THE GEOLOGY OF CLAYS

BY

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CONTENTS.

CHAPTER VII.

Geological Distribution of Clays and Shales.

With the exception of the Sioux quartzite, which presents limited exposures in the northwest corner of the state, every great rock formation exposed in the state contains more or less important argillaceous deposits. Such deposits range in character structurally from the highly fissile shales of the Lower Silurian and certain bituminous members of the Coal Measures to the structureless deposits of loess; in composition, all gradations may be observed from the purest fire clays to the most impure alluvial and drift deposits. The range in plasticity is equally great from the highly plastic potter's clays to the arenaceous shales and sandy surface clays. They not only show great diversity when the members of the different formations are compared, but the shales of the same formation are widely different and require different treatment, a fact which is not always appreciated in the clay industries. In the following pages the shale and clay members of the various formations are treated in chronological order. No attempt is made to describe or even enumerate all of the exposures for any rock series. Attention is directed rather to those exposures which are considered to be the most accessible and at the same time representative. But little space is devoted to the description of clay plants, only as such description throws light on the workability of the materials. Especial stress is laid

on the chemical and physical properties of the raw materials which would commend them to, or cause their rejection by, the clay worker. Workability and availability of the deposits are given the attention their importance merits.

THE SAINT CROIX SANDSTONE.

The Saint Croix Sandstone.—The Saint Croix comprises an essentially non-argillaceous rock series so far as its outcrops in Iowa are concerned. Minnesota geologists separate it into three divisions: the Basal sandstone, the Saint Lawrence shales and the Jordan sandstone is the sequence from the base upwards. As the names imply, the lowest and the uppermost members are almost exclusively sandstone, while the middle member is composed of shales, marls and limestones. The two upper members only appear on the surface in Iowa, and their outcrops are confined to Allamakee and Clayton counties. Their combined thickness, according to Norton, is about 300 feet. Calvin, in his report on the geology of Allamakee County, states that a bed of light colored shale is exposed in the road cutting near the northeast corner of the upland portion of the county, about two miles from New Albin. The shale lies about 200 feet below the summit of the Saint Croix and doubtless may be referred to the Saint Lawrence beds. No attempt has been made, so far as known, to utilize the shale commercially. The general dip to the south and west carries the beds below the stream, and no further exposures are known.

ONEOTA LIMESTONE.

The Oneota limestone extends from Winneshiek through Allamakee into Clayton county. The formation consists largely of the massive dolomite divided by a medial sandstone supposed to be the equivalent of the New Richmond of the Minnesota and Wisconsin geologists. The upper dolomite member often becomes

argillaceous near its summit. Such shale layers are reported by Professor Calvin in his Allamakee County report, but the beds lack persistence and are not of sufficient thickness to warraut their development on a commercial scale.

SAINT PETER SANDSTONE.

As the name implies, the Saint Peter is constituted almost wholly of a clean, well weather-worn, white sand but slightly indurated. The outcrops of the Saint Peter are confined to Winneshiek, Allamakee and Clayton counties. While certain beds of passage from the Saint Peter to the Trenton limestone become more or less argillaceous in character, no shales or clays appear in the surface exposures.

THE GALENA-TRENTON.

The Galena-Trenton comprises the lower limestone series often grading downward into a fissile blue or green shale with intercalated shales of less importance throughout; and an upper massive dolomitic member often designated the Galena-Trenton because it contains most of the workable lead deposits of the Iowa-Illinois-Wisconsin area. The Galena-Trenton extends from Howard to Dubuque and Jackson counties and comprises considerable areas in Winneshiek, Allamakee and Clayton counties. The principal outcrops are confined to the Mississippi, Upper Iowa, Yellow and Turkey rivers and their immediate tributaries.

Allamakee County.—In Allamakee county the shale at the base of the Trenton averages five to six feet in thickness and is generally overlain by rather massive beds, "The Lower Buff Beds." The same may be seen at numerous points in the exceedingly sinuous line that marks the contact of the Saint Peter sandstone with the Trenton.. It is well exposed on the road leading north of Waukon, on both sides of Village creek. In the valley of Paint creek, about two miles below Waukon, it appears at the surface.

The best example for pottery purposes appears in the valley of a tributary of Silver creek in Makee township. The Trenton contains other shaly layers which are generally unimportant, commercially, on account of their thinness or lack of persistency. The most important of all these begins about forty feet above the base of the shales and continues upward some thirty feet. It is often inter-stratified with thin limestone seams which are highly fossiliferous. The shale itself may be rendered useless for brick purposes on account of the fossils and calcareous concretions it contains. The third shale horizon occurs near the top of the Trenton and is perhaps the most important economically, as it attains the thickness of ten to twenty feet in some instances. Exposures may be viewed about two miles north of Postville and at the same geological level in the hillside south of the Yellow river. This seam is not worked in Allamakee county. While outcrops of the Trenton shales are more or less common in the counties in which the lower Galena-Trenton rocks are exposed, they have not, as yet, been utilized in the manufacture of clay goods.

THE MAQUOKETA SHALES.

The Maquoketa comprises a series of beds, mainly shales varying much in color, composition and texture, and attaining a maximum thickness, according to Calvin, of 200 feet. The lower Maqucketa is made up of lean fissile shales, with some earthy, non-laminated beds carrying fossils. The upper Maquoketa consists of plastic clay shales, carrying occasional indurated, fossiliferous bands near the top and passing into thin layers of impure, earthy dolomite, "transition beds", to the Niagara limestone. The area of outcrop of the Maquoketa shales forms a narrow but extremely sinuous zone from Jackson county, on the south, through Dubuque, Delaware, Clayton, Fayette, Winneshiek and Howard counties, to the north. The most important expos-

ures may be viewed in Dubuque, Clayton and Fayette counties.

Clayton County.—The Maquoketa shales are well exposed a mile and one-half northeast of Elgin, on the northwest quarter of section 18, in Marion township. About ten feet of blue shales are exposed here in a ravine, and are overlain by about thirty feet of dolomite. In the southern portion of the county they form the valley bottoms, and the Maquoketa shale may be seen outcropping in what is known as "Newberry Park," one mile and a half northeast of Strawberry Point, and also in "Bixby's Park,"

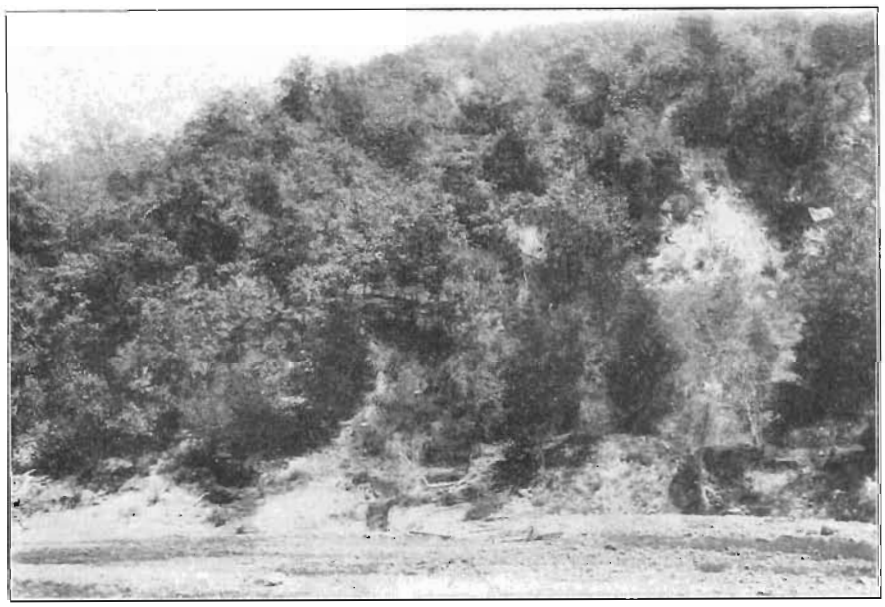


FIG. 41. Section near Edgewood showing over sixty feet of Maquoketa shales.

one mile and a half north of Edgewood. At both of these points the shale is gray-blue and fairly plastic. On the northeast quarter of section 33, in Sperry township, seventy feet of blue shale are exposed along one of the tributaries of Hewett creek. The shale outcrop lies from forty to fifty feet below the Niagara limestone. The upper ten feet of the Maquoketa contains calcareous

beds, highly fossiliferous but below, fifty or sixty feet of almost pure shale occurs. An analysis gave the following results.

Silica	52.29
Alumina	20.64
Combined water	5.17
Clay and sand	78.10
Iron oxide	5.16
Lime	1.89
Magnesia	1.12
Potash	2.77
Soda	8.27
Total fluxes	19.21
Moisture, sulfur trioxide and carbon dioxide	2.76

RATIONAL ANALYSIS.

Clay substance	70.65
Feldspar	2.57
Quartz	26.78
	100.00

The analysis shows a clay excellently adapted to the manufacture of all of the common clay wares, but when taken in connection with its physical properties, it is especially suited to the manufacture of hollow ware.

The Maquoketa shales which outcrop along Bear creek and its tributaries near Edgewood have been utilized to a limited extent in the manufacture of common brick and tile. The shale becomes very plastic when weathered and is mixed with from two to three times its bulk of loess. As a rule, the shale crops are quite fully concealed by talus and the Niagara limestone. The top of the shale is some 200 feet lower than the town of Edgewood. Some of the exposures show the presence of from fifty to sixty feet of workable shale.

A chemical analysis shows the presence of more of the lime and magnesium carbonate and less sodium and aluminum than in

the sample from Newberry Park. The composition was found to be as follows:

Silica	44.39
Alumina	13.72
Combined water	12.18
Clay and sand	70.29
Iron oxide	7.80
Lime	7.88
Magnesia	6.05
Potash	1.56
Soda	5.29
Total fluxes	28.58
Moisture	0.89

RATIONAL ANALYSIS.

Clay substance	40.61
Feldspar	4.62
Quartz	28.00
Lime and magnesium carbonate	26.77
	100.00

Notwithstanding the high percentages of lime and magnesium carbonates present, the ware when properly burned is strong and gives good service.

While the Maquoketa occurs in Winneshiek and Howard counties, it thins materially and carries an increased percentage of the carbonates and has not been utilized economically.

Clinton County.—The Maquoketa shales show numerous exposures in the northeastern corner of the county. One of the best of these is at the northern limit of Lyons, in the bluffs just to the west of the railroad tracks. The Niagara produces a perpendicular escarpment, perhaps fifty feet in height, and contains chert bands. Within six feet of its base the Maquoketa appears nine feet above the track, at the northern end of the bluff, and has been dug out for several feet below the track. The exposure is perhaps sixty feet long, and the pitch is approximately one foot

in thirty. A short distance south of this point the Niagara extends to the water level in the river. From Lyons northward to the northeast corner of Clinton county, the shales are partly exposed at intervals in the bluffs along the river. At Elk River Junction there are a number of incomplete outcrops well up the slope. The shale exposed at Lyons is blue in color and quite hard when unweathered. It slakes rather readily, and on exposure to the action of the weather becomes quite plastic. The clay is highly refractory and ought to make a good quality of the ordinary wares. In the manufacture of common brick and drain tile a blend composed of the Maquoketa shale and the loess might be used advantageously. Some attempts have been made to use the shales, but without satisfactory results.

Delaware County.—Exposures of the Maquoketa shales are confined to the extreme northeast corner of the county, along Little Turkey river and Elk creek, one of its tributaries. No satisfactory sections are available because of the heavy Niagara talus. The beds above the shale exposed at what is known as "Big Spring," in the southeast quarter of the northeast quarter of section 3, in Colony township, are as follows:

	FEET.
5. Steep slopes, sodded over	
4. Niagara limestone in thick, heavy ledges	10
3. Transition beds; soft, yellowish, argillaceous limestone, more shaly below, and becoming more calcareous above, in thin layers	25
2. Hardened shale in two to four-inch layers.	1
1. Bluish shale, indurated, composed of thin laminae and non-fossiliferous	4

The spring issues on top of the shale and is 230 feet lower than the level of the plateau upon which Colesburg is built. One-fourth mile below the spring there is a clay pit from which the Colesburg Pottery Company obtain their clay. The pit is sixty feet lower than the spring, and there is an almost continuous section of shales between.

A chemical analysis of the Colesburg shales gives the following results:

Silica	43.62
Alumina	24.40
Combined water	12.41
Clay and sand	80.43
Iron oxide	2.00
Lime	3.39
Magnesia	0.18
Potash	4 17
Soda	6.19
Total fluxes	15.93
Moisture	3.85

RATIONAL ANALYSIS.

Clay substance	83.57
Feldspar	7.60
Quartz	8 83
	100.00

The Colesburg pottery uses a fissile gray-blue shale, which slakes readily and becomes fairly plastic. When exposed, it weathers rapidly to a yellowish-blue plastic clay. At present the company manufactures only flower pots and plain red earthenware.

On account of the relatively low percentage of silica and high percentage of strong fluxes, the clay burns at a low temperature, and this fact, taken in connection with its plasticity, makes it eminently fitted for the manufacture of hollow building block and drain tile, uses to which it has never been put.

The clay is broken down and permitted to weather through the summer months and hauled during the winter and dumped on the ground outside of the factory building. It is prepared for use by being placed in a tank and permitted to soak two or three days. The soaked clay is shoveled into a vertical pug mill, the counter-

part of the soft mud mill, except this machine is driven by gearing at the top. The clay is tempered to a rather softly plastic condition and then passed through a pair of small rolls. Just before passing through the mill, one-fourth of redder brown top clay is added which is said to make the body work better. Pots ranging from one and three-fourths to seven inches in diameter are made in a flower pot machine. The machine consists of a lower rapidly revolving horizontal platform in the center of which is a depression the size of the pot to be made. In this depression a plunger works up and down, up when ready to receive the clay. After the clay passes the rolls, it is fed into a small horizontal plunger machine with two dies. As the clay issues from this tube it is cut off by wires stretched in a wooden frame into definite lengths for the size of pot desired. The plunger is actuated by a piston from the engine. The largest pots are made in a potter's jigger or jolly, in molds, the clay being taken directly from the rolls. The ware is dried on two floors, the upper of which is slatted, and burned in a small up draft kiln. The finished product is shipped largely to Dubuque, and finds a ready market.

Other exposures occur along the stream-ways in the vicinity of the pit of the Colesburg pottery, but none have been developed. Well sections demonstrate the general distribution of the shale and indicate that it attains a thickness of ninety feet.

Dubuque County.—Professor Calvin, in his report of the geology of Dubuque county, separates the Maquoketa into two well-defined parts; the upper series of plastic clay shales with some indurated fossiliferous bands near the top grading through transitional beds composed of thin layers of impure earthy dolomite into the Niagara dolomite above; the lower beds comprised of lean, fissile shales with some earthy non-laminated beds carrying Orthoceras and other fossils. The upper beds weather more easily than the lower, readily breaking down into highly plastic

clay, and yields readily to the clay-worker's art. The Maquoketa comprises the most irregular area in the northeast portion of the county, while a small area exists in the extreme northwestern corner. From fifty feet to more than one hundred feet of fairly plastic clay shales are available, but are not readily accessible save at a few points—at Kidder and Graf, on the Great Western

FIG. 42. Maquoketa shales west of Graf.

Railway, and at Peosta, on the Illinois Central Railway. Usually the shales are overlain by the Niagara limestone whose heavy talus would render the development of the shales commercially unprofitable. About one-half mile west of Graf the following beds may be observed in the railway cut:

		FEET.	INCHES.
5.	Shale, drab and black, unfossiliferous	2	
4.	Shale, brownish, hard, granular, non-fissile and fossiliferous	1	2
3.	Shale, drab, fissile, non-fossiliferous	1	4
2.	Shale, variable in color, texture, and fissility; numerous fossiliferous bands	11	
1.	Shale, brown or black, non-fissile; fossils rare	6	

The highly fossiliferous layers are usually more or less calcareous or dolomitic, and, as a consequence, unsuited for the manufacture of clay wares.

The analysis of shales developed near Kidder gives the following results:

Silica	42.53
Alumina	16.83
Combined water	15.76
Clay and sand	75.12
Iron oxide	5.66
Lime	5.66
Magnesia	4.82
Potash	3.70
Soda	4.10
Total fluxes	23.94

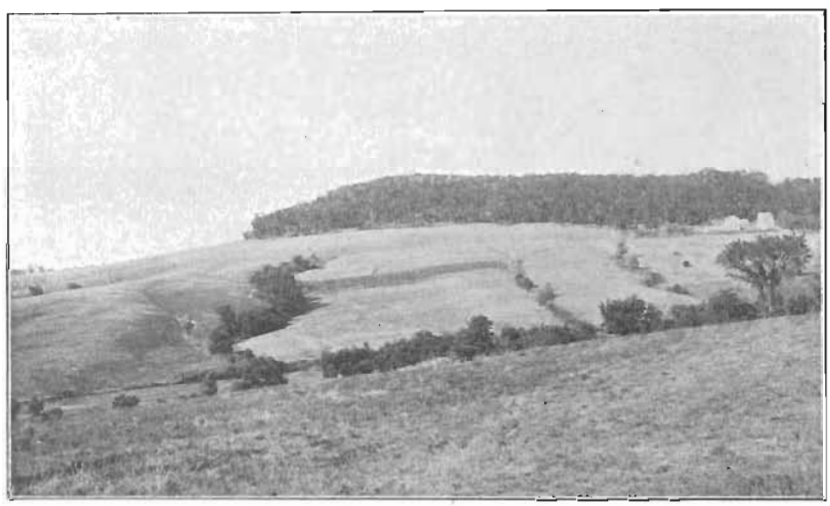


FIG. 43. Characteristic topography of the Maquoketa shales near Graf.

The clay has been tested at Bucyrus, Ohio, and when repressed makes a smooth, cherry red brick of excellent strength and appearance. The clay is also suited for pottery, but would not prove satisfactory for pavers, on account of the percentage of fluxes present.

Fayette County.—Near the town of Clermont, the Clermont Brick & Tile Company have been developing shale beds near the top of the bluff northeast of the railway station and overlooking the town. These beds were formerly supposed to belong to the Trenton series, but recently have been demonstrated by Professor Calvin to contain a Maquoketa fauna. The section is as follows:

		FEET.
3.	Surface materials, "geest," of varying thickness.	0 to 5
2.	Dolomitic limestone, rubbly above and heavy ledges below, cherty throughout, the lower layers become slightly arenaceous to shaly at the surface	15
1.	Shale, light-gray to blue-gray above, deeper blue below. Where much weathered becoming a plastic clay but when fresh shows fair fissility, exposed	20

The base of the section is more than one hundred feet above the terrace upon which the town is built.

The new pit is along a ravine where the limestone has been removed by erosion, and a thin veneer of highly oxidized surface materials, the "geest," rests directly on the shales and is used to a considerable extent in the process of manufacture to give color to the ware, because of the high percentage of iron it contains. The shale burns almost white when used alone, and shows but little shrinkage. Both rational and ultimate chemical analyses were made, with the following results:

Silica	28 82
Alumina	10.37
Combined water	16.24
Clay and sand	55.43
Iron oxide	3 76
Lime	19.14
Magnesia	5.40
Potash	5.38
Soda	7.41
Total fluxes	41.09
Moisture	0.43
Sulfur trioxide	3.01

RATIONAL ANALYSIS.

Clay substance	73 32
Feldspar	4.93
Quartz	21.76
Total	100.00

The analyses show a remarkably high percentage of the alkalis and alkaline earths and consequently a low percentage of silica and alumina.

Winneshiek County.—Frequent outcrops of the Maquoketa shales are known to occur in the southeastern one-third of the county. One of the most important sections may be observed in the vicinity of Fort Atkinson, on the southwest quarter of the west half of section 18, in township 96 north, range 9 west. A tough blue shale is exposed in the bed, and on the bank of a small tributary of Turkey river. The shale rises eight feet above the water and is known to continue below the stream bed. Occasional pyritic concretions and one or two thin seams of hard rock are the only impurities. The shale is but slightly siliceous, slakes slowly and is suitable for the common grades of brick and hollow ware. The exposure is about three-fourths of a mile from the Chicago, Milwaukee & St. Paul railway. Shales very similar to the above are shown in the southwest quarter of section 13. The principal outcrops are about two hundred yards away from the railroad. The surface features indicate that the shales are quite extensive horizontally and lie some twenty feet above the branch. In this vicinity a finely siliceous clay may be observed which has been tested and found to be a good polishing material. The clays in sections 18 and 13 were tested by Mr. F. R. Goddard with satisfactory results. In addition to the localities mentioned, the Maquoketa shales appear at various other points in this portion of the county. They may be observed just beneath the Niagara at a point considerably above the level of Turkey river, about one mile northeast of Fort Atkinson. They also appear directly

under the soil about one and one-half miles south of Calmar, and at intervals along Turkey river as far north as Spillville. As yet they are not being developed.

The Silurian.

Indurated rocks referable to the Silurian cover the larger portions of Fayette, Delaware, Dubuque, Jones, Jackson, Cedar, Clinton and Scott counties. Lesser areas may be found in Winneshiek, Clayton, Buchanan, Linn, Johnson and Muscatine counties. The rocks representing the Silurian system are prevailingly dolomites. While certain of the beds near the base of the series display some tendency to split into thin layers, no clay shales or shales occur in this system. Instead of supporting clay industries, the Silurian dolomites furnished more than four-fifths of the lime and one-half of the building stones produced in the state.

Devonian.

