad. The deposit has been worked for several years by the New York fullers' earth co., and is a fine-grained, dense, Quaternary clay in layers 2 to 8 inches thick, interbedded with layers of sand of similar thickness. The total thickness exposed is about 15 feet, and there is a capping of about 4 feet of sand. To mine the earth, the overlying sand has to be stripped off and the layers of fullers' earth taken off one by one, and spread in the sun to dry, the racks being movable, so that they can be shoved under cover in stormy weather. Thus far this fullers' earth has been used only for cleansing woolen goods, and it has been shipped to several factories in New York and neighboring states. A second mine of the same material has been opened on an adjoining farm by M. A. Penfield. The New York material has thus far not been used for clarifying purposes, and it is doubtful if the deposit from McConnellsville will prove to be suitable for this purpose.

Owing to its absorptive properties fullers' earth has also found an application in the manufacture of certain soaps, which are adapted for removing grease and printers ink stains.

The composition of both English and American fullers' earth can be seen from the following table.

Analyses of fullers' earth

LOCALITY	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	H_2O	Moisture			
1 England....	44.00	23.06	2.00	4.08	2.00	....	....	24.95	....	P_2 O5	SO_3	Na Cl
2 English blue earth............ ...	52.81	6 92	3.78	7.40	2.27	....	.74	14.27	....	.27	.05	.05
3 English yellow earth	59.37	11.82	6.27	6.17	2.09	....	.84	13.19	....	.14	.07	.14
4 Gadsden co., Fla	62.83	10 35	2.45	2.43	3 12	.20	.74	7.72	6.41	....	....	... .
5 Decatur co., Ga................	67.46	10.08	2 49	3.14	4.09	....	....	5 61	6.28	....	....	....
6 Fairborn, S. Dak..................	58.72	16.90	4.00	4 06	2.56	2 11		8.10	2.30	....	....	... .
7 River Junction, Fla	50.70	21.07	6.88	4.40	.30	....	....	9.60	7.90	....	....	..... .
8 Norway, Fla	54.60	10.99	6.61	6.00	3 00	....	....	10 30	7.45	....	....	... .

1 *Penny encyclopedia*, 11, Dr Thompson, anal. 2, 3, 19*th ann. rep't U. S. G. S.* 4, 5, 17*th ann. rep't U. S. G. S.*, P. Fireman, anal. 6, 7, 8, 17*th ann. rept. U. S. G. S.*, E. J. Riederer, analyst.

Filling paper

Clay is one of the several substances used for this purpose. It is mixed in with the paper pulp during the process of manufacture, the object of this being that the fibers of the pulp shall enmesh a certain amount of the clay particles which are in suspension in the water in which the pulp is. The plasticity and sandiness of the clay no doubt exert some influence on the degree of success of the operation, for it is found that a given paper will often retain a much greater proportion of some clays than others, those of which the greatest quantity is retained being the most plastic, of the several tried. Sand is an undesirable constituent of paper clay for the reason that the sand grains tend to wear out the wires of the screens through which the materials have to pass. In certain lines at least clay is not used as much for filling as it formerly was. The color of the clay in its raw condition is all important for the higher grades of paper. For the best quality a very fine white kaolin or sedimentary clay is used, it being first carefully washed, but for the commoner grades, specially the colored ones, the manufacturer does not as a rule have to search very far in order to find the right material, as the requirements are not so strict.

Food adulterants

This use of clay is self-evident. It is used as an adulterant of those food products which it resembles in color, and which are used either in a powdered condition or caked form, either of which would tend to hide the presence of the adulterant.

Ultramarine manufacture

Kaolin in its washed condition or even very fine-grained, white sedimentary clays are used in the manufacture of ultramarine to serve as a nucleus for the coloring material to gather round. For this work the clay should be as low in iron and lime as possible, and an excess of silica is undesirable, but if too little is present it may be added in the form of finely powdered quartz.

Polishing and abrasive materials

Many clays exert a combined polishing and abrasive action on account of the very finely divided grains of sand which they contain. The well-known Bath brick which has such an extensive domestic use for scouring steel utensils is simply a fine-grained silicious clay, which is deposited during high tide along the banks of the Parrot river in England.

Road materials

Clay or shale is used in the construction of wagon roads and railroads.

Wagon roads. Soft plastic clay when used by itself is a very poor road material, for the reason that in wet weather it makes the road almost impassable at times, and in dry weather it is exceedingly dusty.

Shales if soft and very argillaceous are almost as bad, but, if the shale is silicious and well cemented by iron, it often makes a splendid road, specially if the traffic is not very heavy. In many portions of New York state, shale is used to a large extent with good results. In some regions the shale has been partly changed to slate, owing to the folding which the rocks have been subjected to subsequent to their formation, and the value of the shale for road metal is then increased.

Railroads. In many portions of the west where rock is hard to obtain for railroad ballast, clay is used in a very ingenious way. The material is dug up along some railroad siding where a bed of it has been found, and piled in long heaps interbedded with old railroad ties. This mass of ties is then set on fire at the bottom of the heap, and the mass of clay is gradually baked from bottom to top, the result being a mass of burned clay lumps of the right size for putting on the road bed and as hard as almost any ordinary stone that could be used for the same purpose. While this is an important use of clay, it would find no application in the east where stone for railroad ballasting is so plentiful.

For a detailed description of this application of clay, see *Min. ind.* vol. 6.

Puddle

Puddle is a mixture of clay and gravel often used in engineering construction. The clay employed must be such that it will bind the pebbles firmly but not crack in drying. The best results would therefor be yielded by a plastic clay containing an abundance of fine sand.

TESTING OF CLAY WARES

The tests applied to determine the qualities of a clay product depend on the use to which it is to be put. Some wares such as paving bricks are subjected to sudden shocks and abrasion, others, which are placed in exposed positions, must withstand the influence of weather, still others must resist sudden changes of temperature, etc.

Porosity or permeability

The denser a building brick the better it will be able to withstand weathering influences. Soft mud bricks are perhaps an exception to this rule, for they may often exhibit 15% or 20% porosity and still resist frost action. The porosity of course depends on the density, and is determined by the increase of weight which a brick shows when immersed in water. It may also be of interest or importance at times to determine the porosity of the different parts of a brick, in which case the brick is broken up and fragments taken from the center.

The absorption of common building brick may be as much as 20% of their weight, while in the case of hard brick it should not exceed 5%; in paving bricks and bricks for sewers not over 2%, and in sewer pipe and canal brick it should never get above 1%.

According to Dümmler (*Ziegel Fabrikation,* p. 71) it is important in the case of vitrified roofing tile and sewer pipe to determine not only the porosity but also the permeability. With roofing tile, which simply serve to drain off water, this is done by heating the tile first to 100° C., then placing on it a tube whose cross-section is 10 square centimeters, and whose hight is 20 cm. This is fastened to the tile by means of wax, and then filled with 10cc of water. The time is then noted which this water takes to soak in, and additional quantities of 10 to 15 cc are added at a time till drops begin to appear on the under side of the tile. Roofing tile which allow the water to percolate through them in less than six hours should be rejected.

For sewer pipes the water must be put under pressure, which is done by closing the two ends of the pipe with plates of iron, the joints being tightened by means of rubber bands around the edges. The pressure is then applied by means of a piston till the manometer shows the desired pressure, at which point it is allowed to stand. If the pipe is impermeable, the manometer will remain at that point, but if the pipe contains a flaw the liquid in the manometer will fall and moisture will appear on the outside of the pipe at the point where the flaw is.

Breaking strength

This test is made by allowing the stone to lie flat on two parallel supports with sharp edges, while a third edge is caused to press on the upper surface halfway between the two supports. The pressure required to break the stone is then measured. If the upper surface of the stone is not perfectly flat, it can be made so by laying on the upper surface two parallel cleats of portland cement one cm wide. See "Paving brick", p. 745.

Hardness test

The hardness of building material can be determined by means of Moh's scale of hardness. This scale is made up of 10 different minerals, of which each is harder than the preceding one in the series, and softer than the succeeding one. The order, beginning with the softest, is:

1 Talc
2 Gypsum
3 Calcite
4 Fluorite
5 Apatite
6 Orthoclase
7 Quartz
8 Topaz

9 Corundum
10 Diamond

If the hardness of the brick is such that it can be scratched by quartz but not by orthoclase, its hardness is no. 7 of the scale.

Vitrified products should show a hardness of 6–7.

Determination of deleterious impurities

The stone or brick is to be subjected to a damp atmosphere for a period of time. If it contains any lumps of carbonate of lime or pieces of pyrite, these will soon show themselves by causing the brick to flake off. The moist atmosphere can be produced by placing the brick under a bell glass containing a bowl of water. The method suggested by an international committee appointed to decide on a standard test, was that a portion of the brick should be put in a Papin digester containing vapor under one fourth atmospheric pressure for three hours.

It is advisable in all cases to subject the raw material to an examination to see if any harmful impurities are present.

Determination of soluble salts

These are determined by breaking off chips of the brick and grinding these to 100 mesh fineness. 25 grams of this powder are boiled for one hour in 250 cc of water. The water is then filtered, and from this filtrate by evaporation the amount of dissolved salts is determined. Salts of vanadium show themselves by the presence of a green tint on the surface of the wet brick after it has been set aside in a place protected from dust.

Resistance to weathering

One method of testing this is to subject the bricks, which have been immersed in water, to a freezing temperature, which can be easily done by covering them with a mixture of ice and salt. The frozen bricks are then subjected to water having a temperature of 20° C. This process of freezing and thawing is repeated 20 or 25 times. The particles which break off in the operation are weighed, thus the percentage of loss is determined. The bricks themselves are also to be examined for cracks after this treatment.

Resistance to acids

Certain structural clay products, such as bricks for sewer works, pavements and walls, as well as those used in acid works, which are more or less subjected to the action of acids, are to be tested for their resistance to the latter. The best way to do this is to pulverize the product to be tested, separating the fine powder, then subjecting the coarser material to the action of acids of different degrees of concentration for 24 hours. The acid is then filtered off, and the powder is washed, dried and weighed to determine the loss.

Abrasion test

This is described under "Paving brick", p. 745.

SECTIONS OF CLAY DEPOSITS

LOCALITY	Owner	Thickness of clay, ft	Color	Underlying material	Overlying material
Albany	T. McCarthy	15	Blue	Sand	Soil
	A. Hunter	40	Blue and yellow		Soil
	M. Roberts	25	Blue		Loose soil
Rensselaer	Mrs T. Rigney	90	Blue and yellow		Loam
Troy	A. Ferguson	40	Blue and yellow	Slate	Loam
	J. B. Roberts	20	Yellow	Gravel	1 foot loam
Cohoes	J. E. Murray	50	Blue	Slate	Loam
	J. Baeby	40	Yellow and blue	Gravel	Soil
Lansingburg	T. F. Morrissey	75	Red ⅓, blue ⅔	30 ft sand	
Crescent	Newton Bros.	30	Gray and blue		2-4 ft sand
Mechanicville	Mechanicville brick co	50	Yellow 10 ft, blue 40 ft	Sand	3 feet soil
Saratoga	C. L. Williams	6	Blue	Sand	1 foot soil
Middle Granville	J. H. Pepper	45	Blue	20 ft gray soil, slate	
Hoosick Falls	J. Dolin	40			
Plattsburg	J. Ouimet	20	Yellowish brown		1 foot soil
Gouverneur	G. R. Thompson	14	Gray 8 ft, blue 6 ft		Sand 4 feet
Carthage	Wrape & Peck	5	Gray		
Watertown	Watertown brick co	20	Red	Trenton limestone	Soil
Ogdensburg	Paigel Bros	60	Blue	Limestone	Soil
Madrid	R. Watson	20	Blue		Sand 3 feet
Raymondville	Coats Bros.	25	Blue		Fire sand 12 feet
Breesport	Empire state brick co	50	Blue		Soil
Spencer	W. H. Bostwick	6	Red	Sand and gravel	Soil
Newfield	T. C. Campbell	40	Blue		Sand 4 feet
Homer	H. Hall	5	Blue	Quicksand	Soil
Binghamton	Wells & Brigham	6	Blue	Sand and gravel	Soil
Goshen	P Hayne	55		Black gravel	Soil
Florida	W. H. Vernon	10	Red and blue	Sand and hardpan	
Oakland Valley	O. B. Wheeler	46	Blue		
New Paltz	New Paltz brick co	40	Red and blue		Sand few feet
Chittenango	Central N. Y. drain-tile co		Red	Sand	Soil
Allenshill	B. G. Abbey		Blue		Soil
Owasco	A. Lester	10-15			Gravel
South Trenton	H. L. Garrett	4	Yellow, red, blue	Slate	
Amsterdam	H. C. Grimes	6+	Yellow and blue		Soil 1-3 feet
Gloversville	H. McDuffie	2½	Dark brown	Hardpan	Soil
	W. A. Stoutner	3	Red brown	Hardpan	Soil
Ilion	S. E. Coe	8-15	Black, gray and blue		Few feet soil
Rome	W. Armstrong	7-10	Dark gray		
	W. W. Parry	6-9		Gravel	Loam

South Bay	**C. Stephens**	25		**Cemented blue gravel**	
Syracuse	Preston Bros	10	Red and blue	Sand and gravel	Soil
Warner's	Onondaga vitrified brick co	15	Red	Shale	Soil
Oswego Falls	W D. Edgerton	5	Yellow	Gravel	Soil
Baldwinsville	Seneca river brick co		Red and blue	Gravel	Soil
Seneca Falls	F. Siegfried	12		Gravel	Soil
Lyons	F Borck	8	Yellow and blue	Quicksand	
Canandaigua	Burke & Mead	20	Red and blue	Sand	1 foot peat
Rochester	Rochester brick mfg co	5	Red	Hardpan	
Tonawanda	M Riesterer	5	Red and blue		Soil
Buffalo	Brush Bros	6-20	Red		Soil
Evans	W. Bolton	10	Blue	Sand and gravel	Soil
Dunkirk	W. Hilton	20	Yellow and blue	Rock	
Jamestown	J. E. Mecusker & Son	75	Yellow 5, blue 70	Hardpan	Yellow sand 4 feet
Bigflats	J. R. Lowe	75	Gray and blue		

CLAY

The following table of clay analyses is probably the most com-
number of different sources. The analyses are arranged under
clays, slip clays, adobe soils, brick clays, shales, paving brick clays,
the clay whose analysis is given is available for only one purpose,
used for several different products.

The constituents given, in nearly every instance, are silica,
water. In many cases titanic oxid, organic matter, phosphoric

The following abbreviations are used.

a ferrous oxid
b lime carbonate

Residual

No.	State and county	Town	Material	SILICA Combined	SILICA Free	Alumina	Ferric oxid
	Alabama:						
1	Calhoun	Morrisville	From Knoxville limestone		55.42	22.17	8.3
2	Arkansas		From St Clair limestone		33.55	30.18	1.98
	Georgia:						
3	Bartow	Cartersville			58.63	20.47	8.58
4	Polk	Rockmart	Caen stone		61.66	19.64	7.54
	Kentucky:						
5	Graves		From chert		76.78	14 74	1.64
	Massachusetts:						
6	Hampden	Blandford			52.03	31.76	tr.
	Missouri:						
7	Iron	R. R. cut at Tiptop			90.05	4.63	2.31
8	Lincoln	Morris shaft			72.35	15.86	2.25
9	"	Colbert			65.35	21.2	2.05
	North Carolina:						
10	Wake	Cary			54.54	26.43	9 04
	Pennsylvania:						
11	Lehigh	Fogelsville	From slate		72.164	21.764	.99
	Wisconsin:						
12	Wood	Grand Rapids			70.83	18.98	1.24

ANALYSES

plete that has ever been published; it has been compiled from a the following heads: residual clays, kaolins, fire clays, pottery terra cotta clays and pipe clays. This is not intended to mean that for, on the contrary, it frequently happens that one clay can be

alumina, ferric oxid, lime, magnesia, alkalis, combined and free acid and sulfuric acid have been determined.

c titanic acid
d magnesium carbonate
e organic matter

clays

No.	Lime	Magnesia	Alkalis	WATER Combined	WATER Free	Miscellaneous	Firm name, authority, or analyst
1	.15	1.45	2 49	9.86		....	
2	3.89	.26	1.57	10.72		P_2O_5 2.53	From Ark. geol. sur. rep't on manganese
3	tr.	1.42	4.	7.26		....	Georgia geol. sur. 1893
4	tr.	tr.	2 32	....		....	"
5	tr.	.389	1.557	4.894		....	Ky. geol. sur., chem. rep't A, pt 3
6	tr.	.54	....		15	55	Tech quart. 1890
7	tr.	tr.	und.	2.72		....	Mo. geol. 564
8	1.09	1.48	....	3.05	1.46	Loss 2.46	*Ibid.*, 2: 1872, 11: 288
9	.52	1.27	....	4.83	2.14	Loss 2.64	
10	....	....	....	9 87		....	"
11	.224	.698	5.139	4.758		....	Penn. geol. sur. D, p.13
12	.24	.02	2.59	5.45		CO_2 1.02	Wis. ac. sci. 1870-76

No.	State and county	Town	Remarks	SILICA Combined	SILICA Free	Alumina	Ferric oxid
	Alabama:						
1	Calhoun	12 miles southwest of Jacksonville		45.77		39.45	
2	Talladega	Talladega		48.21		37.27	tr.
	Arizona:						
3	Graham	Clifton		42.4		32.5	16.17
	Arkansas:						
4	Pike			48.87		36.54	.98
5	Pulaski			46.27		38.57	1.36
6	Ouachita			48.62		36.52	1.74
	Colorado:						
7	Jefferson	Golden		56.41		26.37	
	Connecticut:						
8		Sharon	Washed kaolin	46.5		37.4	.8
	Florida:						
9	Lake	Palatlakaha		46.11		39.55	.35
	Indiana:						
10	Clay			68.5		17.2	1.3
11	Lawrence			44.54		41.18	
12	“	Huron		41.125		39.26	.2
13	“		Nonplastic white kaolin	44.75		38.69	.95
	Massachusetts:						
14	Hampden	Blandford		52.03		31.76	tr.
	Missouri:						
15	Bollinger	Glen Allen	Used for white ware	72.3		18 94	.4
16	“	“	“	63.5		24.55	
17	Cape Girardeau	Brook's Land	“	91.05		5.04	.69
18	Carter	M. E. L. and M. Co., near Chilton	Kaolin washed: not worked.	73.82		18.16	1.32
19	Stirling (Macy place), Howell		Washed, not worked	57.75		27.6	2.09
20	West Plains (Yates bank), Howell		Not worked	60.55		24.77	.84
21	Lawrence	Aurora	Halloysite	44.12		37.02	.33
22	Lawrence	Porter and Coates shaft, Aurora	Halloysite not worked	34.53		6.41	2.59
23	Lawrence	Louisville shaft, Aurora	Halloysite not worked	32.44		5.53	2.17
24	Oregon	Arnold land, Thayer	Ka'lin (w'sh'd) not worked	81.18		12.14	1.88
25	Shannon	Trusty land, Winons.	Not worked	56.74		27.29	6.87
	North Carolina:						
26		Sylva	Wash'd kaolin	44.08		36.26	1.86
27		Webster	Wash'd kaolin	45.7		40.61	1.39
28		Webster	Crude kaolin.	62.4		26.51	1.14
29		“	Cl'y sub'st'nce of above	50.5		34.24	.74
30		“	Wash'd kaolin	45.78		36.46	FeO*a* 1.08 .28
31		West Mill	Crude kaolin.	53.1		33 06	1.18
32		“	Clay s'b'st'nce	45.41		39.56	.86
33	Four miles west of Troy		Crude, dark kaolin	90.13		4.99	1.86

lins

No.	Lime	Magnesia	Alkalis	Water Combined	Water Free	Miscellaneous			Firm names, authority, or analyst
1	.79	......	......	13.96	......	......	......	......	G. H Bivan, anal.
2	.11	.1	.68	18.5		......	......	......	U. S. geol. sur. bull. 64
3	2.17	tr.	......	......	......	......	......	......	
4	.19	.25	......	13.29		......	......	......	Min. res., 1891
5	.34	.25	.6	13.61		......	......	......	"
6	......	......	......	13.4		......	......	......	"
7	.29	.2	1.55	14.66		......	......	......	
8	tr.	......	1.1	12.49	......	......	......	......	H Regi, anal.
9	......	.13	......	13.78		SO_3.07	......	......	Min. industry, 1893
10	.25	......	.79	.3		......	......	Loss 11.17	Ind. geol. sur. 1878 p. 158
11	......	......	......	......	......	......	......	......	
12	.365	......	......	19.05		......	......	......	Penn. mineral co.
13	.37	.3	.35	15.17	......	......	......	......	Ind. geol. sur. xx, 105.
14	tr.	.54	tr.		15.55	......	......	......	Tech. quart., 1890
15	.68	.39	.42	7.04	......	......	......	......	Mo. geol. sur. 11: 536
16	1.6	.48	......	7.3	......	......	......	2.2	From Glen Allen Kaolin washing co.
17	.24	.22	.12	......	......	......	......	......	Mo. geol sur. 11: 536.
18	tr.	.21	.24	6.16	......	......	......	......	*Ibid.*
19	.24	.31	.6	11.33	......	......	......	......	*Ibid.*, p. 564
20	.25	.41	.68	52.86	......	......	......	......	"
21	.19	......	.24	......	......	......	......	......	Mo. geol. sur. 11: 666
22	2.2	......	......	7.19	9 97	......	......	ZnO. 37.23	*Ibid.*, p. 566.
23	2.58	38.9	......	6.94	11.65	......	......	......	"
24	.16	.14	.18	4.52	......	......	......	......	"
25	.26	.18	1.21	6.20	1.20	......	......	......	*Ibid.*, p 570.
26	.43	.20	.5	13.56	3.07	......	......	......	Mining & manufac. co.
27	.45	.09	2.82	8.98	.35	......	......	......	Harris clay co.
28	.57	.01	.98	8.8	.25	......	......	......	G. Springer
29	.86	.01	.1	13.35	......	......	......	......	"
30	.50	.04	.25	13.4	2.05	......	......	......	"
31	.38	.08	.83	11.32	......	......	......	......	G. Brindels
32	.45	.09	.03	13.58	......	......	......	......	"
33	.13	.01	1.03	1.93	.48	......	......	......	

Kaolins

No.	State and county	Town	Remarks	SILICA Combined	SILICA Free	Alumina	Ferric oxid
	North Carolina (*cont'd*)						
1	"	....	Clay s'b'st'nce and Fe_2O_3..	38.58		33 66	10.46
2	"	....	Washed dark kaolin	86.03		6.46	2.14
3	"	....	Clay s'b'st'nce and Fe_2O_3	43.46		30.04	9.37
4	"	....	Washed white kaolin	63.1		23.33	2 97
5	Bosticks Mills	....	Crude kaolin, 21	68.15		19.99	1.86
6	"	....	Crude kaolin 20 .	70.63		21.81	1.49
7	"	....	Clay s'b'st'nce	47.88		39.04	1 9
8	"	....	Crude kaolin, 22	73.7		16.03	1.57
9	"	....	No. 20 washed.	71. 2		19.61	2.18
10	"	....	Clay s'b'st'nce	49.33		35.9	3.15
11	Cleveland............	Grover	....	55.24		30.84	.84
12	Jackson	Harris mine, near Webster............	....	41 62	2.28	40.66	.14
	Pennsylvania:						
13	Chester	Glen Loch, White land kaolin co..	....	50 96		33 30	
14	"	Thomas	....	43.88		40.96	.82
15	"	"	. ...	70.88		20.99	....
16	"	National kaolin and fire brick works	....	71.02		19.72	1.58
17	"	National kaolin and fire brick works....	....	67.71		20.53	3.12
18	Delaware	Brandywine Summit	....	46.278		36.25	1.644
19	"	....	... .	47.22		34.1	2.49
20	Berks.................	Hunter Mine........	....	66 173		19.89	*a*.783
21	Lancaster.............	Chestnut Hill	....	67.1		20.1	3 9
22	Chester	East Nottingham ...	....	46.34		36.32	.64
23	Berks	Mertztown...........	....	5[illegible].6[illegible]		28.18	2.24
	South Carolina:						
24	Aiken	....	....	44.94		39.18	.52
25							
26							
27							
	Texas:						
28	Edwards.............	....	....	48.61		43.17	....
	Virginia:						
29	Nelson.	....	....	69.5		19.1	....
	Wisconsin:						
30	Wood	Grand Rapids........	....	78.83		13.43	.74
31	"	"	Washed......	49.94		6.8	.72
32	St Croix..............	Hersey...............	Crude kaolin.	58.84		31 18	tr.
33	"	"	Washed kaolin.........	49.7		38.25	.05

(concluded)

No.	Lime	Magnesia	Alkalis	WATER		Miscellaneous			Firm names, authority, or analyst
				Combined	Free				
1	.91	.07	2 7	13.56	....				
2	.17	.04	1	2.9	....				
3	.84	.19	1.33	14.35	....				
4	.15	.09	1.9	7.65	....				
5	.13	.16	2.85	4.7	.17				
6	.20	.29	1.45	4.04	.03				
7	.42	.60	1.04	8.58	....				
8	.38	.47	1.9	4.33	....				
9	.17	.08	2.48	4.33	....				
10	.31	.14	3 15	8.	....				
11	.08	.02	tr.	12.89		....	......	......	W. M. Bowran, anal.
12	....	......	.46	14	.84	....	......	......	J. A. Holmes, T. A. I. M. E., 20
13	....	2.42	....	8.95	....	....	......	......	A. E. Barnes, anal.
14	tr.	tr.	....	13.99	....	....	......	......	10th census, 2, p. 1078
15	.65	.13	....	10.28	....	....	......	......	"
16	.32	.03	.27	7.04	....	....	......	......	*Rep. Penn. geol. sur.* 1885; p. 589
17	.39	.04	.29	7.78	....	....	......	......	
18	.192	.321	2.536	13.535	....	....	......	......	
19	....	.39	1.91	13.68	......	....	......	......	Pa. geol. sur. D. 3
20	.25	1.902	6.211	4.784		....	......	......	"
21	.1	.7	2	5.9		....	......	......	1885 Rep't. Pa. geol. sur.
22	.04	tr.	.77	13.75		....	......	......	
23	.1	2.53	....	7.16		....	......	......	Booth, Garret & Blair, anal.
24	....	....	....	13.38		....	......	TiO_2	U. S. G. S. bull. no. 148, p. 290
25	....	....		....	....	....	......	.65	
26	....	....	....	....	....	....	......	P_2O_5	
27	....	....	....	....	....	....	......	.12	
28	.38	.1	1.78	6.05		....	......	......	Tex. geol. sur., 1890 p. 1.
29	....	....	1	11.12		....	......	......	
30	.64	.07	.44	5.45	$CO_2 \cdot O_1$	....	......	......	Wis. ac. sci. 1870-76 p. 1.
31	tr.	....	.59	11.62	....	....	......	.....	
32	.07	.05	.38	10.04	....	....	.....	......	Superior China clay co.
33	tr.	tr.	.37	12	....	....	......	......	

Fire

No.	State and county	Town	Remarks	SILICA Combined	SILICA Free	Alumina	Ferric oxid
	Alabama:						
1	Randolph	Louina	Clay	37.29		31.92	tr.
2	Calhoun	Jacksonville	White clay	44.6		38.92	.78
3	Choctaw	...	Hard clay	36.3		5.12	1.6
4	Marion	Pikeville	White clay	47.2		37.76	.91
	Arkansas:						
5	Poinsett			61.76		22.91	3.32
6	Greene			70.43		19.15	1.7
7	Lawrence	Black Rock		84.24		11.5	.08
	California:						
8	Amador	Carbondale	Washed clay	59.98		30.29	.27
9	Nevada	Grass Valley	"	57.75		30.6	.48
10	Placer	Lincoln	"	49.08		37.09	1.91
11	San Bernardino	...	"	12.54		42.97	.63
12	Lake	Sulphur banks	Alum clay	66.75		37.35	.25
13	Trinity	Carville	Wash'd white clay	88.3		.85	.15
	Colorado:						
14	Jefferson	Edgemont		46.61		37.2	.15
15	Pueblo	Pueblo	Clay	28.76	34.46	24.72	.43
16	Jefferson	Golden		46.88		35.42	*a* 1.74
17	"	"	Crucible clay	71.81		15.09	*a* 1.75
18	"	"	Shale	49.54		34.04	*a* .88
19	"	"	For crucibles	39.134		33.64	.75
	Delaware:						
20	Newcastle	Wilmington		72.4		14.8	tr.
21	"	Newcastle		72.33		16.75	*a* 1.29
	Georgia:						
22	Baldwin	Stephens pottery		41.2		38.6	1.45
23	"	"		54.32		30.24	.06
	Illinois:						
24	Henry	Geneseo		62.55		29.1	1.67
25	Scott	Winchester		69.85		17.08	3.47
26	Mercer	New Windsor		76.1		15.04	*a* 1.08
	Indiana:						
27	Lawrence	Huron	Indianaite	40.5		36.35	.15
28	Clay	Knightsville		67.87		12.7	7.24
29	Parke	Bloomingdale		69.82		14.27	2.13
30	"	Leather wood creek ½ mile from Bloomingdale		73.32		16.06	1.1
31	"	Mecca (S. L. McCune)	Under clay no. 16	63.		23.57	*a* .46 1.87
32	Vermilion	West Montezuma (J. Burns)	Under clay no. 10	83.44		10.36	*a* .28 .27
	Iowa:						
33	Woodbury	Sergeant bluff		76.8		12.09	3.03
34	Dallas	Van Meter		86.63		10.92	.1
35	"	"		55.11		26.71	4.29
36	"	Crills mills	Cretaceous clay	67.14		19.93	2.34
	Kentucky:						
37	Ballard	Blandville		74.84		16.58	1.4
38	"	Wycliffe		73.24		15.76	1.92
39	Muhlenburg	Ross mine		63.18		26.281	
40		Thomas bank		47.56		46.61	tr.

clays

No.	Lime	Magnesia	Alkalis	Water Combined	Water Free	Miscellaneous			Firm names, authority or analyst
1	....	.72	....	15.09		....	......	......	Trans. inst. min. eng., 10
2	....	1.03	....	13.38		....	......	......	“
3	.46	....	....	6.6		....	......	......	Ala. ind. and sci soc., 2
4	tr.	tr.	tr.	14.24		....	......	......	“
5	.75	.9	1	....	....	....	......	Loss 8.75	Ark. geol. sur. 1889, 139
6	.52	tr.	1.84	....	....	....	......	Loss 24.27	“
7	.52	.02	.42	3.98		....	......	......	Jour. chem. soc. October 1896
8	.28	....	1.02	8.05		....	......	......	Cal. state min., 9th rep't
9	.2	.1	1.3	10.15		....	......	......	“
10	.53	....	....	10.6		....	......	......	“
11	....	....	4.7	38.4		....	......	......	“
12	.2	....	4.32	....	....	....	......	......	“
13	1.03	.48	5.07	5.4		....	......	......	“
14	.44	.25	1.23	13.65	.47				M. Moss, anal.
15	.3	.13	tr.	8.63	1.36	Org. .4	TiO_2 .68	Loss 10.39	Steiger, anal.
16	.44	.2	1.19	14.1		....	......	......	Crossley, Analyses of clays
17	.14	.05	1.02	10.14		....	......	......	Denver fire brick co.
18	.61	.36	tr.	13.91		....	......	*b*.27	Furnished by Golden pressed and fire brick co.
19	....	tr.	.58	11.75	2.13	Clay subs 84.524.	TiO_2.80	Qtz. 11.216	Mon. 27, U. S. G. S., p. 390
20	.35	....	.85	.5		....	......	Loss 12.4	Ind. geol. sur. 1878, p. 158
21	2.	.07	....	7.98		....	......	......	Crossley, Analyses of clays
22	....	.3	.11	16.7		....	TiO_2 1.95	......	Ga. geol. sur. 1893, p. 280
23	.09	.81	.62	12.86		Org. .34	......	......	H. C. White, anal.
24	tr.	tr.	....	7.5		....		.	E. A. Terpening, anal.
25	.28	....	1.1	4 4		....	TiO_2 .9	......	
26	.62	.3	1.55	5.2		....	......	......	Crossley, Analyses of clays
27	....	.13	.14	22.6		....	..	.....	
28	.72	.85	.25	....	....	MnO 1.95	SO_2.29	Loss 6.8	Ind. geol. sur. 1878
29	.9	.6	12.28	....	....	....	......	......	Helwig & Hobbs
30	.7	.7	....	8.12		....	......	......	Ind geol. sur. vol. 20, p. 49
31	.44	.89	2.69	6.45	....	....	......	*c*1.1	*Ibid.*, p. 133
32	.36	.14	.74	3.15	....	....	......	*c*1.29	“
33	.4	2.9	....	4.7		....	......	......	J. H. Hurtz, anal.
34	....	....	....	2.32		....	......	......	W. S. Robinson, anal.
35	....	....	....	9.69		....	......	SO_3.416	“
36	.55	.25	1.28	5.59	2.93	....	......	....	G. C. Patrick, anal. furnished by Iowa geol. sur.
37	.269	.209	1.576	5.126		....	......	......	Ky. geol. sur. Chem. Rep't A, part 3.
38	.325	.579	1.614	6.622		....	......	......	
39	.203	.255	2.425	4.195		....	P_2O_5 .179	SO_3 3.282	*Ibid.*, analysis no. 1613
40	.28	.497	.717	10.036		....	P_2O_5 .49	......	*Ibid.*, no. 1483