The Devonian period was inaugurated and closed by conditions favorable to the deposition of clays and shales. The lower argillaceous beds in the Devonian are known as the Independence shales and are referred to the Wapsipinicon stage. These shales show limited outcrops in Cedar, Linn and Buchanan counties, near the contact with the Silurian. The shales attain a thickness of twenty feet, are dark colored, often alternating with thin layers of limestone. Occasionally the shales are highly carbonaceous and contain plant remains, some of which have been transformed into true coal. The beds are of no economic importance on account of their varying character and inaccessibility.

The upper shaly member is of much greater importance and belongs to the Lime Creek stage. The Lime Creek shales are typically developed along Lime creek, in Cerro Gordo and Floyd

counties. Important exposures appear at Rockford and Mason City, and at numerous points between. The beds are being commercially exploited at both points.

Cerro Gordo County.—At Hackberry Grove, on the northwest quarter of section 35, in Portland township, the following section may be viewed.

	FEET.
4. Brown, yellowish-brown and gray limestone in several layers, fossiliferous, fossils similar to those contained in underlying shale	4
3. Shales, yellowish, very calcareous with bands of shaly limestone, weathering partly into clay and partly into small chips or nodules, very rich in beautifully preserved fossils	20
2. Shales, yellowish, argillaceous, weathering as does the blue clay below and free from fossils	10
1. Shales, bluish, argillaceous, weathering into a smooth, plastic clay, unfossiliferous	40

The Lime Creek shales are most vigorously exploited at Mason City. The pit of the Mason City Brick and Tile Company shows the following sequence:

	FEET.
4. Drift (Iowan)	0 to 2
3. Shale, non-fissile, arenaceous and stained a dark yellow. An indurated ledge of dolomite occurs in places	2
2. Shale, clayey, yellow, often deeply stained along the joints	10
1. Shale, blue, exposed	12

Numbers 1 and 2 are gypseous, small crystals occurring in tabular form or in rosettes, along the joints. Both beds are extremely plastic and remarkably well adapted for the manufacture of drain tile and hollow building block. The clay burns to a light red color and fuses at a low temperature. An analysis of the blue clay was made with the following results:

Silica	54 64
Alumina	14 62
Combined water	3 74
Clay and sand	73.00

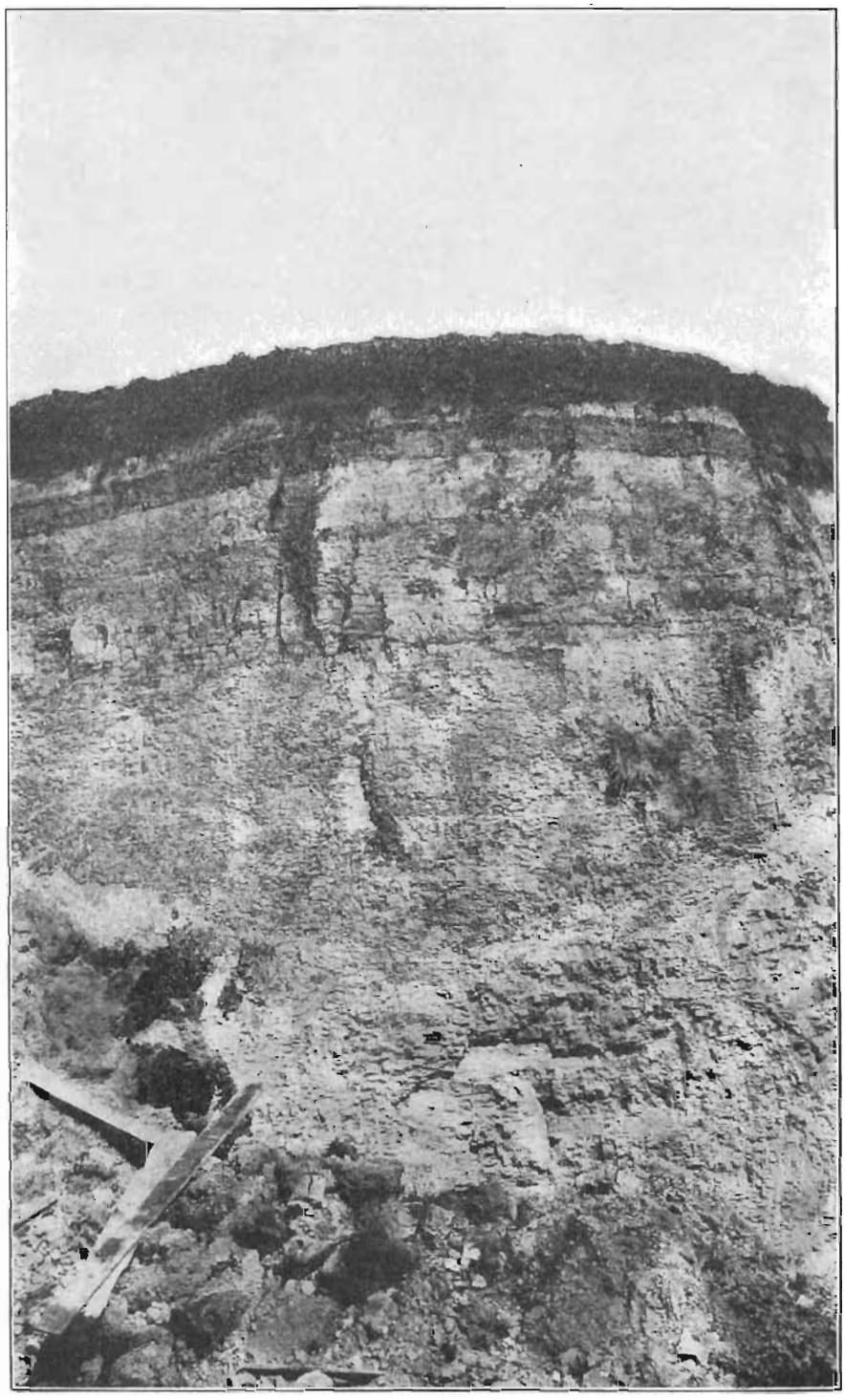


PLATE XVI. Shale pit of Mason City Brick and Tile Company. The dark layer above is the residual siliceous dolomite, Mason City, Iowa.

Iron oxide	5.69
Lime	5.16
Magnesia	2.90
Manganese oxide	0.76
Potash	4.77
Soda	1.12
Total fluxes	20.40
Moisture	0.85

Two other plants located at this place are using the Lime Creek shales. The American Brick and Tile Company opened a pit about one-half mile west of the above pit. An analysis of the clay used gave the following results:

Silica	51.95
Alumina	18.34
Combined water	7.39
Clay and sand	77.68
Iron oxide	7.56
Lime	4.14
Magnesia	3.26
Potash	1.43
Soda	2.69
Total fluxes	19.08
Moisture	0.42
Sulfur trioxide	2.76

RATIONAL ANALYSIS.

Clay substance	47.08
Feldspar	6.98
Quartz	41.45
Calcium sulfate	4.49
	100.00

The aggregate of fluxes is comparatively high in both analyses, and accounts for their low fusion point. The presence of a liberal amount of the carbonates tends to neutralize the coloring effect of the iron and makes the range between incipient and complete fusion very small. Considerable care is necessary in burning to avoid fused pockets in the kiln and yet insure sufficient burning to prevent slaking when exposed to the action of

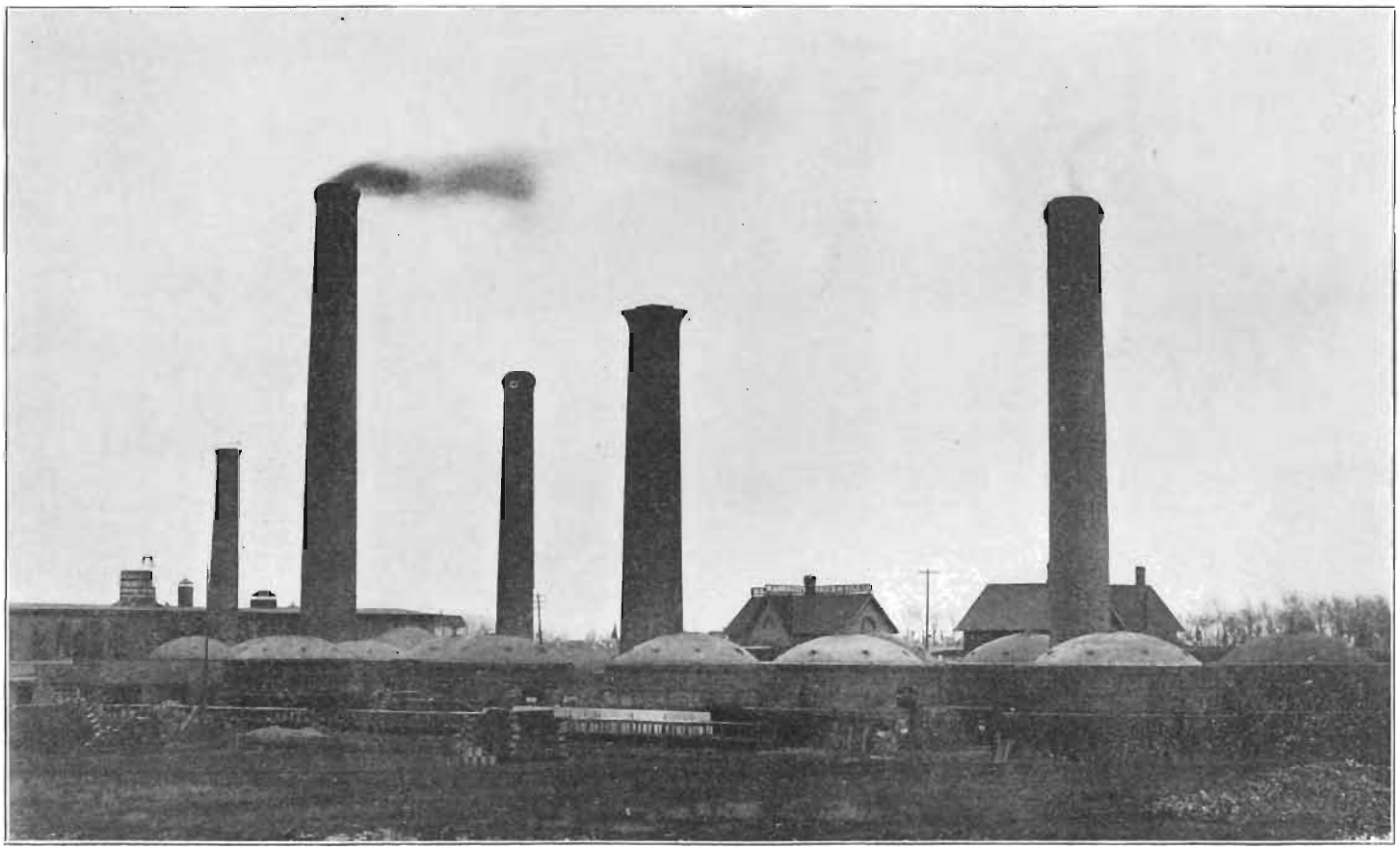


PLATE XVII. Plant of the Mason City Brick and Tile Company, Mason City, Iowa.

wetting and drying. Some attempts have been made to manufacture sewer pipe, but the lower plastic clays will not stand a sufficiently high temperature to make salt glazing a possibility. In the pit of the Mason City Brick and Tile Company the plastic shales dip to the southwest, and beds of residual siliceous dolomite appear. The residuum exerts a beneficial influence when added to the shales in all of the processes of manufacture, and greatly extends the range of temperature between incipient and complete fusion, in addition to making the ware much more refractory. It is possible that a proper blending of the shale and

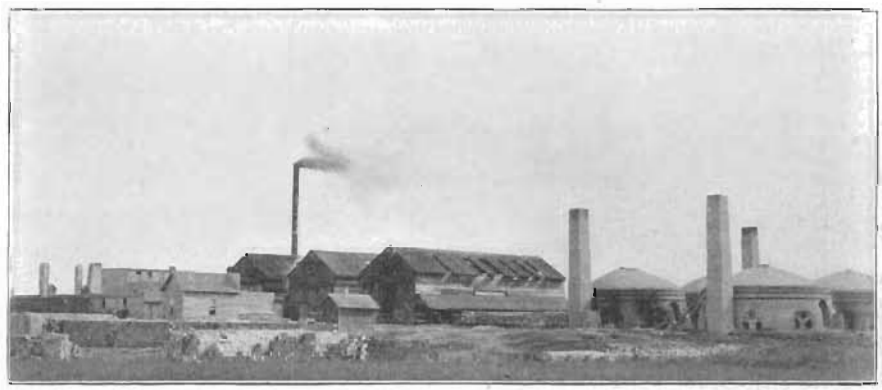


FIG. 44. Plant of the American Brick and Tile Company, Mason City, Iowa.

residuum may give a body suitable for the manufacture of paving brick and sewer pipe. Large tile are made in a sewer pipe machine and are used for culverts on the public highways.

The Lime Creek shales disappear from view west of Mason City and are not known to be accessible below Rockford. In the pit of the Mason City Brick and Tile Company they have an appreciable dip to the southwest and are soon carried below working limits.

Floyd County.—The Lime Creek shales occur more or less interruptedly from Mason City, in Cerro Gordo county, to below Rockford, in Floyd county. The most important exposures ap-

pear on the south side of the creek. The pit of the Cream City Brick and Tile Factory, west of Rockford, shows the following sequence:

	FEET.
7. Drift, variable in thickness, almost absent in the bluffs near the river	1-4
6. Limestone, marly with occasional hard ledges	8
5. Shale, clayey, weathered zone, yellow, lower portion jointed, joints deeply stained a yellowish-brown, clay-ironstone concretions containing calcite crystals not uncommon, limonite pseudomorphs after pyrite are common above	10
4. Shale, clayey, greenish-gray to greenish-yellow	10
3. Shale, deep blue when wet and gray-blue when dry, more or less fissile	8
2. Shale, as above but non-fissile	8
1. Shale, clayey, gray, finely arenaceous, burns a creamy white (exposed)	5

According to a drill section in the immediate vicinity, the shales and clays continue down about forty feet below the base of the section. All of the beds are relatively high in lime and other alkaline fluxes. Number 1 shrinks but little during burning, and can be fused with difficulty. Brick manufactured from this seam show considerable resilience when struck with a hammer, and are very tough. Its chemical composition is as follows:

Silica	58.33
Alumina	15.54
Combined water	3.47
Clay and sand	77.34
Iron oxide	3.84
Lime	9.42
Magnesia	3.03
Potash	1.19
Soda	1.76
Total fluxes	19.24
Moisture	0·42
Carbon dioxide	2.02
Sulfur trioxide	1.10

RATIONAL ANALYSIS.

Clay substance	64.47
Feldspar	11.13
Quartz	18.67
Calcium sulfate and magnesium carbonate	5.73

All of the beds below the marly layers are utilized. A wide variety of the common wares are manufactured on a small scale. No attempts have been made to develop the shales at any other point in the county.

Franklin County.—The Lime Creek shales of the Devonian are believed to constitute the indurated surface rocks over about one-third of the county. So far as known, the shales are exposed at but a single point. About half a mile south of the station at Sheffield the following section may be viewed:

		FEET.
4.	Shale, buff to yellow, slightly gritty.	6
3.	Shale, brownish to red	6
2.	Shale, blue	21
1.	Limestone (not exposed)	

Number 2 is not wholly exposed, but its thickness has been determined by boring. In the railroad cut just east of the yard a brownish, earthy, siliceous limestone is exposed at a level corresponding to the top of number 4. It is from one to four inches thick and is fossiliferous. Occasionally calcareous concretions occur in the upper portion of number 4 in the section, but not in sufficient quantity to give serious trouble. The clay has not been extensively developed as yet, and common brick and drain tile are the only products put upon the market.

Carboniferous Period.

Practically all of the great formations of the Carboniferous contain shales or shale clays of economic importance. Of these, the Kinderhook and the Coal Measures afford the most bountiful supplies. Rocks referable to the Carboniferous comprise the

indurated rocks over nearly one-half of the surface of the state. The period may be divided into two parts, the Lower Carboniferous beds, which are prevailingly calcareous in character, and the Upper Carboniferous, in which arenaceous and argillaceous deposits predominate, with important limestone bands in the upper portion. The latter division contains all of the workable coal in the state. On account of the abundance of raw material suitable for the manufacture of clay wares, and cheap fuel, the Upper Carboniferous or Coal Measures constitute the most important formation to the clay worker in the state.

The Lower Carboniferous comprises a belt averaging from thirty to forty miles in width and extending diagonally across the state from Kossuth and Winnebago counties, on the north, to Des Moines and Lee counties, on the south. Narrow strips have been laid bare by the lower courses of the Skunk and Des Moines rivers, and unimportant detached areas appear in Story and Webster counties. Three stages represent the Lower Carboniferous in Iowa - the Kinderhook, Augusta and Saint Louis.

THE KINDERHOOK.

The Kinderhook rests unconformably on the Devonian, and in southeastern Iowa comprises a heavy **shale member** with important calcareous beds above. The upper member often assumes a decidedly oölitic facies. In central and northern Iowa the shale member thins rapidly and the assemblage of beds as a whole takes on a decidedly calcareous character. The shale outcrops are confined to the Mississippi river and immediate vicinity.

Des Moines County.—The Kinderhook shales attain a thickness of about 150 feet and are more extensively exposed here than in any other portion of the state. About seventy feet of the argillaceous beds lie above the water in the Mississippi river. Almost a continuous outcrop extends across the county, along the bottom of the Mississippi escarpment, occasionally extending some dis-

tance up some of the larger creeks. The shale belt is narrow and generally overlain by scarps of more highly indurated limestones. The Kinderhook section as viewed at Prospect Hill, at Burlington, is as follows:

		FEET.
6.	Limestone, buff, soft, sandy locally	5
5.	Limestone, white, oölitic	3
4.	Sandstone, yellowish, soft, fine-grained fossiliferous	6
3.	Limestone, argillaceous, fine-grained, often with an oölitic band in the bed of impure limestone at base	18
2.	Sandstone, yellowish, soft, friable, clayey	25
1.	Shale, blue, argillaceous, exposed	60

At Cascade, immediately south of Burlington, the shales have been developed quite extensively in the manufacture of common brick and paving brick, by the Granite Brick Company. The small stream has uncovered a considerable area of shales, so that open pit work is possible. The pit and adjoining bluffs present an extensive section to view. The detailed section is given below.

		FEET.
8.	Loess, deeply iron-stained	10
7.	Limestone, cherty	2
6.	Limestone, white to brown, variegated	10
5.	Sandstone, fine-grained to argillaceous	3
4.	Limestone, hard, fine-textured	12
3.	Sandstone, fine-grained, argillaceous	25
2.	Shale, very compact and massive, highly siliceous; sandy below	14
1.	Shale, massive, dark-blue to blue-black, exposed	16

Numbers 1 and 2 in the above section are utilized in the manufacture of clay goods. Both are highly siliceous and are only moderately plastic. Well sections and borings indicate that the shales extend from seventy-five to one hundred feet below the level of the water in the river. The analyses of numbers 1 and 2 give the following results:

PLATE XVIII. Pit of the Granite Brick Company, Burlington, Iowa.

	1. TOP CLAY.	2. BOTTOM CLAY.
Silica	77.39	71.78
Alumina	5.16	11.41
Combined water	1.46	0.67
Clay and sand	84.01	83.86
Iron oxide	2.40	3.35
Lime	3.65	3.18
Magnesia	3.13	3.80
Potash	1.44	0.86
Soda	2.79	0.78
Total fluxes	13.41	11.97
Moisture	0.13	0.42
Sulfur trioxide	1.44	1.25
Carbon dioxide		3.02

RATIONAL ANALYSIS.

Clay substance	24.92	35.82
Feldspar	19.64	14.18
Quartz	51.39	42.14
Calcium sulfate	2.21	2.00
Magnesium carbonate	1.84	5 76
Total	100.00	99 90

FIG. 45. Plant of the Granite Brick Company, Burlington, Iowa.

The lower clay is less siliceous and contains less of the soda and potash but higher percentages of lime, magnesia and alumina. Both contain high percentages of uncombined silica or quartz and are relatively low in clay substance; facts which account for their low plasticity.

The ware burns a mottled gray-brown and becomes very hard. The fusion temperature is comparatively high, and the shrinkage is relatively small during both drying and burning. The lower clay is decidedly more argillaceous than the upper, as may be noted by the rational analysis.

While the Kinderhook shales outcrop at numerous points in the county, they have not yet been developed away from Burlington. On account of the relative ease with which they are eroded, as compared with the more resistant limestones above, the shale crops are limited to a narrow zone along the Mississippi and its larger tributaries. Their extensive development is possible in the stream valleys or by mining. Away from Burlington and immediate vicinity, a section on Oak creek, at a point where the creek breaks through into the Mississippi valley proper, may be taken as fairly representative. The following sequence may be observed:

		FEET.
5.	Loess	8
4.	Drift	4
3.	Limestone, buff and white, heavily bedded below, passing into siliceous shales above	35
2.	Shale, buff, sandy, forming incoherent sandstone in places	10
1.	Shale, blue, exposed	20

Lee County.—The Kinderhook shales dip rapidly below Burlington and are carried below the water in the river before Lee county is reached. They appear in the bed of Spring creek a little more than a mile north of the Des Moines-Lee county line. But a single exposure is known within the confines of the county, and that is along the Skunk river, near the bridge on the Kansas

City division of the C., B. & Q. Ry. At Keokuk the shales lie 130 feet below low water mark, which appears to be their lowest point between Burlington and Hannibal, in Missouri.

It is apparent that the Kinderhook shales can be utilized extensively only by means of shafting and mining. This has been done to a limited extent by the J. C. Hubinger Brick Works, a plant which has not been in operation for some years.

Outside of Des Moines and Lee counties, the Kinderhook shales have never been exploited, although they lie within easy reach for mining operations. In Louisa county the shales can be recognized at a number of points in the channels of the small streams which are tributary to the Iowa river. The most important exposure known may be observed just south of Elrick Junction, on the east bank of Smith creek. The sequence is as follows:

		FEET.
6.	Limestone irregularly bedded and leached; variable thickness.	
5.	Concealed.....	10
4.	Sandstone, fine-grained, soft.....	3
3.	Shale, soft, blue, unctuous.....	9
2.	Shale, dark, carbonaceous.....	1
1.	Shale, blue, with thin seams of calcareous material	6

No exposures of the shale are known beyond the limits of Louisa to the northwest. In Marshall county, near LeGrand, the Kinderhook shales are reached at about ten feet below the water level in the Iowa river. The beds dip to the west, and at Marshalltown are reached at about 150 feet below the water level.

Washington County.—The Kinderhook beds comprise the surface indurated rocks over the northern and eastern portion of the county. Outcrops occur on the South English as far west as Wassonville mill, north of Wellman. Good exposures may be viewed at this point, as well as at Maple mill, Kalona and Riverside. The Kinderhook also occurs on Goose creek, south of Riverside, and doubtless underlies the drift and wash along the Iowa river. Perhaps the most typical section may be observed at Maple mill. The sequence exposed is as follows:

		FEET.
4.	Limestone, earthy, ferruginous and arenaceous in places; fine-grained, with thin chert layers	10
3.	Gritstones, fine-grained, white to buff, fossiliferous	18
2.	Limestone, drab, hard, unfossiliferous	½
1.	Shale, argillaceous, dark blue to drab	12

The basal shale may be traced almost continuously from this point southeast to the base of the section at Burlington. It is suitable for structural brick and hollow ware and would probably yield a fair grade of paving brick. Some of the exposures are fairly accessible but have not been explored.

THE AUGUSTA.

Shales are not especially important in the Augusta, but near its southern extension in the state, notably in Lee county, certain beds are sufficiently argillaceous to merit attention. The most important section is about two miles below the Union depot in Keokuk, where the following sequence of beds may be viewed:

		FEET.
17.	Drift	30
16.	Shale, gray, clayey	2
15.	Sandstone, ferruginous	1
14.	Shale, black, fissile, filled with small nodular concretions	3
13.	Coal	1½
12.	Fire clay and shale passing into a coarse quartzose sandstone	⅓
11.	Limestone, brecciated, interstices filled with green clay; variable in thickness	20
10.	Sandstone, massive, blue, calcareous, weathers brown; fine to coarse-grained	8
9.	Shale, blue, argillaceous	10
8.	Limestone, coarse, irregular, fossiliferous	3
7.	Shale, blue, becoming somewhat friable in weathering	4
6.	Limestone, blue and brown, magnesian, irregular in development	3
5.	Shale, argillo-calcareous, breaking down readily to a yellowish clay	18
4.	Shale, calcareous, with bands of chert, and irregular layers of thin bedded, gray limestone, which are increasingly prevalent toward the base	14

		FEET.
3.	Shale, blue	½
2.	Limestone, blue, encrinital, coarse-grained, composition and stratification somewhat variable, nodular chert in considerable quantity.	12
1.	Limestone, blue, encrinital; "White Ledge" of quarry men	4

Of the above section, numbers 1 to 9, inclusive, are referred to the Augusta. At the mouth of Soap creek, from 12 to 15 feet of shale are exposed near the top of the section. These shales outcrop at numerous points along Soap creek, and have been utilized to a limited extent by the Hubinger Brick Works, but without marked success. The shales are prevailingly calcareous and low in plasticity. The expense for stripping and wasting away the unusable portions in the manufacture of clay goods adds greatly to the cost of production and renders the use of the Augusta shales commercially unprofitable. While the Augusta beds cover considerable areas in Des Moines, Henry, Louisa, Washington and Keokuk counties, the shale members are unimportant and at no place have they been developed for clay manufactures.

THE SAINT LOUIS.

No workable beds of shales or clays are known to belong to the Saint Louis in Iowa. Certain argillaceous beds have been referred to this stage of the carboniferous, but none are sufficiently pure to warrant exploitation for brick and tile.

THE COAL MEASURES.

Nearly one-third of the superficial area of the state is occupied by the Coal Measures, which supply an almost inexhaustible storehouse of raw materials suitable for the manufacture of the various grades of clay wares. The Coal Measures comprise a complicated series of sandstones, shales, limestones usually more or less argillaceous, and occasional seams of coal, all intimately

interbedded and giving place one to another, both laterally and vertically, in a most confusing way. The argillaceous beds greatly predominate, and show a wide range in color and composition and a great diversity of textures and structures. They may be grouped somewhat arbitrarily into: (1) argillaceous, (2) arenaceous, (3) carbonaceous, or bituminous, and (4) calcareous varieties.

While the types are fairly distinct, there is no sharp line separating one from another. By the gradual addition of fine sand the shales merge insensibly into sandy shales, shaly sandstones and finally into sandstones. Similarly, in many instances the shales contain some lime, and are known as calcareous shales, and may grade into marly or argillaceous limestone and even limestone, as the lime content increases. Many of the dark colored shales contain a considerable amount of organic matter, from which their color is due, and are known as carbonaceous or bituminous shales, and merge finally into impure coal. These transitions not only take place laterally in the same horizon, but vertically from one layer to another. The argillaceous shales, or true shale clays, are prevailingly light colored, the most common colors being shades of gray and blue and combinations of the two. They range from the almost white to ash-gray fire clays to the deep blues and their weathered counterparts, the red-browns. The fire clays usually form the underclays for the principal coal seams; occasionally the coal seam is absent and a carbonaceous shale only appears. Fire clays usually show no stratification or other structural features, and are non-fissile, but all those known to occur in the Coal Measures of Iowa are highly plastic. Fire clays are believed to be the old soils which produced the vegetation now preserved as coal, and are leached of most of their soluble constituents, notably the alkalis, soda, potash, lime and magnesia, and their iron constituents. These constituents constitute the fluxes, because they fuse at low temperatures, and clays which

are low in fluxes are resistant to fire, hence the name "fire clays". The more complete has been the leaching, the more resistant are the clays and the less do they shrink during the process of burning. Highly siliceous fire clays somewhat granular in texture are known as gannister, and are used in the manufacture of glass pots and other very refractory wares. The fire clays usually burn a light color, because of the partial loss of iron, which is the great coloring agent in clays. Iowa fire clays vary in thickness from a few inches to four or five feet, and are prized in the manufacture of the higher grade wares, such as face and fancy brick, pottery, terra cotta and sanitary ware.

The gray-blue and blue-gray shales often occur in beds of considerable thickness, and are quite persistent, especially in the upper Coal Measures. When unweathered, these shales occur in massive beds, the bedding planes not being apparent, and are hard and tough. When subjected to weathering agencies, stratification lines become more evident and the beds may show considerable fissility. The shales eventually slake down into an unctuous, highly plastic mass. The dark blue shales are usually denser than the lighter shades, and are better adapted to the manufacture of vitrified clay wares. The clay shales often carry impurities which are detrimental for certain uses. Of these, the commonest are crystals of gypsum and iron pyrites. The gypsum occurs in short diamond-shaped crystals to long tabular forms. Sometimes two crystals are grown together so as to form a re-entrant angle and thus producing the so-called "swallow-tailed twin." Along joint planes the crystals not uncommonly assume a radial arrangement and form rosettes. Gypsum crystals are easily recognized by their light color and transparency, the readiness with which they break into thin tablets and their softness. They can be scratched easily with the thumb nail. Gypsum does not usually occur in sufficient quantity to give trouble, save in the manufacture of fancy wares and faced goods.

Burning drives off the water of crystallization and "dead burns" the gypsum, which may show on the surface as soft, white spots.

Iron pyrite is most common in the darker colored shales, especially in the bituminous varieties, but is widely distributed, even in the lighter shades. It occurs in granular to crystalline aggregates, irregular grains and cuboidal crystals. It can be recognized easily by its golden yellow color and great hardness, being harder than steel. As in the case of gypsum iron pyrite is not detrimental, save in the manufacture of certain faced wares. In burning, pyrite serves as a flux, tending to roughen and mottle the surface by the production of dark-colored slag spots. Iron pyrite is not very stable under atmospheric conditions, and often changes to limonite or brown iron ore in the zone of weathered clay shales.

As has been said, clay shales merge insensibly through arenaceous shales, argillaceous sandstones, into sandstones. Many of the Coal Measures sections in the state show all gradations.

In certain of the arenaceous shales, the clay component so far predominates that the beds are important in clay manufactures either alone or in admixture with fat clays. The shaly sandstones can not be used alone, but when soft enough to be pulverized readily can be used with fat clays often to good advantage, as they facilitate drying, prevent undue shrinkage and help the ware hold its shape through both drying and burning.

Bituminous shales are usually distinctly fissile, breaking readily into thin lamellae, and generally accompany coal seams. Occasionally coal seams are absent. The carbonaceous matter may be present as a solid resembling fine particles of coal of a charry nature, or in some of the brown shales the carbonaceous matter occurs in the form of crude petroleum. Samples of oil shales have a decidedly petroleum odor and carry as high as 15 per cent of crude petroleum. Bituminous shales shrink greatly during drying and burning, and as a consequence are not prized in the

clay working industries. They are used, however, to a limited extent by mingling with other clay deposits.

The calcareous shales are not important in the lower Coal Measures, but assume greater importance in the upper series. The so-called "cap-rock" lying above certain coal seams, is usually calcareous and highly fossiliferous. Calcareous shales grade insensibly through argillaceous limestones to limestones. In addition to the lime which may be present in a finely divided state and disseminated throughout the entire mass, calcareous shales often carry lime concretions which interfere seriously with its use in the manufacture of clay products.

While the Coal Measures are believed to be present in more than one-half of the ninety-nine counties in the state, the clay shales have been developed for the manufacture of clay goods in but sixteen. Over the entire section covered by the Coal Measures, a thick mantle of drift greatly obscures the outcrops of the indurated rocks. Notwithstanding the thick blanket of glacial debris, the larger streams and their immediate tributaries have exposed numerous outcrops of the older rocks. From a purely geological standpoint it is found convenient to separate the Coal Measures into a lower series, typically developed along the Des Moines river, and appropriately designated the Des Moines stage; and an upper series characteristically developed along the Missouri river and with equal propriety designated the Missourian stage of the Upper Carboniferous. The Des Moines stage is characterized by a great predominance of shales of the argillaceous, bituminous and arenaceous types, and sandstones, with most of the workable coal seams of the state, while calcareous shales and limestones are much more prominently developed members in the Missourian stage. In the present discussion the division is believed to be unimportant, and no attempt is made to separate one from the other.

The leading outcrops where clay shales are available are described briefly. The sections are grouped by counties, the counties being taken in alphabetical order. On account of the large number of exposures it is manifestly impossible to mention them all. An attempt is made, however, to treat the most important for each district.

Adair County.—The upper Coal Measures lie directly beneath the drift over the larger portion of the county. Beds supposedly of Cretaceous age overlap the Coal Measures in the western portion. The thick drift sheet, in the absence of large streams effectually obscures the indurated beds. Shales are exposed in one or two inaccessible localities, and as yet they have not been developed. South of Adair a two-foot vein of coal has been mined to some extent. Above it is a heavy shale. Below it is a fire clay, and both clay seams might be mined profitably in connection with the coal.

Adams County.—Good shale outcrops are unknown. At the mining camps of Briscoe, Carbon and Eureka, shales suitable for use in clay working are penetrated in sinking shafts for coal, and are within easy mining distance of the surface. Unimportant exposures appear along the Middle Nodaway river, accompanied by a thin seam of coal, but none of the Coal Measure shales have been developed in the county. A bed of fire clay lies below the principal coal vein worked, is fairly persistent and undoubtedly would furnish a good body for the various grades of dry pressed brick.

Appanoose County.—The shale beds are comparatively persistent and fairly uniform, and are separated by beds of limestone which are remarkably constant. The principal bands are known locally as the "floating rock", "fifty-foot limestone", "seventeen-foot limestone", the "cap rock" and the "bottom rock". The terms are referable to the principal coal seam known as the Centerville vein or mystic seam of Keyes and Bain.

The general section published in the "Geology of Appanoose County", and appended below, gives a good idea of the sequence of beds and their relative importance.

		FEET.	INCHES.
17.	Limestone, gray, sub-crystalline, seen in the railway cut near Anchor No. 1 mine at Centerville, and known among the miners as the "floating rock"...	2 to 4	
16.	Shale, argillaceous, color variable.....	12 to 30	
15.	Limestone, heavy ledges, exposed along the Manson branch and Cooper creek at Centerville as well as at numerous other points in the county, the "fifty foot" limestone.....	4 to 10	
14.	Shale, argillaceous, blue and red in color		14
13.	Shale, arenaceous, frequently forming a well defined sandstone.....		8
12.	Shale, argillaceous, blue and gray		10
11.	Limestone, somewhat variable in thickness; exposed along the C., M. & St. P. railway between Mystic and Brazil, known as the "seventeen-foot limestone" or "little rock".....	1 to 3	
10.	Shale, sometimes gray, frequently bituminous and pyritiferous.....		7
9.	Limestone, sometimes gray, and coarsely sub-crystalline as at the Lodwick mine, Mystic; sometimes fine-grained, bituminous, and grading into the shales above and below, as at the Thistle mine, Cincinnati, known as the "cap rock".....	2 to 4	
8.	Shale, usually bituminous, and known as "slate"; occasionally in part soft and clay like, then known as clod; at times heavy and homogeneous non-fissile, in which form it is known as "black bat".....	1 to 3	
7.	Coal, upper bench, usually.....	1	8–10
6.	Clay parting "mud band.....		2– 3
5.	Coal, lower bench, usually.....		8–10
4.	Clay parting the "dutchman".....		½
3.	Coal, frequently impure.....		2– 3
2.	Fire clay.....	1 to 6	
1.	Limestone, "bottom rock", well exposed along Walnut creek at Mystic.....	3	6

It is obvious from the above section that important beds of clay shales occur between the limestones, and they are much more persistent than those which occur in many of the other Coal Measure counties. The entire section is exposed in the central and north central portions of the county along the Chariton river and Cooper and Walnut creeks; the lowest beds appearing along the latter creek, at Mystic and Brazil. Away from the larger streams and the central portion of the county, the thick veneer of drift effectually conceals the stratified rocks, although the Coal Measures cover the entire county.

At Centerville only, have the clay shales been developed. The Centerville Brick and Tile Company are using the uppermost member, number 16 in the general section. Formerly their pit was located south of the Keokuk and Western railway, near the shaft of the Scandinavian Coal Company and their own plant. At present the company has opened a pit south of the Iowa Central depot and east of the Keokuk and Western track. The shale developed is covered by a thin mantle of loess and drift, the "float rock" having been removed by erosion, and some twelve to fifteen feet of shale clay are available. The clays utilized are of a pale, yellowish-brown color above, and grade downward into gray-blue layers, stained a yellowish-brown along the joints. The entire assemblage of beds is finely arenaceous, works somewhat short and is slightly calcareous. The clay is loaded by hand into flat cars and hauled to the plant, a distance of about one mile, where it is shoveled on a conveyer which leads to a dry-pan. The ware burns a pale red and is fairly strong. The clay is adapted to both dry press and stiff mud processes. It does not appear to be well adapted to the manufacture of paving brick and drain tile. In the vicinity of Centerville the upper shales are exposed quite freely along the stream ways, but could not be developed extensively, save by mining, on account of heavy stripping. In the vicinity of Mystic and Brazil the lower shales

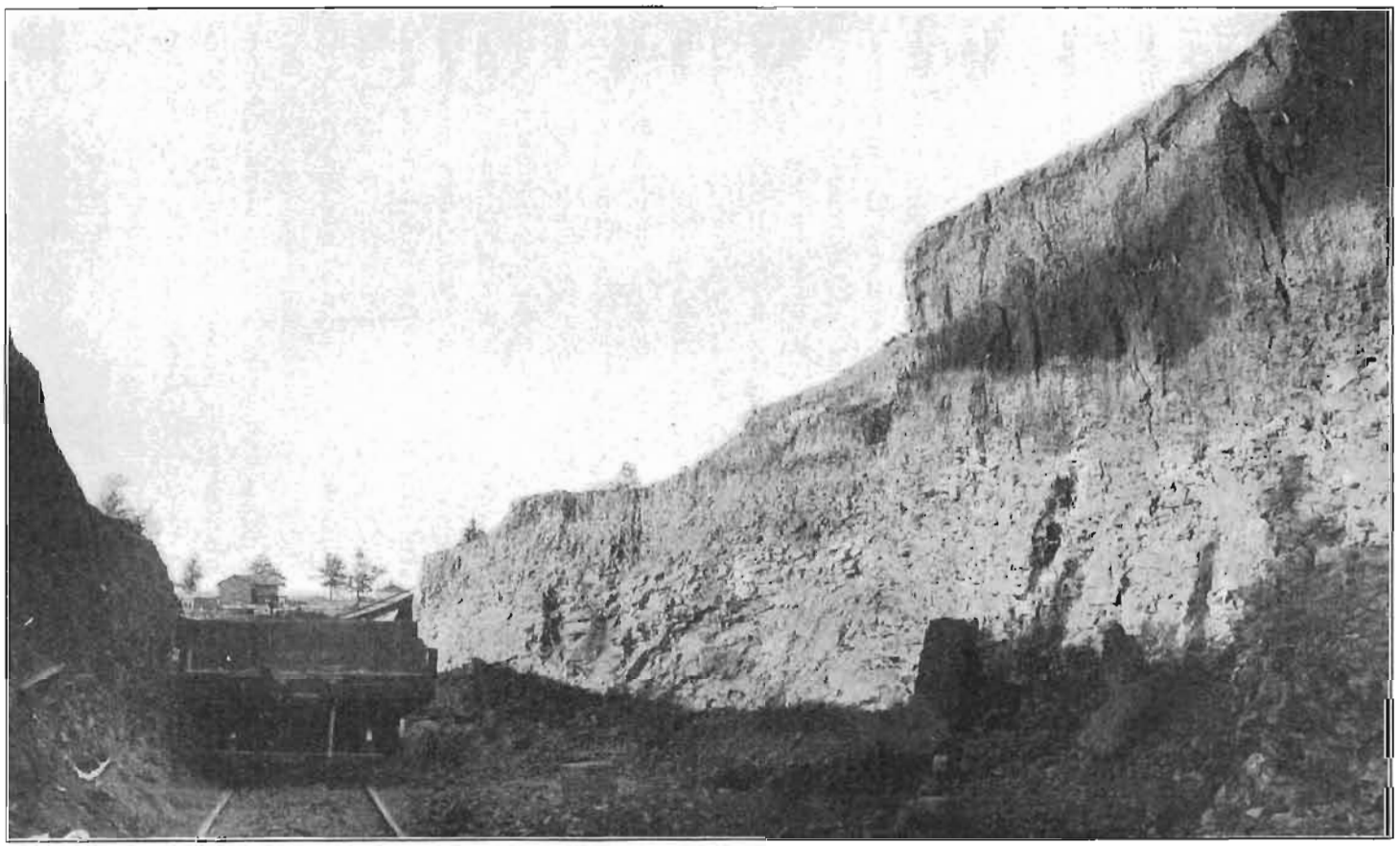


PLATE XIX. Pit of the Centerville Brick and Tile Company, Centerville, Iowa.

appear in the bluff walls of Walnut creek. Some fifteen feet of shales below "bottom rock" are visible as in the following section which may be taken to be fairly representative.

SECTION ON WALNUT CREEK AT MYSTIC.

		FEET.	INCHES.
10.	Drift	12	
9.	Limestone, heavily bedded, gray, fossiliferous	2	10
8.	Shale, bituminous, fissile	1	
7.	Coal	1	6
6.	Clay parting		2
5.	Coal with some pyrite near base	1	
4.	Fire clay	1	6
3.	Limestone, heavily bedded, fossiliferous	2	10
2.	Shale, gray, clayey	11	
1.	Shale, blue, clayey (exposed to water level)	4	

The lower shales could not be developed generally, save by mining. Limited areas uncovered along the streams might be developed cheaply.

A few shale outcrops are known to appear along Sugar creek, in the northeast corner of the county, near Foster. No attempts have been made to prospect, explore or exploit them.