Fire clays

No.	State and county	Town	Remarks	SILICA Combined	SILICA Free	Alumina	Ferric oxid
	Kentucky (*cont'd*)						
1	Carter	Boone furnace		48.56		37.471	tr.
2		Powdermill hollow		62.92		20.735	3.82
3	Hickman	Columbus		85.18		10.26	1.12
4	Carter	Olivehill		50.95		39.49	....
5	“	Gorman		49 75		35.16	.3
6	Boyd	Summit	Crucible clay	67 99		25	....
7	Carter	Louisville	Flint clay	47.2		39.9	....
8	“	Grahm's Station	Plastic clay	45.4		40.04	....
9	Boyd	Ashland	Plastic	40.14		43.72	1.98
10	“	“	Nonplastic	43.58		40.86	.76
11	Fulton		Tertiary clay	81.06		13.609	
12	Graves		“	75.555		16.751	1.198
13	Union			73.9		17.6	3
14	Graves	1½ miles east of Pryorsburg		56.4		30	....
15	Carter	Olivehill		43.76		40.21	.53
16	Carlisle	Milburn		76.54		14.82	.96
17	Calloway (N. W.)		White clay	46.02		38.98	
18	Graves	Boaz Station	Clay	61.92		30.06	.3
19	Marshall	Scale	“	52.58		31.07	1.51
20	Ballard	Lovelaceville	“	66.32		22.93	1.19
	Maryland:						
21	Allegany	Mount Savage	Flint clay	50.46		35.9	*a*1.5
22	“	“		44.4		38.56	1.08
23	“	“		56.8		30.08	1.12
24	“	Mount Savage union mining co.		56.15		33 295	.59
	Michigan:						
25	Genesee	Flushing	Used for fire brick.	70.55		21.2	3.2
	Minnesota:						
26	Blue Earth	Mankato	Cretaceous clay	93.65		2 15	.25
	Missouri:						
27	Crawford	Oak hill		64.32		22 82	1.75
28	St Louis	Cheltenham		38.1	12 7	31.53	1.92
29	“	Evens mine		43.93	.6	40 09	.88
30	“	St Louis	Washed pot clay	61.15	.....	24.55	2 37
31	Audrain	Mexico		55.62		30.71	1.51
32	“	“	Used for buff fire brick.	53.77		30.9	1.74
33	“	“	Used for buff fire brick	51.4		33.64	1.26
34	“	“	Used for buff fire brick.	55.12		30.71	1.51
35	“	Vandalia	Washed fire clay	53.77		32.52	1.42
36	Boone	Columbia (Fay's bank).	Used for stoneware.	61.22		25.17	1.47
37	Callaway	Fulton	Used for fire brick.	47 3		37 54	1.48
38	“	New Bloomfield	Not worked	48.6		35.65	1.95
39	Crawford	Leasburg	Flint clay for fire brick	43.82		38.24	.23
40		Sankey mine	Flint clay not worked.	50.18		33.03	2.31
41	Franklin	Dry branch	Flint clay for fire brick	42.6		41.88	.62

(continued)

No.	Lime	Magnesia	Alkalies	WATER Combined	 Free	Miscellaneous			Firm names, authority, or analyst
1	.112	tr.	.572	13.03		....	P_2O_5 .550	......	Ky. geol sur. Chem. Rep't A, part 3, analysis no. 1337
2	.213	2.281	3.26	6.4		....	P_2O_5 .371	......	*Ibid.*, no. 1478
3	tr.	.064	1.1	2.276		....	......	......	Ky. geol. sur. analysis no 2715
4	.3	.28	.31	9.18		....	......	......	Crossley, Analyses of clays
5	.54	.15	.07	14.03		....	......	......	
6	1.99	undeter.		2.15		....	......	......	
7	tr.	tr.	.21	12.69		....	......	......	
8	tr.	tr.	.21	14.35		....	......	......	Louisville fire brick works
9		1.60	5.216	....		Ign. 7.34	......	......	R. Peter, anal.
10	.29	.14	.24	....		Ign. 14.43	......	......	“
11	.314	.139	.252	.36		P_2O_5.051	......	......	Ky geol. sur., n. s 1, 217
12	tr.	.144	1.11	5.047		....	......	......	*Ibid.*, p. 433
13	.336	undeter.	.1	5.7		....	......	......	Ky. geol. sur. o. s. 361
14	.4	tr.	5.27	7.93		....	......	......	R. Peters, anal.
15	.88	.06	...	14.56	.....	....	......	......	
16	tr.	.331	1.155	6.194		....	......	......	Ky. geol. sur. Chem. Rep't A, pt 3, no. 2570
17	.773	.136	.481	13.61		....	......	.....	*Ibid.*, no. 2639
18	tr.	.064	1.841	5.815		....	......	......	*Ibid.*, no. 2665
19	.137	.245	2.093	12 365		....	....	......	*Ibid.*, no. 2760
20	.437	.209	1.577	7.337		....	......	.....	*Ibid.*, no. 2778
21	.13	.02	....	12.74		....	......	......	Pa. geol sur., M. M. p. 266
22	tr.	.11	.25	14.57		....	......	......	
23	....	....	.8	10.5		....	......	......	N. J. clay rep't, 1877.
24	17	.115	....	9.68		....	......	......	Otto Wuth, anal.
25	1.9	1.5	1.65	....		....	......	......	Saginaw clay mfg co.
26	.2	.12	tr.	....	2.25	....	......	......	Minnesota geol. sur. 1872, 1
27	.45	.12	.77	....		SO_3 .12	......	TiO_2	Chauvenet & Blair, anal.
28	....	tr.	.4	11.3	2.5	....		1.50	Evans & Howard
29	.. ..	....	.2	13.8	.5	....	......	......	“
30	tr.	.68	....	11.25		....	......	......	Christy fire clay co.
31	.54	tr.	1.37	....		Ign. 10.56	......	......	St Louis samp. and test. works, anal.
32	.39	.32	.49	12.68	......	....	......	......	Mo. geol. sur. 11: 563
33	.71	....	1.28	11.48	.....	....	......	......	“
34	.54	tr.	1.37	10.56	......	....	......	......	“
35	.28	.22	.52	12.34	......	....	......	......	“
36	.31	tr.	1.88	8.14	1.66	....	......	......	“
37	.57	....	.5	12.76	......	....	......	......	“
38	.51	.26	.49	12.48	......	....	......	......	“
39	1.93	....	.73	14.94	......	....	......	......	Mo. geol. sur. 11: 564
40	.24	.68	2.06	10.43	1.45	....	......	......	“
41	.28	.2	.54	14	......	....	......	......	“

Fire clays

No.	State and county	Town	Remarks	SILICA Combined	SILICA Free	Alumina	Ferric oxid
	Missouri (*continued*)						
1	Gasconade	Drake	Flint clay not worked	40.5		43.22	.31
2	“	Owensville	Flint clay not worked	44.7		35.92	3.35
3	Lincoln	Baker's shaft		34.4		18.62	tr.
4	Monroe	Clapper (Williamson)	Used for stoneware	70.3		20.35	.15
5	“	“	“	67.76		21.9	.69
6	Montgomery	High hill	Flint clay for fire brick	45.12		40.4	.47
7	Morgan	Versailles	Not worked	68.94		21.18	.78
8	St Louis	St Louis	Washed clay for glass pots	60.31		23.52	2.57
9	Osage	Linn (Gostang)	Flint clay not w'k'd	47.87		37.14	.83
10	Phelps	St James (Buskett bank).		51.05		34.28	.39
11	“	St James (Buskett bank)		46.33		40.07	.5
12	“	St James (Buskett bank)		47.306		38.173	.823
13	“	Rolla (Buskett bank)	Flint clay	61.408		25.551	.281
14	“	“	“	6.339		22.75	.82
15	St Louis	Bartold (Jamieson's)	Flint clay for fire brick	53.9		28.85	4.19
16	“	Bartold (Jamieson's)	Washed fire clay for clay pots	55.61		27.36	2.73
17	“	St Louis	Silica clay	72.17		18.72	1.2
18	“	St Louis Christy clay co	Washed fire clay	64.35		21.16	2.63
19	“	St Louis Christy clay co	“	60.66		24.51	2.28
20	“	St Louis Christy clay co	Used for fire brick	61.73		23.56	.516
21	“	St Louis, Laclede mine	“	57.34		24.68	2.6
22	“	St Louis, Evans & Howard	“	59.36		23.26	3
23	“	St Louis, Parker & Russell	Fire brick and gas retorts	67.47		19.33	2.5
24	“	St Louis, Columbia B. road (Sattler).	Washed clay for glass pots	52.98		28.87	2.48
25	“	St Louis, Jamieson French fire clay co	Washed pot clay	52.52		31.4	2.34
26	“	Columbia B. road, St Louis	Not worked	51.66		30.78	2.9
27	“	Columbia B. road, St Louis		53.54		28.21	4
28	“	Coffin & Co., Gratiot	Washed for glass pots	55		29.62	2.18
29	“	“	Washed for glass pots	56.01		31.68	1.13
30	“	“	Fire brick	48.27		31.35	4.97
31	“	“	“	56.47		28.24	2.26
32	Shelby	Higgins pit, Lakeman	Used for stoneware	58.5		30.5	2.34
33	“	Higgins pit, Lakeman		67.6		18.97	1.25
34	Warren	Chiles bank	Flint clay	46.18		38.12	.32

(*continued*)

No.	Lime	Magnesia	Alkalies	WATER		Miscellaneous			Firm names, authority, or analyst
				Combined	Free				
1	1.11	tr.	.51	14.15	....	....	......	......	Mo. geol. sur. 11; 564
2	15.27	.21	.29	12.20	.42	....	......	......	*Ibid.* 11: 564
3	3	6.25	....	....	....	Loss 23.08	......	......	*Ibid.* 1872, 2:288
4	.67	.33	.49	7.12	.79	....	......	......	*Ibid.* 11:566
5	.96	.24	.24	7.8	.43	....	......	......	“
6	.29	tr	.3	13.34	....	....	......	......	“
7	.61	.43	.66	7.08	....	....	......	......	“
8	tr.	.9	.59	10.11	1.96	....	......	......	Christy fire clay co.
9	.42	.58	.5	13.18	.37	....	......	......	Mo. geol. sur. 11: 568
10	tr.	tr.	.11	14.33	....	....	......	......	“
11	1.26	.24	....	13.4	....	....	......	......	“
12	.058	.09	1.41	13.6	....	....	......	......	“
13	1.32	1.43	....	9.78	....	....	......	......	“
14	.22	.05	.89	8	3.27	....	......	......	“
15	1.01	.11	.85	11.61	1.75	....	......	SO_3 .22 *c*1.05	“
16	.87	.07	.71	11.13	2.26	....	......	SO_3 .51 *c*1.36	“ “
17	.2	.11	....	6.56	1.68	....	......	......	Furnished by H. Burden, 2d.
18	.61	.3	.51	8.94	2.63	....	......	*c*1.07	Mo. geol. sur. 11: 568
19	....	.46	.7	11.39	....	....	......	......	From Christy clay co.
20	.55	.15	1	9.25	2.94	....	......	SO_3 .56 *c*1.96	Mo. geol. sur. 11: 568
21	.9	.49	.67	11.55	2.86	....	......	SO_3 .54 *c*1.6	*Ibid.* 11: 570
22	.65	.42	.63	10.2	2.74	....	......	SO_3 .35 *c*1.01	*Ibid.* 11: 570
23	.41	.07	1.07	7.73	2.72	....	......	SO_2 .24	“
24	.51	.87	1.01	11.42	3.68	....	......	......	“
25	.4	.42	.61	....	....	....	......	*b* 12.42	From the company
26	1.22	.88	.99	11.86	4.06	....	......	*c*1.85	Mo. geol. sur. 11: 568
27	1.01	.11	.76	13.26	....	....	......	......	“
28	.91	.29	.27	11.61	....	....	......	......	“
29	1.17	.21	.09	8.77	.74	....	......	*e*.2	“
30	2.13	.21	1.28	8.42	1.27	....	......	2.1	“
31	1	.32	.45	11.44	....	....	......	......	“
32	1.2	.51	.3	6.74	.4	....	......	......	Mo. geol. sur. 11: 570
33	.2	tr.	.96	10.03	1.42	....	......	......	“
34	.54	tr.	1.2	14.01	....	....	......	......	Mo. geol. sur. 11: 572

b Ignition

Fire clays

No.	State and county	Town	Remarks	SILICA		Alumina	Ferric oxid
				Combined	Free		
	Missouri (*cont'd*).						
1	Warren	Kelly's pit	Flint clay	43.56		41.48	.35
2	"	National pit		44.34		40.8	.27
3	"	"	Sandy clay	78.44		14 08	1.56
4	"	"	Fire clay	56.69		27.18	1.68
5	"	"	"	55 6		28.22	1.02
6	"	National pit	Fire clay	53 14		28.54	1.32
7	"	"	"	52.6		27.54	1.6
	Montana:						
8	Deerlodge	Blossburg		72		17	2
	New Jersey:						
9	Middlesex	Woodbridge		61.6		28.38	.52
10	"	Bonhantown	Clay	17.9	57.35	15.5	1.2
11	"	Woodbridge	Retort clay	40.5	6.4	35.9	1.1
12	"	"	Clay	42.05	5.7	35.83	.77
13	"	Raritan river	"	37.85	10.5	35.75	.95
14	"	Sandhills	"	39.8	8 1	36.34	1.01
15	"	Eaglewood	"	40.4	5.2	38.4	1.2
16	"	S. Amboy	Paper clay	42.71	.7	39.24	.46
17	"	Burnt creek	Washed clay	42.9	1.5	38 34	.86
18	"	Sayreville	Clay	41.1	3.1	38.66	.74
19	"	Martins dock		45.1	.7	38.6	1
20	"	Oldbridge		24.55	44.8	19.85	1
21	Mercer	Trenton		70 05		19.43	1.52
22	Gloucester	Conrad		29.5	34.5	23.3	1.5
23	Cumberland	Miliville	Crossley's clay	77.15		15.65	tr.
24	Middlesex	South Amboy	H. C. Perrine & Co.	61.76		26.14	.8
25	"	Woodbridge	Crossley's clay	75.74		18.34	.06
26	"	S. I. terra-cotta lumber co		56.62		31.5	1.15
27	"	Valentine & Co. Woodbridge		56.82		32.4	.15
28	"	"		64.9		25.28	.52
	New York:						
29	Richmond	Kreischerville		64.28		24.76	.83
	North Carolina:						
30	Moore			75.34		17.06	[a] 1.94
31	Harnett			70.6		20 46	1.82
32	Cleveland	Grover		68.28		18.23	2.6
33	Guilford	Pomona		70.45		17.34	3.16
34	"	One mile north of Pomona		71.6		15.27	3 33
	North Dakota:						
35	Mercer	Plenty coal mine		60 79		16.23	4.49
36	Stark	Dickinson		72.66		17 33	1.05
37	Ward	Minot	Black clay	53.72		17.78	3.85
	Ohio:						
38	Summit	Akron		51.21	8.13	27.62	tr.
39	Scioto	S. Webster		45		40	.8
40	Jefferson	Freeman		66.77		19 35	4.25
41	Trumbull	Niles		44.45		40.15	1.67
42	Jackson	Oakhill		58.25		31.02	....
43	Tuscarawas	Mineralpoint	Flint clay	35.39	17 13	31.84	.67
44	Scioto	Scioto	Clay	44.34	.26	40.05	.8
45	Columbiana	Salineville	Flint clay	59.92		27.56	1.03
46	Perry	Mocahala		49.2		37.78	....

(continued)

No.	Lime	Magnesia	Alkalis	WATER		Miscellaneous			Firm names, authority, or analyst
				Combined	Free				
1	.45	....	.2	14.05	....	....	......	......	Mo. geol. sur. 11: 572
2	tr.	.35	.2	14.18	....	....	......	......	“
3	tr.	.37	.18	5 62	....	....	......	......	“
4	1.08	1.6	2.74	9.68	....	....	......	......	“
5	.81	1.22	2.62	10.64	....	....	......	......	“
6	.7	1.01	.97	14.56	....	....	......	......	“
7	1.22	2.24	2.14	13.68	....	....	......	......	“
8	2.	3.	....	....	....	....	......	......	Mullan fire b. & t. co.
9	.46	.36	....	....	....	Ign. 5.08	*c*3.6	......	J. Pohle, anal., W. B. Dixon, Est.
10	......	....	.17	4.9	1.3	....	*c*1.6	......	N. J. clay rep't, 1878, p. 165
11	....	....	.44	12.8	1.5	....	*c*1 3	......	*Ibid.* p. 82
12	....	.11	.44	12.2	1.5	....	*c*1.1	......	*Ibid.* p. 94-96
13	....	tr.	.37	12.3	4	....	*c*1.6	......	*Ibid.* p. 144
14	....	.04	.15	12.9	1.2	....	......	......	*Ibid.* p. 153
15	.22	.25	.59	12 5	1 3	....	......	......	*Ibid.* p. 135
16	.2	....	.89	13 32	1.58	....	*c*1.6	......	*Ibid.* p. 200
17	....	....	.44	13.5	1.1	....	*c*1 2	......	*Ibid.* p. 197
18	....	....	.46	13.55	1	....	*c*1 2	......	*Ibid.* p. 188
19	....	....	2.49	10.9	1	....	......	......	*Ibid.* p. 170
20	....	....	2.22	5.7	.9	....	*c*1	......	*Ibid.* p. 180
21	....	....	1.6	7	....	....	......	......	*Ibid.* p. 237
22	....	....	1.93	7	1.6	....	......	......	*Ibid.* p. 258
23	.75	....	5.35	....	....	....	......	......	Furnished by H. Burden, 2d
24	....	....	9,6	....	....	....	......	......	
25	.66	....	4.58	....	1.7	....	......	......	
26	tr.	....	9.74	....	....	....	......	......	
27	....	....	10.04	....	....	....	......	......	
28	....	....	6.68	....	....	....	......	......	
29	.73	tr.	2.35	....		....	......	......	H. T. Vulté, anal.
30	2.56		....	3.1		....	......	......	Crossley, Analyses of clays
31	1.85		....	5.27		....	......	......	
32	.7	.13	2.29	.76	6.47	....	......	*c*.27	Eskridge's pit, Bull. 13, N. C. geol. sur. p 81
33	.25	.22	.7	.98	6.63	....	......	Ferr. oxid .33	First pit. Pomona terra cotta co. *Ibid.* p. 84
34	.17	.21	2.12	1.43	5.4	....	......	......	Woodroff's clay bank *Ibid.* p. 85
35	.65	1.02	.47	16.35		....	......	......	
36	.13	....	.74	9.35		....	......	......	
37	.81	.5	2	21.82		....	......	......	
38	....	.029	2.07	....		....	......	......	
39	.2	....	....	14		....	......	......	Webster fire brick co.
40	.65	1	....	5.4		MnO 2.05	......	......	E. Orton, anal
41	tr.	tr.	....	13.77		....	......	......	M. Shiras, anal.
42	....	....	....	10.98		....	......	......	
43	.5	.19	.59	11.68	.69	....	*c*1.68	......	Ohio geol. sur. 7, 1893
44	.27	tr	tr	14.23	..	....	......	......	“
45	tr.	tr.	.67	9.7	1.12	....	......	......	“
46	....	....	....	11.68		....	......	......	A. Tharp

Fire clays

No.	State and county	Town	Remarks	SILICA Combined	SILICA Free	Alumina	Ferric oxid
	Ohio (*continued*)						
1	Shelby	Ballou	Clay	31.07	27.71	26.47	1.22
2	Hocking	Phelps		60.77		25.74	1 61
3	Tuscarawas	Canal Dover		47.6		35.02	2.3
4	Jefferson	Steubenville		29.22	31.34	24.97	1.66
5	"	Newcastle		55 49		28.33	2.46
6	"	Freeman (Freeman fire clay co.)		66.75		19.95	4.25
7	Lawrence	Hanging Rock (Means.Kyle & Co.)	No. 2 fire clay	58.72		25.34	2.34
8	Jefferson	Irondale (Martha L. Lacey)		72.		24.	3.
9	Stark	Massillon		61.58		24.14	1.2
10	"	Canton	For fire brick	69.85		19.43	.51
11	Tuscarawas	Strasburg (Dover fire brick co.)		50.09		36.06	1.01
	Pennsylvania:						
12	Fayette	Connellsville (Soisson mine)		55.38		30.42	tr.
13	Clearfield	Woodland		45.29		40.067	1.074
14	"	Curwensville.	Bilger clay	43.92		38.195	*a* .81
15	Cambria	South Fork	Flint clay	43.46		41.61	1.03
16	Westmoreland	King mine	Flint clay	63.81		26.39	1.23
17	"	Reese, Hammond & Co	Fire brick	53.08		43.41	2.44
18	Clearfield	Clearfield (5 miles southwest)		44.05		37.51	*a* .819
19	Clinton	Queen's run	Raw hard clay	46.65		36.36	1.19
20	"	"	Calcined hard clay	52.73		40.63	1.73
21	Somerset	Savage mountain	Raw flint clay	53.86		35.484	*a* 1.23
22	"	"	Calcined flint clay	59.16		38.7	*a* 1.36
23	Westmoreland	Hunker Station	Flint clay	52.58		33.12	.2
24	"	Bradyss run		62.029		23.656	.896
25	Blair	Benezet	Raw clay	47.233		38.409	.391
26	Cambria	Figart	Hard fire clay	48.878		32 002	3.629
27	Somerset	Keystone Junction.		54.65		30.74	*a* .08
28	Clinton	Farrandsville		45.26		37.84	2.03
29	"	Retort		42.32		37.01	*a* .95
30	Fayette	Brillskin township.	Flint clay	55.28		34.17	2.27
31	"	Wymp's gap	Glass pot clay	54.23		32.8	.21
32	Clinton	Renovo		53.84		32.6	*a* 1.02
33	Armstrong	Kittanning		97.03			.9
34	Elk	Jay township		67.57		21.042	*a* .621
35	"	Glen Mayo colliery.		51.72		21.738	*a* 7.875
36	Clarion	New Bethlehem		44.61		38 01	*a* 1.251
37	"	Sligo		56.63		28.85	*a* 1.26
38	Indiana	Bolivar		59.83		24.58	*a* 1.655
39	Westmoreland	Salina		51.92		31.64	*a* 1.134
40	"	Laughlintown		55.68		29.18	*a* .837
41	"	Jacobs creek		56.78		26.89	*a* 3.22
42	Fayette	Meadow run		52.23		31.31	*a* 1.008
43	Beaver	Vanporte		60.19		24.23	*a* 2.097
44	"	Rochester		61.98		23 88	*a* 1.395
45	Indiana	Bolivar		50.84		30.745	*a* 3.213
46	Clarion	Climax		42.82		40.2	2.59
47	Cambria	Altoona		68.35		22.78	*a* .11
48	Indiana	Black lick	Flint clay	64.83 68.49		23.95 18.46	*a* .9 *a* 1.566 .29

(continued)

No.	Lime	Magnesia	Alkalis	WATER		Miscellaneous			Firm names, authority or analyst
				Combined	Free				
1	.59	.32	.99	9.96	1.04	....	*c*.94	......	Ohio geol. sur. 7, 1893
2	.89	.63	1.2	9.46	....	....	......	......	“
3	.54	.04	....	14.5		....	......	......	
4	.63	.4	.28	8.9	1.69	....	*c*1.3	......	Ohio geol. sur. 1884
5	.26	.08	1.37	11.38		....	......	......	
6	.6	1.	....	5.4		....	......	......	Furnished by company
7	*b*.6	*d*.43	2.28	8.95		....	......	......	
8	....	....	....	10.		....	......	......	Furnished by M. L. Lacey
9	.45	.7	....	11.93		....	......	......	From Massillon stone and fire brick co.
10	.12	.1	2.59	7.35		....	......	......	From Royal brick co.
11	.38	.12	tr.	12.4		....	......	......	J. H. Cremer, anal. for company
12	....	.52	.22	....		....	......	......	J. Soisson & Sons
13	.257	.08	.048	13.184		....	......	......	Woodland fire brick co.
14	.2	.054	.265	14.2		....	*c* 2.61	......	
15	.24	.09	....	Ign. 13.29		....	......	......	1897 Rep't, Pa. state college
16	tr.	tr.	....	Ign. 9.12		....	......	......	*Ibid.*
17	.33	.18	....	Ign. .26		....	......	......	*Ibid.*
18	.49	.181	.065	15.21		....	*c* 1.84	......	Queen's run fire brick co.
19	.08	....	1.3	13.01		....	*c* 2.64	......	
20	.21	.04	1.83	....		....	*c* 2.94	......	
21	.302	.144	....	8.75		....	......	......	Welch, Gloninger & Maxwell
22	.331	1.36	....	....		....	......	......	
23	......	.29	.08	13.68		....	......	......	Westmoreland fire brick co.
24	2.335	.819	1.661	8.049		....	......	......	G. G. Pond, anal.
25	....	.192	....	13.775		....	......	......	Harbison & Walker
26	.374	.079	1.742	....		Loss 15.609	......	......	G. G Pond, anal.
27	.19	.13	.11	....		....	......	......	
28	.08	.02	1.26		13.3	....	Loss 20	......	J. B. Britton, anal.
29	.47	.16	1.29		17.74	....	3.83	Loss.23	E. E. Melick
30	1.31	2.11	....	....		....	......	......	Soisson & Kilpatrick.
31	....	....	....	Ign. 11.24		....	......	......	1897 Rep't, Pa. state college.
32	1.35	.1	.59	5.89		....	4.62	......	Renovo fire brick and clay co.
33	....	.11	....	.15		....	......	......	
34	.1	.147	tr.	9.59		....	.93	......	
35	.06	2.378	4.581	10.78		....	.87	......	
36	.08	.407	1.735	13.63		....	1.02	......	
37	.26	.079	.694	11.85		....	.99	......	
38	.26	.872	3.114	7.83		....	1.17	......	Pa. geol. sur., MM, p. 259
39	.03	.443	.402	13.49		....	1.16	......	
40	.13	.18	.245	12.49		....	1.49	......	
41	.369	.987	3.92	8.38		....	......	......	
42	.13	.165	.72	13.19		....	1.68	......	*Ibid.* p. 260
43	.85	.036	1.669	9.015		....	2.345	......	*Ibid.* p. 263
44	.04	.281	1.217	9.28		....	1.83	......	*Ibid.* p. 262
45	.16	.298	.541	13.05			1.26	......	
46	tr.	.35	1.24	12.8	....	....	......	......	Climax brick works.
47	.82	.37	....	7.57		....	......	......	Otto Wuth, anal.
48	.11 .23	.187 .551	.296 2.755	9.39 6.31		O_2 .88 *c* 2.15	....	....	Pa. geol. sur. H4, p. 194

Fire clays

No.	State and county	Town	Remarks	SILICA		Alumina	Ferric oxid
				Combined	Free		
	Pennsylv'nia *(cont'd)*						
1	Indiana	Layton Station	Glass pot clay......	64.89		24.08	*a* .21
2	Clinton	Lockhaven........	Soft clay	50.8		32.28	1.77
3	"	Lockhaven	Hard clay..........	45.65		36.36	1.19
4	Westmoreland.....	Salina.........	....	43.75		40.966	.769
5	Chester	Valley Forge......	M. J. Bean's clay ..	71.88		19.26	
6	"	Brady's run (B. R. fire brick co.)....	....	68.92		22.38	.98
7	Allegheny	Manown	....	64.17		29.75	2.6
8	"	Hunker Station....	....	41.75		40.09	.65
9	Clarion	Arthurs	....	42.56		43.16	tr.
10	Allegheny	Pittsburg	Silica brick	96.79		.93	.14
	South Dakota :						
11	Pennington	Rapid City.........	Hard clay	84.42		9.41	1.07
12	"	"	C. A. Marshall's...	87.05		6.56	.64
13	"	"	Dark clay, base of hill	83.3		12.3	.8
	Texas:						
14	Montague..........	Bowie	....	60.48		24.6	2.43
15	Henderson.........	....	....	68.55		26.	tr.
16		Athens	....	31.82	37.06	20.71	1.01
	Washington:						
17	King	Black diamond field	....	57.5		34.37	1.24
18	Pierce	Green river fields..	....	69.71		18.39	1.44
19	Skagit	....	....	49.73		32.57	1.52
	West Virginia:						
20	Fayette..........	Great Kanawha....	....	55 67		30.39	.61
21	Kanawha	Charleston	....	39.9	16.9	30.08	1.33
22	Marion............	....	....	45.86		44.23	....
23	Monongalia	....	....	54.27		33.83	.01
24	Preston	....	....	68.16		24.11	.01
25	"	Spragueville	Hard clay..........	47.88		33.985	1.368
26	"	"	Soft clay...........	68.315		19.62	1.575
	Wyoming:						
27	Albany............	Rock creek.........	....	59.78		15.1	2.4
28	Crook	....	....	61.08		17.12	3 17
	Virginia:						
29	Chesterfield	Robins	....	80.76		11.004	1.396

(*concluded*)

No.	Lime	Magnesia	Alkal	WATER		Miscellaneous			Firm names, authority, or analyst
				Combined	Free				
1	.41	.19	1.03	9.29		....	......	......	1897 Rep't, Pa. state college
2	.05	.47	4.56	....	....	....	......	*d* 8.94 *b* 1.25	Queen's run fire brick co., P. W. Shimer, anal.
3	.08	....	1.3	....	....	....	......	*d* 13.01 *b* 2.64	Queen's run fire brick co., P. W. Shimer, anal.
4	tr.	....	....	14.41		....	......	......	Kier brothers, Pittsburg, Pa.
5	1.5	1.04	....	5.4		....	......	......	Furnished by H. Burden, 2d
6	.19	.172	....	6.14	....	....	......	......	F. G. Frick, anal.
7	.4	.12	....	....	....	....	......	......	From Manown mfg co.
8	.03	1.02	....	13.2	....	....	......	......	From Westmoreland fire brick co.
9	.44	.15	....	13.99	.24	....	......	......	From Erskine & Co
10	1.86	....	....	....	.14	....	......	......	From Stuart fire brick co.
11	tr.	.39	....	3.42		....	......	......	Rapid City steam brick works
12	.95	1.243	3.008	....	....	....	......	......	Furnished by F. C. Smith
13	1.3	tr.	2.7	....	....	....	......	......	
14	.89	.75	....	....	....	....	......	......	Montague coal mining co.
15	tr.	.11	tr.	6		....	......	......	Texas geol. sur. 1890, p. 197
16	.22	.39	1.08	7.17	1.82	....	......	Ign. 8.99	G. E. Ladd, anal.
17	.5	1	.68	4.71		....	......	......	1891 Rep't, Wyoming state geol.
18	.35	.15	1.02	....	....	....			
19	.42	1.28	1.1	12.38		*b* .43	$CaSO_4$ .10	Loss. 8.94	
20	.37	tr.	.12	12.87		....	......	......	W. A. Bradford
21	tr.	tr.	2.2	7.6	.9	....	1.15	......	Bull. on min. res. of West Virginia, 1893
22	.24	.36	tr.	9.05		....	......	......	
23	tr.	.02	1	11.01		....	......	......	
24	tr.	tr.	tr.	7.51		....	......	......	
25	.36	.346	.481	12.388		....	3.185	......	I. C. White, anal.
26	.1	.692	2.704	5.58		....	1.37	......	"
27	.73	4.14	....	16.26		....	......	......	Bull. 14, Wyoming exper. sta.
28	2.69	1.82	.2	12.1		....	......	SO_3 .88	
29	.504	.108	.832	5.025		....	.....	......	J. R. Jackson

Pottery

No.	State and county	Town	Remarks	SILICA Combined	SILICA Free	Alumina	Ferric oxid
	Alabama:						
1	Tuscaloosa	....	Tuscaloosa Cretaceous............	66.122		24.781	r
2	"	Prattville	Stoneware clays ...	62.6		26.98	.72
3	Fayette............	W. Doty	" ...	65.58		19.23	4.48
4	"	13 miles from Fayette C. H.	" ...	67.1		19.37	2.88
5	"	Shirley's mills	" ...	72.20		17.42	2.4
6	Colbert	J. W. Williams, Pegram	" ...	66.45		18.53	2.4
7	Pickens	Roberts Hill, coal fire co......	" ...	68.23		20.35	3.2
8	Lamar	I. B. Green, Fernbank	" ...	69.5		13.	6.4
9	Fayette............	H. Wiggins, east of Fayette E. C. H..	" ...	63.27		19.68	3.52
10	Tuscaloosa	H. H. Cribbs, Tuscaloosa..........	" ...	65.35		21.3	2.72
	Georgia:						
11	Baldwin.......	Stephens pottery ..	....	46.07		21.72	15.75
	Illinois:						
12	Pope	....	....	46.9		31.34	.16
	Indiana:						
13	Putnam...........	Reelsville..........	....	60.56		27.	3.48
14	Clay	Martz	....	65.66		17.2	4.05
15	Porter	Sumanville.........	Blue clay...........	68.5		17.55	1.38
16	Fountain	....	Yellow clay	50.43		22.18	4.37
17	Vanderburg........	Evansville..........	Clay	59.5		26.22	.8
18	"	"	"	79.41		10.8	2.07
	Kentucky:						
19	Madison...........	Wasco....	Pottery clay........	59.976		27.64	....
20	Franklin	Frankfort..........	"	69.3		21.78	
21	Hickman..........	....	"	76.36		14.95	2 11
22	Butler.............	....	"	51.66		15.56	7.68
23	Ohio	....	"	70.06		17.94	.38
24	Madison...........	....	Black shale	62.56		24.78	1.8
25	Fulton	....	....	71.021		17.977	3.417
26	Graves............						
27	McCracken	Pryorsburg	....	56.4		30.	....
		Paducab (3 m. s.)..	Black shale	59.5		24.96	.72
28	Calloway						
29	Graves............	Murray (6 m. e.)...	Black shale	54.84		30.34	1.18
		Bell City	Black shale	56.98		32.16	2.16
	Minnesota:						
30	Blue Earth........	Mankato	Red clay	73.34		14.75	5.45
	Missouri:						
31	Barton	Wear mine,Minden.	Not worked	50.94		24.24	7.18
32	"	Waltman's	Stoneware clay	65 32		22.63	1.81
33	Guthrie, Callaway.	Moore place........	Used for stoneware	48.92		32.9	3.1
34	"	"	"	47.13		34.98	2.92
35	Cass	Harrisonville	....	63.93		19.73	3.69
36	"	"	Washed clay, not worked..........	64.62		19.98	2.91
37	Franklin	Union	....	44.14		39.86	.46
38	Henry	Calhoun...........	Used for stoneware	71.94		17 6	2.35
39	"	Dunlap pit, Clinion	"	67.49		21.11	2.45
40	"	Frawe'n pit, Clint'n	"	64.97		22.64	3.28

clays

No.	Lime	Magnesia	Alkalis	WATER		Miscellaneous			Firm names, authority, or analyst
				Combined	Free				
1	....	....	....	6.287	....	....	......	......	Rep't on valley regions, Ala. geol. surv. 20: 180
2	.4	.36	.65	8.6	.7	....	......	......	
3	tr.	tr.	....	5.5	1.4	....	......	......	
4	tr.	.725	.672	6.08	1.71	....	......	......	
5	tr.	tr.	.56	7.4	.12	....	......	......	
6	1.5	1.25	tr.	8 68	.78	....	......	......	
7	.34	tr.	.74	6.1	1.06	....	......	......	
8	.25	tr.	tr.	6.7	3.4	....	......	......	
9	1.36	tr.	1.2	6.05	3.75	....	......	......	
10	.6	.86	tr.	7.35	1.44	....	......	......	
11	.25	.67	.48	11.72		c.34	......	......	R. Peter, anal.
12	....	.1	.95	20.		....	......	......	
13	.725	....	2.8	....	.....	Loss 6.3	SO_2 .27	......	Ind. geol. sur. 1878 p. 159
14	.365	....	2.72	....		Loss 8.1	SO_2 .74	MnO.8	
15	1.2	.25	2 61	8.51		....	......	......	Crossley, Analyses of clays
16	6.58	1.74	2.08	12.62		....	......	......	
17	.56	2.76	2.96	....		....	......	......	U les pottery
18	.6	.62	....	......	6.5	....	......	......	B. F. Harris
19	b.28	.606	4.478	7.02		....	......	......	Ky. geol. sur. chem. rep't A, pt 1, no. 1876a
20	.158	.331	2.936	5 435		P_2O_5 .06	......	......	*Ibid.* no. 2007
21	b.33	.17	.71	4.31		....	......	.....	Crossley, Analyses of clays
22	7.27	.82	3 57	13.44		....	......	.....	
23	tr.	.66	2.96	4.56		....	......	.....	
24	tr.	.32	3.57	6.87		....	......	.....	
25	1.019	.262	.95	5.276		....	......	......	Ky. geol. ur. n. s. p. 430
26	.4	tr.	5.27	7.93		....	......	......	R. Peter, anal.
27	.325	.396	2.22	......	11.879	....	......	......	Ky. geol. sur. chem. rep't A, pt. 3, no. 2777
28	.011	.05	1.137	9.442		....	......	......	*Ibid.* no. 2643
29	tr.	2.	.949	7.542		....	......	......	*Ibid.* no. 2666
30	.28	.05	tr.	4.71		....	......	......	Minn. geol. sur. 1872-1882
31	.95	1.6	3.6	11.58	....	....	......	......	Mo. geol. sur. 11:563
32	.25	.67	1.72	7.42	....	....	......	......	“
33	.4	.3	.82	13.58	....	....	......	......	“
34	.37	.32	.52	13.88	....	....	......	......	“
35	.53	1.21	3.4	7.53	....	....	......	......	“
36	.44	1.31	3.25	7.42	....	....	......	......	“
37	.77	.46	.76	13.84	....	....	......	......	*Ibid.* 11:564
38	.62	.56	1.5	5.27	1.01	....	......	......	“
39	.17	.68	2.88	5 95	1.04	....	......	......	“
40	.61	.8	2.74	5.5	1.2	....	......	......	“

Pottery clays

No.	State and county	Town	Remarks	SILICA		Alumina	Ferric oxid
				Combined	Free		
	Missouri (*continued*)						
1	Henry	Grant farm, Clinton	Not worked	59.33		25.09	4.09
2	"	Missouri clay co. Deepwater	Used also for sewer pipe	72.86		12.99	2.95
3	"	"	"	74.02		15.26	2.02
4	"	Fields creek	Used for stoneware	55.39		25.79	4.83
5	"	Gilkerson ford	Not worked	86.98		14.72	2.48
6	Jasper	Chancy sh'ft, Joplin	"	60.98		21.83	1.93
7	Jefferson	Mammoth mine, Desoto	Ball clay for white ware	49.04		34.85	.71
8	"	Mandel's pit, Regina	Ball clay for white ware	45.97		36.35	1.08
9	Lafayette	Strasburg mine, Mayview		48.12		17.04	3.82
10	Morgan	Pricel'nd, Versailles	Not worked	54.1		24.	4.01
11	Randoph	Lanigan shaft, Moberly	Used also for paving brick	66.24		20.32	2.3
12	St Louis	Rennebergs, Allenton	Not worked	60.07		22.81	2.71
13	Saline	Oer pit, Slater		50.36		32.34	3.9
14	Schuyler	Chariton river, Glenwood		53.54		15.39	4.17
15	Scott	Anderson place, Commerce	Used for stoneware	71.78		17.01	2.01
16	Stoddard	Dexter	"	68.5		20.81	1.79
	New Jersey:						
17	Sussex	Woodbridge	Stoneware clay	19.44	48.4	21.83	1.57
	New York:						
18	Queens	Glencove	"	70.45		21.74	1.72
19	"	Elmpoint	"	62.06		18.09	5.4
20	Suffolk	Littleneck	"	62 66		18 09	.97
	Ohio:						
21	Muskingum	Roseville	"	25.6	43.73	19 08	1.23
22	Perry	Uniontown	"	29.35	35.85	23.05	.99
23	Summit	North Springfield	"	72.1	.	19.38	....
24	Columbiana	East Liverpool	Yellow ware clay	42.28	18.02	24.12	1.46
25	Stark	Greentown	Stoneware clay	72.26	.....	19.23	......
26	Muskingum	Zanesville	Cooking ware clay	25.4	40.81	21.13	1.28
27	Summit	Akron	Stoneware clay	27.68	36.58	22 95	1.28
28	Columbiana	East Palestine	Yellow ware clay	29.93	29.61	25.12	1.57
29	"	Salineville	"	32.33	24.11	26.6	2.
	Pennsylvania:						
30	Beaver	New Brighton	Drift clay	57.67		27.52	*a* 1.494
31	"	Oak Hill	Yellow clay	46.16		26.976	7.214
32	Tennessee	Loudon	Clay	45.06		30.03	*a* 4.5
	Texas:						
33	Henderson	Athens	"	68.57		28.24	tr.
34	Marion	Linden road	"	58.2		23.97	4.43

Slip

No.	State and county	Town	Remarks	SILICA		Alumina	Ferric oxid
				Combined	Free		
35	Michigan	Rowley	Clay	12.85	31.09	11.17	3.81
	New York:						
36	Albany	Albany	"	14.33	46.26	12.46	5.79
	Ohio:						
37	Summit	Brimfield	"	15.65	47.98	13.57	7.77

(*concluded*)

No.	Lime	Magnesia	Alkalis	WATER		Miscellaneous			Firm names, authority or analyst
				Combined	Free				
1	.84	1.17	2.74	8.74	....	....	......	......	Mo. geol. sur. 11: 564
2	.35	.47	1.18	4.76	2.02	....	......	......	“
3	.48	.51	2.37	3.69	.49	....	......	......	“
4	.53	.31	3.39	8.6	1.25	....	......	......	“
5	.65	.58	2.32	.86	.46	....	......	......	“
6	.42	1.95	4.69	8.48	....	....	......	......	*Ibid.* 11: 566
7	1.33	1.04	.85	12.33	....	....	......	......	“
8	1.14	1.09	1.84	12.36	....	....	......	......	“
9	9.9	2.65	2.97	14.98	....	SO_3 .27	......	......	“
10	1.31	1.25	4.01	11.64	....	....	......	......	“
11	.63	.48	2.04	7.8	....	....	......	......	*Ibid.* 11: 568
12	1.65	1.55	4.42	6.48	....	....	......	......	*Ibid.* 11: 570
13	1.04	.37	2.01	8.25	1.69	....	......	......	“
14	8.54	2.17	3.2	12.78	....	....	......	......	“
15	.34	.43	.78	8 13	....	....	......	......	“
16	.77	tr.	.53	7.62	....	....	......	......	“
17	.28	.24	2.24	5.9	.8	....	......	......	N. J. clay rep't, 1878 p. 99
18	.24	.3	5.	....	....	....	......	......	H. T. Vulté, anal.
19	1.05	tr.	6.11	....	....	....	......	......	“
20	.79	....	2.33	....	....	....	......	......	“
21	.6	.63	2.16	5.57	.94	....	*c* .29	......	Ohio geol. sur. 5, 1884
22	.58	.58	1.45	7.59	1.11	....	*c* .55	......	“
23	1.38	.23	......	5.13	.112	....	......	......	“
24	.59	.68	2.42	7.77	.86	....	1.2	......	“
25	....	....	......	10.03	.83	....	......	......	“
26	.51	.18	1.8	6.29	1.65	....	......	......	*Ibid.* 7, 1893
27	.45	.37	1.96	6.74	2.05	....	......	......	“
28	.57	.51	1.95	7.75	2.63	....	......	......	“
29	.47	.63	3 46	7.59	2.48	....	......	......	“
30	.38	.122	.619	9.68		....	*c* 2 54	......	....
31	2 21	1.52	3.246	11.22		*c* .74	......	......	1897 rep't Pa. state college
32	4.7	4.8	....	10.1		....	......	......	Crossley, Analyses of clays
33	tr.	1.25	....	......	1.85	Loss .11	......	......	Miller Brothers
34	......	....	7.11	5.36		....	......	......	Texas geol. sur. 1890, p. 112.

clays

35	11.64	4.7	3.61	3.9	15.66 & CO_2	....	......	......	Ohio geol. sur. 7, 1893,
36	6.84	3.28	4.39	4.36	1.46 & CO_2	....	......	......	“
37	2.55	1.47	2.63	4.75	2.9 & CO_2	....	......	......	“

Slip clays

No.	State and county	Town	Remarks	SILICA Combined	SILICA Free	Alumina	Ferric oxid
1	Ohio *(continued)* Hamilton	Sharonville	Clay	12.04	30.2	11.08	5.07
2			Kaolinite slip	12.	48.4	10.42	5.36
3	Texas: Grimes	Piedmont Springs	Clay	58.5		18.39	3.29

Adobe

No.	State and county	Town	Remarks	SILICA Combined	SILICA Free	Alumina	Ferric oxid
4	Nevada	Humboldt City	P_2O_5 .94	26.67		13.19	5.12 *a*.64
5	New Mexico: Bernalillo	Fort Wingate	P_2O_5 .75	26.67		.91	.64
6	Utah: Summit	Salt Lake City	P_2O_5 .23	19.24		3.26	1.09

Brick

No.	State and county	Town	Remarks	SILICA Combined	SILICA Free	Alumina	Ferric oxid
7	Alabama: Tuscaloosa		Pinkish clay. Tuscaloosa Cretaceous.	68.108		10.858	14.471
8		NE. ¼ of NW. ¼ of S.24, T. 1, R. 14 W.		59.65		27.04	4.75
9	Elmore	Elmore Station	River terrace clay	60.81		21.69	3.43
10	"	"	"	61.15		24.81	2.48
11	Montgomery	Montgomery	"	62.75		21.15	4.
12	Morgan	Lacon		75.52		12.945	*a* 2.605
13	Arkansas:	Johnsonsridge		56.91		19.8	6.68
14	Little River	Williamslake		58.24		13.22	9.25
15	Sebastian	Nigger hill, Fort Smith		58.43		22.5	8.36
16	"	Fort Smith		74.79		12.86	4.9
17	Poinsett	Harrisburg		81.37		8.52	2.88
18	Craighead	Jonesboro		79.49		8.71	3.43
19	Greene	Gainesville		71.17		18.44	2.77
20	"	Paragould		79.07		8.79	2.54
21	Cross	Wittsburg		69.55		15.2	8.1
22	Hempstead	Hope		72.42		14.94	5.54
23	Sevier	Brownstown		79.07		10.53	5.27
24	California: Placer	Lincoln		44.82		34.54	1.86

(*concluded*)

No.	Lime	Magnesia	Alkalis	WATER		Miscellaneous			Firm names, authority or analyst
				Combined	Free				
1	15.99	6.36	2.68	4.58	12. & CO_2	....	......	......	Ohio geol. sur. 7, 1893
2	9.88	4.28	.87	3.64	4.41 & CO_2	....	......	......	"
3	2.34	1.61	7.63	8.7		....	......	......	Tex. geol. sur. 4th ann. rep't
soils									
4	13.91	2.96	2.3	2.26		Cl .14	MnO .13	CO_2 8.55	Bull. U. S. G. S., 64
5	36.4	.51	tr.	2.26		e5.1 Cl .07	SO_3 .82	CO_2 25.84	"
6	38.94	2.75	tr.	1.67		Cl .11	SO_3 .53	CO_2 29 57	
clays									
7	....	....	....	7.085	....	....	......	......	Ala. geol. sur. rep't on valley region, p. 180
8	....	....	....	....	....	....	......	......	*Ibid.*, J. M. Pickel, anal.
9	.17	.57	2.15	7.26	3.6	....	......	SO_3 .1	Ala. ind. & sci. soc. v. 1895
10	.3	.39	2.8	6.45	1.7	....	......	SO_3 .11	
11	.72	.32	2.28	6.	2.7	....	......	SO_3 .11	
12	.867	.936	....	5.5		....	......	......	Standard brick and tile works
13	4.76	.96	3.17	....	....	....	......	Loss 9.57	Ark. geol. sur. 1888, p. 296
14	4.55	4.19	3.22	....	....	....	......	Loss 8.96	
15	.32	1.14	3.21	....	....	....	......	Loss 6.07	
16	.38	.9	3.22	....	....	....	......	Loss 2.91	
17	.44	.5	2.4	....	....	....	MnO_2 1.01	Loss 2.88	*Ibid.* 1889, 2; 85
18		2.1		....	....	....	MnO_2 2.44	Loss 3.83	*Ibid.* p. 87
19	.25	.44	.9	....	....	....	......	Loss 6.03	*Ibid.* p. 107
20	.25	.23	1.89	....	....	....	MnO_2 3.68	Loss 3.55	*Ibid.* p. 112
21	.58	.97	1.02	....	....	....	P_2O_5 .2	Loss 5.72	*Ibid.* p. 138
22	....	2.56	....	....	....	....	......	Loss 4.54	Ark. geol. sur. 1888, p. 296
23	....	.7	....	....	....	....	......	Loss 4 43	
24	1.55	.96	4.74		9 64		......	Loss .44	Cal. state min., 11th rep't

Brick clays

No.	State and county	Town	Remarks	SILICA		Alumina	Ferric oxid
				Combined	Free		
	Colorado:						
1	Pueblo	Pueblo		61		35	.25
2	District of Columbia	Washington	Shale	62.14		25.55	tr.
	Florida:						
3	Escambia	Bluffsprings		52.05		18.87	2 49
	Georgia:						
4	Bartow	Cartersville	Clay	58.63		20.47	8.58
5	"	"	Slate	71.6		11.5	5.59
6		McCamores cave	Plastic clay	69.33		19.01	2.02
7	"	Cartersville	Alluvial clay	69.18		15.43	5.83
8	Floyd	Rome	Surface clay	67.8		13.82	5.74
9	Richmond	Augusta		54.55		18.04	*a* 3.87
	Illinois:						
10	Lasalle	La Salle	Red clay	62		18.1	9.11
11		Woodland		51.36		12.8	9.68
12	Livingston	Cornell		68.22		19.48	
13	Kane	Aurora		49.964		13.64	1.788
14	Peoria	Peoria		72.1		16.1	3.3
15	Lasalle	Utica		56.65		26.45	2.1
16	"	Ottawa	Clay	45.79		22.44	*a* tr.
17	Mercer	Griffin	No. 2 clay	75.83		15.04	1.08
18	"	"	No. 1 clay	64.52		23.52	1.92
19	Lasalle	Lasalle	Red clay	62		18.1	9.1
20	"	"	Buff clay	68.3		18.3	....
21	"	Streator	Brick	61.76		18.32	7.04
	Indiana:						
22	Marion	Indianapolis	Terra-cotta	59 08		31.3	.5
23	Floyd	New Albany	Clay	52.18		19.27	3.13
24	Crawford	Wyandotte cave	Red clay	48.5		19.5	12.3
25	Monroe	Bloomington	Clay	66.14		15.34	6.32
26	"	"	"	55.23		29.66	4.63
27	Martin	Dover Hill		70.73		13.74	4.4
28	Jennings	Vernon	Clay	68.19		18.22	2.43
29	Warren	Covington		34.35		15.5	33.12
30	"	"		66.44		22.09	2.16
31	Perry	Cannelton		66.83		22.94	2.64
32	Jackson	Brownstown		63.6		20.84	3.17
33	Union	Liberty		73.81		13.87	2.66
34	Clark	Jeffersonville		49.83		13.95	2.1
35	Vigo	Terre Haute		71.833		12.64	4.4
36	Wabash	Wabash		62.18		15.9	3.77
37	Fountain	Veedersburg		69.6		13.08	2.98
38	Daviess	Washington		81 71		9.81	3.8
39	Greene	Worthington		63.25		24.81	5.04
40	Jasper	Jasper		68.64		20.18	2.5
41	Parke	Montezuma		54.53		24.66	7.46
42	Dubois	Haysville		70.32		18.2	2.9
43		Lodi		64.27		20.16	2.12
44	Martin	Cale		45.23		29.68	4.60
45	Washington	Salem		73.33		13.94	5.21
46	Madison	Anderson		63.2		23.11	3.8
47	Hamilton	Noblesville	Clay	74.33		12.94	5.2
48	Lawrence	Mitchell	"	68.14		19.05	4.08

(continued)

No.	Lime	Magnesia	Alkalis	WATER		Miscellaneous			Firm names, authority, or analyst
				Combined	Free				
1	....	....	....		3.75		......	......	Stand. fire brick co.
2	.49	....	5.6	....	....	....	......	......	Wellington brick and tile co.
3	$CaCO_3$ 6.2	$MgCO_3$ 4.28	Chlorid 15.32	....	....	....	......	P_2O_5 .79	J. W. Crary jr & Co.
4	....	1.71	1.98	6.83		....	......	......	Ga. geol. sur. 1893, p. 286
5	....	1.3	4.55	3.95		....	*c* 1.1	MnO_2 .6	*Ibid.* p. 284
6	tr.	.87	2.28	7.14		....	......	......	*Ibid.* p. 286
7	tr.	1.42	4	7.26		....	......	......	*Ibid.* p. 286
8	....	.81	2.55	7.6		....	*c* 1.67	......	*Ibid.* p. 287
9	.94	....	4.01	5.41	....	*c* 4.82	......	P_2O_5 2.07	J. F. Elson, anal.
10	....	....	....	....	....	SO_3 .1	Loss 5.66	......	La Salle pressed brick co.
11	....	....	....	....	....	....	......	......	Asst. state chemist, anal,
12	1.16	1.67	3.82		3.86		....	......	J. F. Snyder.
13	23.2	9.433	4.01	4.59		....	Ign. 2	......	E. W. Cook, anal.
14	.61	.77	2.9	3.86		....	......	......	Peoria brick co.
15	....	.3	1.1	11.9		....	*c* 1.15	......	
16	6.35	9	3.99		.92		CO_2 11.51	......	Crossley, Analyse of clays
17	.62	.36	1.55		5.2		......	......	H. A. Weber, anal. Griffin brick, tile, and coal works
18	.07	.2	1.43	7.5		....	......	......	
19	....	....	....	....	....	....	......	5.66	Lasalle pressed brick co.
20	....	....	....	....	....	....	......	SO_3 .14 6	‘‘
21	....	1.45	3.49	....	....	7.94	......	......	Barr clay co.
22	.8	.6	....	....	....	7.72	......	......	Indianapolis terra-cotta co.
23	.09	7.29	5.31	5.66		*c* 2.22	......	......	W. Finnegan brick mfg. co.
24	1.79	.52	1.12	....	P_2O_5 .44	MnO 1.05	Loss 11.7	SO_2 1.11	Ind. geol. sur. rep't, 1878
25	1.227	.921	....	10.07		....	......	..	St Louis works
26	.8	1.96	....	7.72		....	......	......	G. Powell's yard
27	1.17	1.29	....	8.6		....	...	.....	
28	1.65	1.03	9.48	....	....	....	......	......	J. Owens's works
29	1.83	2.41	12.85	....	....	....	......	......	M. Carvite
30	2.04	1.18	6.09	....	....	....	......	......	‘‘
31	3.08	.858	7.43	....	....	....	......	......	
32	2.2	.64	....	9.65		....	.....	......	P. White
33	2.96	1.14	....	5.56		....	......	.....	F. Snyder
34	2.313	9.828	....	21.979		....	......	......	J. C. Summers
35	1.17	1.29	....	8.6		....	......	...	S. Gray
36	2.18	1.13	....	14.84		....	......	......	T. Graves
37	1.	.7	....	17.64		....	......	......	S. White
38	.48	.26	....	3.91		....	......	.....	P. Zike
39	.485	1.009	....	7.33		....	......	......	S. Davis
40	.7	.5	....	7.48		....	......	......	P. West
41	.37	1.28	....	10.7		....	......	......	S. Schumake
42	.7	.7	....	7.18		....	......	......	J. Weber
43	.75	.6	....	13.1		....	......	......	A. Parks
44	1.01	1.76	....	17.72		....	......	......	W. A. McBride
45	.533	.984	....	5.98		....	......	......	G. Walters
46	.5	.282	....	7.46		....	......	......	J. Klein
47	.666	.861	....	5.97		....	......	......	H. Teller
48	.8	2.26	....	5.22		....	......	......	J. W. Jones

Brick clays

No.	State and county	Town	Remarks	SILICA		Alumina	Ferric oxid
				Combined	Free		
	Indiana (*continued*)						
1	Wells	Bluffton	Clay	51.95		30.36	2.88
2	Owen	Gosport	“	75.33		11.94	3.2
3	Madison	Frankton	“	73.19		16.21	2.18
4	Orange	Paoli	“	69.33		17.84	4.033
5	Washington	Salem	“	75.88		11.22	5.04
6		Edwardsport	“	56.02		24.23	9.2
7	Warren	Williamsport	“	45.22		25.98	13.6
8	Fountain	Stone bluff	“	73.1		12.64	3.16
9	Martin	Shoals	....	54		25.13	7.36
10	Putnam	Greencastle	....	66.14		15.34	6.32
11	Kosciusko	....	....	43.1		20.78	4.77
12	Vigo	Terre Haute	Used for brick, but good for vitrified ware	66.11		13.78	5.35
13		SE. ¼, sec. 4, T. 20 N., B. 8 W.	Was used for roofing tile. Cracked in burning	73.2		13.38	2.19
14	Gibson	Princeton	Yellow surface clay. Used for pressed brick	71.2		18.56	*a*.15 1.34
15	Knox	Vincennes	Burns yellow white.	65.315		28.473	3.12
16	Parke	Under-clay 8, S. L. McCune, Mecca	....	54.46		25.71	*a*.91 5.51
17	Vanderburg	Evansville	W. Schnute's yard.	77.93		12.16	4.48
18	Vermilion	Cayuga	Dry press brick—mixture of shales 3 and 4	65 78		14.79	8.03
19	“	“	Bastard shale no. 5. Makes buff dry press brick	55.09		20.76	*b*4.01 3
	Iowa:						
20	Cerro Gordo	Mason City	Blue shale	54.8		14.91	{ 2 47 *a*2.9 }
21	Adair	Bridgewater	Alluvium	77.13		10.95	2.36
22		Gillett brickyard	....	....		....	....
23	Guthrie	Guthrie center	Brick and tile loess clay. W. E. Barry yard	68.62		14.98	4.16
24	Fayette	West Union	....	35.6		14.08	
25	Warren	Indianola	Loess clay, plastic.	63.31		16.57	4.06
26	“	“	Gray or yellow loess clay	72.24		12.58	4.02
27		Lime creek	Mason City shale	54.64		14.62	5.69
28	Montgomery	Redoak	Cretaceous clay	69.75		18.68	1.94
29	Clay	Spencer	Altered loess	52.42		13.04	6.24

(continued)

No.	Lime	Magnesia	Alkalis	WATER		Miscellaneous			Firm names, authority, or analyst
				Combined	Free				
1	1.31	1.22	....	12.25		....	......	......	J. N. Goodyear
2	.633	.894	....	3.97		....	......	......	J. Smith
3	1.16	.6	....	6.6		....	......	......	H. Pierce
4	1.633	.994	....	5.89		....	......	......	J. Peterson
5	.476	.349	....	6.76		....	......	......	A. Shrunn
6	.47	1.459	....	8.62		....	......	......	
7	.336	.21	....	15.2		....	......	......	S. Field
8	.9	.9	....	9.3		....	......	......	J. W. Shuster
9	.57	1.18	....	10.7		....	......	......	H. A. Barton
10	1.22	.91	....	10.07		....	......	......	O. M. Johnson
11	*b*20.51	10.8	....	....		....	......	......	Dr Hurty, anal. Ind. geol. sur. 1885-86, p. 43
12	1.67	1.78	3.26	6.38	9.25	....	......	......	Ind. geol. sur. 20:76
13	.97	1.01	....	....	....	....	......	......	*Ibid.* p. 59
14	.14	.52	1.58	6.3	....	....	......	......	*Ibid.* p. 1:4
15	.179	2.741	....	....	.17	....	......	......	*Ibid.* p. 95
16	.24	.83	3.01	8.5	....	....	......	*cl* 2	*Ibid.* p. 133
17	.347	.571	....	4.501	....	....	......	......	*Ibid.* p. 119
18	.54	1.42	3.79	4.98	....	....	......	Ign. 1 CO_2 .26	Ind. geol. sur. 20: 129
19	1.51	1.18	2.7	7.01	....	....	......	Ign. 1.2 CO_2 3.04	"
20	5.2	3.76	6.32	....		CO_2 4.8	.....	......	Iowa geol. sur.
21	2.08	.83	1.33	2.22	1.45	....	......	......	G. C. Patrick, anal.
22	....	....	....	....	....	....	......	......	Furnished by Ia. geol. sur.
23	1.48	1.09	3.36	3.55	2.78	MnO .64	......	......	G. C. Patrick, anal. Furnished by Ia. geol. sur.
24	15.25	11.03	3.94	2.08	......	P_2O_5 .43 CO_2 18.25	.....	......	L. A. Youtz, anal.
25	1.11	1.1	3.16	6.89	3.76	MnO .49	......	......	G. C. Patrick, anal. From Ia. geol. sur.
26	1.4	.99	4.14	5.33	1.7	....	. ....	......	
27	5.16	2.9	5.89	3.74	.85	MnO .76 CO_2 4.8	......	......	
28	1.07	.95	2.96	3.85	1.33	....	......	......	
29	7.98	2.24	8.08	4.06	2.67	CO_2 7.57	......	......	