Boone County.—As in the foregoing counties, Boone lies wholly within the Coal Measure area. Outcrops are limited to the immediate vicinity of the Des Moines river, with the exception of an unimportant exposure along Squaw creek, near the northeast corner of the county. The Des Moines river has cut a deep trench across the county from north to south, and numerous shale crops appear in the steep valley walls, generally more or less obscured by drift-slides and talus slopes. The best sections are exposed near Boone, along the Des Moines river and small tributaries. The pit at the Boone Clay Works, located southwest of Boone, on a small tributary of the Des Moines river, shows the following sequence of beds:

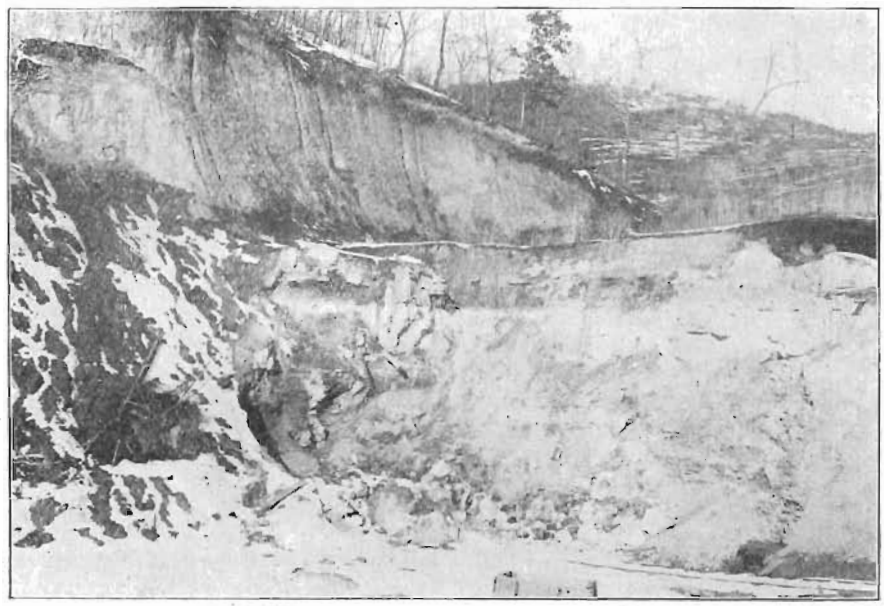


FIG. 46. Pit of the Boone Clay Works, Boone, Iowa.

		FEET.
9.	Drift	15+
8.	Potter's clay	1½
7.	Clay shale, gray-blue	2
6.	Clay shale, gritty, ash colored, iron-stained in the upper part	4
5.	Clay shale, variegated, red, blue and gray	12
4.	Shale, ochreous band, stained a deep red	⅔
3.	Clay shale, similiar to No. 6	2
2.	Fire clay	1½
1.	Shale, impure, exposed	3

The drift here, as in most of the exposures in the county, abounds in lime pebbles and bowlders, and must be removed. Number 5 is the principal clay used. It is of excellent quality and contains sufficient iron to give a good color to the finished product. The entire assemblage below the drift, blends to good advantage and affords first-class material for the manufacture of building and paving brick, and drain tile. Directly west of Boone, the Des Moines river has removed the drift from a con-

siderable area, exposing some seventy feet of shales, which are being developed by the Boone Brick, Tile and Paving Company. The beds exposed in the pit are as follows:

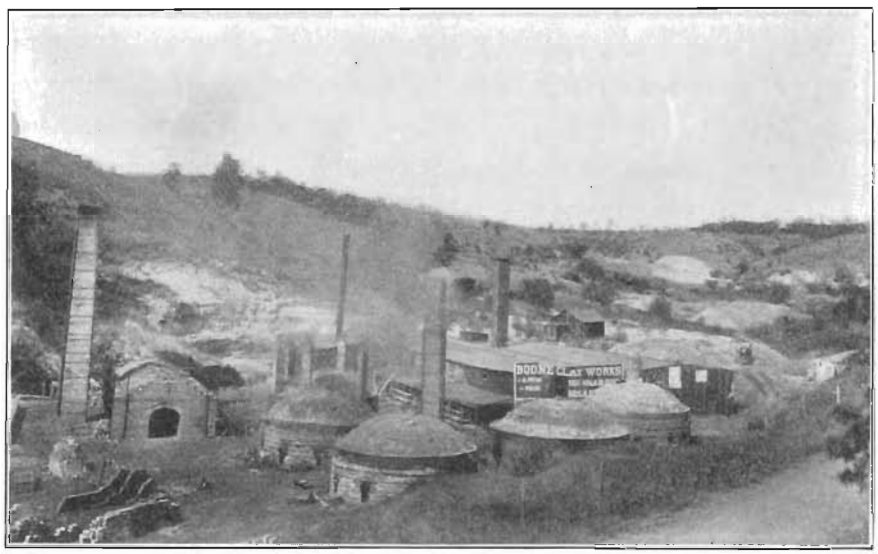


FIG. 47. Plant of the Boone Clay Works Boone, Iowa.

PIT SECTION OF BOONE BRICK, TILE AND PAVING COMPANY.

		FEET.
8.	Drift and talus, varying in thickness, average for pit at the present time	5
7.	Shale, variegated, gypseous, much weathered and shrinks considerably during drying and burning	15
6.	Shale, gray-blue, arenaceous below, in places a hard ledge appears and must be wasted	4
5.	Shale, purplish, variegated, somewhat fissile	4
4.	Sandstone, argillaceous in part, hard ledge appears in places	4
3.	Shale, dense, gray-blue to deep blue, but slightly fissile, the most important bed in the pit	14
2.	Shale, bluish-gray, weathers almost white, finely arenaceous, massive	4
1.	Shale, dark blue to bluish-black, gypseous.	

At the present time numbers 2 to 7, inclusive, are being developed. Portions of 4 and 6 must be wasted. Number 7 is used largely in the manufacture of hollow ware, while number 3 gives

the best results when vitrified wares are desired. The base of number 1 is about twenty feet above the Des Moines river, while the plant is located on the bluff, about 200 feet above. The clay is loaded on small cars and pulled up an incline by means of a rope. An ordinary hoisting engine is used. The weight of the empty car is sufficient to carry it back. The plant is turning out an excellent quality of paving brick, common builders and hollow ware. Chemical analyses were made of the principal seams. The results are given in tabular form below.

	1	2	3
Silica	47.40	73.70	53.40
Alumina	22.20	16.60	20.39
Combined water	7.90	4.30	8.71
Clay and sand	77.50	94.60	82 50
Iron oxide	12 40	0.20	12.24
Lime	0.70	0.10	0.99
Magnesia	1.10	1 60	1 42
Potash	3.10	0.70	1.42
Soda	0 50	0.30	0.71
Total fluxes	17.80	2.90	16.78
Moisture	2.10	0.70	0.52
Sulfur trioxide	2.40	1 70	0.55
RATIONAL ANALYSES.			
Clay substance	74.90	37.13	67.06
Feldspar	8.81	15 33	4 82
Quartz	12.70	47.54	28.12
Calcium sulfate and Magnesium sulfate	3.59	.....	.....
	100.00	100.00	100.00

No. 1 was selected from one of the test pits before the plant was opened, and doubtless came from number 5 in the section; number 2 came from 6 in the section. Number 3 gives the composition of a sample compounded from all of the argillaceous members which appear in the section, according to their relative thicknesses.

PLATE XX. Pit of the Boone Brick, Tile and Paving Company, Boone, Iowa.

While the shales are exposed at numerous other points in the county, no attempt has been made to utilize them, save in the instances mentioned. The great thickness of the drift is a serious obstacle to their economic development, even along the larger streams. The contact between the drift and the Coal Measures is a plane of weakness, and drift-slides are of common occurrence. Where the slopes are subject to inundation of this kind, great expense is entailed in the removal of landslides. In some instances it is found to be more economical to abandon the pit.

Dallas County.—Dallas county is provided with an abundance of shale clays of excellent quality, and are unusually accessible in the southern portion, along the Raccoon river. The Coal Measures cover the entire county, but outcrops are rare in the northern half of the county, owing to the thickening of the drift northward and the absence of large streams, save the North Raccoon. Some of the best shale sections are given below, and may be considered to be fairly representative. The shale series exposed near Booneville is as follows:

	FEET.
14. Drift, overlain by loess	30
13. Sandstone	10
12. Shale, black, fissile	1
11. Shales, gray and red	10
10. Shales, black	1
9. Shales, gray	3
8. Coal	¾
7. Shales, gray	9
6. Limestone, fragmental, fossiliferous	2
5. Shales, gray	13
4. Limestone	2
3. Shales	16
2. Sandstone	¼
1. Unexposed to river	20

Continuing westward from Booneville to Van Meter, the Platt Pressed and Fire Brick Company are developing the clay shales south of the Raccoon and well up the bluff. The pit shows the following layers:

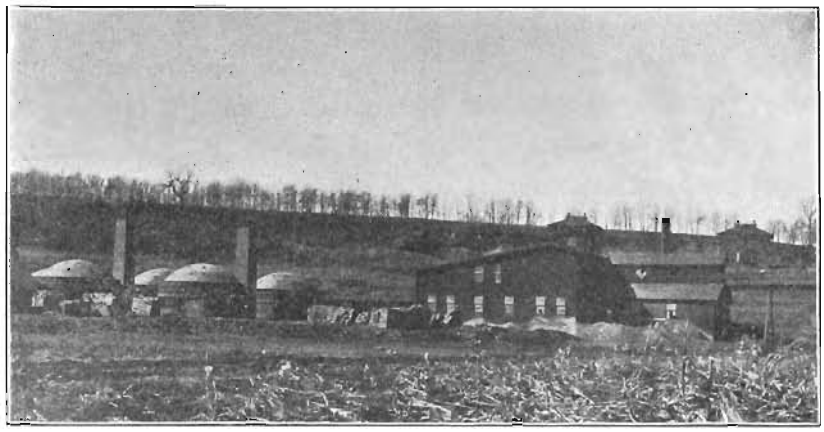


FIG. 48. Plant of Platt Pressed and Fire Brick Company, Van Meter, Iowa.

	FEET.
5. Drift and waste	1 to 4
4. Sandstone	⅔
3. Shale, gray, arenaceous	2
2. Sandstone, blue, compact	1½
1. Shales, variegated, red and gray, exposed	15

These clays are developed for the manufacture of red brick and tile. The firm also manufactures buff brick and fire brick. The raw material is obtained from a depth of some 265 feet, by mining out the three to seven feet which occurs between the upper and middle coal seams of the locality. The lower part of the section at the mine is as follows:

	FEET.	INCHES.
9. Shale, argillaceous	90	
8. Coal	1 to 1½	
7. Fire clay, impure, gray	2 to 4	
6. Fire clay, "flint clay"		6 to 18
5. Fire clay		6 to 18
4. Coal	1½ to 4	
3. Sandstone	16	
2. Shale, bituminous	1	
1. Coal	2 to 4	

Number 7 is used in the manufacture of buff brick, either alone or mixed with number 5. Number 6 gives a good grade of fire brick,

Number 9 burns a pink color and gives a good strong brick. By mixing the mined clays with the surface red burning shale, almost any desired color can be secured. The buff burning clay furnishes a good body for the manufacture of the various shades of mottled and ornamental brick and enameled wares. The three grades of fire clays have been analyzed, and gave the following results:

	No. 5.	No. 6.
Silica	55.11	86.63
Alumina	26.71	10.92
Iron oxide	4.28	0.10
Sulfuric acid	4.16	.....
Water	9 69	2.33
	99.96	99.97

The analyst was W. S. Robinson, chief chemist of the Union Pacific railway, Omaha, Nebraska. While the constituents are given in the form of oxides, the iron in number 5 doubtless occurs in the form of the sulfide. None of the strong fluxes, soda, potash, lime and magnesia, were reported. Number 6 is highly siliceous and extraordinarily low in fluxing constituents and ought, when properly manufactured, to yield a superior quality of fire brick.

Number 7 was analyzed by Charles Ferry, of Troy, New York, and gave the following results:

Silica	53.21
Alumina	25 74
Combined water	10.19
Clay and sand	89.14
Iron oxide	7.07
Lime	0 48
Magnesia	0.98
Potash and soda	4.30
Total fluxes	12.83

The clay is manufactured, dry press process, into an exceedingly dense, strong, homogeneous brick, much prized for front

brick and interior finish work. It is one of the most durable dry press brick on the market.

About three miles east of Redfield, near Cottonwood mills, fifty feet of Coal Measure strata appear in the bluff north of the river. Shales greatly predominate and but little stripping would be required in their utilization. The section is as follows:

	FEET.
11. Drift	3
10. Shales, sandy, buff	10
9. Sandstone, yellow	½
8. Shales, sandy, buff	1
7. Shales, blue	1
6. Sandstone, yellow, soft	3
5. Shales, sandy, buff and gray	10
4. Sandstone, soft, gray	3
3. Shales, sandy, blue	12
2. Sandstone, yellow	1
1. Shales, sandy	4

South of Redfield, near the junction of the Middle and South forks of the Raccoon river, at "Hanging Rock," a massive sandstone makes up the principal portion of the section. In the west edge of the town, close to the right-of-way of the Chicago, Milwaukee & St. Paul railway, the sandstone member has entirely disappeared and a splendid series of shales may be observed. The clay pit of the Redfield Brick and Tile Company displays the following layers:

	FEET.
5. Drift and hillside wash	0–10
4. Shale clays, variegated, yellow, gray, blue, purple and red. Fissility somewhat obscured by weathering.	8
3. Shale, red, fissile, with occasional very hard, hematite concretions	4
2. Shale, blue to blue-gray when weathered; jointed, contains occasional finely arenaceous streaks, and limonitic seams	12
1. Fire clay	4

The plant is very favorably located. Practically no stripping is required and the transference of raw material to the factory and the manufactured product from the factory to the car, can be

very cheaply done. All of the shale beds are used, and the composite is well adapted to the manufacture of all grades of common brick, paving brick, sidewalk brick, drain tile and hollow block. West of Redfield the arenaceous members again become prominent. Near the old mill site south of Linden, on the Middle Raccoon, the following section appears:

	FEET.
12. Drift	
11. Sandstone, buff, shaly in part	7
10. Shales, gray, sandy above	8
9. Coal	½
8. Shales, gray	6
7. Limestone, gray, very fossiliferous	1
6. Shales, gray	6
5. Limestone, buff, 18-inch layer below, brecciated and yellow above	4
4. Shales, gray	12
3. Sandstone, gray	2
2. Shales, gray	13
1. Clay shales, red, exposed to river	2

The thin seam of coal is forty-six feet above the river.

North of the Middle Raccoon there are few exposures of the Coal Measures. Just north of Adel, on a small tributary of the North Raccoon river, much obscured siliceous and argillaceous beds may be observed. A local brick plant has developed the beds to a limited extent. The pit shows the following layers:

	FEET.
3. Shale, variegated, siliceous and gypseous, with hard ferruginous and clayey concretions	14
2. Coal, impure, clayey and with calcareous layers	⅓
1. Shale, light gray to white at top, variegated below (exposed)	

To the west the shales cut out rapidly, and within one hundred feet the drift rests directly on number 1. Common brick and drain tile only are attempted.

Just above High Bridge the Coal Measures appear in the west bluff. The following beds may be observed:

	FEET.	INCHES
5. Drift	4	
4. Sandstone, thinly bedded	3	
3. Shale, light colored, with sandy concretions, grading downward into bituminous shale.	18	
2. Coal	1	8
1. Fire clay, exposed		4

The above section may be accepted as being a fair example of the Coal Measures for the northeastern portion of the county. No attempt has been made to utilize the beds in this vicinity.

Decatur county.—The county lies wholly within the Coal Measures. The lower measures appear sparingly along the Grand river and in the southeast corner of the county. The shale clays have not been utilized, and are not very accessible. Along a small ravine, north of Davis City, the following shale section belonging to the Des Moines stage, may be observed:

	FEET.
5. Shale	3
4. Shale, black, fissile	1
3. Shale, drab, arenaceous	4
2. Shale, sandy, yellow	6
1. Shale, drab, clayey, with several thin bands of blue-black, non-fossiliferous limestone	4

By mingling numbers 2 to 5, doubtless a good strong brick could be produced. None of the beds are especially well adapted to the manufacture of clay wares, and the bituminous shale might have to be rejected. The heavy stripping would make extensive open pit work impossible, and mining would scarcely be found practicable.

The upper Coal Measures carry so much lime that good shale sections are rare. One of the best in the county may be viewed at DeKalb, near the wagon bridge just north of the railway station. The section exposed is as follows:

	FEET.
5. Limestone, thinly bedded, very fossiliferous	2
4. Shale, soft, gray	2
3. Shale, fine, black, fissile	1
2. Shale, black, soft	2½
1. Shale, drab	4

Here, again, the shales could be worked only by mining, and while the limestone would afford a good roof, the quality of the raw material would hardly warrant the expense.

Des Moines County.—The Coal Measures occupy small detached areas in the southwest corner of the county, near the Skunk river. Southwest of Danville the following beds may be viewed:

	FEET.	INCHES.
7. Drift	20	
6. Shale, light colored	20	
5. Shale, bituminous	3	2
4. Coal	1	
3. Fire clay	3	6
2. Shale, brownish, gray, gritty	1	6
1. Shale, light, brownish, sandy in places (exposed)	4	

While the area is small and at present somewhat inaccessible, the shale clays are excellently adapted to the manufacture of the various grades of clay wares. Certain of the layers below the coal seam have for more than half a century been used in the manufacture of pottery.

On the farm of B. B. Jester, near Parrish, a clay shale is being developed which has gained quite a local reputation as a fire clay. It lies below the thin coal seam, and attains a thickness of four feet. The section here exposed is as follows:

	FEET.
5. Drift	10
4. Shales, argillaceous	20
3. Shale, hard, dark gray in color above, bituminous below	3
2. Coal	1+
1. Shale	8

The coal vein has been worked from time to time since 1834. Number 1 in the section is separable into three parts, consisting of three and one-half feet of fire clay, gray, slightly iron-stained; one and one-half feet of hard, brownish-gray, gritty shale and at the bottom four feet of lighter brownish-gray clay, quite hard. The lowest layer is best adapted to the manufacture of fire brick

and when washed can be used for a fine grade of pottery. Chemical analyses, both complete and rational, of the fire clay are given below:

Silica	74.82
Alumina	15.54
Combined water	4.97
Clay and sand	95.33
Iron oxide	2.72
Lime	0.73
Magnesia	0.45
Potash	0.32
Soda	0.38
Total fluxes	4.60
Moisture	0.22

RATIONAL ANALYSIS.

Clay substance	21.77
Feldspar	9.79
Quartz	68.94
	100.50

The total fluxes calculated on a water free basis amount to 4.85 per cent. The physical tests and furnace tests support the chemical analyses and indicate that the clay deserves more attention than it has yet received.

The clays at prsent used by the local potteries are gypseous and concretionary and washing is necessary. The removal of these impurities is accomplished by mixing the clay to a slurry with water, then passing over two screens, an upper 60-mesh and a lower 70-mesh to the inch.

The screens vibrate longitudinally and the coarser particles are removed at one end. This slip is run into a tank dug into the ground, where the water evaporates. If arrangements were such that the water could be tapped off instead of being permitted to evaporate the soluble matter could be removed instead of being permitted to remain in the clay as at present and later

appear in the surface of the unglazed ware as a white efflorescence.

Fremont County. The upper Coal Measures are believed to cover the entire county and lie immediately beneath the drift. They are prevailingly argillaceous or marly in character with immediate beds of hard limestone exposed in nearly every section. At Hamburg in the southwest portion of the county, just south of the school house on D street, a shallow pit shows the following section:

	FEET.
5. Shale, calcareous, variegated, fossiliferous; containing hard nodules of pyrite and lime	15
4. Limestone, impure, gritty, fossiliferous	18
3. Shales, red and gray	4
2. Limestone, impure, color dark gray	2
1. Shale, gray, argillaceous	12

The above section may be taken as fairly representative. No attempt, as yet, has been made to utilize the indurated beds at this point. About three miles east of Nebraska City Junction a stratum of shale with a thickness of four or five feet is exposed immediately above a ledge of sandstone. The shale is quite free from grit and varies from pale to dark red in color. Some prospecting has been done with a view to using it for paint. It would doubtless give better results in the manufacture of clay wares. No other shale sections worthy of notice are known to exist in the county.

Greene County.—The county lies only partially within the Coal Measures, the western portion being overlapped by the Cretaceous. The few outcrops of shales in the county appear along the Raccoon river, southeast of Jefferson, but at only one point are they utilized, and that is at Grand Junction, where the raw material is mined in conjunction with the mining of an eighteen-inch coal vein. The Grand Junction Brick and Tile Company has operated successfully for a number of years, notwithstanding they could obtain their clay only by mining. The coal seam

worked lies about 140 feet below the surface, and the clay used is a semi-fire clay which lies directly under the coal. The principal output is drain tile, although some brick are produced. The ware burns buff to pale red and gives excellent satisfaction.

Along the Raccoon river, near the southeast corner of the county, shale outcrops may be noted. Usually the drift mantle is quite thick, and considerable stripping would be necessary. In some instances the shales exposed are of excellent quality, but not very accessible. Near the Riverside mine the following section may be observed:

	FEET.
5. Drift, variable in thickness up to	50
4. Sandstone	1 to 2
3. Shale, plastic	2
2. Shale, argillaceous, more or less massive	3½
1. Sandstone	Exposed.

The shaft section in the immediate vicinity demonstrates that the sandstone is forty feet in thickness and is underlain by twenty feet of shale, in part bituminous, which rests directly upon the principal coal seam of the district. The coal is underlain by the usual layer of fire clay. No attempts have been made, as yet, to utilize the argillaceous deposits.

Guthrie County.—The Cretaceous is believed to cover the greater portion of the county, but the Coal Measures occur in the east quarter and appear along the Middle Raccoon river into the northwest corner township. The best exposures may be viewed along the Raccoon river. Shale clays constitute an important part of the Coal Measure series as developed in the county. The following sections may be considered fairly representative for the county. Southwest of Linden, in Dallas county, near the old Tann mill site, on the Middle Raccoon, the following beds are more or less imperfectly visible.