Brick clays

No.	State and county	Town	Remarks	SILICA		Alumina	Ferric oxid
				Combined	Free		
	Kansas:						
1	Greenwood	Flintridge		58.2		29.8	*a*5.4
	Kentucky:						
2	Ballard	Wickliffe	Yellow clay	44.84		22.83	20.35
3	Graves	Lynnville	Clay	62.68		25.88	2.9
4	Marshall	Highland	“	60.98		18.48	7.5
5	Campbell	Newport	“	72.66		20.50	
6	“	Mount Vernon		82.56		12.223	
7	Boone	Burlington	Clay	48.36		33.06	
8	Grayson	Canolaway creek	Ferrug, clay	68.38		12.282	7.588
9			Clay	61.58		23.946	5.814
10	Ohio	Elm lick	“	70 86		19 24	3.12
11	“	Bald knob church	“	62.76		26.42	1.58
	Louisiana:						
12	Ouachita	Forksville (5 m. e.)	Gray clay	58 43		22.45	3.23
13	Catahoula	Rosefield	“	61.91		18.38	2.14
14	Claiborne	Homer	Clay	82.83		6.48	1.42
15	New Orleans		Sandy clay	16.36	48.27	14.07	4.06
16	Maine	Quinnipiac	“	63.69		17.02	10.18
	Massachusetts:						
17	Middlesex	West Cambridge	Glacial clay	48.99		28.9	3.89
18	Dukes	Gayhead, so. end	Red clay	57.5		31.21	
19	Berkshire	Clayton	Brick and terra-cotta clay	50		44	*a*1.07
	Maryland:						
20		East of Baltimore	Red sandy, 8 feet from top	77.62		12.46	4.1
21		“	Gray, less sandy, 22 feet from top	72.02		16.66	1.38
22		“	Blue, no sand, 38 feet from top	71.66		16.92	1.82
	Michigan:						
23	Kent	Grand Rapids	Clay	58.7		25.95	
24	Marquette	Marquette		54.62		12.82	2
25	Jackson	Springport township	G. H. Wolcott's yard	52.26		22.95	8.15
	Minnesota:						
26	McLeod	Hutchinson		48.25		36.60	
27	Hennepin	Minneapolis		60.31		23.77	7.96
28	Lesueur	Ottawa		59.72		30	....
29	“	Coon Creek		60.31		23.77	7.96
30	Blue Earth	Mankato	Clay shale	70.1		16.99	tr.
31	“	“	Washed brick clay	87.7		7.24	tr.
	Mississippi:						
32		Clingscales		90.877		2.214	.126
	Missouri:						
33	Marion	Hannibal		70		15.94	1 4
34	Cass	Creighton		59.65		37.27	1.13
35	Carroll	Norborne, Davy clay ballast co.	Gumbo clay, for ballast	54.9		18 03	6 03
36	Cole	Jefferson City	Makes red brick	74.39		12.03	4.06

(continued)

No.	Lime	Magnesia	Alkalis	WATER		Miscellaneous			Firm names authority, or analyst
				Combined	Free				
1	6	....	....	.6		....	......	......	Crossley. Analyses of clays
2	.101	.138	....	11.741		....	......	......	Ky. geol. sur. chem. rep't A, pt 3, no. 2568
3	tr.	.319	2.075	6.146		....	......	......	*Ibid.* analysis no. 2663
4	.78	1.128	2.891	7.841		....	......	......	*Ibid.* no 2762
5	*b* tr.	$MgCO_3$ .932	1.243	4.2		Loss .373	P_2O_5 .192	.....	*Ibid.* pt 1, no. 1319
6	*b*.16	*d*$MgCO_3$ tr.	.957	4.1		....	......	......	*Ibid.* analysis no. 1320
7	3.057	.367	6.37	8.786		....	......	......	*Ibid* no. 1697
8	*b*1.38	1.643	6.109	8.25		....	......	......	*Ibid.* no. [illegible]78[illegible]
9	.201	.850	.904	5.705		....	......	......	*Ibid.* no. 1873
10	tr.	4.25	2.604	3.751		....	P_2O_5 tr.	......	*Ibid.* no. 2075
11	.325	tr.	1.184	7.731		....	......	......	*Ibid.* no. 2076
12	.84	.83	2 25	11.01		....	......	......	
13	.68	.49	1.8	14.18		....	......	......	
14	.15	.08	....	1.84		....	.....	.....	
15	....	1.67	6.97	7.06	......	....	......	......	J. A. Blaffer & Son
16	.97	....	4.02	4.15		....	.....	......	A. J. S. (3), p. 407
17	7.1	3.66	4.73	3.31		....	......	......	J. Card, anal.
18	.19	.2	.4	....	....	....	Loss 9.83	......	7th Rep't U. S. G. S., p. 359
19	.024	....	1.24	....	....	....	......	......	White brick and terra cotta co.
20	.52	.46	....	4.58	....	....	......	......	Furnished by Cromwell brothers of Baltimore
21	.12	.85	....	6.35	....	....	......	......	
22	....	.93	....	6.14	......	....	......	......	
23	1	.74	5.54	8.07		....	....	......	S. P. Sharpless, anal.
24	13.68	4.25	....	....	......	....	CO_2 & loss 12.01	......	Min. res. Mich., 1889, p.61
25	4.48	1.32	....	10.56	....	....	....	......	Mariner & Hoskins, anal.
26	*d*1.49	*b*.7	....	8.5	....	....	4.46		M. C. Madsden
27	2.5	1.75	2.42	....	....	....	......	......	A. Humphreys
28	.82	.51	....	10.34	......	....	......	......	Ottawa brick co.
29	2.5	1.75	2.42	1.79		....	...	......	J. Dunn
30	....	....	10.69	1.98		....	SO_3 .23	.....	Minnesota geol. sur., final rep't, 438
31	.67	.07	3.66	tr.		*e* tr.	......	......	
32	.14	tr.	....	6.93		....	......	......	Hilgard, Geol. Miss. 1890
33	.66	....	7.04	...	....	....	......	......	G. Ross, anal.
34	....	tr.	.17	1.8	1	....	......	......	Creighton, brick and tile co.
35	2.88	1.1	3.4	6.9	6.75	....	...	......	Mo. geol. sur. 11 : 563
36	1.5	1.52	3.01	3.17	.....	....	......	......	*Ibid.* p. 563

Brick clays

No.	State and county	Town	Remarks	SILICA Combined	SILICA Free	Alumina	Ferric oxid
	Missouri (*contin'd*)						
1	Cooper	Boonville	Makes red brick	81.11		11.62	3.9
2	Henry	Gilkerson Ford	Not worked	74.72		15.72	4.32
3	"	Hartwell	"	60.93		21.51	6.72
4	Jackson	Kansas City, Diamond brick and tile co	Shale clay	54.8		23.73	8.67
5			Average of 7 analyses	56.81		25.77	6.06
6	"	Kansas City	For red brick	72		11.97	3.51
7	"	"	"	74.6		12.26	3.37
8	Marion	Hannibal	Not worked	73.8		13.19	3.43
9	Randolph	Clifton, Davy clay ballast co	For railroad ballast	62.8		17.22	5.21
10	"	Moberly, Moberly B. T. & E. co	For paving brick also	65.01		19.3	4 91
11	St Charles	St Peters	Not worked	61.19		15.48	5.49
12	St Louis	St. Louis hyd. pressed brick co.	Red brick	73.92		11.65	4.74
13	"	Prospect hill	Also for roofing tile	60.7		18.22	7 58
14	"	St Louis	Alluvial Mo. riv. settlings	51.68		23.65	6.63
	Montana:						
15	Deerlodge	Blossburg		72		17	2.
	Nebraska:						
16		Unknown		61.8		13.9	5.01
17	Douglass county	Omaha	Red clay	72.53		12.05	4.28
18	"	"	Buff clay	79.5		11.61	2.57
	New Jersey:						
19	Middlesex	Sayreville	Front brick clay	28.3	27.8	27.42	2.68
20	"	Cheesequake creek		28.3	28.7	21.5	4.31
21	Burlington	Kinkora		25.5	31.8	17.7	6.4
22	Cumberland	Millville	Phil. fire-proofing and brick	75.3		17.82	4.78
23	Morris	Whippany		64.62		13.74	9.86
	New York:						
24	Suffolk	Southold	Clay	59.05		22.11	6.54
25	"	Farmingdale	"	62.39		23 6	3.39
26	"	Wyandance	Black clay	59.83		24.45	tr.
27	"	Fishers Island	Brown clay	53.77		20.49	9.23
28	"	West neck	"	61.01		19.23	5 43
29	Queens	East Williston	Gray clay	69.73		16.42	2.58
30	Orange	Roseton	"	55		34.54	
31	Ulster	Rondout	"	57.8		22.6	
32	Columbia	Barrytown	"	59.81		22	
33	Clinton	Plattsburg	Red clay	65.14		13.38	7.65
34	Cortland	Homer	Clay	32.12	4.239	51.18	*a*2.122
35	Tompkins	Newfield	"	51.3		12.21	3.32
36	Monroe	Rochester	"	50.55		15.46	4.38
37	Ontario	Canandaigua	"	62.24		16.01	6.96
38	Onondaga	Warner	Blue shale	57.79		16 15	5.2
39	St Lawrence	Ogdensburg	Blue clay	49.2		17.47	6 23
40	Saratoga	Glens Falls	"	48.35		11.33	4.02
41	"	"	Red clay	57.46		21.15	5.52
42	Chemung	Breesport	Clay	52.48		16.78	6.79
43	Erie	Buffalo	"	57.36		16.2	4.55
44	Orange	Warwick	"	53		23	7.2
45	Monroe	Rochester	Niagara shale	28.35		10.47	1.9
46	Otsego	Richfield Springs		49.65		23.82	
47	Allegany	Alfred Center	Chemung shale	53.2		23.25	10.9
48	Ontario	Canandaigua	For hydraulic dry press brick, Quaternary clay	45.12		12.76	5.44

(*continued*)

No.	Lime	Magnesia	Alkalis	WATER		Miscellaneous			Firm names, authority, or analyst
				Combined	Free				
1	2.37	1.47	3.14	6.71	......	....	......	......	Mo. geol. sur. p. 563
2	.5	1.08	2.34	4.74	1.61	....	......	......	*Ibid.* 11: 564
3	.52	.88	2.34	5.3	1.85	....	......	......	"
4	.64	2.23	3.8	6.	......	....	......	......	"
5	1.02	1.58	....	....	....	....	......	......	"
6	1.8	1.12	3.25	6.42	....	....	......	......	"
7	1.69	1.12	3.26	2.7	....	....	......	......	"
8	.86	.68	2.94	5.26	....	....	......	......	*Ibid.* 11:566
9	.98	.78	3.63	7.82	2 06	....	......	......	*Ibid.* 11:568
10	1.4	.4	2.6	5.51	1.03	....	......	......	"
11	1.95	1.56	2.82	9.02	3.11	....	......	......	"
12	1.45	.6	3.13	3.08	2.18	....	......	......	*Ibid.* 11:570
13	2.68	tr.	3.67	7.77	....	....	......	......	"
14	1.4	.2	2.23	8.75	5.14	....	......	......	
15	2	3.	....	.....	....	....	......	......	Mullan Brk. and T. co.
16	*b*9.11	1.7	4.01	3.7		Loss .77	......	......	Phys. geog. and geol. of Nebr., 1880, p. 255
17	1.03	1.2	3.1	3.36	2.45	....	......	......	From Omaha hydraul. dressed brick co.
18	....	.68	1.29	3.5	.85	....	......	......	
19	....	.18	2.71	6.6	2 9	....	1	......	Sayre & Fisher........
20	....	.82	1.9	8.04	1.7	SO_3 1	CO_2 3.8	......	Rep't of clays, N. J. geol. sur. 1878, p. 317
21	.16	.65	1.55	11.8	3.5	SO_3 .48	c .9	......	*Ibid.* p. 317
22	....	....	....	....	....	....	......	......	Furnished by H. Burden, 2d.
23	.85	1.33	3.65	4.65	....	....	c.1.85	......	From Whippany clay mfg. co.
24	2.19	2.64	6.22	....	....	....	......	......	H. T. Vulté, anal.
25	.7	.1	5.89	....	....	....	......	......	"
26	.23	.59	8.75	....	....	*e*4.28	......	......	"
27	2.04	4.22	9.6	....	....	....	......	......	"
28	.96	1.88	4.6	....	....	....	......	......	"
29	1.66	.69	6.27	....	....	....	......	......	"
30	5.33	3.43	.48	1.22		....	......	......	Jova brick works
31	4.85	2.07	....	12.68	....	....	......	......	H. T. Vulté, anal.
32	4.35	2.29	....	....	8.26	....	......	......	"
33	2.18	2.36	8.51	....	....	....	......	......	"
34	*b*2.063	*d* .088	....	....	6.7	*e*1.277	cl .004	SO_3 .116	
35	11.63	4.73	4.33	....	....	*e*1.50	.....	......	"
36	10.95	3.35	6.3	....	....	....	......	......	"
37	1.24	2.21	5.08	....	....	....	..	......	"
38	2.73	4.67	5.33	....	4.5	....	CO_2 3.42	......	R. Froehling, anal.
39	7 86	4.87	9.82	....	....	....	......	......	H. T. Vulté, anal.
40	15.38	3.17	6.05	....	....	....	Loss 1.18	......	"
41	3.65	1.5	4.72	....	....	....	......	......	"
42	6.63	3.59	7.16	....	....	....	......	......	"
43	5.34	3.9	6.98	....	....	....	......	......	"
44	.7	2.6	4.1	9.7		....	c .5	......	N. J. geol. surv. anal.
45	21.47	8.24	5.73	....	....	....	......	......	H. T. Vulté, anal.
46	6.48	tr.	....	....	....	Ign 16.18	......	......	U. S. G. S , bull. no. 2
47	1.01	.62	2.7	6.3	....	....	......	......	From C. T. Harris
48	*a* 23.32	5.42	....	....	....	....	......	......	R. Chauvenet & brother, anal.

No.	State and county	Town	Remarks	SILICA Combined	SILICA Free	Alumina	Ferric oxid
	New York (*cont'd*)						
1	Ontario	Canandaigua	For hydraulic dry press brick, Quaternary clay	46.55		12.66	4.92
2	Westchester	Croton point	Blue clay	51.61		19.2	8.19
3	“	“	Yellow clay	56.75		20.15	8.82
4	Ulster	E. Kingston	Champlain clay	55.45		18.91	7.39
5	“	“	“	61.65		15.24	5.61
	North Carolina:						
6	Wilkes	Wilkesboro		54.808		30.924	*a* .787
7	Harnett	Spoutsprings	Purple clay	56.63		26.22	5.93
8	Robeson	Shoe heel depot		60.93		26.53	1.71
9	Lenoir			72.25		11.28	3.62
10	Bladen	Prospect hall	Upper brick clay	56.13		17.8	5.85
11	“	“	Middle brick clay	63.3		15.87	5.48
12	“	“	Lower brick clay	55.65		20.86	5.11
13	Buncombe	Emma	Upper clay, Penniman's yard	66.27		19.95	3.16
14	“	“	Lower clay, Penniman's yard	70.66		17.21	3.44
15	“	Fletcher	Brick clay	75.08		13.73	3.47
16	Burke	Morganton	McDowell's yard	67.03		16.88	6.50
17	Cleveland	Grover	Pow. clay mfg co., clay for white face brick	53.07		29.54	1.27
18	“	“	Same company, pit ½ mile east of Grover	64.13		22.35	1.95
19	“	“	Under clay for red brick, Cleveland brick co	61.75		23.3	3.34
20	“	“	Upper clay, same company	65.45		20.02	4.18
21	Cumberland	Fayetteville	E. A. Poe's brick clay	64.93		17.08	5.57
22	“	“	So-called “tough clay,” same yard.	58.17		20.1	7.43
23	Forsyth	Bethania	Carter & Shepard, lower brick and tile clay	64.39		19.11	5.39
24	“	“	Upper clay, Carter & Shepard	55.81		20.06	11.79
25	Gaston	Mount Holly	Not worked	61.28		20.83	5.51
26	Guilford	Greensboro.	Dean's brick clay	59.27		22.31	6.69
27	“	“	Greensboro brick and tile co	56.81		20.62	6.13
28	“	“	Kirkpatrick's brick clay	69.7		12.87	6.13
29	Halifax	Roanoke rapids	Upper sandy brick clay	67.55		13.16	8.54
30	“	“	Middle brick clay	65.58		17.14	5.76

(continued)

No.	Lime	Magnesia	Alkalis	WATER Combined	 Free	Miscellaneous			Firm names, authority, or analyst
1	14.02	4.67	2.05	.9	....	....	......	CO_2 14.62	H. A. Wheeler, anal.
2	7.6	1.25	5.32	7.25 and CO_2		....	......	......	
3	3.14	1.2	4.5	5.52 and CO_2		....	......	SO_3	
4	5.40	3.39	....	7 8	5.58	....	......	.74	From Terry brothers
5	5.67	2.8	....	6.85	2.026	....	......	*b* 1.18	"
6	.872	1.011	.678	7.148		....	......	*c* 3.772	Mound city brick co.
7	.30	....	....	10.92		....	......	......	Geol. North Carolina 1, p. 357
8	.99	.35	....	9.44		....	......	......	
9	....	1.75	....	11.1		....	......	......	
10	.1	.79	2.45	11.6	4.5	....	......	.....	Bull 13, N. C. geol. sur. p. 102
11	.27	.21	2.4	8.25	2.8	....	......	Sulfur 1 78	*Ibid* p. 103
12	.3	.64	2.13	9.94	4.26	....	......	Sulfur 1.18	"
13	.2	.32	1.85	6.17	1.15	....	......	Ferrous oxid, .67	*Ibid.* p. 104
14	.1	.07	2.45	.05	.8	....	......	......	*Ibid.* p. 105
15	.3	.17	1.48	4.65	1.1	....	......	......	*Ibid.* p. 107
16	1	1.16	.9	4.78	1.8	....	......	......	"
17	.15	.14	2.15	9.93	1.29	....	......	Ferrous oxid, 1.	*Ibid.* p. 82
18	.1	.22	2.8	5.98	.95	....	.....	......	*Ibid.* p. 83
19	.27	.25	1.31	7.75	1.18	....	......	Ferrous oxid, 0.5	*Ibid.* p. 108
20	.25	.29	1.51	6.58	.63	....	......	......	*Ibid.* p. 109
21	.43	.59	3.85	6.58	2.48	....	......	......	*Ibid.* p. 110
22	.6	.77	2.6	7.34	3.23	....	......	......	*Ibid.* p. 111
23	.8	.22	1.72	7.75	.9	....	......	......	*Ibid.* p. 112
24	.33	.16	1.42	8.8	1.85	....	......	......	"
25	.49	.14	.84	8.79	1.43	....	.....	......	*Ibid.* p. 113
26	.25	.13	.9	9.	1.9	....	......	......	*Ibid.* p. 115
27	.65	.58	4.47	8.6	1.64	....	......	......	*Ibid.* p 114
28	2.55	.57	2.79	4.08	1.5	....	......	.....	*Ibid.* p. 116
29	.17	.28	2.65	5,08	1.63	....	......	......	*Ibid.* p. 117
30	.72	.28	2.3	5.58	2.45	....	......	......	"

No.	State and county	Town	Remarks	SILICA Combined	SILICA Free	Alumina	Ferric oxid
	N. Carolina (*cont'd*)						
1	Halifax	Roanoke rapids	Under brick clay	59.68		16.09	8.91
2	Harnett	Spout springs	Not worked	64.16		21.76	1.58
3	"	"	"	50.68		32.51	3.06
4	"	"	"	53.65		28.66	4.5
5	Jackson	Sylva	¾ mile south of station. Not worked.	66.7		19.75	3.25
6	Mecklenburg	Charlotte	D. K. Cecil's yard	68.35		13.13	6.87
7	"	"	F. W. Shuman's yard	59.15		18.36	6.04
8	"	"	Sassamon's brick clay	65.95		14.67	7.61
9	"	"	Upper clay, Asbury's yard	60.33		18.57	10.03
10	Rowan	Salisbury	D. K. Cecil's yard.	69.89		15.31	4.39
11	Richmond	4 miles north of Rockingham	R. L. Steele's brick clay	59.59		22.07	4.27
12	Robeson	Red Springs	Sandy brick clay	78.16		8.26	4.09
13	Union	Monroe	J T. Shute's brick clay	76.16		9.98	4.46
14	Wake	Raleigh	Penitentiary clay pits.	70.03		15.64	2.88
15	Wayne	Goldsboro	H. L. Grant's brick clay	66.05		17.81	6.69
16	"	"	Weil's clay pit	67.9		18.74	3.16
17	"	"	Grant's brickyard	65.95		13.51	4.64
18	Wilkes	Wilkesboro	D. Smoak's upper clay	53.75		24.91	7.99
19	"	"	D. Smoak's bottom clay	52.25		20.66	11.14
	North Dakota:						
20	Grand Forks	Grand Forks		51.27		9.33	3.52
21	Burleigh	Bismarck		58.73		14.98	5.63
22	Williams	Williston	Clay with coal	57.8		9.47	3.16
23	Ward	Minot (Cottons mine)	Blue clay	56.86		25.03	6.11
24	Stark	Dickinson	Buff clay	56.03		24.23	9.46
25	"	Lehigh mine	White clay	55.77		12.15	4.27
	Ohio:						
26	Stark	Canton	Shale	57.1		21.29	7.31
27	"	Waynesburg	"	49.3		24	8.4
28	Franklin	Columbus	Clay	14.5	56.8	12.63	5.07
29	Lawrence	Coal grove	Brick and tile clay.	56.9		28	1.5
30	Lake	Wickliffe	Shale	58.26		24.64	7.29
31	"	"	"	59.24		24.73	5.07
32	Lorain		"	60.38		18.39	2.714
33	"	"	"	60.55		18.29	4.7
34	Trumbull	Doughton	Semi-plastic blue-gray clay	63.69		23.91	3.57
35	"	"	Yellow clay	62.86		23.91	9.21
36	"	"	Plastic, whitish gray	66.28		21.49	3.21

(*continued*)

No.	Lime	Magnesia	Alkalis	WATER		Miscellaneous			Firm names, authority, or analyst
				Combined	Free				
1	1.35	.14	3.24	6.33	2.05	....	......	......	Bull. 13, N. C. geol. sur. p. 118
2	.23	.15	.77	8.3	1.42	....	......	Ferrous oxid 1.08	*Ibid.* p. 119
3	.3	.02	.58	11.08	1.35	....	......	......	*Ibid.* p. 120
4	.1	1.35	.29	10.79	1.05	....	......	......	*Ibid.* p. 121
5	.45	.16	2.12	6.65	.45	....	......	......	“
6	2.1	.32	2.82	5.3	1.35	....	......	......	*Ibid.* p. 123
7	.2	.34	1.72	7.47	7.1	....	......	......	*Ibid.* p. 124
8	2.57	.25	2.55	5.52	1.27	....	......	......	“
9	.2	.14	.55	7.83	.63	....	......	......	*Ibid.* p. 125
10	.55	.16	.7	6.37	1.91	....	......	......	*Ibid.* p. 127
11	.65	.49	2.7	7.53	1.98	....	......	......	*Ibid.* p. 126
12	.4	.22	2.91	4.14	1.09	....	......	......	“
13	.3	.27	2.25	4.3	1.65	....	......	......	*Ibid.* p. 129
14	.8	.57	1.47	6.37	1.6	....	......	......	*Ibid.* p. 130
15	.3	.25	1.04	6.32	1.58	....	......	......	*Ibid.* p. 132
16	.4	.45	1.85	6.03	1.85	....	......	......	*Ibid.* p. 134
17	.35	.36	2.82	11.58	1.12	....	......	......	“
18	.7	1.12	2.94	7.6	1.03	....	......	......	“
19	.6	1.08	4.62	7.45	2.1	....	......	......	*Ibid.* p. 135
20	11.15	2.31	2.58	....	....	....	......	......	Rep't labor bureau 1891-92.
21	2.1	.74	1.148	16.672		....	......	......	
22	7.91	2.84	....	....	....	....	......	......	
23	.71	.76	.66	10.014		....	......	......	
24	....	.31	.808	9.39		....	......	......	
25	5.92	1.9	1.248	18.742		....	......	......	
26	.29	1.53	4.05	6	1.3	....	......	......	Ohio geol. sur. 1884
27	.56	1.6	4	9.4	1.2	....	......	......	“
28	1.05	....	....	7.3	....	....	......	......	“
29	....	....	....	13.6	....	....	......	......	From Forestdale brick and tile works
30	.72	1.246	1.14	.. ..	6.704	....	......	......	From Buckeye brick co.
31	.6	1.714	2.13	5.16	....	....	......	......	“
32	.94	1	9.12	1.66	....	....	......	......	From Lorain brick co.
33	.2	.81	3.38	....	....	....	CO_2 1.49 SO_2 1.18	......	“
34	.44	tr.	....	....	8.36	....	......	......	
35	.34	.48	....	....	6.26	....	......	......	
36	tr.	5.75	....	....	5.85	....	......	......	

Brick clays

No.	State and county	Town	Remarks	SILICA Combined	SILICA Free	Alumina	Ferric oxid
	Pennsylvania:						
1		Kittaning	Soft brown shale	53 31		24.54	8.75
2		“	Blue gray shale	55.17		19.92	12 01
3		“	Fissile shale	59.8		19.72	5.92
4		“	Fire clay used for brick	60.4		26.23	1.34 a.23
5		Charleroi	Red clay.	56.32		21.44	9.92
6		“	Gray shale.	51.12		24.6	10.49
7	Allegheny	Pittsburg	Shale for terra cotta lumber	57.537		20.127	a5.797
8	Montgomery	Norristown	Red shale	64.4		18.54	6.06
9	Cumberland	Pinegrove		74.97		13.86	a 2.7
10	Clinton	Lockhaven	Red shale	56.55		21.46	9.72
11	Erie	Corry	“	46.491		33.119	2.84
12	Venango	Franklin	“	61.06		21.76	7.04
13	Indiana	Bells Mills	Plastic clay	68.49		18.46	a 1.566
14	Somerset	Hooversville	Clay	45.73		29.693	a 6.857
15	Huntingdon	Lewiston	Upper clay	73.9		13.07	a 6.1
16	Warren	Little brokenstraw valley	Clay	65.12		15.939	a 5.464
17	Lehigh	Schneiders mine	“	53.17		23.431	a 5.4
18		Chapman station		60 53		17 4	9.29
19	Monroe	Stroudsburg	Clay	64.7		28.39	1.28
20	Beaver	New Brighton	Terrace clay	67.78		16.29	4.57
21	Crawford	Titusville		51.01		20.93	6.831
	Tennessee:						
22	Scott	Robbins	Clay	70.57		15.19	7.97
	Texas:						
23	Harrison	Marshall		71		20.2	2.2
24	Harris	Harrisburg		78		6.3	6.3
25	Grimes	Courtney	Clay	40.69		12.68	3.9
26	McCulloch	Milburn	“	57.6		19.34	6.14
27		Waldrip Bed, Cisco division		55.57		22.04	7.35
28	Cass	Queen City	Clay	82 6		10.25	2 25
29	“	Gideon Story H'd't.	“	66.7		11.43	3.77
30	“	A. Duncan H'd't	“	68.3		12.2	
31	Marion	. Richardson H'd't	“	62.4		20.66	8.54
32	Smith	Garden Valley	“	69.05		22.6	1.4
33	Rusk	Henderson	“	64.4		24.17	3.23
34	Smith	Tyler	“	85.4		10 02	2.18
35	Panola	Carthage	“	82.8		9.83	2.77
36	“	Tatum station	Gray clay	57.8		18 94	7.55
37	Orange	Millville	Loamy clay	62		12.12	8.08
38	“	West of Henderson	Dark clay	71.25		18.58	1.62
	Washington:						
39	Pierce	Tacoma	White clay	62.43		18.79	4.2

(continued)

No.	Lime	Magnesia	Alkalis	WATER		Miscellaneous			Firm names, authority, or analyst
				Combined	Free				
1	....	....	....	8.55	......	....	......	......	Kittaning clay mfg co. 1897 Rep't Pa. state college, p. 123
2	....	....	....	6.81	......	....	......	......	
3	....	....	....	8.59	......	....	......	......	
4	.14	.54	2.94	8.71	......	....	......	......	
5				6.73	......	....	......	......	*Ibid.* p. 131
6	....	....	....	6.59	......	....	......	......	
7	by diff. 9.022			7.517	......	....	......	......	Pittsburg ter. cott. lumber co.
8	.41	.46	....	......	......	Ign. 3.82	......	......	Perkiomen brick co.
9	.12	1.02	....	2.05		....	......	......	Fuller brick and slate co.
10	*c* .474	*d* 1.68	5.37	4.48		....	......	......	Mill hall brick works
11	$CaCO_3$ 8.93	$MgCO_3$ 2.581	3.692	......	......	SO_3 2.847	......	......	J. F. Elson, anal.
12	.58	.23	4.55	......	......	Ign 4.8	......	.....	H. Froehling, anal.
13	.23	1.551	2.775	6.31		....	*c* 2.15	......	Pa. geol. sur. MM, p. 294
14	.44	1.005	3.415	12.86		....	......	......	*Ibid.* HHH, p. 123
15	.06	.526	.909	5.435		....	......	......	*Ibid.* HHH
16	1.55	1.848	3.58	3.16		....	CO_2 2.81	......	*Ibid.* 3
17	.13	3.376	8.383	4.86		....	*c* 1.25	......	"
18	.08	1.92	5.27	5.51		....	......	......	Pa. geol. sur. D. p. 53
19	.32	.2	.23	....		Ign. 4.88	......	......	Monroe brick and tile co.
20	.6	.727	2.001	6.34		$T O_2$ .78	......	......	1897 Rep't Pa. state college
21	3.01	2.511	4.372	3.84	....	....	*c* 1.09 CO_2 5.78	.....	Pa. geol. sur. no. 3, p. 103
22	.78	.32	2.3	....		....	......	......	Clay worker, Dec. 1893
23	....	....	7.4	....		....	......	......	2d Rep't on iron ore dist., E. Texas. 1890
24	tr.	....	7.41	....		Ign. 2	......	......	Texas geol. sur.
25	18.12	.92	1.14	H_2O and CO_2 22.55		....	......	......	4th Rep't Texas geol. sur.
26	1.22	....	4.75	1.7		Loss 7	......	......	Rep't on Col. coal field, Tex. geol. sur.
27	.35	....	4.5	1.7		Loss 7.07	......	......	1890 Rep't Tex. geol. sur. p. 91
28	tr.	....	4.46	....		....	......	......	
29	1.3	.08	4	....		Loss 13	......	......	
30	tr.	tr.	6.42	....		Loss 13.6	......	......	
31	.4	tr.	8.89	....		....	......	......	*Ibid.* p. 111
32	tr.	tr.	3.02	4.12		....	......	......	*Ibid.* p. 219
33	tr.	tr.	3.5	7.25		SO_3 tr.	......	......	"
34	.1	....	tr.	1.95		....	......	......	*Ibid.* p. 229
35	tr.	tr.	5.46	....		....	......	......	"
36	tr.	tr.	6.67	9.01		....	......	......	"
37	....	....	....	......	......	....	......	......	*Ibid.* p. 257
38	tr.	.6	4	5.5		....	......	.....	"
39	2.12	1.53	....	....		Ign. 10.93	.....	......	L. J. Clark

Brick clays

No.	State and county	Town	Remarks	SILICA Combined	SILICA Free	Alumina	Ferric oxid
	West Virginia:						
1	Marshall	Moundsville		71.78		16.01	2.86
2	Monongalia	Morgantown	Clay near river	73.88		12.73	5.78
3		Morgant'n brick co.	"	75.12		11.2	5.22
4	Marshall	Moundsville		74.62		16.01	2.86
	Wisconsin:						
5	Milwaukee	Milwaukee	Clay	38.22		9.75	2.84 *a* 1.16
6	Dane	Madison		75.8		11.07	3.53 *a* .31
7		Whitneys rapids		70.25		17.68	2.32
8	Milwaukee	Granville station	Clay	52.18		19.27	3.13
9	"		From the Chase brick co	38.07		9.46	2.7

Sha

	Indiana:						
10	Fountain	Stone bluff	J. W. Shuster	68.46		16.08	*a* .06 1.92
11	"	"	F. Landers	67.82		13.6	*a* .45 4.04
12	Gibson	Princeton	Near Air line shops	62.04		18.49	*a* .06 7.54
13	Knox	Vincennes		64.05		16.	*a* 5.85 .89
14	Greene	Linton	Island coal co., shale no. 8, shaft 1	55.31		22.46	*a* .23 7.18
15	Parke	Mecca	S. L. McCune, shale no. 5	58.83		22.34	*a* 1.44 5.13
16	"	"	S. L. McCune, shale no. 9	59.02		20.93	*a* 1.56 4.45
17	"	"	S. L. McCune, shale no. 2	59.77		20.6	*a* 3.7 2.22
18	Perry	Cannelton	American cannel coal co., sh'le no. 7	53.26		25.77	*a* 3.82 3.32
19	Spencer	Railroad cut near Lincoln	Mixture of shales	56.68		20.33	*a* 3.69 4.35
20	Vermilion	West Montezuma	J. Burns, shale no. 6	46.07		24.22	*a* .34 9.65
21	"	"	J. Burns, shale no. 11	56.32		24.34	*a* .24 5.6
22	Vigo	Terre Haute	H. T. Thorp	61.05		21.46	*a* .71 5.57
23		Rocky run		55.2		14.4	9.4
	Missouri:						
24	Bates	Foster	Not worked	55.96		20.62	8.12
25	Christian	Billings	Used for terra-cotta	63.11		23.11	1.79
26	Cooper	Boonville	Not worked	53.24		23.62	9.02
27	Henry	Clinton	"	52.7		26.86	4.49
28	"	Town Creek, Cl't'n.	"	54.69		25.96	4.97
29	"	Gilkerson Ford	"	55.02		24.38	5.79
30	"	Fields Creek.	"	55.44		22.88	5.86
31	"	Vickey Lands	"	59.06		23.05	7.31
32	Jackson	North bluff, Kansas City	Used for press brick	55.75		21.16	5.69
33	Jasper	Briggs Shaft, Joplin	Not worked	55.84		22.78	5.24
34	Johnson	Clear Fork	"	60.82		23.98	4.37

(concluded)

No.	Lime	Magnesia	Alkalis	WATER Combined	WATER Free	Miscellaneous			Firm names, authority, or analyst
1	.32	.43	1.98	5.45		....	......	......	Mound City brick co.
2	....	.1	1.67	4.64	1.12	....	......	......	A. R. Whitehall, anal.
3	....	.18	1.67	5.1	1.3	....	......	......	"
4	.32	.43	1.98	. .....	6.62	....	......	......	From Mound City brick co.
5	13.24 *b* 23.2	*d*15.83	2.81	2.80		....	......	......	Geol. Wisconsin, 2: 236
6	.39 *b* 2.45	.17	3.14	3.7		....	......	......	
7	.33	1.49	2.08	5.61		....	......	......	*Ibid.*, p. 469
8	.09	7.29	2.87	....	12.64	2.22	......	......	B. Schmidt & Co.
9	15.84	8.5	2.76	....	2.49	CO_2 20.46	......	......	....

les

No.	Lime	Magnesia	Alkalis	WATER Combined	WATER Free	Miscellaneous			Firm names, authority, or analyst
10	.99	.05	3.71	7.04	....	....	......	*c* 1.49	Ind. geol. sur. 20:130
11	.57	.44	2.86	9.72	....	....	......	*c* 1.1	"
12	.16	.91	2.97	6.5	....	....	......	*c* 1.3	"
13	.42	2.	3.78	3.79	....	....	......	*c* 1.	"
14	.66	.93	4.11	7.48	....	....	......	*c* 1.15	"
15	.49	1.56	4.81	5.22	....	....	......	*c* .7	Ind. geol. sur. 20:129
16	.51	1.66	3.33	7.59	....	....	......	*c* 1.1	"
17	.64	1.98	3.95	4.53	....	....	......	*c* .8	"
18	.32	1.9	2.98	7.	....	....	......	*c* 1.05	Ind. geol. sur. 20:130
19	.57	2.09	3.78	6.54	....	....	......	*c* .9	"
20	.19	1.31	3.42	9.76	....	....	......	*c* 1.19	"
21	.31	.54	5.19	6.33	....	....	......	*c* 1 07	"
22	.25	.7	2.64	6.94	....	....	......	*c* 1.2	Ind. geol. sur. 20:129
23	6.12	.9	.52	8.6		....	......	MnO 1.8	Ind. geol. sur. 20:57
24	1.91	1.96	3.34	7 32	....	....	......	......	Mo. geol sur. 11:563
25	.42	.7	3.71	7.05	....	....	......		"
26	1.17	1.41	4.38	6.94	....	....	......	......	"
27	.57	.68	2.47	8.66	1.48	....	......	......	*Ibid.* 11:564
28	.18	.15	3.58	8.9	1.41	....	......	......	"
29	.58	1.5	3.32	8.88	1.08	....	......	......	"
30	.38	.69	3.02	11.95	.....	....	......	......	"
31	.46	.86	2.8	6.03	....	....	.....	......	"
32	3.25	2.84	3.02	8.45	.....	....	......	......	"
33	.73	1.26	4.1	9.84	....	....	......	......	*Ibid.* 11:566
34	.46	.45	3.16	6.6	....	....	......	......	"

Shales

No.	State and county	Town	Remarks	SILICA Combined	SILICA Free	Alumina	Ferric oxid
	Missouri (*cont'd*)						
1	Lafayette	Lexington		54.03		22.5	7.9
2	Marion	Hannibal	Not worked	75.7		9.61	1.79
3	Pike	Minor's Land, Bowling Green	"	66.57		15.32	3.82
4	"	Louisiana	"	57.01		24.43	5.77
5	Polk	Aldrich	"	46.26		10.76	2.65
6	"	Humansville.	"	56.82		24.48	3.82
7	Randolph	Hammet's farm, Huntsville	"	66.03		21.74	2.13
8	"	Stuarts mine	"	56.86		17.97	9.35
9	"	1½ miles northwest of Huntsville	"	58.44		25.36	6.61
10	Ste. Genevieve	Sexaner farm	"	50.97		21.15	5.2
11	St Louis	Laclede mine	Used for sewer pipe	54.57		23.61	7.88
12	"	Barretts	Not worked	49 69		17.4	4.01
13	Vernon	Deerfield	"	58.9		21.38	7.09
14	"	Prewitt's bank		54.54		23.26	7.34

Paving brick

No.	State and county	Town	Remarks	SILICA Combined	SILICA Free	Alumina	Ferric oxid
	Arkansas:						
15	Sebastian	Fort Smith	Shale	57.1		23.74	8.18
	California:						
16	San Mateo	San Francisco	Clay	56.51		21.33	.29
	Colorado:						
17	Jefferson	Golden		52.41		32.21	*a* .66
18	"	Morrison		71.8		15	3.29
19	Florida	Bartow		69.03		*b* 18.21	8.53
	Illinois:						
20	Sangamon	Springfield		62.78		23.25	2.83
21	Scott	Winchester		23.15		17.08	....
22	McLean	Bloomington		67.8		11.55	6.5
	Indiana:						
23	Vermilion	Clinton	Shale	43.128		40.875	*a* 3.437
24	Clay	Brazil		68.83		23.11	1.84
25	(?)		Mixture of shales and surface clay for paving blocks	59.55		16.21	*a* 7.13 2.18
26	Vanderburg	Evansville	Mixture of shales and surface clay	65.87		14.66	*a* 1.37 6.23
27	Vermilion	Clinton	Mixture of shales and surface clay	61.46		16.54	*a* 3 71 3.77
	Iowa:						
28	Lee	Burlington		77.4		11.74	12.31
29	Clinton	Clinton		73 82		15.88	.16
	Kansas:						
30	Leavenworth	Leavenworth	Carb shale	58.45		21.96	8.43
	Maryland:						
31	Allegheny	Mount Savage		39.9		30.08	.88
	Missouri:						
32	St Louis	Cheltenham	Clay	61.22		25.64	3.47
33	"	"	"	38.1		31.53	4.31
34	Montgomery	Montgomery	"	43.93		40.09	1.7

(concluded)

No.	Lime	Magnesia	Alkalis	WATER		Miscellaneous			Firm names, authority or analyst
				Combined	Free				
1	.85	2.7	4.12	7.54	....	....	......	......	Mo. geol. sur. 11: 566
2	2.54	2.11	2.65	6.16	......	....	......	......	"
3	3.2	1.03	2.94	6.42	1.42	....	......	......	*Ibid.* 11: 568
4	1.4	.49	3.81	7.2	.43	....	......	......	"
5	11.08	7.84	3.17	8.02	....	....	......	......	"
6	.83	1.81	3 8	8.16	....	....	......	......	"
7	.5	1.01	1.64	6	1.34	....	......	......	"
8	1.67	1.12	2.61	6.96	2.45	....	......	......	Mo. geol. sur. 11: 568
9	tr.	tr.	2.97	5.74	1.41	....	......	....	"
10	1.55	1.1	3.88	5.71	1.25	....	......	......	"
11	.52	1.48	3.55	6.67	....	....	......	SO_3 .44	*Ibid.* 11: 570
12	8.07	4.16	2.73	13.37	1.16	....	......	......	"
13	.57	1.66	1.52	8.69	....	....	......	......	"
14	1.44	1 82	4.12	7.71	....	....	......	......	"
clays									
15	.53	1.04	2.4	....	....	....	......	Ign. 7.31	
16	....	3.53	tr.	6.3		....	......	......	Byrnes on Roadways
17	.2	.6	.61	14.05		....	......	......	"
18	3 8	....	....	8.3		....	......	......	"
19	tr.	....	....	....	4.2	....	......	......	Min. resources, 1893
20	1.72	2.12	tr.	....	......	Ign. 6.69	......	.....	J. S. Cary, anal.
21	....	.28	1.1	....	....	SO_2 6.3	1.2	P_2O_5 .9	Byrnes on Roadways
22	8.9	5.32	2.42	.2		....	tr.	......	
23	$CaCO_3$ 2.00_9	.97	.99	9.482		....	......	.....	J. F. Elson, anal.
24	.382	.551	....	......	17 11		......	......	S. B. Hart
25	.75	1.58	3.09	5.62		....	......	CO_2 3.15 *c* 1.	Ind. geol. sur. 20: 129
26	.39	1.54	3.97	4.59		....	......	*c* 1.1	"
27	.66	1.81	4.37	5.09		....	CO_2 1.45	*c* 1.2	"
28	1 6	1.91	4.23	....		....	......	......	
29	tr.	tr.	4.5	3.5		....	......	......	
30	1.05	1.57	4	6.51		....	......	......	Clay worker, Dec. 1893
31	....	....	2.3	13.9		P_2O_5 1.15	......	......	
32	....	....	1.31	9.68		SO_3 .04	..	......	Byrnes on Roadways
33	....	tr.	.4	13.8		....	*c*1.5	......	"
34	....	....	.2	14.6		....	tr.	......	"

Paving brick

No.	State and county	Town	Remarks	SILICA		Alumina	Ferric oxid
				Combined	Free		
	Missouri (*cont'd*)						
1	Jackson	Kansas City	Carb. shale	64.37		19.73	9.07
2	Henry	Deepwater, Missouri clay co		68.54		18.49	3.38
3	Jackson	Kansas City		56.8		25.7	6
4	Johnson	Boyd's pit Knobnoster		69.65		20.41	2.11
	Michigan:						
5	Saginaw		Gray shale	63.		21.8	8.8
6	"		Black shale	54.5		30.75	3.5
	Nebraska:						
7	Otoe	Nebraska City		61.63		21.41	7.03
	New Jersey:						
8	Middlesex	Woodbridge		42.23		39.53	.5
9	Warren	Phillipsburg		56.78		17.38	.5
	New York:						
10	Onondaga	Warner	Clay	44.74		18.7	4.25
11		"	Shale	52.3		18.85	6.55
12	Steuben	Hornellsville	"	67.29		15.85	6.16
13	Greene	Cairo		68.		15	12
	Ohio:						
14	Athens	Glouster	Shale clay	57.15		20.26	7.54
15	Richland	Darlington	"	57.45		21.06	7.54
16	Franklin	Columbus	"	58.38		20.89	5.78
17	Stark	Canton	"	53.38		19.36	14 86
18	"	North Industry	"	56.61		21.63	7.08
19	Columbiana		Fireclay	54.53		27.88	2.41
20	Jefferson		"	51.72		30.1	1.94
21	"	Island siding	"	51.82		28.69	2.77
22	Columbiana	East Palestine	"	57.8		25.54	2.51
23	Jefferson	Toronto	"	70		19.35	2.22
24	"	Elliottsville	"	77.65		12.78	3.32
25		"	"	59.2		26.1	2.7
26		Croxton run	"	58.1		29.6	1.2
27	Hocking	Haydensville	Shale	69.92		23.46	.2
28	Montgomery	Brookville	Clay	62.05		27.71	.6
	Pennsylvania:						
29	Beaver	Monaca	Shale clay	63.37		19.08	6.42
30	"	Rochester		66		23.1	.65
31	Mercer	Sharon	Red shale	62.86		20.65	9.21
32	"	"	Blue shale	63.69		23.9	3.57
33	Beaver	Woodlawn	Clay	42.15		31.43	2.32
34	"	New Brighton	"	67.36		22.05	5.61
35		Corry		44.44		26.84	8.1
	Tennessee:						
36		Powdes station	Clay	68.35		12.96	6.44
37	Hamilton	Chattanooga	"	68.96		20.42	1.84
38	Scott	Robbins	"	70.57		15.19	7.97
	Texas:						
39	Henderson	Morrisons	"	72.3		19.33	2.47
	West Virginia:						
40		Cumberland	"	69.02		22.07	4.53
41	Marion	Nuzums mills	"	59.25		32.36	1.67

clays (*concluded*)

No.	Lime	Magnesia	Alkalis	WATER		Miscellaneous			Firm names, autho y or analyst
				Com-bined	Free				
1	.82	2.32	3.78	....		....	......	......	Clay worker, Dec. 1893
2	1.03	.88	2.37	4.62	1.52	....	....	......	Ind. geol. sur. 20: 564
3	1	1.5	....	....	....	....	......	......	From Diamond brick and tile co.
4	1.21	tr.	8.52	5.34	....	....	......	......	Ind. geol. sur. 20: 566
5	1.7	2	2.65	....	....	....	......	......	From Saginaw clay manufacturing co.
6	1.05	1.69	3	5.51	....	....	......	......	"
7	2.13	.94	.98	4.96	....	....	......	......	"
8	.01	... .	.49	13.59	1.21	....	c1.4	......	N. J. clay rep't, 1878
9	4.14	3.15	3.42	7	.6	SO_2 .89	P_2O_5 .13	......	"
10	11.25	1.29	1.2	9.25		SO_3 2.78	CO_2 7.50	......	
11	3.36	4.49	6	....	5.3	....	CO_2 3.04	MnO tr.	R. Froehling, anal.
12	.95	.19	8.71	.. ...	....	....	......	......	
13	....	....	....	5	....	....	......	......	From Catskill shale and paving brick co.
14	.9	1.62	3.63	5.5	2.7	....	......	......	Ohio geol. sur. 1893, 7: 134
15	.29	1.22	3.66	5.9	1.9	....	......	......	
16	.44	1.57	5.02	7.53	....	....	......	......	
17	1.48	1.06	....	....	....	....	......	......	
18	1.11	1.41	3.99	....	....	....	....	......	
19	.42	.68	3.43	8.87	.76	....	*c* 1.26	......	*Ibid.* p. 137
20	.62	.53	2.74	9.95	1.05	....	*c* 1.35	......	"
21	.77	1.41	2.82	9.67	1.72	....	*c* .72	......	"
22	.25	.61	2.69	8.35	2.25	....	......	......	"
23	.15	.34	2.9	5.39	....	....	......	......	"
24	.55	.45	1.3	4.1	....	....	......	......	"
25	1.05	.75	1.53	8.55	....	....	......	......	"
26	.4	.54	1.75	8.7	....	....	......	......	"
27	.48	.4	1.43	3.84	....	....	......	......	*Ibid.* v. 1884, p. 139
28	.15	.2	2.4	6.67		....	......	......	"
29	.06	.33	3.24	7.5		... .	*c* 1.26	......	Monong. fireclay co.
30	.41	1.18	2.19	5.38		FeS1.09	......	......	Park fireclay co.
31	.48	.34	....	....		Ign.6.26	......	......	Eclipse paving brick and clay mfg. co.
32	.44	tr.	....	....		Ign.8.36	......	......	
33	.32	2.01	....	10.6		....	*c*1	......	
34	.86	.36	5.4	....		....	......	......	
35	*b*12.84	*d*5.85	3.55	....		....	......	......	From F. Stanford, Corry, Pa.
36	.23	1	2.14	....		Ign. 7.8	MnO.9	......	J. W. Slocum, anal.
37	.16	.33	2.18	6.5	......	....	MnO tr.	......	Tennessee paving brick co.
38	.78	.32	2.3	....		....	.....	......	Clay worker, Dec. 1893
39	tr.	.5	4.44	....		....	......	......	Tex. geol. sur. 1890, p. 199
40	1.7	.38	2.68	....		....	......	......	Clay worker, Dec. 1893
41	7.16	....	....	6.3		....	......	......	Byrnes on Roadways

Terra cotta

No.	State and county	Town	Remarks	SILICA Combined	SILICA Free	Alumina	Ferric oxid
	California:						
1	Monterey	Jolon	Clay	85.07		7 85	1.16
2	Butte	Chico	"	88.7		4.5	.5
	Colorado:						
3	Jefferson	Golden		68.4		18.88	1.56
	New York:						
4	Allegany	Alfred Center	Chemung shale	53.2		23.25	10.9
5	Saratoga	Glens Falls (*see* Brick clays)					
	Pennsylvania:						
6	Beaver	New Brighton		61.97		22.94	[a]1.818
	Virginia:						
7	Augusta	Staunton		75.86		13.4	2.66
	South Dakota:						
8	Pennington	Rapid City	Shale clay	70.78		16.73	2.73

Pipe

No.	State and county	Town	Remarks	SILICA Combined	SILICA Free	Alumina	Ferric oxid
	Georgia:						
9	Baldwin	Stephens Pottery		52.78		32.3	.05
	Indiana:						
10	Perry	Cannelton, William Clarke	Under-clay	65.83		22.94	2.64
11	Greene	Worthington	S. Davis's	63.25		24.81	3.04
	Kentucky:						
12	Calloway	New Providence	White clay	61.68		28.5	1.68
13	Marshall	Pughs place	Clay	62.92		29.88	
	Missouri:						
14	Henry	Dickey sewer pipe co., Deepwater	Used for sewer pipe	60.12		21.35	7.06
15		Laclede mine, St Louis	"	59.96		15.76	7.72
	Minnesota;						
16	Goodhue	Red Wing	"	69.84		23.07	.48
	New Jersey:						
17	Middlesex	Woodbridge	"	67.7	.....	19.91	1.69
18		"	"	33	29.1	23.8	1.6
	New York:						
19	Erie	Angola	Shale	65.15		15.29	6 16
	North Dakota:						
20	Cavalier	Langdon	Clay	50.45		17.57	2.8
	Ohio:						
21	Jefferson	Freeman. (*see also* analyses of Ohio paving-brick clays)		39.03	15.5	27.88	2.41
22	Columbiana	Walker's Station	Under-clay	54.53		27.88	2.41
	Pennsylvania:						
23	Wayne	Texas township	Catskill red shale	59.26		19.877	10.071

clays

No.	Lime	Magnesia	Alkalis	WATER		Miscellaneous			Firm names, authority, or analyst
				Combined	Free				
1	0.25	.35	.93	4.35		....	......	......	9th rep't Cal. state min. p. 302
2	.93	.36	.63	4.46		....	......	......	
3	.55	.45	1.71	8 2		....	......	......	
4	1.01	.62	2.7	6.39	....	MnO .52	*c* .91	SO_3 .41	Celadon terra-cotta co.
5	....	....	....	....	....	....	......	......	
6	.44	.522	1.75	8.85		....	*c* 1.975	......	Pa, geol. sur. **MM**, p. 262.
7	.28	.822	1.737	5.206	......	SO_3 tr.	......	......	Terra cotta tile works
8	.21	.9	....	6.71		....	......	......	Rapid City steam brick works

clays

No.	Lime	Magnesia	Alkalis	Combined	Free	Miscellaneous			Firm names, authority, or analyst
9	....	.42	.55	13.54		.36	......	......	H. C. White, anal.
10	.308	.858	....	7.434	....	....	......	......	Ind. geol. sur. 20: 125
11	.48	1.01	....	7.33	....	....	......	......	Ind. geol. sur. 20: 90
12	.101	.136	1.98	5.923		....	......	......	Ky. geol. sur. chem. rep't A. pt 3, no. 2640
13	tr.	.209	1.736	5.255		....	......	......	*Ibid.* no. 2763
14	.52	1.08	3.43	6.32	1.05	....	......	......	Mo. geol. sur. 11: 564
15	.6	.93	3.66	7.7	....	SO_3 .73	......	......	Mo. geol. sur. 11: 570
16	.11	.14	tr.	6.35	....	....	......	......	From J. H. Rich, sewer pipe works
17	....	.72	2.56	5.5	1	....	TiO_2	......	N. J. clay rep't, 187, p. 82
18	tr.	.57	2.77	6.7	1	....	TiO_2 1.7	......	*Ibid.* p. 113
19	3.5	1.57	5.71	....	....	....	......	......	H. T. Vulté, anal.
20	.25	1.79	.93	22.55		Loss 3.66	......	......	Rep't labor bureau, 1891–92
21	.42	.68	3.43	8 87	.76	....	TiO_2 1.26	......	Ohio geol. sur. 5 1884
22	.42	.68	3.43	8.87	....	....	TiO_2 1.26	......	Ind. geol. sur. 20 p. 133
23	.25	1.917	4.855	3.60	....	....	......	SO_2 012 P_2O_5 .158	Pa. geol. sur. **no. 3**, p. 109

Pipe clays

No.	State and county	Town	Remarks	SILICA Combined	SILICA Free	Alumina	Ferric oxid
	Pennsylvania (*con.*)						
1	Beaver	Cannelton		67.67		18.28	1.03
2	Butler	Butler		59.01		21.77	10.73
	South Dakota:						
3	Pennington	Rapid City	Soft shale	74.22		16.38	1.95
4	"	"	Fort Benton shale	63.59		20.309	*a* 2.952
	Tennessee:						
5	Knox	Powell Station	Clay	68.35		12.96	6.44
6	"	"	Shale	62.3		19.17	6.88

(concluded)

No.	Lime	Magnesia	Alkalis	WATER		Miscellaneous			Firm names, authority, or analyst
				Combined	Free				
1	....	tr.	3.08	7.66	....	....	......	*a* 2.28	From J. W. Suthoriu & co.
2	.79	1.69	6.01	....	....	....	......	......	Butler brick and tile co.
3	.4	tr.	2.58	....	4.47	....	......		Rapid City steam brick works
4	.52	.612	1.402	3.8	....	....	......	*c* 6 63	Furnished by F. C. Smith
5	.23	1	2.14	7.8	....	....	......	MnO .9	
6	tr.	.4	3.36	7.45	....	....	......	......	

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No attempt has been made to give a complete list of works relating to clays and the ceramic arts. While such a list is of value in its proper place, it is considered that the purpose of this report will be far better served, if only titles of value to the practical clay worker, or the general student of clays are given. For an exhaustive list of works on this subject the reader is referred to the bulletin by Branner mentioned below. Not a few of the many valuable works in the German or French language, while reasonable in price, are at times hard to obtain; therefore only the titles of the more important ones are given here.

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DIRECTORY OF CLAY WORKERS IN NEW YORK STATE

B.: Common brick
P. B.: Pressed brick
D. T.: Drain tile
F. P.: Flower pots
Pa. B.: Paving brick
T. C.: Terra cotta
E. W.: Earthenware
H. B.: Hollow brick
R. T.: Roofing tile
T.: Floor tile or glazed tile
F. B.: Fire-brick
O. B.: Ornamental brick
S. P.: Sewer pipe
C.: China

LOCATION OF WORKS		NAME
Town	*County*	
Albany	Albany	George Dunn. B.
		A. Hunter & Son. B.
		J. H. Leonard. B.
		Moore & Babcock. B.
		Newton & Co. F. B.
		Jackson Bros. B., P. B., O. B., D. T.
		A. Poutre. B.
		E. J. Smith. B.
		D. H. Stanwix. B.
		Stanwix & McCarty. B.
Alfred	Steuben	Celadon terra cotta co. R. T., T. C.
		Alfred clay co. P. B., R. T.
Amenia	Dutchess	Wilson & Eaton. B.
Amsterdam	Montgomery	H. C. Grieme. B.
		Hart Bros. B.
Angola	Erie	J. Lyth & Sons. S. P., H. B.

LOCATION OF WORKS		NAME
Town	*County*	
Arlington	Dutchess	Flagler & Allen. B., P. B.
Athens	Greene	W. W. Rider. B.
Attica	Erie	Attica brick & tile works. B.
Auburn	Cayuga	F. W. Harvey. B.
		N. Saunders. B.
Baldwinsville	Onondaga	Riverside brick co. P. B.
		Mrs F. A. Mawhiney. B.
Berkshire	Fulton	A. Stoutner. B.
Binghamton	Broome	Ogden brick co. B.
Blackrock	Erie	Buffalo sewer pipe co. S. P.
Border City	Seneca	Geneva brick works. B.
Brighton	Monroe	Rochester brick & tile co. B., H. B.
		German brick & tile co. B., H. B.
Brooklyn	Queens	A. Benkert. E. W.
		Brooklyn fire brick works. F. B.
		Brooklyn stove lining co. F. B.
		H. Bieg. E. W.
		Graham chemical stoneware works. S. W.
		Green Point fire brick works. F. B.
		J. Cooper. E. W.
		W. T. Dufek. E. W.
		Empire china works. C.
		Charles Kurth.
		Green point porcelain works. C.

LOCATION OF WORKS		NAME
Town	*County*	
Brooklyn	Queens	New York vitrified tile co. T.
		Union porcelain works. C.
Buffalo	Erie	Henry Bender. B.
		Charles Berrick's Sons. B.
		H. Betz & Bro. F. P.
		Brush Bros. B.
		H. Dietschler & Son. B.
		F. W. Haake & Son. B.
		Hall & Sons. B.
		G. W. Schmidt. B.
		E. A. Schusler. B.
Canandaigua	Ontario	A. M. Hollis & Co. B., D. T.
		N. Y. hydraulic pressed brick co. P. B.
Canton	St Lawrence	L. O'Brien. B.
Carthage	Jefferson	C. Houghton. B., D. T.
		Wrape & Peck. B.
Catskill	Greene	Eastern paving brick co. P. B.
		Ferrier & Golden. B.
		J. Walsh. B.
		G. W. Washburn & Co. B.
Chittenango	Madison	Central N. Y. drain tile & brick co. D. T.
		Chittenango pottery co. S. W.
Coeymans	Albany	Corwin & Cullough. B.
		H. Footit. B.
		Sutton & Suderly. B.
Cohoes	Albany	J. Murray. B.

LOCATION OF WORKS		NAME
Town	*County*	
Coldspring	Suffolk	Dr O. Jones. B.
Corning	Steuben	Brick, terra cotta & supply co. P. B., Pa. B., T. C., O. B.
Cornwall on the Hudson		C. A. & A. P. Hedges. B.
Corona	Queens	Corona pottery co. E. W.
Coxsackie	Greene	J. Fitzgerald & Sons. B.
Coxsackie Station	Greene	Walsh Bros. & Co. B.
Crescent	Saratoga	J. Borden. B.
Croghan	Lewis	A. J. Vickler. B.
Croton on Hudson	Westchester	Croton brick co. B.
		W. A. Underhill brick co. B., P. B.
		Kitchawan brick co. B.
		John Morton. B.
Crugers		Mrs A. Fisher. B.
		B. J. Maguire. B.
		J. H. Manning. B.
DeKalb	Jefferson	Nathan T. Frank. B.
		E. A. Tillspaugh. B.
Dewitt	Onondaga	C. & L. Merrick. B.
Dolgeville	Herkimer	Gow & Guile. B.
Dunkirk	Chautauqua	J. Hilton. B.
Dutchess Junction	Dutchess	Aldridge Bros. & Co. B.
		G. H. Bontecou. B.
		W. D. Budd. B.
		F. Timoney. B.
East Bethany	Genesee	R. Peck. D. T., B.
East Kingston	Ulster	Brigham Bros. B.
		Herrick & Miller. B.
		D. S. Manchester. B.
		D. C. Overbaugh. B.

LOCATION OF WORKS Town	 County	NAME
East Kingston	Ulster	A. S. Staples. B.
		Streeter & Hendricks. B.
		U. F. & J. T. Washburn. B.
East Williston	Queens	W. & J. Post. B.
Edwards	St Lawrence	W. Payne. B.
Elmira	Chemung	Elmira sewer pipe & fire brick co. S. P., F. W.
		E. W. Farrington. B.
		J. P. Weyer & Co. B.
Falconer	Chautauqua	M. J. Mecusker & Son. B.
Farmingdale	Queens	Garden City brick co. P. B.
		Queens county brick mfg. co. B.
Fishers Island	Suffolk	Fishers Island brick mfg. co. B.
Fishkill on the Hudson	Dutchess	C. C. Bourne. B.
		Brockway brick co. B.
		Dennings point brick co. B.
		William Lahey. B.
		J. Paye. B.
		Aldridge & Page. B.
		Thomas Dinan. B.
		O'Brien, McConnell & Vaughey. B.
Flatbush	Ulster	A. Rose & Co. B.
Fort Edward	Saratoga	Hilfinger Bros. E. W.
		A. Smith. B.
Florida	Orange	M. H. Vernon. B.
		Fly Mountain. B.

LOCATION OF WORKS		NAME
Town	*County*	
Fly Mountain	Ulster	M. E. Turner. B.
Fort Salonga	Suffolk	G. S. Longbotham. B.
Geneva	Seneca	W. F. Delamater. B.
		W. G. Dove. B.
Glasco	Ulster	H. Corse. B.
		Catherine Lent. B.
		W. Maginnis & Son. B.
		W. Porter. B.
		T. Porter. B.
		F. M. Vandusen & Co. B.
		Washburn Bros. & Co. B.
Glens Falls	Saratoga	Glens Falls brick co. B., P. B.
		Glens Falls brick & terra cotta co. P. B., T. C.
Glenville	Schenectady	S. A. Case. B.
Goshen	Orange	I. Van Lenven. B.
Gouverneur	St Lawrence	Smith & Anthony. B.
Grassy Point	Rockland	P. Brophy. B.
		E. T. Carroll. B.
		Kelly & Byrnes. B.
Greenfield	Saratoga	David Davidson. B.
Greenport	Suffolk	Long Island brick co. B.
Greenridge	Richmond	Kieran & Monahan. B.
Haverstraw	Rockland	B. J. Allison & Co. B.
		Allison & Wood. B.
		Estate of M. A. Archer. B.
		S. W. Babcock. B.
		Barnes & Farley. B.
		William Bennett. B.

LOCATION OF WORKS		NAME
Town	*County*	
Haverstraw	Rockland	Byrnes & Palmer. B.
		A. Donnelly & Son. B.
		Excelsior brick co. B.
		Denton, Fowler & Son. B.
		D. Fowler jr & Co. B.
		P. Goldrick. B.
		M. Gormley & Co. B.
		F. Grimes. B.
		Haverstraw clay & brick co. B.
		Heitlinger & Co. B.
		Lynch Bros. B.
		McGowan & McGovern. B.
		Maguire & Lynch. B.
		Terance Maguire. B.
		T. O'Malley. B.
		C. A. Marks & Bro. B.
		Morrissey & Co. B.
		Nicholson & Reilly. B.
		T. G. Peck & Co. B.
		T. G. & G. H. Peck. B.
		E. N. Renn & Co. B.
		Riley & Farley. B.
		Rowan & Scott. B.
		T. Shankey & Son. B.
		Snedeker Bros. B.
		U. F. Washburn & Co. B.
		Washburn & Fowler. B.
		G. S. Wood & Allison. B.
		Worrall & Byrnes. B.
Homer	Cortland	Horace Hall. B.
Hoosick Falls	Rensselaer	John Dolin. B.