		FEET.	INCHES.
16.	Drift, Kansan	6	4
15.	Limestone, thin bedded, buff	1	6
14.	Shales, gray, argillaceous; becoming blue below	20	
13.	Limestone, nodular, impure		6
12.	Shales, bituminous, mixed with impure coal	1	6
11.	Shales, light colored	8	
10.	Sandstone, coarse, yellow, with flakes of coaly matter and remains of poorly preserved Neuropteris	10	
9.	Shales, arenaceous, blue and yellow	3	
8.	Coal, impure		6
7.	Shales, dark and light blue	7	
6.	Limestone, thin, irregular	1	
5.	Shales, blue	2	
4.	Limestone, earthy, irregularly bedded	1	6
3.	Shales, blue	1	
2.	Limestone, impure	1	
1.	Shales, blue and gray, exposed about twenty feet above the river	2	

Northward exposures are not uncommon, and good outcrops of clay shales may be seen in the vicinity of Panora. The pit of the Panora Brick and Tile Company shows the following sequence.

		FEET.
3.	Shale, clay, argillaceous, red	12
2.	Coal and bituminous shale	2
1.	Shale, argillaceous sandy, blue to white with irregular bands of calcareous material; exposed to within six feet of the river	18

Practically the entire section is utilized, and very little stripping is necessary. Drain tile is the chief product. The raw material is of good quality and vitrified ware could be manufactured satisfactorily if desired.

Panora is the only point in the county where the shales have been used as yet. Other outcrops, quite accessible, are not rare. About one-half mile north of Glendon, in a cut on the Rock Island railway, excellent material is exposed, although some stripping would be required in the cut. In the near neighborhood, doubtless, areas could be found where the upper beds have

been removed and the lower shales are more easily accessible. The cut section is as follows:

		FEET.
6.	Sandstone, soft, yellow to red, irregularly bedded.	2
5.	Clay, yellow, free from grit, much like geest.....	1½
4.	Limestone, brecciated, gray, with common Coal Measure fossils.....	2
3.	Shales, yellow, clayey.....	8
2.	Limestone, soft, sandy.....	½
1.	Shale, clayey, red to greenish.....	12

Hamilton County.—Hamilton lies almost wholly within the area of the Coal Measures but few good outcrops are visible. Practically the only exposures appear along the Boone river between Webster City and the Webster county line, and these are almost wholly concealed by landslides and vegetation. No attempts have been made to explore or develop the shale clays. Some coal has been mined in this vicinity, but no mines are in operation today. The Silver mine, located on a small ravine west of the Boone river, (Tp. 88 N., R. XXVI W., Sec. 36, southeast quarter, southeast quarter) shows the following section:

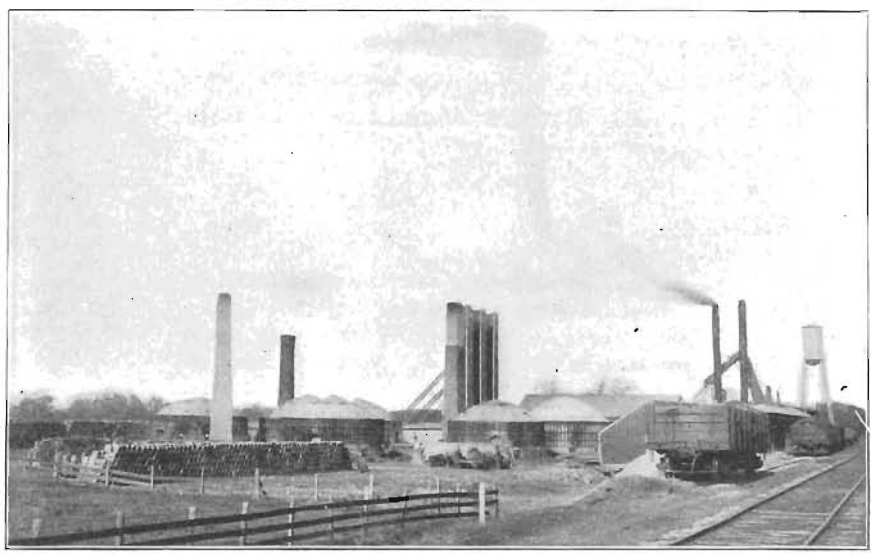


FIG. 49. Plant of Webster City Brick and Tile Company, Webster City, Iowa.

		FEET.	INCHES.
5.	Drift	2	
4.	Shale, light to dark colored, somewhat sandy in places	5	
3.	Sandstone, massive, with occasional bands of bituminous shale	3	4
2.	Coal	1	2
1.	Shale, drab and fire clay (exposed)	2	

The coal seam and fire clay band are visible at a number of points, but are not very accessible. There is no railroad, nor are there any towns in the vicinity of the outcrops.

Hardin County.—The Coal Measure shales have been developed at three points in the county; Iowa Falls, Eldora and Gifford; the first along the north fork of the Iowa river and the last two below the junction, and also on the bottom land of the South fork. Along the north fork of the Iowa river, from about a mile and one-half north of Gifford to some distance above Steamboat Rock, a red-brown sandstone appears prominently in the bluffs. In the vicinity of Eldora, clay shales appear in the valley walls. North of town along the Iowa river, on either side of the wagon road, two coal seams appear a few feet above the water in the river. The fire clay below the lower seam has a good reputation and was used formerly in the manufacture of pottery. East of Eldora, along on the east side of the river, the following section may be observed:

		FEET.
5.	Drift	5–15
4.	Sandstone, red, ferruginous	30–40
3.	Shales, variegated, fissile, oxidized to a yellowish-brown above but gray-blue to deep blue below. The variegated appearance is due in large measure to the seams and flattened lenses of fine, white sand	12
2.	Talus slope, beds concealed but probably made up of shales largely	20-30
1.	Sandstone, friable	10–20

The beds are repeated west of the river; the sandstone, however, is much more prominent. The clay shales, number 3 in

the section, have been used to a limited extent by the clay plants in Eldora, but with results not altogether satisfactory, on account of the sand seams.

On the Iowa river bottom north of Eldora, a clay pit has been opened by the Eldora Pipe and Tile Company, who haul the clay to their plant in the city. A fair grade of fire clay is obtained in the vicinity, an analysis of which is given herewith.

Silica	72.09
Alumina	16.24
Combined water	5.18
Clay and sand	93.51
Iron oxide	1.08
Lime	0.48
Magnesia	0.48
Potash	1.08
Soda	0.77
Total fluxes	3.89
Moisture	2.46
Sulfur trioxide	0.14

Calculated on a water free basis, the total fluxes amount to scarcely more than four per cent, or more accurately, 4.36 per cent. The clay is highly plastic, shrinks but little during the processes of drying and burning, is excellently adapted to the manufacture of pottery, fancy and mottled brick, and would doubtless give a fair grade of fire brick when mixed with a liberal amount of "grog" and properly made.

High grade clays also occur south of Eldora, about one-half mile north of Gifford, on the bottom land of the south fork of the Iowa river. From two to four feet of stripping is required, below which is a section of nearly twenty feet of shale clays. These beds have been developed for some forty years, and are at present used by the Eldora Pipe and Tile Works and by the Marshalltown Pottery Company. Analyses of two of the types give the following results:

CLAY No. 1.

Silica	78.49
Alumina	10.24
Combined water	3.33
Clay and sand	92.06
Iron oxide	4.32
Lime	.51
Magnesia	.44
Potash	1.23
Soda	.81
Total fluxes	7.31
Moisture, sulfur trioxide and carbon dioxide	.84

CLAY No. 2.

Silica	63.27
Alumina	20.21
Combined water	8.50
Clay and sand	91.98
Iron oxide	4.32
Lime	.99
Magnesia	.42
Potash	.64
Soda	.55
Total fluxes	6.92
Moisture, sulfur trioxide and carbon dioxide	.98

RATIONAL ANALYSES.

	1	2
Clay substance	14.81	41.10
Feldspar	48.21	12.22
Quartz	36.98	46.68
	100.00	100.00

Both clays are relatively low in fluxes and are highly plastic.

Just south of the town of Gifford the Coal Measure shales outcrop along a small stream and have been developed by the Gifford Brick and Tile Works. The pit shows the following beds:

		FEET.
2.	Drift, on north side of pit arenaceous to gravelly below, loosely compacted dirty, yellow.....	0–3
	On south side of pit a heavy, blue joint clay, oxidized a red brown along the joints.....	0–3
2.	Shale, deep blue (almost black when wet) considerably oxidized where unprotected by drift, becomes arenaceous eastward and contains but little iron.....	8

The shale burns a pale red, works rather easily and makes a strong tile when properly burnt.

No other shale outcrops are known below this point within the limits of the county.

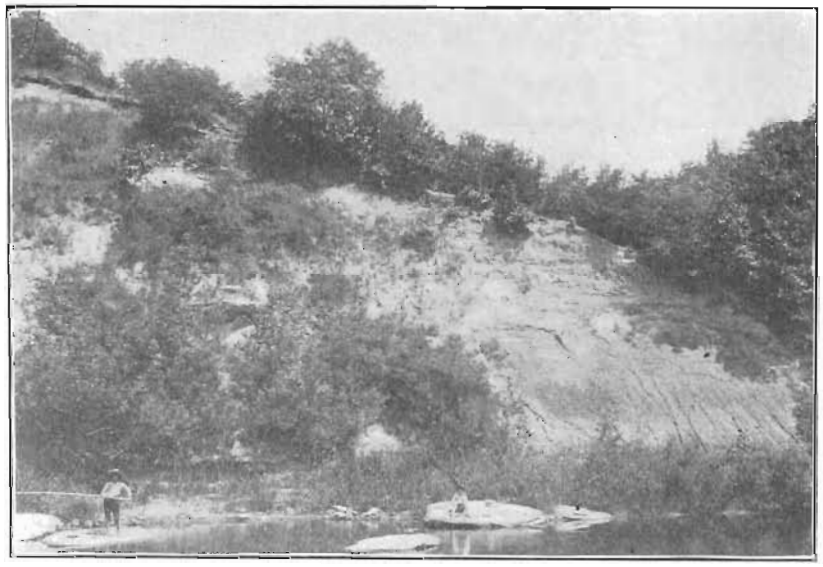


FIG. 50. "Honestone Quarries" showing Coal Measure shales on the Iowa river west of Iowa Falls, Iowa.

West of Iowa Falls the Coal Measures form two small detached areas along the Iowa river. Near the so-called "Honestone Quarries" the following beds may be viewed:

		FEET.
7.	Drift of variable thickness up to	50
6.	Shale, arenaceous	10
5.	Shale, sandy to shaly sandstone	3
4.	Shale, variegated, blue to yellow	4
3.	Sandstone, fine-grained, gray-blue, forming a projecting ledge	2
2.	Shale, fissile, gray-blue, to deep blue when wet	30
	UNCONFORMITY.	
1.	Limestone, cherty and much weathered, exposed	5–10

Near the streams which are tributary to the Iowa river, the drift covering is much thinner and the shales are much more accessible. These beds are being developed by the Iowa Falls Brick and Tile Company. A semi-fire clay appears in the section, from which a fair quality of fire brick is being manufactured. All of the clays run low in fluxes and are fused with difficulty.

Humboldt County.—The Coal Measures are believed to cover the southern portion of Humboldt county. Along the west fork of the Des Moines river, a short distance southwest of Bradgate, a white, arenaceous shale outcrops near the wagon bridge. The white shale is quite plastic when wet, and several feet of variegated shales rest upon it. The section continued upward consists of five feet of green, siliceous shale and, finally, twelve feet of gray plastic clay. Over this lies fourteen feet of gravel and yellow bowlder clay. The major portion of the section is believed to be suitable for the manufacture of any of the common clay wares, and might possibly be suitable for sidewalk block and vitrified wares. None of the seams have been exploited.

Jasper County.—The Coal Measures cover almost the entire county, but shale outcrops are not very common, owing to the great thickness of the drift, especially in the northern and eastern portions, and consequent talus slopes. In the southern portion of the county the "Redrock" sandstone appears prominently along the stream ways. Two miles above Lynnville a coal shaft, known as the Black Oak shaft, penetrated the following beds:

		FEET.
11.	Drift	5
10.	Clay shale, light colored above, unctuous	6
9.	Coal	4
8.	Fire clay	5
7.	Sandstone, soft, massive, upper six inches indurated	5
6.	Shale, somewhat fissile, irregular concretionary bands of iron-stone at base	20
5.	Coal	1¾
4.	Fire clay	¼
3.	Shale, bituminous	8
2.	Coal	1⅓
1.	Fire clay, (exposed)	2

The shale above the upper coal seam is quite persistent and could be mined readily with the coal. It has been tested, and gives a good quality of structural brick. It has not been developed, owing to lack of transportation facilities. Near the head of Birch creek, about one mile from the town of Monroe, the Coal Measures are being developed by the Monroe Brick and Tile Company.

Stoneware is also manufactured on a small scale. The pit section is as follows:

5.	Bowlder clay, occasionally lime bearing	3½
4.	Shale, strong, plastic, pink	2
3.	Shale, dark blue, plastic	3½
2.	Shale, bituminous, fissile	2¼
1.	Shale, white siliceous, in lower part	10½

Number 1 has been used in the manufacture of pottery. The entire section, with the exception of number 5, can be utilized in the manufacture of common brick, hollow ware and probably vitrified brick.

Jefferson County.—The Coal Measures cover much the greater portion of the county. As the county has been considerably dissected by streams and the drift is comparatively thin, numerous shale sections are exposed, although shales are being utilized at but a single point, at Fairfield.

Near the southeast corner of the county, along a small ravine running into Cedar creek, on the southeast quarter of section 35, Round Prairie township, the following section may be observed:

		FEET.
5.	Shale, black	12
4.	Sandstone, white, with imbedded fragments of charcoal	1½
3.	Clay, arenaceous	1
2.	Shale, white, arenaceous	3
1.	Sandstone, white	3

To the westward numerous good exposures of shales are visible along Cedar creek and small tributaries. Among the best of these may be mentioned the bluff on the south side of the creek on section 29, Cedar township, which shows the following beds:

		FEET.
6.	Sandstone, yellow	3
5.	Shale, yellow	3
4.	Coal of the common bituminous kind above, changing into cannel coal below	1½
3.	Fire clay	3
2.	Shale, dark, becoming highly carbonaceous and bituminous below	6
1.	Shale, green, extending down to the bed of the creek	4

On the northwest quarter of section 32, in Fairfield township, the beds are decidedly more arenaceous and the sequence is as follows:

		FEET.
7.	Shale, soft, arenaceous with alternating bands of sandstone	7
6.	Sandstone, cross-bedded, somewhat coarse-textured	10
5.	Shale, gray, arenaceous, thinning toward the west.	3
4.	Sandstone, gray, slightly cross-bedded and micaceous	7
3.	Coal, thinning to the east and running out to the west, greatest thickness	1½
2.	Fire clay, gray and arenaceous	3
1.	Fire clay and shale (partly concealed)	7

One-fourth of a mile south of the center of section 28 is located the clay pit of Raney Brothers Brick and Tile Plant. The pit section is as follows:

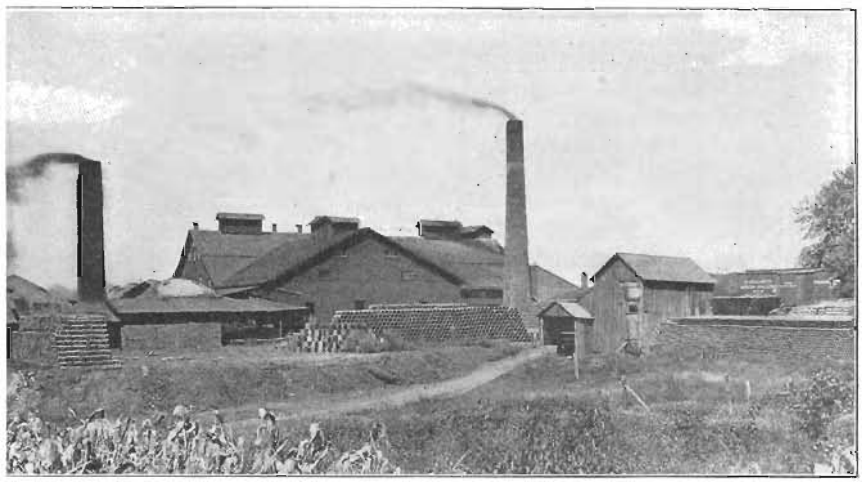


FIG. 51. Raney Brothers Brick and Tile Plant, Fairfield, Iowa.

		FEET.
7.	Loess and bowlder clay	15
6.	Coal	½
5.	Fire clay, white	2
4.	Shale, black, with some crystals of gypsum	3
3.	Coal	1
2.	Fire clay, white	4
1.	Sandstone, greenish, fine-grained, micaceous	1

Exposures similar to the pit section continue along the small creek. In Liberty township sections are common along Cedar creek. A good exposure may be viewed in the north bluff east of the wagon bridge in section 3, and shows the following beds:

		FEET.
7.	Shale, gray, disintegrated and containing crystals of gypsum, and a calcareous seam which bears fossils and concretions	25
6.	Coal	1
5.	Sandstone, brown	1–5
4.	Shale, black	1
3.	Coal	1
2.	Fire clay and shale	10
1.	Coal, partially concealed near bed of creek	2

A generalized section of the Coal Measures for Liberty township would be as follows:

		FEET.
9.	Concretionary limestone	1–5
8.	Shale, gray	5
7.	Coal	0–3
6.	Fire clay	0–4
5.	Sandstone, hard, gray	0–5
4.	Shale	30
3.	Shale bituminous	1–3
2.	Coal	3
1.	Fire clay, and shale	7

The preponderance of shales in the above section is obvious, and yet none are being utilized in clay manufactures.

In the western tier of townships, shale exposures are still common. On the west bank of Competine creek, in the southeast quarter of section 21, in Locust Grove township, a representative section may be seen. The sequence is as follows:

		FEET.
5.	Shale, bituminous	1
4.	Shale, sandy, greenish, in places dark and with septarian nodules	15
3.	Sandstone, argillaceous, greenish and calcareous	½– 1
2.	Shale, arenaceous, green	8–10
1.	Limestone, brecciated, concretionary	3

Jefferson county possesses good railway facilities, and doubtless the shale clays which are more than ordinarily accessible will receive, at some future time, the attention their importance merits.

Keokuk County.—The Pleistocene deposits cover the entire county and attain an unusual thickness, averaging from 100 to 200 feet over the uplands. Only the larger streams have cut through the drift, exposing the older rocks. The Coal Measures occupy the greater portions of Prairie and Washington townships, and a number of isolated patches occur over the southern half of the county. Along Coal creek, in the vicinity of What Cheer, unimportant crops of shales appear, but are usually much obscured by drift-slides. The principal coal horizons are usually

accompanied by important fire clay seams. One of these has been tested for pottery, and the results were all that could be desired. None of the beds, however, have been exploited commercially. Extensive development of the shales and clays could only be done by using mining methods.

The fire clay which accompanies the principal coal seams of the What Cheer district has been analyzed, and the results are as follows:

Silica	62.75
Alumina	22.00
Combined water	6.92
Clay and sand	91.67
Iron oxide	2.28
Lime	0.65
Magnesia	0.39
Potash	1.93
Soda	1.49
Total fluxes	6.74
Moisture	0.84
Sulfur trioxide	0.69
RATIONAL ANALYSIS.	
Clay substance	40.11
Feldspar	5.52
Quartz	54.37
	100.00

The fluxes run low, and the clay is highly plastic. It burns a light buff and requires more than 2,800 degrees Fahrenheit to fuse it.

Near Delta the glacial debris is somewhat thinner. About one mile and a quarter southeast of town, a shaft sunk by Martin Fisher penetrated the following beds:

		FEET.
5.	Drift	4
4.	Shale, bituminous below	9
3.	Coal	41½
2.	Fire clay	41½
1.	Shale, bituminous	

A small Coal Measure outlier about two and one-half miles north of Martinsburg furnishes a fair grade of clay which has been used to a limited extent by the local brick and tile plants in admixture with the surface clays. Other small outliers would furnish, doubtless, good material for the various grades of clay wares, but no attempts have been made as yet to utilize them.

Lee County.—Several more or less detached Coal Measure outliers form the country rock in the northern and western portions of the county. In Franklin township some coal has been mined. On the northeast quarter of the northeast quarter of section 4, the old Hardwick mine and slope along Sugar creek show the following section:

		FEET.
5.	Drift	3
4.	Shale, bituminous	1
3.	Coal	3½
2.	Fire clay, arenaceous	2
1.	Shale, arenaceous (exposed)	3

On the northwest quarter of section 10, in the same township, a more extensive outcrop is exposed. The following beds come into view, the upper beds, only, belonging to the Coal Measures:

		FEET.
7.	Drift	10
6.	Coal	2
5.	Fire clay	2
4.	Sandstone, soft, quartzose	5
3.	Limestone, coarse, irregular	2
2.	Shale, calcareous	1
1.	Limestone, shaly above to sandy below	11

North of Keokuk, near Rand Park, some exploratory work for coal has been done. The section is as follows:

		FEET.
6.	Drift	20
5.	Shale, dark, bituminous	6
4.	Coal	1½
3.	Fire clay	½
2.	Sandstone, brown, coarse-grained	10
1.	Limestone, brecciated (exposed)	8

Below Keokuk, above Nassau slough, shale beds appear but they have not been developed. Clays and shales are available at other points, but as yet but feeble attempts have been made toward their utilization. In many instances sufficient coal is found in the immediate locality to burn the clays.