LOCATION OF WORKS		NAME
Town	*County*	
Hornellsville	Steuben	Hornellsville brick, tile & terra cotta co. B.
		Preston brick co. Pa. B., B.
Horseheads	Chemung	Horseheads brick co. B.
Hudson	Columbia	Arkison Bros. B.
		Bartlett brick works. B.
Ilion	Herkimer	S. E. Coe. B.
Ithaca	Tompkins	C. D. Johnson. B.
Jamestown	Chautauqua	Jamestown shale paving brick co. Pa. B.
		Mahoney & Son. B.
Jewettville	Erie	Brush & Schmidt. P. B.
Johnstown	Fulton	Cayadutta brick co. B.
		R. Kilmer. B.
Kingston	Ulster	The Hutton Co. B.
		R. Main & Co. B.
		Charles A. Schultz. B.
		Schultz Bros. B.
Kreischerville	Richmond	B. Kreischer & Sons Co. B.
Lancaster	Erie	Buffalo star brick co. B.
		Lancaster brick co. B., D. T.
Lansingburg	Rensselaer	T. F. Morrissey. B.
LaSalle	Niagara	H. A. Tompkins. B.
Lestershire	Broome	Wells & Brigham. B.
Little Valley	Suffolk	J. R. Heber. B.
Lockport	Niagara	A. Mossell. B.
Long Island City	Queens	Joseph Newbrand pottery. E. W.
		N. Y. architectural terra cotta co. T. C., P. B.

LOCATION OF WORKS		NAME
Town	*County*	
Low Point	Dutchess	G. A. Dow. B.
		Meade Bros. B.
Lyons	Wayne	F. Borck. B.
		Lyons pottery. S. W.
Madrid	St Lawrence	R. B. Watson. B.
Malden	Ulster	Cooney & Farrell. B.
Maplewood	Monroe	Estate of Hiram Sibley. B.
Mechanicville	Saratoga	Mechanicsville brick co. B.
		Best brick co. B.
		Champlain brick co. B.
		M. W. Hart & Co. B.
Middlefalls	Washington	Pullman & Co. B.
Middle Granville	Washington	J. H. Pepper. B.
Middletown	Orange	Smith & Co. B.
		Smith & Wood. B.
Montrose	Westchester	Orrin Frost. B.
		Montrose point brick co. B.
		E. H. & W. J. Peck. B.
		Henry Young. B.
Newburgh	Orange	Mrs E. L. Chrystie. B.
		William Lahey. B.
Newfield	Tompkins	Newfield brick works. Pa. B., B.
New Paltz	Ulster	A. M. Lowe. B.
New York	New York	Charles A. Bloomfield. F. B.
		Anton Boss. B.
		D. Robizek & Sons. C.
New Windsor	Orange	David Carson. B.
		H. Davidson's Sons. B.
		Estate of E. Lang. B.

LOCATION OF WORKS		NAME
Town	*County*	
Niskayuna	Schenectady	Mohawk brick works. B.
Northport	Suffolk	Rinaldo Sammis. B.
Oakfield	Genesee	G. L. Drake. D. T.
Ogdensburg	St Lawrence	R. Montgomery. B.
		A. A. Paige. B.
Olean	Cattaraugus	McMurray Bros. B.
Oneida	Madison	F. L. Hall. B.
Oneonta	Otsego	Clapsaddle, Moore & Getman. B.
		Oneonta brick co. B.
Oswego Falls	Oswego	W. D. Edgarton. B.
		A. B. Fletcher. B.
Owasco	Cayuga	A. Lester. B.
Oyster Bay	Queens	Dunn, Dolan & Co. B.
Oneida Valley	Madison	Clinton Stephens. B.
Pamelia	Jefferson	Watertown pressed brick co. B., P. B.
Peekskill	Westchester	S. D. Horton. F. B.
Plattsburg	Clinton	J. Ouimet. B.
		Gilliland & Day. B.
		C. W. Vaughn. B.
Port Ewen	Ulster	J. Kline. B.
Port Jefferson	Suffolk	Johanna Lillis. B.
Raymondville	St Lawrence	William Coats. B.
Rensselaer	Rensselaer	J. J. Rigney. B.
Riceville	St Lawrence	B. Thompson & Son. B.
Rochester	Monroe	Rochester sewer pipe works. S. P.
		Flower city pottery. E. W.
		Standard sewer pipe co. E. W.

LOCATION OF WORKS		NAME
Town	*County*	
Rome	Oneida	W. W. Parry. B.
Romulus	Seneca	J. M. Yerkes jr. B.
Rondout	Ulster	T. Frederick. B. Manchester & Streeter. B. Terry Bros. B. G. Washburn. B.
Roundlake	Saratoga	J. Davey. B.
Roseton	Orange	Jova brick works. B. Rose & Co. B.
Sag Harbor	Suffolk	Sag Harbor brick co. B.
Salina	Onondaga	G. W. Pack & Son. B. Preston Bros. B.
Sangerfield	Oneida	P. B. Haven & Son. B.
Saratoga Springs	Saratoga	B. F. Bloomfield. B.
Saugerties	Ulster	
Seneca Castle	Ontario	A. S. Childs. B.
Seneca Falls	Seneca	F. Siegfried. B.
Smiths Dock	Ulster	T. Brousseau. B.
Southampton	Suffolk	Southampton brick & tile co. B.
South Bay	Madison	Clinton Stephens. B.
South hill	Tompkins	S. Wilcox. B.
Southold	Suffolk	C. L. Sanford. B.
South Trenton	Oneida	H. L. Garrett. B.
Spencer	Tioga	Spencer brick co. B.
South Plattsburg	Clinton	J. McCarty. B.
Stanley	Ontario	William Preston. B.
Stonypoint	Rockland	T. F. Clarke. B. Reilly & Clarke. B. Reilly & Rose. B.
Stormking	Dutchess	Mosher Bros. B.
Stuyvesant	Columbia	Edouard Brousseau. B.

LOCATION OF WORKS		NAME
Town	*County*	
Syracuse	Onondaga	J. Brophy. B.
		F. H. Kennedy. B.
		N. Y. brick & paving co. Pa. B., B.
		Onondaga pottery co. C.
		Pass & Seymour. Insulators
		Syracuse pottery co. E. W.
		Syracuse pressed brick co. P. B.
Tarrytown	Westchester	Tarrytown porcelain tile works. T.
Thiells	Rockland	J. M. Felter. B.
Throopsville	Cayuga	Fred Webber. B.
Tonawanda	Erie	J. M. Riesterer. B.
Troy	Rensselaer	A. Ferguson. B.
		Kelley & Morey. B.
		McLeod & Henry Co. B.
Troy	Rensselaer	Ostrander fire brick co. F. B.
		C. R. Painton. B.
		Roberts brick works. B.
Union Springs	Cayuga	Clark & Sons. D. T.
Utica	Oneida	Callahan & Doyle. B.
		Central N. Y. pottery. E. W.
		Utica brick mfg co. B.
		George F. Weaver's Sons. B.
Verplanck	Westchester	Bonner brick co. B.
		King & Lynch. B.

LOCATION OF WORKS		NAME
Town	*County*	
Verplanck	Westchester	W. H. Macky. B.
		O'Brien & McConnell. B.
Victor	Ontario	W. E. Peck. B.
F. Lock.— Insulators		F. Lock.
Warner	Onondaga	Onondaga vitrified brick co. Pa. B., B.
Waterloo	Seneca	E. W. Foster. B.
		M. Whiteside. B.
Watertown	Jefferson	J. H. Gotham. B.
Watervliet	Albany	Tupper & Retallick. B.
West Bloomfield	Ontario	G. N. Webb. B.
West Fayette	Seneca	Willower & Pontius. B.
Whitehall	Washington	Jeremiah Adams. B.

ERRATA

Page 530, line 30, “grain” should be “gram”.

“ 532, lines 19, 20 and 21, “grain” should be “gram”.

“ 842, line 3, put “O” after K_2.

“ 878, line 39, 3d column, “Clinion” should read “Clinton”.

Page 891, line 18, last column, “dressed” should be “pressed”.

“ 905, line 17, “TiQ_2” should be “TiO_2”.

INDEX

The superior figures tell the exact place on the page in ninths: e. g. 543^3 means page 543, beginning in the third ninth of the page, i. e. about one third of the way down.

Abbey, B. G., drain tile works, 771^8.
Abbott, M., tests of Haverstraw brick, 648^1.
Abrasion tests of paving brick, 747^6–48^7, 752^6–55^8.
Abrasive materials, 852^9–53^1.
Absorption, of building brick, 854^5; of clays, 515^6, 528^8–29^9, 546^5; of common brick, 643^6, 644; of floor tile, 775^3; of shales, 825^4.
Absorption test of paving brick, 746^9–47^5, 748^8–49^4.
Acids, resistance to, 857^2.
Adobe soils, analysis, 882^4–83^5.
Adsit, M., clay bank, 726^4.
Adulterants, food, 852^6.
Alabama, clays, 523^5, 525^5, 611^4–12^4.
Albany, terrace, 591^2; brick yards, 706^4–7^4; clay deposits, 706^4–7^4; sewer pipe manufacture, 770^1; drain tile works, 771^5.
Albany county, brick yards and clay deposits, 704^9–7^5, 708^1; underlying material, illus. facing p. 578; drain tile works, 771^5.
Albany slip, 806^9–9^1.
Albion, brick yard, 722^4.
Aldridge & Sherman, brick yard, 697^5.
Aldridge Bros., brick yard, 696^9–97^2; clay bank, illus. facing p. 577.
Aleksiejew, W., on plasticity, 541^2.
Alfred Center, brick yard, 726^5; roofing tile manufacture, 765^2–66^1; illus. facing p. 765; shale, 831^4, 837^7–38^8.
Alfred clay co., 726^5, 766^2, 839^1.
Alfred Station, Chemung shale, 838^9–39^1.
Alkaline compounds, 513^6–15^5.
Alkalis in clay, 512^8–15^5, 569^1, 680^4, 861^8. *See also* Analyses.
Allegany county, Chemung shale, 837^7–38^8.
Allen's creek, Cashaqua shale, 834^8.
Allenshill, drain tile works, 771^8.
Allophane, 505^6.
Altitudes, table, 589^7.
Alumina, 511^2, 568^8, 569^7, 640^3, 861^8. *See also* Analyses.
Amber, 509^9.
Amenia, clay deposits, 572^9.
American magnesite, 785^5.
Ammonia, 512^9, 513^1.
Amsterdam, brick yard, 714^7; clay deposits, 714^1.
Analyses, feldspar, 498^9, 499^2, 842^7; fire brick, 786^1; fullers' earth, 851; kaolin, 610^3, 862–65; porcelain, 794^5, 796^1;
clays: table, 860–90; methods of analysis, 530^8–38^7; mechanical analysis, 561^2–63^9, rational, 533^2–38^7; abode soils, 882–83; brick clays, 638^2–39^8, 882–99; buff clay, 692^3; fire clays, 536^1–37^9, 789^3–90^6, 866–77; flint clays, 617^7; determining fusibility, 559^4; paving brick clays, 900^5–3^9; pipe clays, 904^4–7^3; clays and shales used in manufacture of Portland cement, 847; pottery clays, 878^1–81^8; residual clays, 860–61; slip clays, 807^2, 880^8–83^3; stoneware clays, 792^6, 818^4, 819^8–20^3, 820^6; terra cotta clays, 760^4, 904^1–5^4;
at Barrytown, 702^3; Breesport, 727^7; Brockway brick co., Fishkill, 688^8; Buffalo, 723^6; Canandaigua, 719^4; Catskill, 702^7; Coeymans Landing, 705^2; Dillsboro (N. C.), 540^2; Drowned lands, 732^8–33^2; East Williston, 733^7; Edgar (Fla.), 540^2; Farmingdale, 739^2; Fishers island, 738^2; Hornellsville, 726^1; Newfield, 728^6; Ogdensburg, 712^2; Plattsburg, 710^8; Rathenow, 570^2; Rochester, 720^5; Rondout, 699^5; Southold, 737^1; Verplanck, 692^3; Warner, 716^7; Watertown, 711^5; West Deerpark, 742^8; West Neck, 735^1;
shale: 716^1, 769^6, 847, 899^4–901^4; Chemung, 838^1, 839^5, 840^8; Hamilton, 833^7; Medina, 827^7; Niagara, 828^7; Portage, 835^5; Salina, 830^4.
Anchor brick co., 689^5–90^6.
Angola, sewer pipe works, 769^8; illus. facing p. 767–69, 774; shale, 831^4; Portage shale, 835^2–36^3.
Annandale, well record, 608^8.

Arch brick, 645^4, 677^7.
Archaean rocks, 587^2.
Arches, arrangement, 674^5; number of bricks in, 674^5; number of courses, 674^5; labor required to tend, 677^8.
Arkansas, clay deposits, 612^4.
Arkison Bros., brick yard, 703^6.
Arlington, brick yard, 701^7–2^2; clay deposits, 701^7–2^2.
Armstrong, W., brick yard, 714^8.
Arrochar, clay deposits, 607^7.
Arthur's Kill, 609^1.
Athens, terraces, 590^5, 591^8; brick yards, 704^4; clay deposits, 704^4.
Auburn, brick yard, 718^5.
Auger machine, 663^4, 745^8; illus. facing p. 773.
Aurora, depth of clay, 574^8.

Babcock, J., brick yard, 706^7.
Baeby, J., brick yard, 708^3.
Baker, I. O., crushing tests, 751^8–52^5.
Baldwin, Mrs, brick yard, 718^7.
Baldwinsville, brick yards, 717^6–18^2; clay deposits, 717^6–18^2.
Ball clay, 614^7, 793^6.
Ball mills, 657^5–58^4.
Ballou, M., brick yard, 715^5.
Baltimore, clays near, 511^9.
Barium, 683^6.
Barnard college, illus. facing p. 763.
Barrytown, clay deposits, 702^2.
Bartlett, W. E., brick yard, 703^8.
Basin-shaped deposits, 573^4, 584^6.
Bat, 805^7.
Bath brick, 852^9–53^1.
Beauport, terraces, 594^9.
Bedford, feldspar, 842^3; quarries, 843^2.
Belgian white earthenware, composition, 796^1.
Belgium, glass-pot clays, 787^8.
Belleek ware, 798^1.
Benches, working in, 631^9–32^2.
Bender, M. H., brick yard, 706^5.
Benkert, A., stoneware works, 823^8.
Bennett, C., brick yard, 718^7.
Bennett, Rowan & Scott, brick yards, 694^5.
Berrick, Charles & Sons, brick yard, 723^5.
Berthier, P., experiments, 517^8–18^9.
Beryllium oxid in clays, 511^8.
Bibliography of clay literature, 908–12.
Bigflats, brick yard, 726^8–27^1.
Binghamton, brick yards, 731^5.
Bischof, C., experiments on action of silica, 526^3; on testing plasticity, 543^3: formula for relative fusibility of clays, 552^7; method of determining temperature, 558^2.
Biscuit burn, 814^8.
Biscuit ware, 796^6, 816^9; illus. facing p. 806.
Bishop, I. P., test of Hamilton shale, 833^2–34^5.
Blasting, 632^8.
Blistering of ferruginous clays, 517^5.
Blue clay, characteristics, 577^8.
Bohemia, glass-pot clays, 787^8.
Bolton, William, brick yard, 724^6.
Bone china, 794^3.
Bonner & Cole, brick yard, 693^2.
Bonner brick co., 693^3.
Borck, F., brick yard, 718^8.
Bostwick, W. H., brick yard, 728^3.
Boulders, 577^6, 582^2, 584^2, 584^8, 586^9, 588^2, 592^4, 595^2.
Boyd dry clay presses, 665^5; illus. facing p. 665.
Brazilian clays, 511^9.
Breesport, brick yards, 727^5–28^2; clay deposits, 576^5, 727^5–28^2.
Brennan, J., brick yard, 694^2.
Brick, time of burning, 676^8; time of cooling, 676^7; cost of production, 685^5–86^8; cracks in, 651^1, 676^3; crushing strength, 643^6, 647^8–50^4, 695^2; drying, 668^8–72^3; efflorescence on, 679^9–85^4; ground, used to prevent shrinkage, 548^1; methods of manufacturing, 653^8–56^1; repressing, 668^4, 745^4; sorting, 679^5; weight, 528^9. *See also* Building brick; Common brick; Cost; Enameled brick; Fire brick; Glazed brick; Hollow brick; Ornamental brick; Paving brick; Pressed brick; Testing; Vitrified brick.
Brick clays, alkalis in, 515^5, 569^1; alumina in, 569^1; analyses, 638^2–39^8, 882–99; burning, 639^8–42^8, 672^4–79^4; illus. facing p. 674–79; characteristics, 636^1–39^8; color, 639^8–42^7; ferric oxid in, 520^2, 520^4, 569^1; lime in, 523^7, 569^1, 636^7, 640^2, 641^4; magnesia in, 524^8, 569^1, 640^2; silica in, 525^8; tensile strength, 545^5;
  in Alabama, 611^5–12^1; Arkansas, 612^6; Colorado, 613^4; Delaware, 614^5; Florida, 614^6, 615^1; Georgia, 615^8; Kentucky, 617^4; Louisiana, 618^7; Michigan, 620^4; Mississippi, 620^8; Missouri, 622^5; Nebraska, 623^7; North Carolina, 624^5; Ohio, 625^4; Pennsylvania, 625^9; South Dakota, 626^2; Texas, 626^9; Virginia, 627^8; Wyoming, 627^6.
Brick yards, three kinds, 669^8–70^2; ownership, 685^9; detailed account, 686^9–743^4.
Brickbuilder, extracts from, 680^8.
Brickmaking industry, 643^1–757^5.
Brigham Bros., brick yard, 699^8, 700^1.
Brighton, clay deposits, 575^2.

Briquet method of testing plasticity, 542^6, 544^9.
Brockway brick co., 688^8, 697^6; illus. facing p. 697.
Brookfield brick co., 731^6.
Brooklyn, pottery works, 823^8; illus. facing p. 793–94, 799, 800–1, 808, 816, 824.
Broome county, brick yards, 731^5.
Brophy, J., brick yard, 715^7.
Brousseau, Theodore, brick yard, 700^6.
Brush & Schmidt, brick works, 650^7, 724^2; illus. facing p. 662, 664, 665, 672, 724.
Brush Bros., brick yard, 723^5.
Buckley & Carroll, brick yards, 694^2.
Buff brick, manufacture, in Massachusetts, 620^2.
Buff clay deposits, analysis, 692^8.
Buffalo, clays, 523^5, 574^6, 723^4–24^2; brick yards, 723^4–24^2.
Buffalo star brick co., 722^8–23^1.
Buhrstone mill, illus. facing p. 793.
Building brick, clays for, 636^2; tests, 648^9–50^4; side-cut, 664^5; manufactured in New York state, 650^5–53^7; properties, 854^8–57^4.
Building stone, resistance to fire, 759^5; illus. facing p. 759.
Burlington, clay deposits, 595^2.
Burned clay, 549^6–50^2.
Burning, brick clays, 666^2, 639^8–42^8, 672^4–79^4; illus. facing p. 674–79; china, 811^4–14^6; cost, 676^8; drain tile, 770^5; fire brick, 785^2; illus. facing p. 784, 786; modern methods, 495^3; paving brick, 745^6; illus. facing p. 745; sewer pipe, 768^8; stoneware, 809^2; sulfates arising during, 681^8; terra cotta, 762^5; time of, 676^8; white earthenware, 811^4–14^6.

C. C. ware, 793^3.
Cable haulage, 633^7, 686^7.
Cairo, shale, 831^4, 832^5–34^5, 841^2.
Calcareous clays, 731^1; for common brick, 636^5; burning, 642^2. *See also* Lime in clay.
Calciferous sandrock, 582^2, 584^8.
Calcite, 506^9–7^4. *See also* Lime.
Callanans Corners, terrace, 591^2.
Campbell, F. C., brick yard, 728^4–29^5.
Campbell brick co., Newfield, 650^7.
Canandaigua, brick clays, 636^8; brick yards, 650^6, 719^1–20^2; use of hydraulic dry press machine at, 665^6; clay deposits, 719^1–20^2.
Canastota, brick yard, 715^5.
Capital pottery, Brooklyn, 823^8.
Carpenter Bros., stoneware clay bed, 818^7–19^8.
Cars, haulage with, 633^8.
Cartersville, Salina shale, 829^9.
Carthage, brick yards, 710^9–11^2; clay deposits, 710^9–11^2.
Carts, haulage with, 632^9–33^8.
Cashaqua creek, clay deposits, 575^1; shale, 834^7.
Casting of pottery clay, 806^2.
Catskill, brick yards, 702^5–3^5; illus. facing p. 659; paving brick manufacture, 756^2; illus. facing p. 679; terrace, 578^8, 591^2;
  clays: 577^4, 702^5–3^5; characteristics, 578^2; stratification, 578^4.
Catskill creek delta, 577^5.
Catskill mountains, terrace, 590^9.
Catskill shale paving brick co., 832^5.
Cattaraugus county, brick yards, 725^6.
Cayuga county, brick yards, 718^4; drain tile works, 772^5.
Cedar Pond brook, delta deposits, 583^6, 588^9.
Celadon terra cotta co., 765^2–66^1, 838^1, 838^6; illus. facing p. 765.
Cement, clays used in manufacture of, 699^5, 716^7; manufacture in Michigan, 620^6. *See also* Portland cement.
Center Island, brick yards, 734^8; clay deposits, 597^5, 602^1, 606^1.
Central New York drain tile and brick co., 771^6.
Central New York pottery, 824^5.
Ceramics, *see* Pottery.
Cerium oxid, 511^3.
Chamotte, used to prevent shrinkage, 549^6–50^2.
Champlain valley, clays, 594^6–95^5; terraces, 594^7; illus. facing p. 592; stratification, 595^3.
Chaser mill, 803^5.
Chautauqua county clay deposits, 576^1; brick yards, 724^7–25^5; Chemung shale, 837^2.
Chemical pottery works, 823^4.
Chemical properties of clay, 510^7–38^7. *See also* Analyses.
Chemung county, brick yards, 726^8–28^3.
Chemung shale, 725^7, 765^3, 826^6, 831^2, 836^4–41^2; analyses, 838^1, 839^5, 840^8; physical tests, 831^2.
Chicago, clays, 523^5.
China, value of output, 494^6; ironstone, 793^5; burning, 811^4–14^6; decoration, 815^2–17^4; manufacturers, 913^8–25^4. *See also* Porcelain.
China clays, in Alabama, 612^1; in Missouri, 621^8.
Chittenango, drain tile works, 771^6.
Chittenango pottery co., 824^6.
Chlorite in clay, 524^2.

Chromium, 511^3, 567^5.
Chromium oxid, 777^6.
Chromolithographic decoration, 816^6–17^4.
Cimolite, 505^7.
Cistern brick, 645^5.
Clamp, 674^2.
Clarkson, brick yard, 722^2.
Classification of clays, 564^1–71^6.
Clay, absorption, 515^6, 528^8–29^9, 546^5; methods of analyzing, 530^8–38^7; burned, 549^6–50^2; chemical effects of heating, 561^9–63^9; chemical properties, 510^7–38^7; classification, 564^1–71^6; clay substance, 497^3, 510^6; color, 515^2, 515^6, 517^6, 519^3, 521^7, 527^7–28^2, 565^6–71^7, 574^6, 577^7, 610^5; crumpling, 593^3, 597^8, 603^7, 606^5; definition, 496^3, 497^1; formation, 500^9; fusibility, 512^4, 550^8–61^2, 562^8; impurities, 508^9, 511^5–28^4; adaptable to different molding methods, 667^2–68^7; mineralogy, 503^1–9^9; origin and nature, 496^1–502^5; physical properties, 510^7, 538^7–61^2; plasticity, 496^5, 504^3, 528^3, 530^7, 539^1–44^7, 637^3, 845^2; porosity, 522^6, 672^5; preparation of, 655^7–60^7; properties, 510^1–63^9; pure, 500^8, 505^9, 510^1, 511^4, 511^6; purification, 633^9–35^3; refractoriness, 511^6, 526^2, 563^7; shrinkage, 522^5, 529^3, 530^6, 545^7–50^8, 636^3–37^1, 637^3, 639^7, 672^8; method of counteracting shrinkage, 547^9–50^7; tensile strength, 541^5, 544^8–45^6, 637^3; uses, 564^8–65^5, 636^1–42^8, 845^1–53^9. *See also* Analyses; Brick clays; China clays; Fire clays; Flint clays; Glass-pot clays; Kaolin; Paving brick clays; Pottery clays; Residual clays; Sedimentary clays; Slip clays; Stoneware clays.
Clay banks, ownership, 685^9–86^2.
Clay conveyor, illus. facing p. 660, 761.
Clay deposits, geologic distribution, 572^2–627^7; unstratified material found with, 592^6; illus. facing p. 592; structure, 628^1–29^2; sections of, table, 858–59.
Clay dogs, 507^2.
Clay industry, statistics, 493^5–94^7; growth, 494^1; adoption of modern methods of molding and burning, 495^3; conduct of business, 685^9–86^2.
Clay wares, testing, 854–57.
Clay workers, directory, 913^1–25^4.
Clay working, 628^1–35^6.
Cleansing clay, 633^9–35^3.
Clifton, clay deposits, 607^8.
Clinton county, brick yards, 709^8–10^4.
Clinton shale, 828^2.
Coal, used in burning calcareous clays, 642^6.
Coal dust in brick, 675^2, 676^5.
Coats, William, brick yard, 712^8.
Cobalt oxid, 567^5, 777^6.
Cobbles, 582^1, 583^4, 583^9, 586^1, 587^2, 592^6.
Coe, S. E., brick yard, 714^7.
Coeymans Landing, terrace, 591^1; brick yards, 704^9–6^3; clay deposits, 588^1, 704^9–6^3.
Cohoes, brick yards, 708^1; clay deposits, 708^1.
Coke, used to prevent shrinkage, 548^1, 550^5.
Coke oven brick, 785^5.
Coldspring, delta deposits, 588^8; brick yard, 695^9.
Coldspring Harbor, stratification, 597^8–98^3; clay deposits, 734^6; illus. facing p. 735.
Collins, J. H., on kaolinization of feldspars, 498^8.
Collyrite in clay, 505^8.
Color, of clay, 515^2, 515^6, 517^6, 519^8, 521^7, 527^7–28^2, 565^6–71^7, 574^6, 577^1, 610^5; of brick clay, 639^8–42^7; of decorative tile, 777^6; of fire clay, 782^4; of paving brick, 744^7; of pressed brick, 646^1.
Colorado, clay deposits, 572^3, 612^7–14^1.
Columbia county, brick yards, 703^6–4^2; shale, 826^3.
Common brick, absorption, 643^6, 644; burning, 672^6, 673^1, 673^6; crushing strength, 643^6; different grades, 645^2–47^2; table of dimensions, 643^7; requisites, 643^2; standard size, 643^8; tests, 648^6; value of output, 493^6, 494^3;
  manufacture: 645^1, 650^5; clay used, 521^5, 636^4; in Colorado, 613^7; continuous kilns used, 679^4; manufacturers in New York state, 913^2–25^4; shale used, 495^2, 686^8. *See also* Brick clays.
Concretions, sand, 585^5; clay, 593^5–94^6, 602^1, 604^3.
Cones, Seger, 553^8–58^2.
Conewango, clay deposits, 576^1.
Connecticut, clay deposits, 572^8, 614^3.
Continuous kilns, 495^4, 678^7–79^4, 814^6; illus. facing p. 679.
Cook, G. H., on quartz in clay, 525^4; on plasticity of clays, 539^6.
Cooney & Farrell, brick yard, 700^8.
Copenhagen biscuit ware, composition, 796^6.
Copper oxid, 777^6.
Cornell university, New York state veterinary college, illus. facing p. 719.

Corning, shales, 831^4, 839^9–40^5.
Corning brick and terra cotta co., 650^7, 755^9–56^1, 763^9, 764^6; illus. facing p. 764, 839.
Cornwall (Eng.), kaolin mines, 498^7, 499^9, 500^2.
Cornwall (N. Y.), terraces, 582^9–83^1, 590^5; delta deposits, 588^9, 589^4.
Cornwall-on-the-Hudson, clay deposits, 577^4; brick yards, 696^2.
Cortland county, brick yards, 731^4.
Corwin & Cullough, brick yard, 705^8–6^8.
Cost, of burning, 676^8; double-coal bricks, 675^3; dredging clay, 690^7; enameled bricks, 651^3; flue driers, 671^6; ornamental brick, 646^6; production of brick, 685^5–86^8; working clay, 631^5.
Covered yards, 669^8, 670^1.
Coxsackie, terrace, 591^2; clay concretions, 593^8–94^1; brick yard, 704^2; clay deposits, 704^2.
Coykendall, S. D., brick yard, 699^1.
Cracks in bricks, 651^1, 676^3.
Cramer, E., cones, 554^3; mixture in glass-pot clay, 787^5.
Crandall & Marble, brick yard, 731^7.
Crazes, 797^2; cause of, 651^1; tendency to, 653^7.
Cremiatschenski, P. A., on plasticity, 541^2.
Crescent, brick yard, 708^6; clay deposits, 708^6.
Cretaceous clay deposits, 572^8, 596^4, 602^5, 605^6, 606^8, 608^8, 609^6, 610^6, 788^2; illus. facing p. 608, 781, 819–20.
Cretaceous plant impressions, illus. facing p. 611.
Cripple creek mines, production of kaolinite, 500^5.
Cross-breaking tests of paving brick, 749^5–50^2.
Crossman Bros., brick yard, 735^3.
Croton, clay deposits, 577^4; delta deposits, 585^4, 589^4; illus. facing p. 589.
Croton brick co., 690^6–91^3.
Croton landing, clay deposits, 585^2, 689^6; terrace, 591^5; use of steam shovel, 632^8; brick yards, 689^5.
Croton point, clay deposits, 585^4, 691^4; clay concretions, 594^2; dredging, 632^5; brick yards, 691^4.
Croton river, delta deposits, 588^8; terraces, 591^4.
Crucibles, 613^9.
Crugers, clay deposits, 585^6; brick yards, 691^7–92^2.
Crumpled layers, 593^8, 597^8, 603^7, 606^5.
Crushers, 656^2; illus. facing p. 653, 656, 759, 765.
Crushing rolls, illus. facing p. 660.
Crushing strength, of brick, 643^6, 647^8–50^4, 695^2; of paving brick, 750^2, 751^7–52^5; of clay wares, 855^4.
Cupola brick, manufacture, 788^3.
Cuylerville, depth of clay, 574^2.

Dana, J. D., on origin of Long Island sound, 607^1.
Daub, use of, 674^9.
Daubrée, A., on kaolin, 499^8.
Davenport, W., brick yard, 713^5.
Davidson, D., brick yard, 709^8.
Decoration, of tile, 777^1–80^5; of pottery, 814^7–17^4; illus. facing p. 805, 808.
Deerfield, brick yard, 715^3; clay deposits, 715^3.
Delaney & Lavender, brick yard, 705^8–6^3.
Delaware, clay deposits, 614^4.
Delft ware, 797^3.
Delta deposits, 576^8, 577^4, 581^7, 582^6, 583^6, 588^5–89^6, 592^1.
Demond, C.D., use of Bishof's method, 558^4.
Dennings Point, clay deposits, 586^8.
Denton, J., & Son, brick yard, 731^7.
Deposits, *see* Clay deposits; Delta deposits.
Derbyshire brick co., 703^8.
Devonian shale, 825^7.
Diamond brick co., 694^5.
Diatoms, 594^4, 595^9, 597^3, 597^7, 598^5, 603^2, 609^5; illus. facing p. 600–1.
Dietschler, H., & Son, brick yard, 723^5.
Dillsboro (N.C.), clay analysis, 539^6–40^7.
Dinan & Butler, brick yard, 697^7.
Dinas brick, 784^3.
Diorite, 584^1.
Directory of clay workers, 913^1–25^4.
Disintegrators, 656^7–57^4.
Dolan, John, clay bank, 709^6.
Dolgeville, brick yard, 713^7.
Dolomite, 508^7, 520^7, 524^4.
Donnelly & Son, brick yard, 693^7.
Double-coal brick, 675^1.
Dove, W. G., brick yard, 718^7.
Down-draft kiln, 673^6, 674^1, 677^9–78^3, 745^6, 814^5; illus. facing p. 677–78, 745, 768, 784.
Drain tile, value of output, 493^7, 494^5; characteristics of clay for, 770^2; four kinds, 770^8–71^4; size, 771^8; manufacture: 770^2–72^9; illus. facing p. 768; in Missouri, 622^4; manufacturers in New York state, 771^5–72^9, 913^2–25^4; in Texas, 626^9.
Drainage, of clay bank, 630^6; of brick yards, 669^5.
Dredging clay, 632^5, 690^7.

Drowned lands, clay deposits, 732^7, 733^8.
Dry clay process, 664^6–66^9; illus. facing p. 664–66; cost, 686^8.
Dry pan crushers, illus. facing p. 653, 656, 759, 765.
Dry press machines, 495^8, 664^6; illus. facing p. 666, 816.
Dry pressed brick, *see* Pressed brick.
Drying, bricks, 655^3, 668^8–72^3; drain tile, 770^4; pottery clay, 806^4.
Dufek, W. T., stoneware works, 823^5.
Dummler, C., on weight of sand, 549^4; table of analyses, 566^2.
Dunkirk, brick yard, 724^7–25^2; clay deposits, 574^5, 724^7–25^2.
Dunn, Dolan & Co., brick yard, 734^3.
Dutchess county, brick yards, 696^1, 696^8–98^2, 701^7–2^5.
Dutchess Junction, clay deposits, 577^4, 586^2, 696^8–97^2; illus. facing p. 577; terrace, 586^2; illus. facing p. 592; delta deposits, 588^7; brick yards, 696^8–97^2.

Earthenware, description, 791^4, clay used in manufacture, 521^5; manufacturers, 823^3–24^5, 913^8–25^4; value of output, 494^6. *See also* White earthenware.
East Bethany, clay deposits, 771^9–72^4; drain tile works, 771^9–72^4.
East Kingston, brick yards, 699^8–700^5, illus. facing p. 700; clay deposits, 699^8–700^5.
East Williston, brick yards, 733^6–34^2; clay deposits, 605^4, 733^6–34^2.
Eastern hydraulic pressed brick co., 650^6.
Eastern paving brick co., 756^2; illus. facing p. 679.
Eddyville, stratification, 579^6–80^2.
Edgar (Fla.), clay analysis, 539^8–40^7.
Edgarton, W. D., brick yard, 718^3.
Efflorescence on bricks, 679^9–85^4.
Eggshell ware, 798^1.
Eighteen Mile creek, Cashaqua shale, 834^8.
Electric supplies, 798^3; manufacturers, 824^1, 824^3; illus. facing p. 809, 814–17.
Elko mining and milling co., 848^4.
Elm Point, clay deposits, 596^3; terra cotta clays, 761^2; stoneware clays, 817^5–18^6, 820^6.
Elmira, brick yard, 727^4; clay deposits, 576^5.
Emmons, Ebenezer, on boulders, 595^2.
Empire brick works, Horseheads, illus. facing p. 840.
Empire china works, 823^6.
Empire state brick co., 727^5, 728^2.
Enameled brick, manufacture, 650^7–52^8.
Encaustic tile, 774^3; manufacture, 514^9, 775^6–76^2; painting, 778^4.
Endaly kilns, 674^4.
England, glass-pot clays, 787^8; kaolins, 793^8.
English ball clays, plasticity, 542^2.
Epsom salts, *see* Magnesium sulfate.
Erie county, brick yards, 722^8–24^7; shale, 829^5.
Eskars, 575^3. *See also* Kames.
Estuary deposits, 576^8, 592^2.
Eureka pressed brick co., 714^6.
European clays, per cent of quartz in, 525^6; glass pot clays, 787^8.
Evans, brick yard, 724^6.
Excelsior brick co., 693^7, 694^4.
Expansion tests of fire brick, 785^6.
Experiments on glazes, 653^1.
Exploring for clay, 629^8–30^2.
Eye brick, 677^7.

Fairport, Salina shale, 829^9.
Farmingdale, brick works, 738^7–42^5; illus. facing p. 665, 678, 740; clay deposits, 604^6, 738^7–42^5; illus. facing p. 604.
Feldspar, 497^8, 506^7, 514^4, 578^2, 652^9, 705^7, 841^3–44^2; analyses, 498^1, 499^2, 842^7; effect on color of clays, 515^2, 565^9, 635^4; aid to fusion, 512^3, 563^5; kaolinization, 498^8–501^1; lime in, 520^7; mineralogic characters, 841^8–42^3; occurrence, 793^9, 842^3–43^2; preparation, 843^3; illus. facing p. 793; price, 843^9–44^2; properties, 534^8; source of potash and soda, 513^4; source of alkaline compounds, 514^8; uses, 547^5, 843^4; varieties, 497^9.
Felter & Mather, brick yard, 695^6.
Ferguson, Alexander, brick yard, 707^6.
Ferric carbonate, *see* Siderite.
Ferric oxid, *see* Iron oxid.
Ferrier & Golden, brick yard, 703^2; ring pit; illus. facing p. 659.
Ferruginous sandstone, 605^8.
Ferruginous shale, 646^8.
Fickes, E. S., tests of common brick, 648^6.
Filling paper, 852^1.
Finnegan T., brick yard, 705^8–6^3.
Finnimore, D. W., brick yard, 711^2.
Fire brick, 783^4–84^2; analyses, 786^1; use as chamotte, 550^3; expansion tests, 785^6; specific gravity, 786^8; value of output, 493^7, 494^4;
manufacture: 784^4–86^4; illus. facing p. 783–86; in Colorado, 613^9; in Kansas, 617^2; in Tennessee, 626^8; manufacturers in New York, 913^8–25^4.
Fire clays, 568^6, 781^1–90^6; illus. facing p. 781; alkalis in, 515^4; analyses, 536^1–37^9, 789^8–90^6, 866–77; ferric

oxid in, 520^2; fluxes, 512^7; lime in, 523^7; magnesia in, 524^8; silica in, 525^8; used for paving brick, 743^7;
  in Alabama, 612^4; Colorado, 613^6; Delaware, 614^4; Indiana, 615^9; Kansas, 617^2; Kentucky, 617^4; Maryland, 619^8; Missouri, 621^8; New Jersey, 623^2; New York, 788^1–90^6; North Carolina, 623^8, 624^3; Ohio, 536^1–37^9, 625^1; Pennsylvania, 625^6; South Dakota, 626^5; Texas, 627^1.
Fire gases, effect on color, 641^1, 641^9–42^3.
Fire sand in New Jersey, 623^2.
Fireproofing, bricks used for, 773^5; forms, illus. facing p. 773; value of output, 493^8, 494^5.
Fires, time of crossing, 675^7.
Fishers island, clay deposits, 597^5, 603^6, 606^1, 737^7–38^6; crumpled layers, 606^7; brick yards, 737^7–38^6.
Fishers Island brick manufacturing co., 737^7–38^6.
Fishkill, clay deposits, 577^4, 697^3–98^2; illus. facing p. 697; terrace, 586^9, 590^6; illus. facing p. 586; brick yard, 688^3, 697^3–98^2.
Fishkill creek, delta deposits, 588^8.
Fitzgerald, J., sons, brick yard, 703^6.
Flagler & Allen, brick yard, 701^7.
Flange tile, 770^9.
Flashed brick, 646^7; illus. facing p. 464.
Flint, 506^3; used to prevent shrinkage, 549^1.
Flint clay, 781^6;
  in Kentucky, 617^6; Maryland, 619^8; Missouri, 621^5; Ohio, 624^9.
Floor driers, 671^6–72^3; illus. facing p. 672.
Floor tile, 774^1–76^2; manufacturers, 913^2–25^4.
Florida, clay deposits, 614^5–15^2, 732^1; brick yard, 732^1; ball clays, 793^8.
Flower city pottery, 824^5.
Flower pots, manufacture, in Missouri, 622^4; New York manufacturers, 913^3–25^4.
Fluxes in clays, 511^5–12^8; purification, 635^3.
Fonda, brick yard, 713^5.
Food adulterants, 852^6.
Fort Edward, pottery works, 824^5.
Fossils, 587^3, 595^3, 600–1, 602^2, 602^6, 603^8, 604^5, 605^7, 609^3, 610^6.
France, glass-pot clays, 787^8.
Free silica, 525^2.
Freshpond, clay deposits, 597^5, 603^5, 606^1, 735^4–36^3; crumpled layers, 606^7; brick yards, 735^4–36^3; stratification, 735^6.
Frit, 810^3.
Front brick, 639^6; repressed, 668^4; clays for, 639^6; manufacture, 771^5.
Fuel, cost, 676^9, 686^6.
Fullers' earth, 848^7–51; analysis, 851; properties and uses, 848^9–49^6;
  in Florida, 614^6, 615^1; New York, 849^6–50^3; South Dakota, 626^6.
Fulton county, brick yards, 714^4.
Fusibility of clay, 512^4, 550^8–61^2, 562^8; fire clays, 783^1; slip clay, 808^4; feldspar, 841^1.
Fusion, temperature of, 506^4, 552^5, 562^6.

Ganister, 784^8.
Gardeau shales, 834^9–35^2.
Garden City brick co., 740^2–41^1; illus. facing p. 604, 665, 678, 740.
Gardiner's island, clay deposits, 603^8, 605^7; crumpled layers, 606^7.
Gardonas, N., brick yard, 708^3.
Garnet, 516^3, 520^7, 578^2, 705^7; source of alkaline compounds, 514^3.
Garrett, H. L., brick yard, 713^8.
Gas retorts, manufacture, 788^3.
Gay, Robert, brick yard, 722^1.
Geddes, paving brick manufacture, 756^8–57^6.
Genesee county, drain tile works, 771^9–72^4; shale, 829^5.
Genesee river, clay deposits, 573^8; Medina shale, 826^9–27^1; Cashaqua shale, 834^8; Chemung shale, 836^8–37^1.
Geneva, brick yards, 718^6.
Geologic distribution of clays, 572–627.
Georgia, clay deposits, 615^3; kaolins, 793^8.
Gerlach, O., on efflorescence, 680^6–81^1, 682^3–83^4.
German brick and tile co., 720^3.
Germany, glass-pot clays, 787^8.
Gilette, Mrs C. S., brick yard, 718^4.
Gilliland & Day, brick yard, 710^2.
Glacial action, at Long Island, 606^5; at Staten Island, 607^8.
Glacial deposits, 575^3, 576^6, 584^7, 591^6, 604^1, 609^6, 620^4.
Glacial scratches, 577^6, 579^3, 582^4, 584^2, 588^2.
Glaciated boulder, illus. facing p. 582.
Glasco, terrace, 579^1; brick yards, 700^9–1^7; clay deposits, 700^9–1^7.
Glass-pot clay, 618^3, 786^5–87^9.
Glass pots, manufacture, 544^5.
Glazed brick, 650^8, 652^4.
Glazed tile, 777^3, 779^3.
Glazes, calcareous clays used in manufacture, 521^5; use of Hudson valley clays for, 689^2; pottery, 796^9–97^7.
Glazing, brick, 652^4; terra cotta, 762^4; sewer pipe, 767^6; stoneware, 806^6–9^2;

white earthenware and porcelain, 809^7–11^3, 813^3–14^1.
Glencove, clay deposits, 596^5, 605^8; crumpled layers, 606^7; stoneware clays, 817^6, 818^7–20^3, 820^6.
Glens Falls, tests of brick, 647^7.
Glens Falls brick and terra cotta co., 650^6, 760^6–61^1, 763^9, 764^5.
Glost kiln, 814^3; illus. facing p. 807.
Gloversville, brick yard, 714^4.
Gneiss, 582^3, 583^4, 584^1, 584^8, 585^2, 586^1, 586^4.
Gold work, 816^2.
Goldrick, Philip, brick yard, 694^2.
Goodwin & Delamater, brick yard, 718^7.
Goshen, brick yard, 731^8.
Gouverneur, brick yards, 710^5; clay deposits, 710^5; stratification, 710^6.
Graham chemical stoneware works, 823^4; illus. facing p. 800–1, 824.
Granite, 583^4, 584^3, 584^8, 585^2, 586^4.
Graniteware, 793^5.
Graphite, used to prevent shrinkage, 548^1, 550^3.
Grassy Point, clay deposits, 583^8.
Gravity planes, 633^8.
Greatneck, clay deposits, 596^3, 605^8; stoneware clays, 817^6.
Grecian magnesite, 785^4.
Green Point porcelain works, 823^6.
Greenbush, *see* Rensselaer.
Greene county, brick yards, 702^5–3^5, 704^2; shale, 832^5–34^5.
Greenport, clay deposits, 604^1, 736^4; brick yard, 736^4.
Greenridge, clay deposits, 607^7, 609^2, 609^6; brick yard, 742^6.
Griggs, C. G. & Co., brick yard, 698^1.
Grimes, H. C., brick yard, 714^1.
Grogs, used to prevent shrinkage, 548^1; purification, 635^3.
Gumbo clay, in Missouri, 622^7.
Gypsum in clay, 507^5, 520^7, 522^8–23^4.

Haake, F., brick yard, 723^5.
Hacking, 669^7.
Half Moon, brick yard, 708^8.
Hall, Horace, brick yard, 731^4.
Hall, James, on Chemung shale, 836^5–37^2; on clay deposits in N. Y., 574^5; on Gardeau shales, 834^9–35^2; on divisions of Hamilton shale, 832^2; on impressions in clay, 594^5; on Niagara shale, 828^5; on Salina shale, 829^4–30^1.
Halle, Germany, kaolin, 499^8.
Halloysite, 505^1, 505^8.
Hamilton shale, 831^5–34^5; physical tests, 831^2; analysis, 833^7.
Hammond, William, brick yard, 735^8; illus. facing p. 735.
Hand-picking, 634^5, 635^4.
Hand-power dry-press machine, illus. facing p. 665.
Harris & Ginley, brick yard, 697^3.
Harvey, John, brick yard, 718^5.
Haulage, machines used, 654^5; cable, 633^7, 686^7; with cars, 633^8; with carts, 632^9–33^3; with gravity planes, 633^8; with locomotive, 633^5; steam, 686^7.
Haverstraw, tests of brick, 648^1, 695^1; brick yards, 693^4–94^6; clay concretions, 593^7; clay deposits, 577^3, 584^5; illus. facing p. 693; delta deposits, 588^7, 589^4; dredging, 632^5; terraces, 583^2, 590^5.
Hayne, P., brick yard, 731^8.
Hecht, H., on cones, 554^8; on glazes, 653^1, 796^9–97^7; investigations on composition of porcelains and white earthenware, 795^7–97^7.
Hedges, C. A. & A. P., brick yard, 696^2.
Hematite, 516^1.
Hempstead harbor, clay deposits, 596^5.
Herkimer county, brick yards, 713^7, 714^7.
Hilfinger Bros. pottery works, 824^5.
Hill, R. T., on uses of clays, 564^7–65^5.
Hilton, William, brick yard, 724^7–25^2.
Hofman, H.O., use of Bischof's method, 558^4; experiments on refractoriness of clay, 563^7; experiments on fusibility of clay, 782^8.
Hog neck, clay deposits, 603^8.
Hollick, Arthur, fossils found by, 602^2; identification of fossils, 602^5; on glacial origin of Long Island hills, 606^6; on origin of Long Island sound, 607^3; on plant remains, 609^4, 610^7.
Hollow brick, 773^1; manufacture, 769^8; illus. facing p. 767, 769, 773–74; manufacturers, 913^2–25^4.
Homer, brick yard, 731^4.
Hoosick Falls, brick yard, 709^6; clay deposits, 709^6.
Hornblende, in clay, 509^2, 516^8, 520^7, 524^3; source of alkaline compounds, 514^3.
Hornellsville, brick yards, 725^7–26^5; paving brick manufacture, 756^4; illus. facing p. 756; shale, 831^4, 839^1.
Hornellsville brick and tile co., 725^7.
Horseheads, Chemung shale, 840^6–41^2.
Horseheads brick co., 727^2; illus. facing p. 653, 679, 727.
Horseheads, Empire brick works, illus. facing p. 840.
Horseshoe tile, 770^9, 771^2.

Hudson, clay deposits, 588^1, 703^6; brick yards, 703^6.
Hudson river brick co., 692^7.
Hudson river shale, 578^8, 826^8.
Hudson valley, terraces, 578^3–91^6, 629^5; illus. facing p. 592; depth of preglacial channel, 581^4; probable geologic history, 584^9, 591^6; delta deposits, 588^5; brick yards, 689^5–709^5;
clays: 523^6, 576^8; stratification, 577^3; illus. facing p. 577; underlying material, 577^9–78^3; illus. facing p. 578; recent borings, 588^3; physical character, 687^7; uses, 689^1.
Hunter, Alfred, brick yard, 707^1.
Hussey mountain, terrace, 590^8.
Hutton, W., brick yard, 699^8, 700^8.
Hyatt, C., brick yard, 692^8–93^1.
Hydraulic dry press machine, 665^6.

Ilion, brick yard, 714^7; clay deposits, 714^7.
Impurities of clay, 508^9, 511^5–28^4; testing for, 856^3.
Indian bay, brick yard, 710^2.
Indian creek, delta deposits, 588^8.
Indiana, clay deposits, 615^7–16^9.
Indiandite, 505^8.
Iron, in clay, 512^4, 566^8, 569^7; in brick clay, 636^6, 640^2; separation from clay, 634^9–35^3; sulfates of, 680^4.
Iron carbonate, *see* Siderite.
Iron oxid, in clay, 508^4, 508^9, 511^2, 512^4, 515^6–20^5, 565^6, 569^1, 639^6, 861^3; in feldspar, 635^5; in decorative tile, 777^6. *See also* Analyses.
Ironstone china, 793^5.
Ithaca, clay deposits, 576^6.
Ivory creek valley, 584^6.

Jamestown, brick yards, 725^3; stratification, 725^4; shale, 831^4, 837^2.
Jamestown shale paving brick co., 756^7, 837^2; illus. facing p. 663, 677, 757, 837.
Japanese porcelain, composition, 796^1.
Jefferson county, brick yards, 710^9–11^2, 711^4.
Jewettville, brick yards, 650^7, 724^2; illus. facing p. 662, 664, 665, 672, 724; Hamilton shale, 833^2.
Jigging, 805^3–6^1.
Jollying, 805^3–6^1.
Jones, C. C., on Hudson river clays, 588^5.
Jones, Gomer, method for testing the resistance of paving brick to abrasion, 752^6–54^7.
Jones, O., brick yard, 734^7.
Jonespoint, clay deposits, 583^2; terrace, 589^2.
Jova, J. J., brick yard, 698^8.

Kames, 584^7, 591^6. *See also* Eskars.
Kansas, clay deposits, 617^1.
Kaolin, alkalis in, 515^4; analyses, 610^8, 862–65; composition, 510^2, 512^7, 534^5; structure of deposits, 628^5; ferric oxid in, 519^8, 520^5, 793^6; impurities, 510^7; lime in, 523^8; magnesia in, 524^9; mica in, 503^8, 535^3; origin of name, 497^6; pure, 497^5, 510^2; silica in, 525^9; tensile strength, 545^5; use of term, 497^4; washing, 504^7, 800^4–3^4; water in, 530^5;
in Arkansas, 612^5; Delaware, 614^4; Florida, 614^6; Georgia, 615^4; Indiana, 615^8; Long Island, 596^9; Maryland, 619^8; Massachusetts, 620^2; Missouri, 621^4; North Carolina, 623^8, 624^8; Pennsylvania, 625^7; Staten Island, 607^7, 609^5; Virginia, 627^3.
Kaolinite, 497^7–501^6, 503^3–4^9, 510^5, 525^2; formation, 497^7; properties, 534^8; use of term, 497^3;
in Missouri, 621^4; New Jersey, 623^8.
Kennedy, F. H., brick yard, 715^7.
Kentucky, clay deposits, 617^8–18^4; flint clays, 781^7; ball clays, 793^8.
Keramics, *see* Pottery.
Kilns, building, 674^5; continuous, 495^4, 678^7–79^4, 814^6; cooling, 676^7; downdraft, 673^6, 674^1, 677^9–78^3, 745^6, 814^5; for enameled brick, 652^3; for paving brick, 745^7; scove kiln, 674^2, 674^4–77^3, 689^4; for stoneware, 809^6; types, 495^4, 655^5, 673^6, 677^4–79^4, 814^5; for white earthenware and china, 814^2.
King & Lynch, brick yard, 692^5.
Kinkel, P. H., & Son, feldspar quarry, 842^6.
Kirkover, L., brick yard, 723^5.
Kline, J., brick yard, 699^2.
Kneading machines, 804^5.
Kreischer, B. Sons, brick industry, 650^6; illus. facing p. 782–86; terra cotta factory, 763^9, 764^4; illus. facing p. 763–64; fire brick factory, 788^2, 788^3; illus. facing p. 784–86.
Kreischerville, clay deposits, 607^7–9^2; illus. facing p. 608, 781; brick yard, 650^6, 743^3; terra cotta manufacture, 763^9, 764^4; stoneware clays, 817^5, 820^6.
Kyser, A. C., brick yard, 713^7.

Lahey Bros., brick yard, 697^7.
Lancaster, brick yards, 722^8–23^3; clay deposits, 722^8–23^3; stratification, 723^2.
Lancaster brick co., 722^8, 723^2.
Lansingburg, brick yard, 708^4; clay deposits, 708^4.
La Salle, clay deposits, 574^7; brick yard, 722^5.

Leaves, in clay beds, 576^4, 594^5, 605^4, 610^7; illus. facing p. 611, 820; in sandstone, 596^5, 605^8.
Le Chatelier's thermoelectric pyrometer, 560^1–61^2.
Lefever Falls, stratification, 580^6.
Lemberg, J., on kaolinization of feldspars, 498^4.
Leroy, shale, 831^1.
Lester, A., brick yard, 718^5, 772^5.
Levant, clay deposits, 576^1.
Lewis county, shale, 826^8.
Lewiston, clay deposits, 575^1; shale beds, 827^1–28^1.
Lignite, in clay, 596^4, 609^8.
Lignitic shales, in Louisiana, 619^4.
Lime, in clay, 506^9–7^4, 511^2, 512^4, 520^5–23^8, 547^5, 565^9, 568^3, 569^7, 652^9, 861^8; in brick clay, 523^7, 569^1, 636^7, 640^2, 641^4; separation from clay, 634^5, 728^9; sulfates of, 680^4. *See also* Analyses.
Limestone, 520^7, 582^1, 584^4, 587^2; pebbles, 573^6, 585^2, 722^9, 723^8.
Limonite, 516^1, 585^2, 603^5. *See also* Iron oxid.
Linden, clay deposits, 574^8.
Lithia, 512^6.
Lithium, 511^3.
Littlefield, C. H., brick yard, 701^5.
Little neck, stoneware clay, 602^2, 817^6, 820^6; illus. facing p. 819–20; clay deposits, 605^7.
Lloyd's neck, sponge spicules, 599^3.
Loams in Alabama, 611^5.
Locke, F., manufacturer of electric supplies, 824^3.
Lockport, shale, 828^6.
Lockport brick co., 722^4.
Lockville, shale, 829^7.
Locomotive, haulage with, 633^5.
Locomotive blocks, 613^9.
Locy Bros., brick yard, 727^5, 728^1.
Loess, per cent of quartz in, 525^4; in Colorado, 613^1; in Kansas, 617^1; in Missouri, 622^5.
Long Island, glacial origin, 606^5; cost of producing brick, 685^7; brick yards, 733^6–42^5.
Long Island brick co., 736^4.
Long Island City, pottery works, 823^3.
Long Island clays, 495^2, 572^3, 573^3, 595^6–607^6, 629^5, 823^4; probable geologic history, 605^5; stoneware clays, 817^5–22^9; terra cotta clays, 761^2.
Long Island sound, preglacial origin, 607^1.
Longbottom, G., brick yard, 735^5.
Louisiana, clay deposits, 618^4–19^4.
Low point, terrace, 586^9; delta deposits, 588^7; brick yard, 697^5.
Lowe, J. R., clay bank, 726^9–27^1.
Lyons, brick yard, 718^8.
Lyons pottery co., 824^5.
Lyth, John, & Sons, sewer pipe works, 769^3, 835^2; illus. facing p. 767–69, 774.

McCabe Bros., brick yard, 742^6.
McCarthy, T., brick yard, 706^8.
McConnellsville, fullers' earth, 849^6–50^3.
McDuffie, H., brick yard, 714^4.
Machines, 495^8; used in manufacture of brick, 654^5–55^6, 689^3; used in manufacture of pottery, 804^5.
McLean, Alexander, brick yard, 702^5–3^1.
Madison county, brick yards, 715^5, 731^6; drain tile works, 771^6.
Madrid, brick yard, 712^5; clay deposits, 575^6, 712^5.
Magnesia in clay, 511^2, 523^8–24^9, 565^9, 861^3; in brick clays, 524^8, 569^1, 640^2. *See also* Analyses.
Magnesite, 508^7, 512^3.
Magnesite bricks, 784^4, 785^5.
Magnesium, 512^4.
Magnesium sulfate, 524^5, 680^4.
Magnetite, 509^8.
Magnets, use of, 635^2.
Maine, R., & Co., brick yard, 699^8, 700^8.
Maine, clay deposits, 619^5.
Majolica, 798^4, 815^2.
Malden, clay deposits, 578^9, 700^8; brick yard, 700^8.
Malley, R., brick yard, 694^2.
Manchester, D. S., brick yard, 699^8.
Manganese, 512^4, 639^7.
Manganese brick, 646^3.
Manganese oxid, 511^2, 512^4, 567^5, 777^6.
Maplewood, brick yard, 722^1.
Marcellus shale, 830^9–31^4.
Markets, for bricks, 687^3.
Marl, 507^3, 508^7, 640^5.
Maryland, clay deposits, 619^7.
Massachusetts, clay deposits, 620^1.
Mastodon bones, 583^1.
Mather, W. W., on leaves in clay beds, 594^5.
Meade, J. V., brick yard, 697^3; clay bank, illus. facing p. 592.
Mechanical analysis of clays, 561^2–63^9.
Mechanicville brick co., 708^8.
Mecusker, M. J., & Son, brick yard, 725^3.
Medina shales, 825^8, 826^9–28^1.
Merrick, C. H., brick yard, 715^7.
Merrill, F. J. H., on clay near Farmingdale, 605^1; on clay at Gardiner's island, 603^8; on delta deposits of Hudson river tributaries, 588^8–89^6; on geologic history of Hud-

son valley, 591^{7}–93^{8}; geology of Long Island, 596^{1}; glacial origin of Long Island hills, 606^{5}; on origin of Long Island sound, 607^{1}; on plant remains in clay, 597^{2}; on terraces, 579^{5}; on occurrence of white fire clay, 597^{6}.
Merrill, G. P., definition of clay, 496^{5}.
Meyers, M., brick yard, 738^{7}–40^{1}.
Mica, 503^{8}, 507^{7}–8^{8}, 512^{8}, 513^{4}, 514^{6}, 516^{8}, 524^{2}, 549^{2}; source of alkaline compounds, 514^{3}; a clay substance, 534^{9}–35^{3}.
Michigan, clay deposits, 620^{3}.
Micro-organisms from clays, 598–601; illus. facing p. 600–1.
Middle Granville, brick yards, 709^{7}; clay deposits, 709^{7}.
Milwaukee brick, 636^{8}.
Mineral paint, 848^{1}.
Mineralogy of clays, 503^{1}–9^{9}.
Mining clay, methods, 631^{3}–33^{8}, 654^{4}.
Minisceongo creek, delta deposits, 588^{9}; clay deposits, 693^{5}; brick yards, 694^{3}.
Mississippi, clay deposits, 620^{7}.
Missouri, clay deposits, 621^{1}–22^{7}; brick clays, 638^{4}; flint clays, 781^{7}; glass-pot clays, 787^{3}; ball clays, 793^{8}.
Mohawk valley, clay deposits, 576^{7}.
Molding, 661^{5}–68^{7}; illus. facing p. 661–66; modern methods, 495^{3}; machines used, 655^{1}, 665^{1}; electrical supplies, illus. facing p. 816; fire brick, 784^{7}; hollow brick, illus. facing p. 773; pottery clays, 799^{3}, 804^{3}–6^{3}; roofing tile, illus. facing p. 765; stoneware, illus. facing p. 800–1; terra cotta, illus. facing p. 762–64.
Molding sand, 670^{5}.
Monroe county, brick yards, 720^{3}–22^{8}; shale, 828^{6}.
Montauk point, clay deposits, 606^{1}.
Montgomery county, brick yards, 713^{7}, 714^{1}; shale, 826^{8}.
Montmorillonite, 505^{3}.
Montrose, clay deposits, 585^{6}; brick yards, 691^{7}–92^{2}.
Moodna river, delta deposits, 581^{7}, 582^{8}, 696^{3}.
Moore, J. C., brick yard, 706^{7}.
Morley, C. A., brick yard, 725^{8}.
Morrisania, pottery works, 823^{3}.
Morrisey, T. F., brick yard, 708^{4}.
Morton, J., brick yard, 692^{8}–93^{1}.
Mosher Bros., brick yard, 696^{1}.
Mosquito inlet, clay deposits, 596^{5}.
Mottled brick, 646^{3}, 650^{5}.
Mt Marion, clay deposits, 578^{9}.
Mt Morris, depth of clay, 574^{3}.
Muffle kiln, 814^{4}.
Muffles, 613^{9}.
Muhlheim clay, 544^{1}.
Murder creek, terrace, 591^{3}.
Murray, J. E., brick yard, 708^{1}.
Muscovite, 513^{4}, 514^{6}.

Nebraska, clay deposits, 623^{6}.
New Hamburg, terrace, 581^{1}; delta deposits, 588^{3}.
New Jersey clays, 572^{3}, 622^{6}–23^{6}, 823^{4}; titanium in, 526^{3}; plasticity, 542^{2}; continued on Staten Island, 608^{1}; fire clays, 788^{2}; ball clays, 793^{8}.
New Paltz, clay deposits, 732^{4}.
New Paltz brick co., 732^{4}.
New Windsor, clay deposits, 577^{4}, 581^{7}, 696^{5}; illus. facing p. 582; delta deposits, 588^{7}, 589^{4}; brick yards, 696^{5}.
New York Anderson pressed brick co., 743^{3}.
New York architectural terra cotta co., 650^{6}, 760^{1}, 761^{2}, 763^{9}, 764^{1}; illus. facing p. 759, 761–63.
New York city, depression of land, 591^{8}; pottery manufacturers, 823^{2}.
New York fullers' earth co., 849^{7}.
New York hydraulic brick co., 719^{7}–20^{2}.
New York paving brick co., 756^{8}–57^{8}; illus. facing p. 757.
New York state, occurrence of clay, 572^{5}–611^{2}; sedimentary origin of clay, 629^{2}.
New York state drain tile works, 771^{5}.
New York state veterinary college, illus. facing p. 719.
Newbrand, Joseph, pottery works, 823^{3}.
Newburgh, clay deposits, 581^{7}; delta deposits, 588^{9}.
Newell, J. L., use of Bischof's method, 558^{7}.
Newfield, clay deposits, 576^{6}, 728^{4}–31^{3}; tests of brick, 648^{4}; brick works, 650^{7}, 728^{4}–31^{3}; illus. facing p. 656, 668; paving brick manufacture, 756^{6}.
Newton Bros., brick yard, 708^{6}.
Newtonite, 505^{5}.
Niagara county, clay deposits, 575^{1}; brick yards, 722^{5}.
Niagara Falls, clay deposits, 574^{7}.
Niagara shale, 828^{4}–29^{1}, 829^{5}.
Nickel oxid, 777^{6}.
Noble, F. W., brick yard, 704^{2}.
Nolan, T., brick yard, 715^{7}.
Norite, 583^{9}.
Norman tile, 646^{5}; illus. facing p. 463.
North Carolina, kaolin, 500^{4}, 793^{8}; clays: 623^{8}–24^{6}; per cent of quartz in, 525^{5}; tests, 541^{7}; brick clay, 638^{3}.
North Dakota, clay deposits, 624^{7}.
Northport, diatoms, 603^{4}; stoneware clay, 820^{4}–22^{9}.