Lucas County.—Although the county lies well within the Coal Measure area, good sections are rare, on account of the generous drift covering and absence of large streams. The shale clays have not been developed within the confines of the county. The best exposures occur on the Chariton river, Whitebreast creek and along the Little Whitebreast and its tributaries in the vicinity of Chariton and Cleveland. Five miles northeast of Cleveland, the bluff section along Whitebreast creek is as follows:

		FEET.
12.	Drift	5
11.	Shale, argillaceous, variegated	4
10.	Coal	1½
9.	Fire clay	1
8.	Shale, variegated	8
7.	Limestone, impure, earthy in places	2
6.	Shale, ash colored, calcareous below	6
5.	Limestone, bluish, nodular in places	2
4.	Shale, black, bituminous, fissile	1½
3.	Coal	1½
2.	Fire clay	2
1.	Shale, light colored, sandy in places	

Here, as elsewhere in the county, wherever the Coal Measures are exposed the shales and clays are greatly in the predominance and most of them are suitable singly or in combination for the manufacture of the various grades of clay wares.

Madison County.—The upper Coal Measures occupy a considerable portion of the county. The margin is deeply lobular, owing to profound stream dissection. The lower Coal Measures form the country rock over the northeast quarter of the county and follow the more important stream ways well toward the western and southern boundaries of the county. Good exposures are common and easily accessible; the best for the lower

Coal Measures may be observed in South township. The most complete section occurs on a small branch of Chariton creek, which takes a west and north course across sections 35, 34 and 27. The section heads near the Des Moines and Kansas City railroad, while the base of the section reaches almost to the right-of-way of the Chicago Great Western railroad. The sequence is as follows:

		FEET.	INCHES.
22.	Shales, drab, argillaceous	12	
21.	Shales, red, argillaceous	3	
20.	Limestone, fragmental, earthy, with bits of fossils		2
19.	Shales, blue to green, argillaceous, grading into red below	3	
18.	Shales, blue to green, sandy, with nodular segregations of limestone	12	
17.	Shales, blue, calcareous	12	
16.	Limestone, compact		2
15.	Limestone, fragmental, loose		10
14.	Limestone, fragmental, but firmly cemented, reddish color	1	
13.	Shales, green, argillaceous	29	
12.	Limestone, blue to black, in two ledges	1	
11.	Shale, carbonaceous	2	
10.	Shale, clayey, drab	1	
9.	Shale, yellow, sandy, with marked horizontal bedding planes	4	
8.	Shales, black to drab, carbonaceous		6
7.	Limestone, nodular, sandy	1	4
6.	Shale, gray, sandy	3	
5.	Limestone, similar to No. 7		10
4.	Shale, clayey, drab to blue		10
3.	Shale, carbonaceous	1	
2.	Limestone, thin bedded, leaf-like in texture		3
1.	Clay, green	3	

North of St. Charles, on the road leading south across section 11, the following beds are exposed along a gully. The section starts 100 feet below the upland.

		FEET.	INCHES.
15.	Drift	6	
14.	Sandstone, soft, gray, with flakes of yellow mica	8	
13.	Shales, sandy, gray	15	

		FEET.	INCHES.
12.	Limestone, sandy, fossiliferous	1	2
11.	Shales, carbonaceous, coaly below	1	4
10.	Shales, gray	4	
9.	Sandstone, heavily bedded, with Lepidondendrons	4	
8.	Shale, sandy above	6	
7.	Coal		6
6	Shales, clayey, variegated	20	
5.	Shales, bituminous	2	
4.	Limestone, fragmentary	5	
3.	Shales, blue to gray	6	
2.	Shales, carbonaceous	2	
1.	Shales, blue, clayey, exposed	5	

One of the most important sections of clay shales exposed in the county may be viewed on the south bank of the Middle river, about two miles southwest of Bevington. The indurated beds exposed are as follows:

		FEET
11.	Limestone, weathered, clayey	2
10.	Shale, gray and drab in color	2
9.	Shale, yellowish-gray, grading into bituminous below	2½
8	Coal, decomposed	½
7.	Fire clay more or less impure	4
6.	Shale, yellow to gray, sandy, somewhat ferruginous	12
5.	Shale, red, siliceous, fissile	3
4.	Sandstone, micaceous	1
3.	Shale, similar to No. 6	7
2.	Shale, down to the river	15
1.	Coal	1½

Similar beds occur along Jones creek westward from Hawley. At Winterset the shales are less important, limestone becoming the most prominent member in the series and is extensively quarried.

South of Patterson an exposure along a ravine in section 32, northwest quarter of southeast quarter, in Crawford township, yields the following section:

		FEET.	INCHES.
14.	Shale, black	2	
13.	Unexposed, probably shales	21	
12.	Shale, blue, clayey above, gray, sandy below	16	
11.	Limestone, dense, drab, fossiliferous	1	
10.	Shale, blue, clayey	3	
9	Sandstone, gray		5
8	Shale, clayey, blue and gray	27	
7.	Sandstone, gray, nodular	1	
6.	Shale, sandy, drab	27	
5	Limestone, arenaceous, gray, fossiliferous.		9
4.	Shale, black	2	
3.	Shale, gray, clayey (only partly exposed)	30	
2.	Coal		6
1.	Shale, red (only partly exposed)	32	

In addition to these sections, numerous other outcrops are visible, but the above are the best and are believed to be fairly representative of the lower Coal Measure series. It is obvious from a casual inspection of the sections that shales are in great predominance, and shales of the light colored, argillaceous type. The beds are easily accessible and could be reached readily by the extension of railway spurs. Yet no exploratory nor development work has been done with a view to using the shale clays.

Shales are not so conspicuous in the upper Coal Measure portion of the county. Beds accessible and of sufficient extent to be important economically could be found, doubtless, if sought, but no efforts have been made in that direction.

Mahaska County.—The Coal Measure beds underlie the superficial materials over nearly the whole county and consist largely of shales. The larger streams uncover the indurated rocks and render the shales accessible. The sections are obscured very largely, however, by the glacial debris. In the southwestern part of the county, shaft No. 8 of the Consolidation Coal Company may be considered a type section for the district. The shaft is located on the divide between the Des Moines river and Muchakinock creek, section 34, Des Moines township. The section is as follows:

		FEET.
8.	Drift	18
7.	Shale, gray, argillaceous	32
6.	Coal	1½
5.	Sandstone	4
4.	Shale, bituminous	49
3.	Coal	7
2.	Fire clay grading into gray shale	35
1.	Limestone (Saint Louis)	——

Usually the drift is so thick on the divides that open pit work is impossible; the shales could be developed only through mining. Numerous outcrops along Muchakinock creek display a wide assortment of shale clays, none of which have been utilized. The only point in the county where the shales are utilized is at Oskaloosa. The pit of the Oskaloosa Paving Brick Company shows the following beds:

		FEET.
5.	Drift, largely altered loess with some gneiss pebbles and a few large bowlders disseminated in it	20
4.	Shale, blue, makes a good brick but does not stand the frost as well as the bottom clay	10
3.	Shale, very bituminous	2
2.	Coal, good quality, apparently the attenuated edge of a four-foot seam formerly worked in the southern slope of the same ridge	1½ to 2
1.	Shale, gray, homogeneous except for thin lines of coal and occasional pyrite balls. Plant remains abundant	30

Numbers 1 and 4 are blended and the resultant mixture, when properly burned, yields a good quality of paving brick as well as builders and face brick. The fire clay below the coal seam burns a buff color, and when made into brick by the dry press process, gives a superior face brick. Some experimental work has been done in the manufacture of mottled face brick and floor tile, with good success. For ordinary builders, some of the loess may be added without harm to the product. No analyses of the clay or tests of the ware have been made.

The Coal Measure shales appear west of town, one of the best sections being exposed on an extension of Third street, about one-half mile beyond the city limits. The following beds may be here observed:

		FEET.
6.	Soil	2
5.	Gravel, fine	2
4.	Clay, yellow, jointed	12
3.	Shale, clayey, blue	10
2.	Coal	3
1.	Fire clay, exposed	——

A number of years ago, numbers 3 and 4 were used in the manufacture of common brick. Number 1 is used to a limited extent at the present time at a small factory west of the old Guthrie yard. The Coal Measure clay is mixed with the surface soil and manufactured into common soft mud brick.

Most of the fire clays which accompany the principal coal seams are of economic importance, and one or two were used to some extent a few years ago in the manufacture of pottery. No pottery is made within the limits of the county at present.

Marion County.—The Coal Measures cover the entire county with the exception of narrow areas along the principal waterways in the eastern part of the county, where they have been removed through erosion. Shales and clays are less predominant here than in most of the Coal Measure counties. The "Red Rock" sandstone assumes considerable importance and gives character to the topographic features along the Des Moines river. Good shale sections are not common. Along Whitebreast creek some of the most extensive outcrops may be observed, but they are far removed from railway lines at present. In the northeast quarter of section 4, in Dallas township, the following beds occur:

		FEET.	INCHES.
11.	Loess and drift	10	
10.	Shale, yellow, argillaceous	5	
9.	Shale, bituminous	3	
8.	Coal, very soft	1	2
7.	Fire clay	2	3
6.	Coal		4
5.	Fire clay	2	6
4.	Sandstone, thinly laminated, white	1	
3.	Sandstone, massive, buff	4	
2.	Shale, gray, arenaceous	3	
1.	Shale, bituminous (exposed)	10	

Other exposures appear on Whitebreast creek. One of the best occurs about four miles to the northeast, in the southeast quarter of section 19, in Knoxville township. The section is as follows:

		FEET.	INCHES.
9.	Clay, yellow, derived from decayed shale.	5	
8.	Shale, bituminous	5	
7.	Coal, very soft	1	6
6	Fire clay, arenaceous, extremely hard, much fractured and filled with root casts	2	
5.	Sandstone, gray, thinly laminated above and massive below	12	
4.	Shale, arenaceous	1	4
3.	Sandstone, gray, soft	2	6
2.	Shale, arenaceous	5	9
1.	Sandstone, massive, buff to gray, irregularly cross-bedded, exposed to water	25	

Farther east and south, the sandstone members become much more important, although certain beds of shale persist and doubtless are thick enough to merit consideration. Along Coal creek, in Pleasant Grove township, the Coal Measures are quite well exposed; the following section may be taken as a fair sample. (Northwest quarter, northeast quarter of section 20.)

		FEET.
8.	Surface waste	5
7.	Coal	1½
6.	Fire clay	2
5.	Shale, light, argillaceous	2½
4.	Shale, drab, arenaceous	5½
3.	Sandstone, gray, thinly laminated usually, massive in places	3
2.	Shale, gray, arenaceous	3
1.	Shale, bitumiuous, exposed to water	13

A workable coal seam lies but a few feet below the stream bed. Here, as in other coal counties, fire clays of workable thickness accompany the coal seams and could be mined readily.

Monroe County.—The stratified shale clays of the Coal Measures cover almost the entire county, although they are only exposed along the stream ways. The most accessible sections appear in the northeast half of the county. Almost every ravine in the vicinity of Buxton and Hiteman exhibits liberal sections of argillaceous beds above the water line and are not deeply covered by surface materials. Shales appear lower in the valley walls along Coal and Cedar creeks and their tributaries, and the streams draining east from the divide. Many of the exposures are located directly on railroad lines, or within easy reach of such lines. Near the center of the northwest quarter of section 8, Pleasant township, an excellent section of shale clays is exposed which may be considered fairly representative for the district. The sequence is as follows:

	FEET.
7. Drift, exposed	5
6. Shale, clayey	10
5. Coal	1
4. Clay	2½
3. Sandstone	3
2. Shale	35
1. Coal	4

With the exception of the drift, which contains considerable calcareous matter, and the coal seams, the entire assemblage of beds could be utilized. Here, as elsewhere, the drift has greatly obscured natural sections, but systematic prospecting would undoubtedly show the presence of an abundance of suitable material near the railroads. In Bluff Creek township, at the point where the Chicago & Northwestern railroad crosses the creek in section 5, shale beds may be observed as follows:

	FEET.
3. Shale	4
2. Coal	5
1. Shale	10

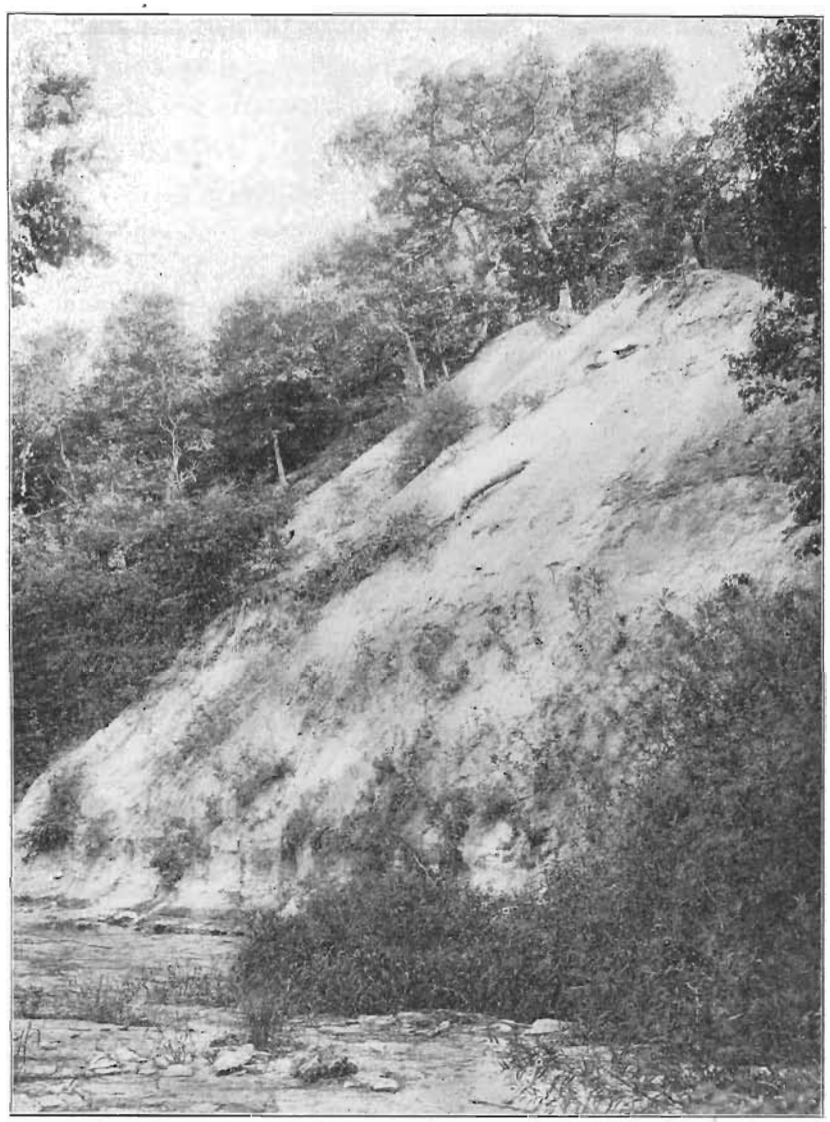


PLATE XXI. Section on Gray creek, Pleasant township, Monroe county. More than fifty feet of shales are exposed here.

The drift at this point is of variable thickness, usually not great. Coal is easy of access, and could be produced cheaply for burning the product. Nearly all of the ravines and small tributaries in this vicinity exhibit clays and shales suitable for manufacturing purposes, and many of the exposures are easily accessible and could be developed cheaply. One of the prospect holes put down by the Consolidation Coal Company gives a fair idea of the wealth of shales and clays available.

Tp. 73 N., R. XVII W., Sec. 17, Ne. qr., Ne. ¼.

	FEET.
11. Drift and surface wash	9
10. Clay, shale, unctuous	16
9. Shale, black, somewhat bituminous	5
8. Coal	½
7. Sandstone, friable	10
6. Shale, argillaceous	79
5. Coal	1⅛
4. Sandstone	2⅛
3. Shale	45
2. Shale, bituminous, bowldery	6
1. Coal, impure above	4½

In Guilford township the Wapello Coal Company has done considerable prospecting with the core drill. On the upland the drift is prevailingly thick, but on the lowlands, or second bottom lands, the drift has been removed in large part and the shales and clays are within easy working range. A drill hole put down in the northeast quarter of the southwest quarter of section 12 may be considered typical for the vicinity. The sequence of beds penetrated is as follows:

	FEET.
12. Drift and surface wash	17
11. Shale, clayey	16
10. Coal	1½
9. Fire clay, impure	7½
8. Sandstone	12
7. Shale, somewhat bituminous	5⅛
6. Coal	3⅛
5. Sandstone	5⅛
4. Shale, blue black	6
3 Sandstone	22
2. Shale, bituminous below	44½
1 Coal	5½

In the vicinity of Hocking, in Troy township, the Coal Measures are more arenaceous in character; at least, the arenaceous beds predominate in the outcrops exposed along the small streams. West of Hocking, the outcrops along Cedar creek paralleled by the Chicago, Burlington and Quincy railway, are prevailingly arenaceous in character, although accompanied by important shale seams. In the eastern portion of the county, along Soap creek and the Averies, shale crops are common, but no very extensive beds are known. Most of the outcrops are greatly obscured by the heavy drift talus and vegetation. No systematic prospecting has been done in the county for shales and clays, and no serious attempt has been made toward their utilization. By far the largest amount of clay wares consumed are imported, notwithstanding the fact that Monroe county possesses unsurpassed facilities in the way of an abundance of excellent raw materials and cheap fuel.

Montgomery County.—Thick beds of Coal Measure shales are known to exist over the northeast corner of the county, but owing to the thickness of the drift covering they are not very accessible. Their availability is seriously impaired, also, on account of the absence of good railway facilities in that portion of the county. The limestone members in the upper Coal Measures here, as in other counties in southwestern Iowa, are quite strongly developed, while the shales are much less important than in the counties farther east. The shales which do occur are often calcareous or carry calcareous concretions, both of which seriously impair their usefulness for clay working. The section exposed in the Fate quarry, at Stennett, gives a good idea of the upper Coal Measures as they are developed in the county. The details of the section are shown in the accompanying figure and are as follows:

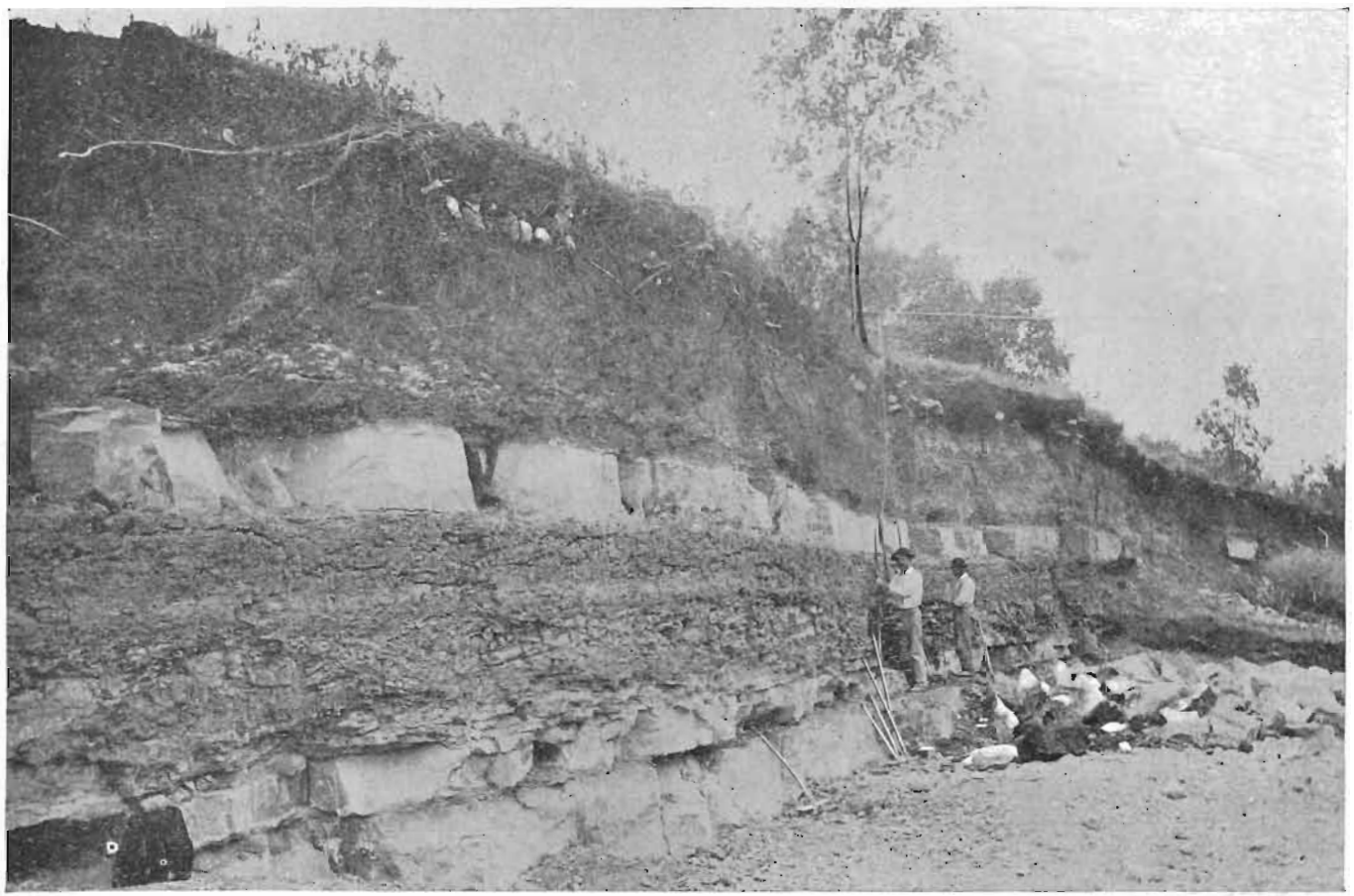


PLATE XXII. Representative section of the upper Coal Measures as exposed at Stennett, Montgomery county, Iowa.

	FEET.	INCHES.
10. Limestone, residual	5	6
9. Shale, calcareous		6
8. Limestone, gray, fine-textured	1	7
7. Shale, buff to gray, argillaceous	3	4
6. Limestone, variable, earthy below	5	
5. Clay, buff	1	
4. Limestone, blue above, cherty	6	
3. Shale		2
2 Limestone, variable	5	
1. Shale	1	6

Numbers 1 to 5 are not exposed in the figure. At Villisca the limestone beds are less prominent. Just south of town the Villisca Brick and Tile Company have opened a pit in which limestones are absent. The section is as follows:

	FEET.
5. Loess, yellow to brown or gray, jointed in upper part.	12
4. Sand, clean; thickness varies from one inch to	2
3. Shale, argillaceous, dark gray to green in color	4
2. Shale, argillaceous, light gray	3
1. Shale, gray to light, rather finely siliceous	

Number 3 is of good quality; number 2 contains thin shells and crinoid stems in considerable abundance, but is usable. Number 1 is from twenty to sixty feet in thickness as determined by borings, but is imperfectly exposed at the pit. It can be used when mingled with some of the beds above, but is too siliceous to be used satisfactorily alone. This is the only point in the county where the Coal Measure shales are being developed.

Muscatine County.—The Coal Measures occupy a considerable portion of Montpelier, Sweetland and Bloomington townships. This basin extends into Scott county, following the great bend of the Mississippi river. The series of beds as they are developed in this basin are very variable. A thin seam of coal appears at a number of points and is usually accompanied by an important bed of fire clay which has been developed to some extent by the local potteries at Fairport. In section 30 of Sweetland township, the series is essentially made up of shales. The old Hoor

coal bank in the east half of the section is reported to have shown the following beds:

	FEET.
5. Shale, bluish, argillaceous	10
4. Sandstone, rather compact	2
3. Coal	3
2. Fire clay, soft, gray	4
1. Concealed to the river	30

Some of the clay used by the potteries is obtained from the Illinois side. A portion is secured along Pine creek and from a pit along a small stream north of Fairport. Only the commoner varieties of pottery are attempted. The results are satisfactory, but operations are carried on on a small scale.

The Coal Measure shales present limited exposures at Muscatine. One of the best is known as the Powder House Clay Pit, and is situated above the track about one-half mile east of the river bridge. The sequence of beds is as follows:

	FEET.
4. Shale, hard, gray, impure	2
3. Coal, decomposed, soft	1½
2. Shale, dark gray, siliceous	½
1. Shale, light gray, slightly sandy	4

Number 1 has been used to some extent by the local potteries. It bears some iron oxide in seams, otherwise it is nearly free from impurities. The drift rests unconformably upon the Coal Measures and is covered with loess. At Butlerville, about two miles northwest of Muscatine, an argillaceous shale appears. It is gray to blue in color, fairly plastic, but lacks "body" and cripples under high temperatures. It is reported about six feet in thickness and rests on sandstone. It could doubtless be blended with some of the surface clays and used satisfactorily in the manufacture of hollow ware. A good section of shales was formerly developed at Montpelier. It is located about one-half mile north of town. The sequence is as follows:

		FEET.
13.	Drift, lime bearing	3
12.	Shale, light blue, darker below	10
11.	Limestone, impure, ferruginous	$\frac{5}{6}$
10.	Shale, impure, pyritiferous	3
9.	Coal, sandy and pyritiferous	$1\frac{2}{3}$
8.	Shale, finely siliceous, gray	17
7.	Sandstone, fine-grained	$1\frac{1}{2}$
6.	Shale, bituminous	$\frac{2}{3}$
5.	Coal, rather pure	$2\frac{1}{2}$
4	Shale, dark gray, in part impure	5
3.	Shale, black	$\frac{5}{6}$
2.	Coal	3
1.	Sandstone	$7\frac{1}{2}$

The lower four members are not visible, but have been explored by drilling. Number 12, only, has been used in clay manufacturing. It is of good quality, fairly pure, containing occasional sulfur balls which could be readily removed. The other shale members could be used by blending with number 12, but no attempts have been made in that direction. The beds dip southeastward, and at the present time the plant is not in operation.

Page County.—With the exception of a few small and undefined patches of Cretaceous sandstone, the rocks beneath the drift belong to the Carboniferous system and to the upper Coal Measures, or Missourian stage. These strata consist of limestones and shales, the shales predominating as to thickness, but the limestone appearing in the greater number of exposures, owing to their greater powers of resistance. The shales and limestones found in Page county occupy a position from 500 to 600 feet above the Bethany or Winterset limestones that lie at the base of the upper Coal Measures. There are two limestone horizons in the county, one represented by the exposures at Hawleyville and Bradyville, and the other by the ledges outcropping in the valley of the East Tarkio. These limestones are separated by more than 100 feet of shale. Shales similar to these are manufactured on a large scale into paving and structural brick, at Nebraska City, Nebraska, and they are used extensively in brick

making at Villisca. They have not yet been developed in the county. The shales above the Tarkio limestone are usually calcareous to marly and perhaps would not prove very satisfactory in the clay industries unless carefully selected.

The shales between the limestone are not well shown in the county, but an excellent section is exposed near Burlington Junction, in Missouri, from which a good idea of their nature and thickness may be gained.

	FEET.	INCHES
20. Shale, blue	10	
19. Shale, yellowish-green, calcareous		3
18. Shale, marly, concretionary	2	
17. Shale, bluish-green, not calcareous	3	
16. Shale, yellowish, calcareous, concretionary	1	6
15. Shale, greenish-blue	1	
14. Sandstone, calcareous, ferruginous		6
13. Shale, sandy, with septarian nodules in the upper part	10	
12. Limestone, impure, with obscure impressions of fossils		2
11. Shale, sandy	2	
10. Limestone, impure, in thin bands alternating with sandy shale which carries septarian nodules near the bottom, fossiliferous	5	
9. Shale, gray	3	
8. Thin layer showing cone-in-cone at top and bottom, structureless in the middle		7
7. Shale, gray with occasional large septarian nodules	25	
6. Calcareous band, fossiliferous		4
5. Shale, dark, with some calcareous bands, fossiliferous near top, down to level of water in river	25	
4. Shale, below level of river	30	
3. Cap-rock	2	
2. Shale	4	
1. Coal (Nodaway)	1	6

The colors in the above section have been modified somewhat by weathering, the yellows would be replaced, doubtless by grays and blues in protected sections. The shales above the Tarkio limestone are not well shown in the county.

Polk County.—Polk county is centrally located in the lower Coal Measure district of the state, and in this county the shales have received most attention. Des Moines, located south of the center of the county, is the greatest clay manufacturing city in the state, and one of the greatest west of the Mississippi river, and bids fair to hold her well earned premiership as a clay working center. The industry is yet scarcely past its infancy. The presence, in the immediate vicinity, of almost inexhaustible quantities of clays and shales, with countless possibilities as to manufactured products, and easily accessible, with coal at hand, unrivaled transportation facilities, and ever increasing demand for clay goods, the industry may confidently be expected to make rapid progress until it becomes the leading manufacturing industry in the city. The generalized section of the Coal Measures for Des Moines, according to Bain,* is as follows:

		FEET.	INCHES.
18.	Variegated clay shales	13	
17.	Limestone, blue, nodular, weathering brown, fossiliferous	0	8
16.	Shales, variegated	8	
15.	Shales, bituminous, with calcareous concretionary masses below, fossil bearing.	3	
14.	Coal	2	
13.	Shale, light yellow and drab	7	
12.	Clay shale, variegated	4	
11.	Limestone	0	8
10.	Shales, variegated, clayey	4	
9.	Limestone, nodular, earthy, passing in places into marl, highly fossiliferous		6
8.	Clay shale, light colored	5	
7.	Sandstone, soft, micaceous, becoming in places an arenaceous shale	20	
6.	Shale, clayey, gray, yellow and red in color	8	
5	Sandstone, grayish, soft	4	
4.	Coal, impure, divided in places into three thin seams, which vary considerably in thickness	2	
3.	Shale, light gray, fissile	5	
2.	Shale, light to dark gray, micaceous below bituminous above	6	
1.	Shale, white, siliceous	10	

*Geology of Polk county, Geology of Iowa, Vol. VII, pp. 292 and 293.

Numbers 1 to 7, inclusive, are shown at the pit of the Iowa Pipe and Tile Company, east of the river; numbers 7 to 12 are exposed at the south end of Capitol Hill; numbers 12 to 18 are shown in street cuttings and clay pits in the northwestern portion of the city. It is obvious from the above sections that the shales greatly predominate. They vary greatly in composition, texture and adaptabilities. They are used for the manufacture of the various grades of building and paving brick, sewer pipe, conduits and drain tile, and have been used for common pottery. Certain seams are believed to possess the requisite properties to adapt them to the manufacture of terra cotta, mottled and fancy brick, floor tile and enameled ware. The shale clays have been developed at numerous points in and about the city of Des Moines, and the great variety of shades and grades, with their adaptabilities, can best be brought out by a consideration of the individual pits. At no other place in the state have the clays and their manufactured products been so thoroughly studied and tested.

The Des Moines Brick Manufacturing Company.—This company was the pioneer in the paving brick industry of Des Moines and the state. At one time it was the most extensive plant in the state, but in 1899 a fire destroyed the principal buildings, which have never been restored, and the plant has been dismantled. The clay pit section is included here because it is believed that the beds are available further west, and because elaborate tests have been made of the raw materials. The pit is located along the tracks of the Chicago, Rock Island and Pacific railway and the Spirit Lake branch of the Chicago, Milwaukee and St. Paul, and shows the following beds under a thin veneer of drift:

		FEET.
8.	Clay, variegated, highly refractory, burning to a brick of medium toughness, high porosity and low breaking strength; thickness, three to eight feet, average	5

		FEET.
7.	Shale, streaked in color, medium fusibility, high in iron and fluxes; burns to a brick of medium toughness, medium porosity and low resistance to rupture; thickness, three to eight feet, average	4
6.	Shale, solid chocolate, brown color, clear definition; brick show medium toughness, low porosity and high modulus of rupture	5
5.	Shale, solid color, clear to poor definition, an average clay with medium iron and fluxes, lower than the clays above; bricks show low toughness, low porosity, high modulus of rupture	5
4.	Shale, variegated clear to poor definition, low in iron and fluxes, high alumina, bricks show medium toughness, low absorption, high modulus of rupture	3
3.	Shale, sandy, solid color; bricks show low toughness, low absorption, medium modulus of rupture	10
2.	Shale, sandy, clear definition, solid color, granulated texture, pulverizes in the hand	5
1.	Shale, gray, clear definition, easily fused; brick good toughness, high porosity, low modulus of rupture	20 to 25

Each bed in the above section was analyzed by C. O. Bates, Chemist. The results are given below:

	8	7	6	5	4	3	2	1
Silica	70.29	59.18	64 60	64.41	63 23	76.01	67 76	55 56
Alumina	15.18	21.63	19.20	20.43	24.52	11.94	14.46	21.33
Combined water	2.18	3.80	3.96	3.93	2.55	1.41	3.53	4.65
Clay and sand	87.65	84.61	87.75	88.77	90.30	89.36	85.75	81.54
Oxide of iron	7.32	9.00	7.68	5 88	5.28	5.40	8.52	10.56
Lime	0.80	1.06	1.02	0.34	0.32	1.57	1.16	1.59
Magnesia	1.72	1.85	1 37	1.71	0.99	1.04	2.36	2.94
Soda and potash	1.49	1.52	1 25	1.90	1.16	1.80	1.24	2 38
Total	11.33	13.43	11.32	7.83	7.75	9.81	13.28	17.47
Moisture	1.02	1.95	0 92	1.27	1.75	0.65	0.67	0.97
Total	100.00	99.99	100.01	98.77	99 80	99.82	99.70	99.98

For the entire assemblage the clay and sand aggregates 85.67 per cent and the fluxes 13.22 per cent, a blend which, when the mixing had been thoroughly done, yielded a good quality of pav-

ing brick. The bricks were thoroughly tested and gave excellent satisfaction. As they are no longer on the market, the results of the tests are omitted. The plant was equipped throughout with up to date machinery and was the only plant in the state to make use of the steam shovel in mining and loading the clay.

On the east side of the river, in Oak Park, the Flint Brick Company is operating an extensive plant which was established in 1893. The company mine their own coal from a nearby shaft. The product is shipped over the Flint Valley line of the street railway or hauled by team to the various parts of the city. The old pit section operated up to 1902 is as follows:

		FEET.	INCHES.
12.	Bowlder clay up to	15	
11.	Shale vari-colored, the lower portion is of the nature of a fire clay	8	
10.	Shale, buff to gray, gritty	6	
9.	Limestone, impure	0	6
8.	Shale, red and bluish-gray, laminated	6	
7.	Shale, brick red in color, clean, unctuous	4	
6.	Shale, light gray	0	4
5.	Shale, crumbly, gray	1	6
4.	Shale, blue	28	
3.	Shale, bituminous	0	8
2.	Coal, soft "pockety"	1	
1.	Fire clay	1	

The section above number 4 is fully exposed in the pit. The lower numbers were encountered in sinking the shaft. In working the pit numbers 9 and 12 were wasted. The new pit opened just north of the wagon road which leads down to the plant, does not show the limestone ledge, as the beds dip slightly to the south and the drift is much thinner, ranging from zero up to three or four feet. The beds from 4 to 2, inclusive, are used without waste. Chemical analyses of the raw materials used give the following results:

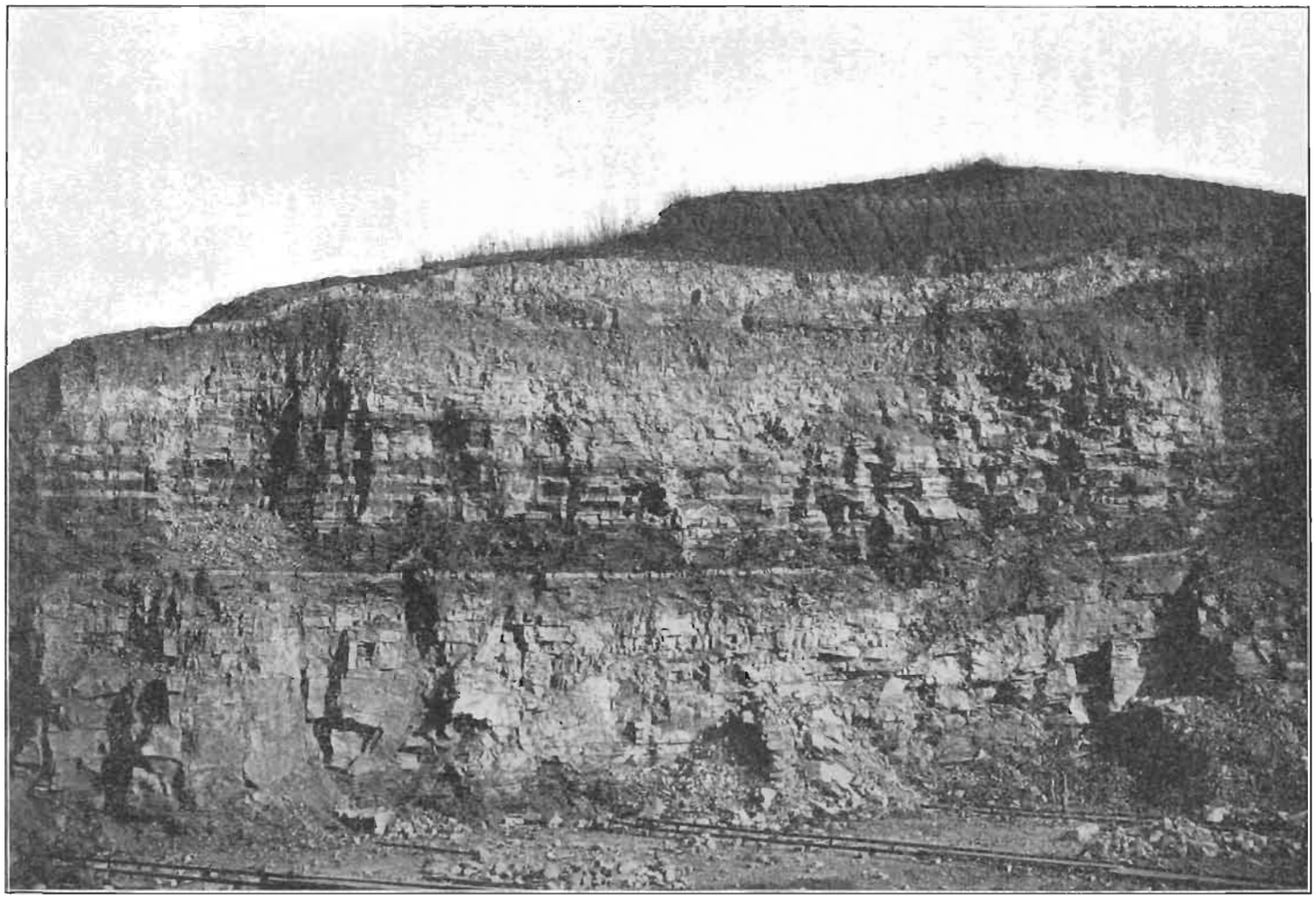


PLATE XXIII. Present pit of the Flint Brick Company, Des Moines, Iowa. About fifty feet of shales are exposed.

	Bottom Clay.	Middle Clay.	Top Clay.	Green Brick.
Silica	67.50	61.22	67.15	63.75
Alumina	15.75	21.12	15.47	19.78
Combined water.	3.22	33.75	4.37	2.92
Clay and sand	86.47	116.09	86.99	86.45
Iron oxide	4.80	5.28	2.88	5.75
Lime	2.57	1.80	3.17	1.55
Magnesia	1.57	1.44	2.72	1.22
Potash	0.95	0.63	0.24	0.54
Soda	1.56	0.89	0.58	1.20
Total fluxes	10.45	10.04	9.59	10.26
Moisture, sulfur trioxide, carbon dioxide	2.88	3.78	3.29	3.88

RATIONAL ANALYSES.

Clay substance	52.85	59.12	53.79	61.57
Feldspar	15.80	25.32	8.76	13.47
Quartz	25.99	9.59	33.31	20.53
Calcium sulfate, Magnesium sulfate, Calcium carbonate	5.36	5.97	4.41	4.43
	100.00	100.00	100.00	100.00

The green brick was taken as it came from the brick machine, and is supposed to represent the blend produced in actual practice from the various beds exposed in the pit. The mixture shrinks moderately in drying and burning and but small loss is sustained in either the drier or the kiln. The ware burns to a blue-black and produces a high grade paver. The finished product has been subjected to an elaborate series of tests, the results of which will be found in a later chapter. The plant is equipped with modern machinery throughout and is one of the largest producers of paving brick in the state. Building brick are also made to a limited extent.

Across the river from the Flint plant are the works of the Iowa Brick Company, which were installed about ten years ago. The pit worked until 1903 was as follows:

PLATE XXIV. Plant of the Flint Brick Company, Des Moines, Iowa.

FIG. 52. Pit of the Iowa Brick Company, Des Moines, Iowa.

		FEET.
8.	Shale, variegated, reddish-brown, mahogany reds, yellowish, bluish-drab, dark gray almost black, the colors mottled parallel to beds	6
7.	Shale, sandy, light yellowish-white, solid color	6
6.	Shale, slightly sandy at top, pale blue streaked with chocolate brown	5
5.	Shale, clear chocolate brown	4
4.	Shale, granular, dark solid drab with purple nodules	3
3.	Shale, bluish-drab	6
2.	Shale, streaks of brownish-drab and greenish to chocolate brown; stratification well defined	6
1.	Shale, clear dark drab, with olive green tinge	2

The diversity of the shales is emphasized when the chemical analyses are inspected. As the pit was worked back into the bluff

the drift covering thickened greatly and stripping became so expensive that a new pit was opened west of the wagon road. The beds being developed at the present time are similar to those in the old pit and less expense is involved in wasting away the surface materials. The results of the analyses of beds 2 to 7, inclusive, are given below:

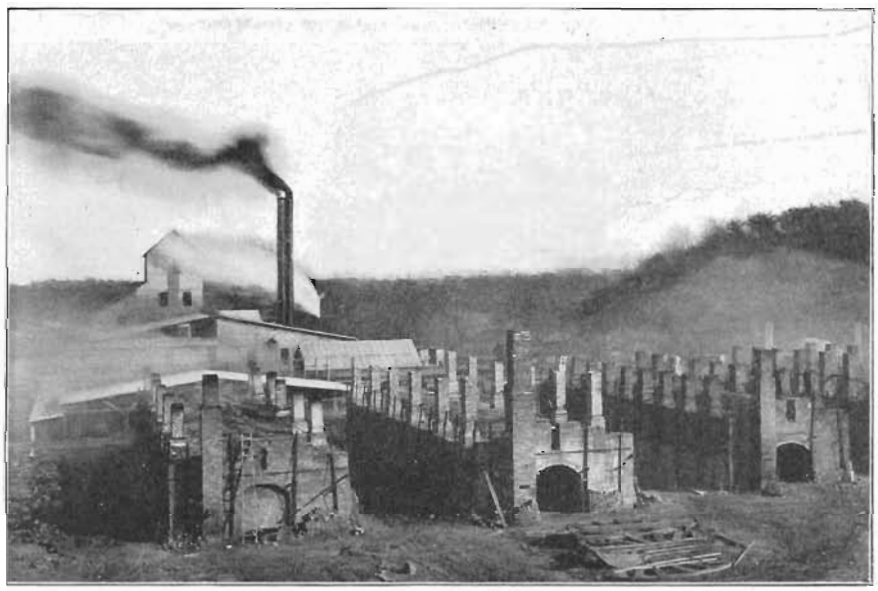


FIG. 53. A portion of the plant of the Iowa Brick Company showing multiple stack kilns in the foreground and the machinery buildings in the background.