Northport bay, stoneware clay, 602^2; illus. facing p. 819–20.
Northport clay and fire sand co., 820^4–22^9; illus. facing p. 820.
Northrup, E. B., clay pit, 724^5.
Northrup, J. I., on rhizomorphs, 593^9.

Oakland valley, brick yards, 732^3; clay deposits, 732^3.
Ocher, 598^4, 848^2.
Ogden brick co., 731^5.
Ogdensburg, clay deposits, 575^5, 711^9–12^4; brick yards, 711^9–12^4.
Ohio, clay deposits, 624^8–25^4; fire clay, 536^1–37^9; flint clays, 781^7; glass-pot clays, 787^8.
Oldfield Bros., brick yard, 693^3.
Olschewsky, W., on plasticity, 540^8–41^1; on per cent of water in clays, 543^3.
Oneida county, brick yards, 713^8, 714^8–15^5; shale, 826^3.
Oneonta, brick yards, 731^7.
Onondaga county, brick yards, 715^6–18^2.
Onondaga pottery co., 823^7; illus. facing p. 792, 795–97, 802, 804–7.
Onondaga vitrified pressed brick co., 715^9–17^5, 830^2; illus. facing p. 663, 671, 678, 715, 744, 773, 830.
Ontario county, brick yards, 719^1–20^2; drain tile works, 771^8; shale, 829^5.
Open yards, 669^3.
Orange county, brick yards, 696^2, 698^3, 731^8–32^2, 732^6–33^5.
Ore-balls, 782^1.
Organic matter in clay, 509^9, 511^2, 527^6–28^4, 860^3. *See also* Analyses.
Orleans county, brick yards, 722^4.
Ornamental brick, 646^6; value of output, 493^7, 494^5; manufacturers, 913^3–25^4.
Orton, Edward, jr, cones for sale by, 554^6; rattling tests on paving brick, 751^2.
Oswego Falls, brick yard, 718^3; clay deposits, 718^3.
Oswego valley, clay deposits, 575^4.
Otis & Gorsline, sewer pipe works, 769^9.
Otsego county, brick yards, 731^7.
Ouimet, J., brick yard, 709^9; illus. facing p. 661, 674.
Overbaugh, D. C., brick yard, 701^5.
Owasco, brick yard, 718^5; drain tile works, 772^5.
Ownership, of brick yards, 685^9; of clay banks, 685^9–86^2.
Oyster bay, clay deposits, 597^5, 734^8; brick yard, 734^8.

Paige Bros., brick yard, 711^9–12^4.
Paint, 848^1.
Painting, *see* Decoration.
Pale bricks, 676^6, 677^2.
Paleozoic fossils, *see* Fossils.
Pallet driers, 670^3; illus. facing p. 669.
Pallet-squarer, 670^7.
Pallet yards, 669^3; illus. facing p. 670.
Pan crushers, 656^4; illus. facing p. 653, 656, 759, 765.
Paper clay, 852^1.
Parian ware, 798^7.
Parker M., brick yard, 722^3.
Parry, W. W., brick yard, 647^8, 715^1.
Pass & Seymour, pottery works, 824^1; illus. facing p. 791, 809, 814–15, 817.
Paving brick, 673^6, 743^5–77^5; cities using, 743^6; end-cut, 664^5; total number produced in 1897, 743^5; repressed, 668^4; tests, 729^4–30^9, 745^8–50^8, 854^2; value of output, 493^7, 494^4; wearing power, 750^9–55^7;
  manufacture: 745^2; illus. facing p. 744–45; shales used, 502^5; auger machine used, 664^3; continuous kilns used, 679^4;
  in Arkansas, 612^7; Colorado, 613^8; Kansas, 617^2; Louisiana, 619^4; Maryland, 619^8; Michigan, 620^7; Missouri, 622^4; New York industry, 755^8–57^8, 913^3–25^4.
Paving brick clay, fluxes in, 512^7; composition, 743^8–45^1; analysis, 900^5–3^9.
Pebbles, 573^6, 578^1, 582^3, 585^2, 587^2, 592^6, 596^8, 705^7, 722^9, 723^8, 728^9; separation from clay, 634^5.
Peck, B. F., drain tile and brick manufacture, 771^9–72^4.
Peconic bay, clay deposits, 603^8.
Peekskill (stream), delta deposits, 588^8; illus. facing p. 588.
Peekskill (town), terrace, 585^9–86^1, 590^6; brick yard, 693^2.
Pegmatite, 584^8.
Penfield, M.A., fullers' earth mine, 850^2.
Penn Yan, Cashaqua shale, 834^7.
Pennock, J. D., experiments on refractory brick, 785^4–86^4.
Pennsylvania clays, 625^5; titanium in, 526^9; flint clays, 781^7; glass-pot clays, 787^8.
Pepper, J. H., brick yard, 709^7.
Permeability of clay wares, 854^8–55^8.
Phosphoric acid, 511^2, 860^8. *See also* Analyses.
Physical properties of clay, 510^7, 538^7–61^2.
Piffard, depth of clay, 574^2.
Pipe clay, in New Jersey, 623^8; analysis, 904^4–7^8.
Pipe tile, 770^9.
Plant impressions, illus. facing p. 611.

Plasticity, of clays, 496^5, 504^3, 528^3, 530^7, 539^1–44^7, 637^3, 845^2; of paving brick, 744^4; of glass-pot clays, 786^8; of stoneware clays, 791^8–92^1; of shales, 825^3.
Platting, 674^7.
Plattsburg, clay deposits, 595^5, 709^8–10^4; brick yards, 709^8–10^4; illus. facing p. 661, 674.
Plows, use of, 631^6.
Plunger machine, 663^3; illus. facing p. 664–65.
Pocantico river, delta deposits, 588^8.
Polishing and abrasive materials, 852^9–53^1.
Pompeian brick, 646^4.
Porcelain, 794^1–98^8; analysis, 794^5, 796^1; and white earthenware, comparative composition, 796^1; decoration, 814^7–17^4; illus. facing p. 805, 808; glazing, 809^7–11^3; manufacture, 514^9; illus. facing p. 791–92, 794–99, 802, 804; manufacturers, 823^6; value of output, 494^6; vitrification, 796^5.
Porcelain clays, 568^2; rational analysis, 538^3.
Porosity, of clay, 522^6, 672^5; of clay wares, 854^3–55^3.
Port Ewen, clay deposits, 577^4, 579^3, 699^1; terraces, 590^5; brick yards, 699^1.
Port Kent, terraces, 594^9.
Port Washington, sands and gravels, 607^5; illus. facing p. 596.
Portage shale, 769^3, 826^7; physical tests, 831^2; distribution, 834^6–36^3; analysis, 835^5.
Porter, I. R., brick yard, Athens, 704^8.
Porter, J., brick yard, Glasco, 701^4.
Portland cement, 845^6–47^9; clays and shales used in manufacture of, 689^2, 847.
Post, W. & J., brick yards, 733^6–34^2.
Potash, 511^2, 512^4, 512^7, 512^9, 513^4, 515^2.
Potsdam, brick yards, 711^2; clay deposits, 711^2.
Potters' clay, in Kentucky, 618^2; in New Jersey, 623^2; in South Dakota, 626^4.
Pottery, 791^1–824^5; decoration, 814^7–17^4; different grades, 791^3–98^8; glazes, 689^2, 810^2–11^3; manufacture, 620^3, 798^9–814^5; illus. facing p. 791–808; manufacturers, 823^1–24^5; value of output, 493^9, 494^5.
Pottery clays, 799^1–806^3; alkalis in, 515^5; analysis, 878^9–81^8; lime in, 523^7; magnesia in, 524^8; silica in, 525^8; tensile strength, 545^5;
in Colorado, 613^6; Kentucky, 617^4; Maryland, 619^8; Mississippi, 620^9; North Carolina, 624^5.
Poutre, M., brick yard, 707^3.
Preparation of clay, 655^7–60^7; machines used, 654^7; pottery clays, 799^1, 799^5–803^4.
Prepleistocene clays, 606^3.
Pressed brick, 645^7–46^2; burning, 666^4; repressed, 668^4; illus. facing p. 463–64, 668; sorting, 679^6;
manufacture: clays used, 521^5, 639^4; use of shale, 827^4;
in Colorado, 613^5; Indiana, 616^8; Louisiana, 619^2; value of output in New York, 493^6, 494^3; New York manufacturers, 650^9, 913^2–25^4.
Preston brick co., 756^4; illus. facing p. 756.
Preston Bros., brick yard, 715^7.
Printed ware, 815^8–16^1.
Prospecting for clay, 629^3–30^2.
Puddle, 853^8.
Pug mills, 660^2, 804^2; illus. facing p. 660, 663, 761, 782.
Purification of clay, 633^9–35^3.
Putnam county, brick yards, 695^9.
Pyramids, *see* Seger cones.
Pyrite, 508^5, 516^3, 604^3, 646^3, 680^5; separation from clay, 634^5.
Pyrometer, 553^6, 560^1–61^2.
Pyrophyllite, 505^3.
Pyroxene, source of alkaline compounds, 514^3.

Quartz, 506^2, 525^1, 526^2, 565^9, 578^1, 596^8, 652^9, 705^7, 793^8, 841^3–44^2; aid to fusion, 563^6; mineralogic characters, 841^3–42^3; preparation, 843^3; illus. facing p. 793; price, 843^9–44^2; properties, 534^8; uses, 547^3, 548^7, 843^6. *See also* Silica.
Quartzite, 584^3.
Quassaic creek, delta deposits, 581^7, 588^9.
Quaternary clay deposits, 572^4, 573^3.
Queens county, brick yards, 733^6–34^5.

Railroads, use of clay in construction, 853^5.
Randolph, clay deposits, 576^1; brick yard, 725^6; shale, 848^4.
Rathenow, analysis of clay from, 570^2.
Rational analysis, 533^2–38^7.
Rattlers, 746^4, 752^6.
Rattling tests on paving brick, 751^2.
Ravena, quaternary plain, illus. facing p. 591.
Ravenswood, New York architectural terra cotta co., 763^9, 764^1.
Raymondville, brick yard, 712^8; clay deposits, 712^8

Rectorite, 505^4.
Refractoriness of clay, 511^6, 526^2, 563^7; of fire clays, 563^7, 781^8, 782^7–83^3; of glass-pot clays, 786^8; of stoneware clays, 792^2.
Refractoriness of shale, 841^2.
Refractory clay products, 639^6, 783^4–84^8.
Remole, ——, on color of hard-burned clays, 517^3.
Rensselaer, brick yard, 707^4; clay deposits, 707^4.
Rensselaer county, brick yards, 707^4, 708^4, 709^6.
Repressed power brick, illus. facing p. 464.
Repressing bricks, 668^4, 745^4; illus. facing p. 668, 784.
Residual clays, 501^1, 501^6; occurrence, 572^7–73^2; structure, 628^1; analysis, 860^4–61^8.
Rhinebeck, stratification, 587^4.
Rhizomorphs, 593^9.
Ries, Heinrich, on terrace altitudes, 590^9.
Reisterer, Martin, brick yard, 722^7.
Rigney, Mrs T., brick yard, 707^4.
Riley & Clark, brick yards, 694^8.
Riley & Rose, brick yard, 694^8.
Ring pits, 659^4–60^1; illus. facing p. 659.
Road materials, clay or shale used for, 853^2.
Roberts, J. B., brick yard, 707^8.
Robitzels's Sons pottery works, 823^8.
Rochester, brick yards, 720^8–21^9; clay deposits, 720^8–21^9; pottery works, 824^5; sewer pipe manufacture, 769^9; shale, 828^8; stratification, 720^8.
Rochester brick and tile co., 720^8–21^9; illus. facing p. 652, 660, 669, 679, 720, 773.
Rock face brick, 647^1; illus. facing p. 463.
Rockingham ware, 793^1, 814^9.
Rockland county, brick yards, 693^4–95^8; illus. facing p. 693.
Rockwell, G. A., use of Bischof's method, 558^7.
Roman tile, 646^4; illus. facing p. 463.
Rome, clay deposits, 576^7, 714^8–15^2; brick yards, 714^8–15^2.
Rondout, clay deposits, 699^5; terrace, 579^1.
Rondout creek delta, 577^6.
Rönne, Denmark, kaolins, 498^4.
Roofing tile, manufacture, 765^1–66^8, 837^7; illus. facing p. 765; properties, 854^6–55^1; manufacturers, 913^2–25^4.
Roots, separation from clay, 634^5.
Rose & Co., brick yard, 688^3, 698^3; illus. facing p. 658, 698.
Rose, A., & Co., brick yard, 701^5.
Rose, H. R., brick yard, 702^1.
Rosendale, stratification, 580^3.
Rosendale plains, stratification, 580^8.
Roseton, clay deposits, 581^2, 698^3; delta deposits, 589^2; brick yards, 688^3, 698^3; illus. facing p. 658, 698.
Roseville, terra cotta clays, 759^9–60^5.
Rough hard bricks, 678^5.
Russia, glass-pot clays, 787^8.
Rutile, 509^4.
Ryan, T., terra cotta clays, 759^9–60^5.
Ryder, William, brick yard, 704^5.

Sag Harbor, clay deposits, 603^8.
Saggers, 652^3, 811^4–12^2.
St Johnsville, brick yard, 713^1; clay deposits, 713^1; stratification, 713^2.
St Lawrence county, clay deposits, 575^6; brick yards, 710^5, 711^2, 711^9–12^9.
St Louis fire clays, per cent of quartz in, 525^4.
Salina shale, 825^7, 829^2–30^8; illus. facing p. 830.
Salmon brick, 645^3, 677^5.
Salt group, 829^4–30^8.
Saltpeter, 680^1.
Salts, 512^4; in brick clay, 639^5, 640^8, 680^2; determination of, 856^6.
Sammis, R., brick yard, 736^1.
Sand, 525^2, 592^6; used to prevent shrinkage, 548^1, 548^7–49^6; in estuaries, 592^2; importance to clay industry, 629^9; in brick clay, 637^8.
Sandford, C. L., brick yard, 736^7.
Sandrock, 582^2, 584^8.
Sandstone, 582^2, 584^1, 584^8, 587^2, 596^8, 597^2, 605^8.
Saratoga, brick yards, 709^1; clay deposits, 709^1.
Saratoga county, brick yards, 708^6.
Sawdust, used to prevent shrinkage, 550^6.
Sawmill river, delta deposits, 588^8.
Schenectady, clay deposits, 576^7; terrace, 591^8; depression of land, 591^8.
Schenectady county, shale, 826^8.
Schist, 583^4, 584^8, 585^2, 586^4.
Schmidt, G. W., brick yard, 723^8.
Schodack terraces, 590^6.
Schrötterite, 505^8.
Schultz, C. A., brick yard, 699^8, 700^2.
Schusler & Co., brick yard, 723^5.
Scorifiers, 613^9.
Scotland, glass-pot clays, 787^8.
Scove kiln, 674^2, 674^4–77^3, 689^4; illus. facing p. 674.
Screens, 660^7–61^4, 801^9–2^4.

Sedimentary clays, 501^4, 501^7–2^5; occurrence in N. Y. state, 573^2–93^5; structure, 628^7–29^2.
Seger, H., classification of clay, 564^8, 567^7; on color of clay, 519^5, 565^5, 566^2, 566^6; on effect of iron in clay, 640^2; on ferrous condition of iron, 517^6; on marly clays, 522^5; on effect of heating plastic clay, 562^4; on plasticity, 543^5; method of rational analysis, 535^7; experiment on effect of titanium on clay, 527^2.
Seger cones, 553^8–58^2; composition and fusing points, 555^1.
Seger's porcelain, 795^4, 796^6.
Semi-dry process, 667^1.
Seneca county, brick yards, 718^6; shale, 829^5.
Seneca Falls, brick yard, 718^6.
Seneca river brick co., 717^6–18^2.
Sewer brick, 645^5.
Sewer pipe, clays, 767^1; porosity or permeability, 854^6, 855^2;
  manufacture: 768^1–70^1; illus. facing p. 767–69, 774; in Colorado, 613^8; Missouri, 622^4; New York manufacturers, 769^8–70^1, 913^8–25^4; value of output in New York, 493^8, 494^5; in Tennessee, 626^8.
Shale, 825^1–44^2; illus. facing p. 830, 837, 839–40; analyses, 716^1, 769^6, 899^4–901^4; distribution and properties, 502^3, 572^2, 578^1, 587^2, 826^8–41^2; formation, 502^1, 826^2; in Indiana, 615^9; in Michigan, 620^7; in Missouri, 622^3;
  uses: 494^8–95^2, 765^3, 769^3, 840^8, 845^2–53^9; for common brick, 686^8, 727^2; for mottled brick, 646^3; for paving brick, 502^5, 725^7, 743^8, 745^2.
Shankey, J. D., brick yard, 694^2.
Sharon Station, clay deposits, 572^8.
Shells in clay, 575^8.
Shrinkage, of clay, 522^5, 529^3, 530^6, 545^7–50^8, 636^8–37^1, 637^3, 639^7, 672^8; of porcelain, 795^4.
Siderite, 508^4, 516^3.
Siegfried, F., brick yard, 718^6.
Sienna, 848^3.
Sieves, use of, 634^6.
Signor, W. H., brick yard, 726^4.
Silica, 511^2, 511^7, 525^1–26^5, 860^8; and bases, action of heat on mixture of, 518^1. *See also* Analyses; Quartz.
Silica brick, 784^3, 785^5.
Simpson dry press brick machine, illus. facing p. 664.
Slags, 512^8.
Slip clays, 620^6, 806^6–9^1; analyses, 880^8–83^8.
Slumming, 561^4.
Smith, C. H. L., porcelain works, 823^7.
Smith, E., brick yard, 706^7.
Smith, J. S., brick yard, 713^1.
Smith's dock, terrace, 578^7; clay deposits, 700^6; brick yard, 700^6.
Soak pits, 658^6–59^8; illus. facing p. 658.
Soda, 511^2, 512^4, 512^9, 513^4.
Sodus Point, shale, 828^2.
Soft brick, 645^3.
Soft mud brick, illus. facing p. 464.
Soft mud process, 645^1, 661^5–64^5, 745^4; cost, 686^2; machines, 784^7; illus. facing p. 661.
Sole tile, 770^9, 771^1.
Sorting of bricks, 679^5.
South Bay, brick yard, 715^4; clay deposits, 715^4.
South Bethlehem, terrace, 591^2; illus. facing p. 591.
South Dakota, clay deposits, 626^1.
South Trenton, brick yard, 713^8; clay deposits, 713^8.
Southold, brick yards, 736^7–37^6; clay deposits, 604^1, 736^7–37^6.
Spar, *see* Feldspar.
Spar china, 794^2.
Spatting, 669^6.
Specific gravity of fire brick, 786^3.
Speckled bricks, 646^2.
Spencer, brick yard, 728^3; old lake bottom, illus. facing p. 573.
Sponge spicules, 594^4, 599^8, 609^5; illus. facing p. 600–1.
Springbrook, clay deposits, 724^5.
Staatsburg, terrace, 581^1.
Stanwix, D. H., brick yard, 706^7.
Staples, A. S., brick yard, 699^8, 700^8.
Staten Island, brick yards, 742^6–43^4; terra cotta manufacture, 763^9, 764^4;
  clays: 573^8, 607^6–11^2, 622^9, 628^9, 742^6–43^4; plant impressions, illus. facing p. 611; terra cotta clays, 759^9–60^5; fire clays, 788^2–90^6; stoneware clays, 817^5.
Statistics, clay industry, 493^5–94^7.
Steam drying, 671^8.
Steam power, use of, 662^5, 686^7.
Steam shovel, 632^8.
Stedman, disintegrator, 656^7.
Stephens, C., brick yard, 715^4.
Steuben county, brick yard, 725^7–26^8; Chemung shale, 839^1.
Stewart, brick yard, 740^2.
Stiff mud process, 645^1; machines, 495^8, 662^9–64^5, 784^7; illus. facing p. 662–63, 765; cost, 686^3.
Stock brick, 645^4.
Stockport, clay deposits, 588^1.
Stoneware, 791^5–92^9; burning, 809^3; decoration, 814^8–15^1; glazing, 806^6–9^2;
  manufacture: in Colorado, 613^8; Michigan, 620^7; manufacturers in

New York, 823^3–24^5; value of output in New York, 494^6; illus. facing p. 800–1.
Stoneware clays, 568^6, 602^2, 817^5–22^9; illus. facing p. 820; analyses, 792^6, 818^4, 819^8–20^3, 820^6;
in Alabama, 612^1; Missouri, 622^1; New Jersey, 623^4; Pennsylvania, 625^9.
Stonypoint, clay deposits, 577^4, 583^3; terraces, 590^5; brick yards, 694^6–95^5.
Stormking, terraces, 590^6; brick yards, 696^1; clay deposits, 696^1.
Stoutner, W. A., brick yard, 714^5.
Stove linings, 617^9.
Stratification, *see* Tables.
Streeter & Hendricks, brick yard, 699^8.
Stripping, 630^4.
Stuyvesant, clay deposits, 588^1, 703^9–4^2; brick yard, 703^9–4^2.
Suffolk county, brick yards, 734^6–52^5.
Sulfur, 642^4, 792^4.
Sulfur-balls, 508^7.
Sulfuric acid, 511^2, 861^3. *See also* Analyses.
Sullivan county, brick yards, 732^3.
Sutton & Suderly, brick yard, 705^1.
Syracuse, clay deposits, 575^4, 715^6; brick yards, 715^6; paving brick manufacture, 756^8–57^6; illus. facing p. 757; pottery works, 823^7–24^2; illus. facing p. 791, 792, 795–97, 802, 804–7, 809, 814–15, 817; Salina shale, 829^8.
Syracuse pottery co., 824^2.

Tables, crushing strength of brick, 647^6, 695^2; dimensions of common brick, 643^7; composition of paving brick, 744^1; brick testing, 730; depth of clay in Genesee valley, 574^1; sections of clay deposits, 858–59; value of clay output, 493^6; tests of North Carolina clays, 541^7; composition of Copenhagen biscuit ware and Seger's porcelain, 796^6; composition and fusibility of feldspar species, 842^1; Seger cones, 555^1–57^5; number of terraces, 590^5; terrace altitudes, 589^7;
stratification: at Coldspring Harbor, 598^1; Eddyville, 579^6–80^2; Farmingdale, 604^7; Freshpond, 735^6; Gouverneur, 710^6; Jamestown, 725^4; Jova's brick yard, 698^5; Kreischerville, 608^3; Lancaster, 723^2; Lefever Falls, 580^6; Levant, 576^3; Madrid, 575^6; Rhinebeck, 587^4; Rochester, 720^8; Rosendale, 580^8; Rosendale plains, 580^8; St Johnsville, 713^2; West Deerpark, 604^8, 741^3. *See also* Analyses.
Talbot, Prof., method of testing paving bricks, 754^7.
Tarrytown, delta deposits, 588^8.
Tarrytown porcelain tile co., 777^8.
Tempering, definition, 658^8; machines used, 654^7; methods, 655^7; of pottery clays, 799^2, 803^5–4^2.
Tennessee, clay deposits, 626^7.
Tensile strength, of clay, 541^5, 544^8–45^6, 637^8; of clay wares, 855^6–56^2; of glass-pot clays, 787^3; of stoneware clays, 792^1.
Terra cotta, general properties, 758^1–59^6; resistance to fire, 759^5; illus. facing p. 759; use of term, 758^4;
manufacture: 761^3–64^6; in Massachusetts, 620^2; Missouri, 622^4; manufacturers in New York, 763^8–64^6, 913^3–25^4; value of output in New York, 493^8, 494^5; illus. facing p. 759–64; in Pennsylvania, 625^9; Texas, 626^9.
Terra cotta clays, 759^9–61^2; analysis, 904^1–5^4.
Terra cotta lumber, 769^8, 773^2.
Terra cotta vase, frontispiece; illus. facing p. 764.
Terraces, table of altitudes, 589^7; Champlain valley, 594^7; forming at present, 591^5; Hudson valley, 578^3–91^6, 629^5; number of, table, 590^5; quality of soil, 591^8.
Terry Bros., brick yard, 699^8, 700^3; illus. facing p. 700.
Tertiary clay deposits, 572^3, 605^6, 606^2.
Testing, brick, 647^5–50^4, 729^4–30^9, 745^8–50^8; clay, 541^7, 631^2; clay wares, 854–57.
Texas, clay deposits, 626^9–27^2.
Thermoelectric pyrometer, 560^9–61^2.
Thickness of beds, varying, 629^7.
Thiells, brick yard, 695^6; clay deposits, 584^6, 695^6.
Thompson, G. R., brick yard, 710^5.
Three River point, 575^4.
Tibbitt's brook, delta deposits, 588^8.
Tile manufacture, in Kentucky, 617^9; Missouri, 622^4; New York manufacturers, 913^2–25^4; value of output in New York, 493^8, 494^5; illus. facing p. 745. *See also* Decoration of tile; Drain tile; Encaustic tile; Floor tile; Glazed tile; Roman tile; Roofing tile.
Timoney, F., clay bank, 697^2.
Tioga county, brick yards, 728^8.
Titanic acid, 511^2.
Titanic oxid, 860^3. *See also* Analyses.
Titanite, 509^8.
Titanium, 526^6–27^5.
Tompkins, T., & Son, clay bank, 694^9.

Tompkins & Smith, brick yard, 722^8.
Tompkins county, brick yards, 728^4–31^8.
Tonawanda, clay deposits, 574^7; brick yard, 722^7.
Tonawanda creek, Cashaqua shale, 834^8.
Topography, indications of clay deposits from, 629^3.
Torrey park land co., 718^7.
Townsend, P. M. C., brick yard, 727^6, 728^2.
Troy, brick yards, 707^6; clay deposits, 707^6; sewer pipe manufacture, 770^1.
Tunnel driers, 670^8–71^6; illus. facing p. 671.
Turner, J., brick yard, 725^6.
Turning, pottery clay, 804^9–5^2.

Ulster county, brick yards, 699^1, 699^8–701^7, 732^4.
Ultramarine manufacture, 852^7.
Underhill, W. A., brick yards, 691^4.
Undermining, 632^6.
Union porcelain works, 823^6; illus. facing p. 793–94, 799, 808, 816.
United States, occurrence of clay, 611^3–27^6.
Up-draft kiln, 673^6, 677^4.
Upham, Warren, on eskars, 575^8.
Uranium oxid, 777^6.
Uses of clay, 564^8–65^5, 636^1–42^8, 845^1–53^9.
Utica, pottery works, 824^5.
Utica shale, 579^2.

Vanadiates, 509^6.
Vanadium, 511^8.
Van Cortland, delta deposits, 588^8.
Van Dusen, F. M., brick yard, 701^8.
Vaughn, Charles, brick yard, 710^1.
Vernon, W. H., brick yard, 732^1.
Verplanck, clay deposits, 585^6; brick yards, 691^7–92^4.
Verplanck point brick yard, 692^8.
Vicat's needle for testing plasticity, 542^3.
Victor, pottery works, 824^8.
Virginia, clay deposits, 627^8.
Viscosity, 551^7, 563^3.
Vitrification, 551^5, 563^8.
Vitrified brick, 494^4, 551^5; glazing, 652^4;
  manufacture: in Alabama, 611^8; in Kentucky, 617^5, 617^9–18^1.
Vogt, G., on plasticity of clays, 504^2.
Von Buch, Leopold, on kaolin, 499^7.
Vulté, H. T., methods of analyzing clay, 530^8–38^7.

Walling up kilns, 674^8.
Wallkill valley, terrace, 590^8.
Walsh Bros., brick yards, 703^9–4^2.
Wappinger creek, delta deposits, 581^6, 588^3.
Ward, D. B., on diatoms, 599^1, 609^5.
Warners, brick yards, 715^9–17^5; illus. facing p. 671, 678, 715, 744, 773, 830; Salina shale, 829^3.
Warsaw, depth of clay, 574^8.
Warwick, clay deposits, 732^6–33^5.
Washburn, U. F. & Co., brick yard, 693^7.
Washburn Bros., brick yard, 700^9–1^8.
Washed brick, 645^6, 669^9.
Washing clay, 799^7–800^3.
Washington county, brick yard, 709^7.
Water in clay, 528^4–30^7, 543^3, 544^7, 860^3. *See also* Absorption; Analyses.
Water-smoke, 675^5.
Water-smoking, 529^4, 680^1, 681^8.
Watertown, clay deposits, 575^5, 711^4; brick yard, 711^4.
Watertown pressed brick co., 711^4.
Watson, Robert, brick yard, 712^5.
Wayne county, brick yards, 718^8; shale, 828^6, 829^4.
Weathering, 655^8, 856^8–57^1.
Weaver, G. F., sons, brick yard, 715^3.
Websters Corners, Hamilton shale, 833^9–34^2.
Weedsport, brick yard, 718^4.
Wegeli porcelain, composition, 796^1.
Weight, of brick, 528^9; of sand, 549^4.
Wells & Brigham, brick yard, 731^5.
West Deerpark, clay deposits, 604^2, 741^2.
West neck, clay deposits, 597^5, 602^1, 606^1, 734^6–35^4; crumpled layers, 606^5; brick yards, 734^6–35^4; illus. facing p. 735.
Westchester county, brick yards, 689^5–93^3.
Wet pan crushers, 803^7–4^1.
Weyer, P. J., brick yard, 727^4.
Wheeler, H. A., on plasticity, 541^8; on quartz in clay, 525^4; formula for relative fusibility of clays, 552^8.
White earthenware, burning, 811^4–14^6; decoration, 815^2–16^5; glazing, 809^7–11^3; manufacture, 514^9; New York manufacturers, 823^6; illus. facing p. 791–92; and porcelain, comparative composition, 796^1.
White granite, 793^5.
Whitehall, terraces, 594^8.
White wash, 681^1.
Whitfield, R. P., on crumpling of clay, 593^4.
Williams, C. L., brick yard, 709^1.
Williams H., tests made by, 647^5.
Willis, H. M., clay bank, 733^6.

Windom, Hamilton shale, 833^3, 834^2.

Wire-cut machines, 662^9; illus. facing p. 662–63.

Wire rope, haulage with, 633^7, 686^7.

Wolcott furnace, shale, 828^3.

Wood & Keenan, brick yard, 743^1.

Working clay, methods of, 631^8–35^6.

Wrape & Peck, brick yard, 710^9–11^2.

Wyandance, clay deposits, 741^5; illus. facing p. 741.

Wyoming, clay deposits, 574^8, 627^5.

Yards, *see* Brick yards.

Yates Center, clay deposits, 574^8.

Yellow clay, characteristics, 577^7.

Yellow gravel, 607^6, 607^9, 610^2.

Yellow ware, 793^1, 814^8–15^1.

Yonkers, delta deposits, 588^8.

York, depth of clay, 574^2.

Yttrium oxid, 511^8.

Zettlitz, Bohemia, kaolin, 544^1; kaolin mines, 500^2.

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Chatham Center
New Concord
Chatham
Ghent
Harlemville
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UNIVERSITY OF THE STATE OF NEW YORK
NEW YORK STATE MUSEUM
FREDERICK J. H. MERRILL
Director and State Geologist

MAP
OF THE
STATE OF NEW YORK
SHOWING THE
LOCATION OF CLAY AND SHALE DEPOSITS
AND
MANUFACTORIES
BY
HEINRICH RIES
1900

SCALE : 1 INCH = 12 MILES