	2	3	4	5	6	7
Silica	61.59	67.40	60.43	56.29	65.22	73.43
Alumina	21.01	16.68	20.43	21.97	19.22	11.94
Combined water	4.51	1 44	6.82	3.59	2 66	4.33
Clay and sand	86.81	85.52	87.68	81 85	87.10	89.70
Iron oxide	4.79	4.31	1.91	8.63	3 35	3.83
Lime	3.58	3.17	6.59	3.17	2 89	1.00
Magnesia	2.16	1.42	1 87	1.34	1.44	0.86
Potash	0.52	0.36	0 21	0.60	0.59	0.05
Soda	1.13	1.38	0.90	1 48	1.59	0.95
Total fluxes	12.18	10.64	11.48	15.22	9.96	6.69
Moisture	0 42	0.25	.89	0.83	0.39	0.63
Sulfur trioxide	0 95	1.00	0.45	1.15	1.80	1.65
Carbon dioxide		2.99		1.58	1.58	0.90

RATIONAL ANALYSES.

	2	3	4	5	6	7
Clay substance	56.79	31.00	60.70	70.66	49.30	41.47
Feldspar	21.96	32.77	2.33	3.95	13.09	3.24
Quartz	19.63	30.56	36.97	21.79	34.01	55.29
Calcium sulfate, Calcium carbonate, Magnesium carbonate	1.62	5.67		3.60	3.60	

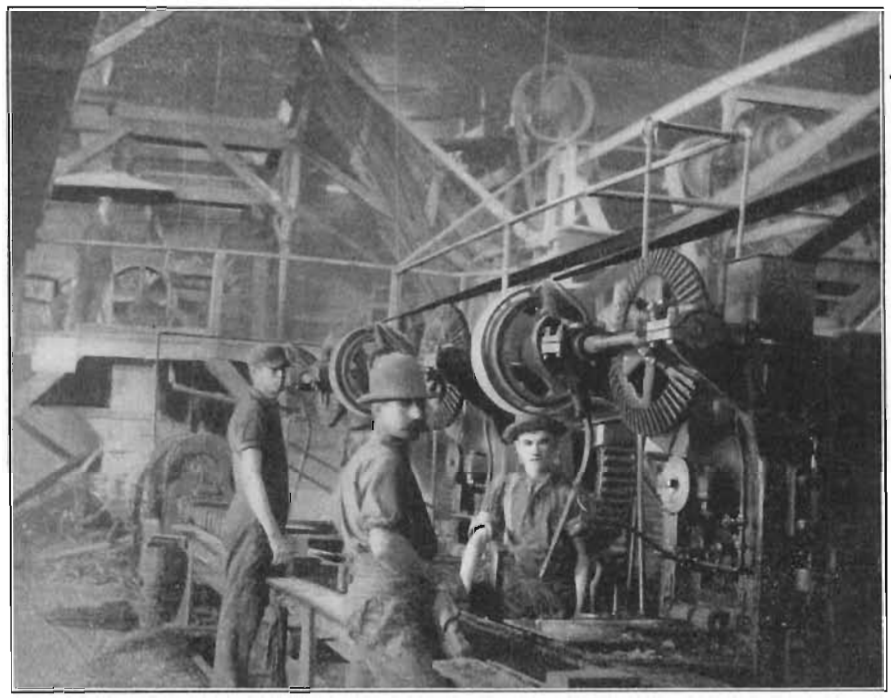


FIG. 54. Represses used by the old Iowa Brick plant, Des Moines, Iowa.

In the analyses where no carbon dioxide is given a separate determination was not made and the carbon dioxide is included in the loss on ignition. In the rational analyses where the sulfates and carbonates are not given separately, they are included in clay substance. Paving brick, common builders and hollow ware are the chief products. The company formerly turned out a small amount of terra cotta, which is of interest now as a dem-

onstration that certain of the clay seams could be used successfully in that line of work.

Southwest of the city, south of the Raccoon river, the shales are being developed extensively by the Barber Asphalt Company, successors to the Capitol City Brick and Pipe Company, and the Merrill Brick Company. The Barber plant is located on the Chicago and Great Western and the Keokuk and Western railways. The pit, below the glacial debris, shows the following shale series.

		FEET.
7.	Shale, medium light drab with slight seams of rust, plastic, very slightly gritty	7
6.	Shale, mottled and streaked, maroon to sea green, greenish and purplish-brown rust in seams.	4½
5.	Shale, medium dark bluish-drab, clean	7
4.	Fire clay, impure, mottled purplish-blue, dark gray, slight rust in seams	4
3.	Shale, soapy, but containing some grit, clear greenish-drab	15
2.	Shale, very dark, greenish-gray with slight seams of rust	1½
1.	Shale, clear blue, sandy	10

It is evident, on a casual inspection of the above section, that the clays south of the city show an even greater diversity than those to the north. The analyses of the leading types of clays in the pit gave the following results:

	1	3	4	5	6&7	X
Silica	51.16	57.64	69.40	62.22	67.46	58.56
Alumina	22.26	16.22	16.39	17.90	17.89	22.33
Combined water	7.15	7.43	5.75	5.02	4.04	7.11
Clay and sand	80.57	81.29	91.54	85.14	89.39	88.00
Iron oxide	11.20	10.32	3.36	5.52	5.12	2.87
Lime	1.29	1.78	0.81	1.58	0.75	3.60
Magnesia	1.94	1.58	0.42	1.55	1.72	1.44
Potash	2.92	2.17	1.04	2.81	1.09	0.29
Soda	0.87	12.41	0.54	2.76	1.87	1.08
Total fluxes	18.22	18.26	6.17	14.22	10.55	9.28
Moisture, Sulfur trioxide, Carbon dioxide	1.51	0.49	2.37	.64	0.40	2.98

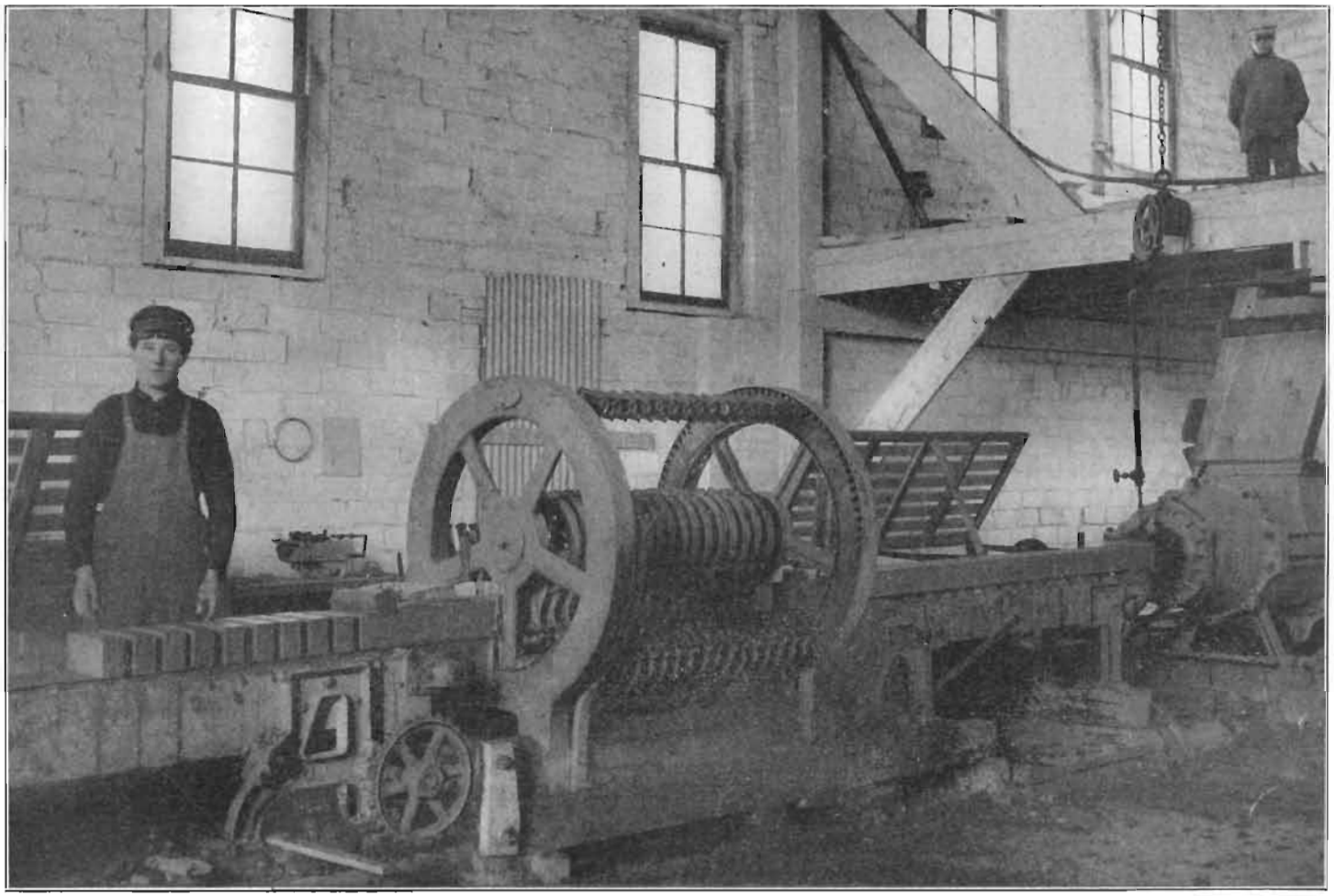


PLATE XXV. A modern rotary cutting table used by the Iowa Brick Company, Des Moines, Iowa.

RATIONAL ANALYSES.

Clay substance	51.53	44.49	44.12	39.79	38.00	64.45
Feldspar.....	4.42	9.54	8.57	9.72	11.19	4 38
Quartz.....	44.05	45.97	47.31	50.49	50.81	31.17
	100.00	100.00	100.00	100.00	100 00	100 00

In the analyses the carbon dioxide is included in the loss on ignition and the calcium and magnesium sulfates and carbonates are included under clay substance in the rational analyses. Paving brick, common builders and drain tile are the chief manufactured products.

FIG. 55. Pit of the Merrill Brick Company, Des Moines, Iowa.

The shales become less constant to the southwest, and a thin section of coal and a band of bituminous shale appear. The pit of the Merrill brick plant, located about one-half mile to the southwest of the Barber, shows the following section:

	FEET.
7. Soil and loess	3
6. Shale, bituminous	$\frac{5}{6}$
5. Shale, blue to gray and buff	4
4. Shale, red-brown, more or less variegated, containing iron stone concretions	20
3. Shale, blue to gray	6
2. Coal	$1\frac{1}{2}$
1. Shale, light gray	7

All of the material in the pit, except the coal and bituminous shale, is used in the manufacture of common builders and paving brick.

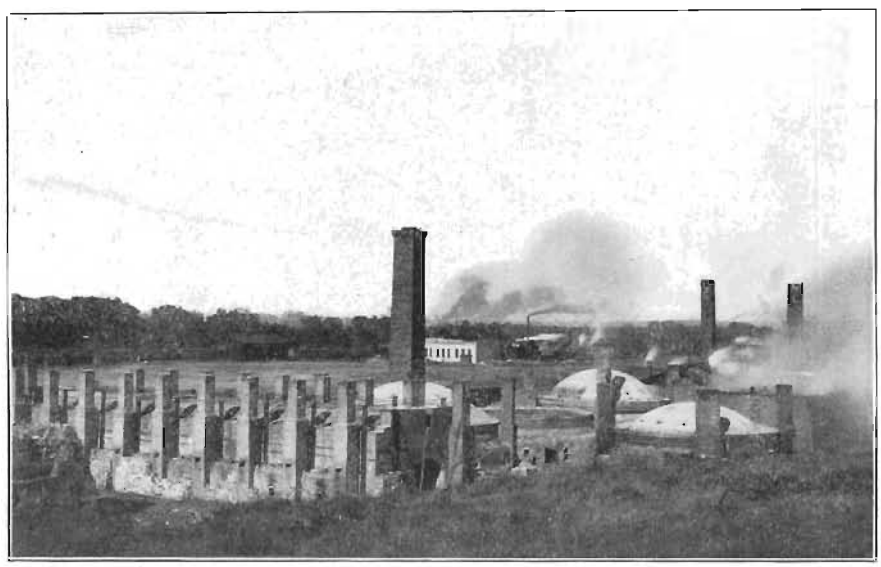


FIG. 56. A portion of the plant of the Merrill Brick Company, Des Moines, Iowa.

The Coal Measure outcrops around the base of Capitol Hill present a decidedly arenaceous facies which renders them undesirable for clay working. At the south end of the hill some twenty-five feet of irregularly bedded sandstone appear above the railway tracks. Northward along the river, the beds rise slowly and an excellent section may be viewed in the pit of the Iowa Pipe and Tile Company, which is given herewith:

	FEET.
9. Shale, argillaceous, yellow	20
8. Shale, clayey, gray, yellow and red	8
7. Sandstone, gray, soft	4
6. Shale, black, in part clayey	1½
5. Sandstone, gray	4
4. Coal, impure, shaly	1½
3. Shale, light gray	5
2. Shale, light gray to dark	6
1. Shale, white, siliceous	10

Sewer pipe and drain tile only are produced. Some difficulty is experienced in securing a good salt glaze, owing to the gypseous character of the clays.

The Iowa Pipe and Tile Company has opened a second plant about a quarter of a mile below the Flint plant. The shales used are closely similar to those developed in the pit of the Flint Brick Company. Drain tile, hollow block and common brick constitute the manufactured products.

Several other plants in and about Des Moines are using the shale clays in part or wholly, the most important being the Shackelford yard in North Des Moines, the Dale Brick Company in southeast Des Moines and the Newman Brick Company just outside the corporate limits, near Hastie.

The beds developed show no new phases of especial importance. The Pixley Conduit Company is operating a plant in South Des Moines.

Outside of the city the Coal Measure shales have been little used, although they are available at a number of points. At Altoona, the waste from a local coal mine was used formerly by mixing with surface material, which has later been abandoned. The Polk City Tile Works, at Polk City, uses shales which are hauled from a pit near the Des Moines river.

Poweshiek County.—Owing to the great thickness of drift and the fact that the streams have done little work in cutting, exposures of indurated rocks are rare. The Coal Measure shales show

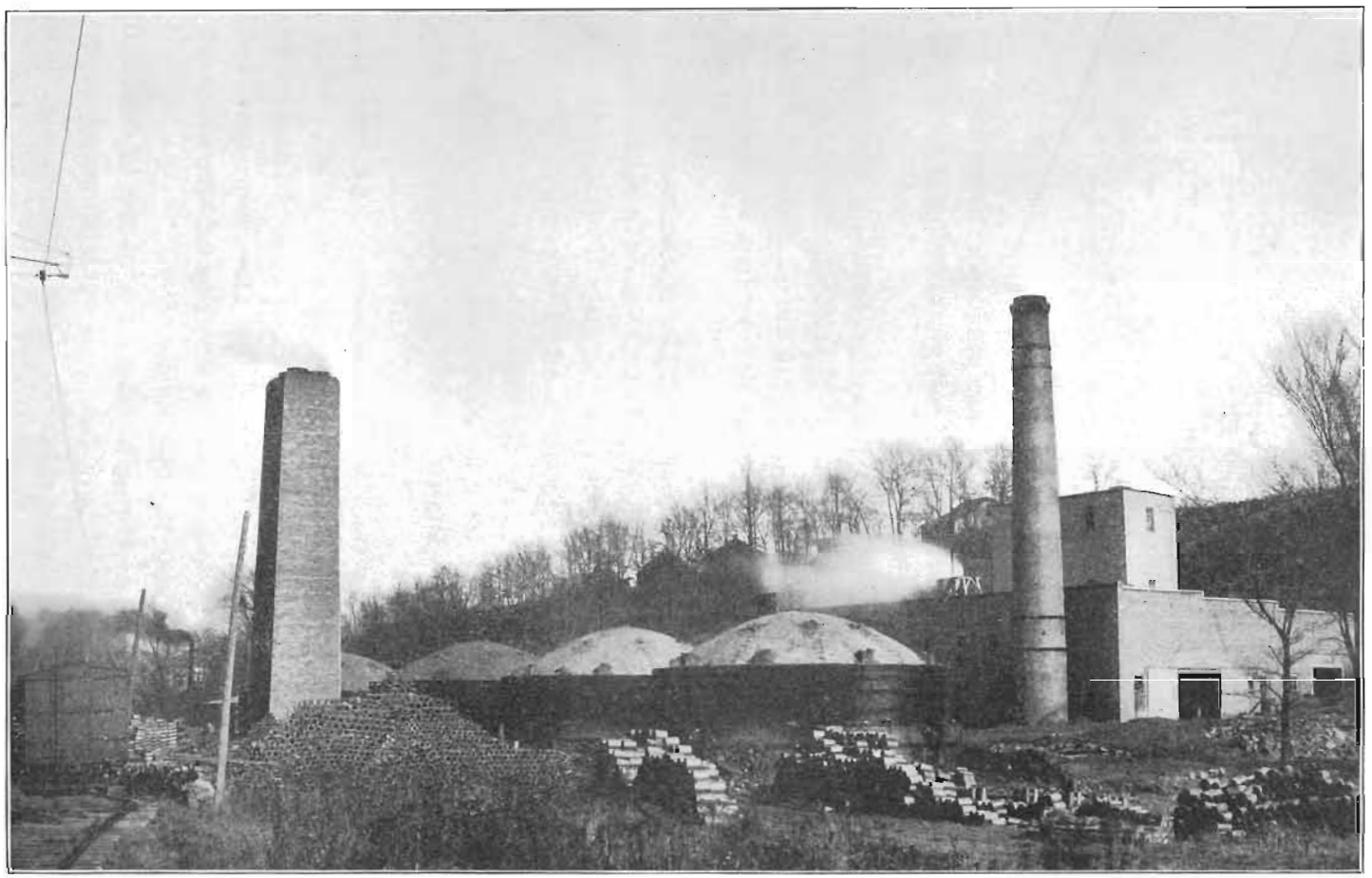


PLATE XXVI. Plant of the Des Moines Brick and Tile Company, Des Moines, Iowa.

somewhat obscure sections in Union and Sugar Creek townships. Even here beds which are accessible are not common. Near the old Petit mine workable shales are exposed. Some twenty-five feet of clay shales somewhat variable in character could be used in the manufacture of clay wares. No attempts have been made toward their utilization.

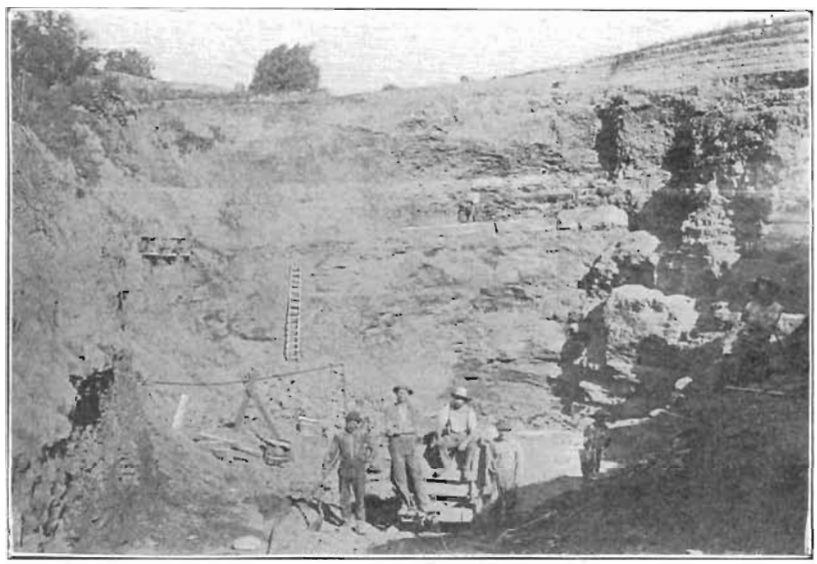


FIG. 57. Clay pit of the Davenport Brick and Paving Company, Buffalo, Iowa.

Scott County.—A number of Coal Measure outliers occur here which appear to belong to the Illinois coal field, but have been separated but recently by the narrow valley of the Mississippi river. The most extensive tract covers most of Buffalo township, in the southwestern part of the county, and sometimes about an equal distance into Muscatine county. The Davenport Brick and Paving Company are developing the shales at Buffalo. The pit shows the following beds:

	FEET.
8. Loess	7
7. Bowlder clay, red, brownish-red	5
6. Shale, weathered gray and ochreous yellow readily disintegrating, joints and seams and spaces between laminae filled with ochreous accumulations	5
5. Shale, black, finely laminated	12
4. Shale, gray	3
3. Shale, dark drab and black, brittle, fine-grained, containing ferruginous nodules and nodular layers	42
2. Shale, gray, disclosed in shaft below bottom of pit	26
1. Rock, hard ledge	

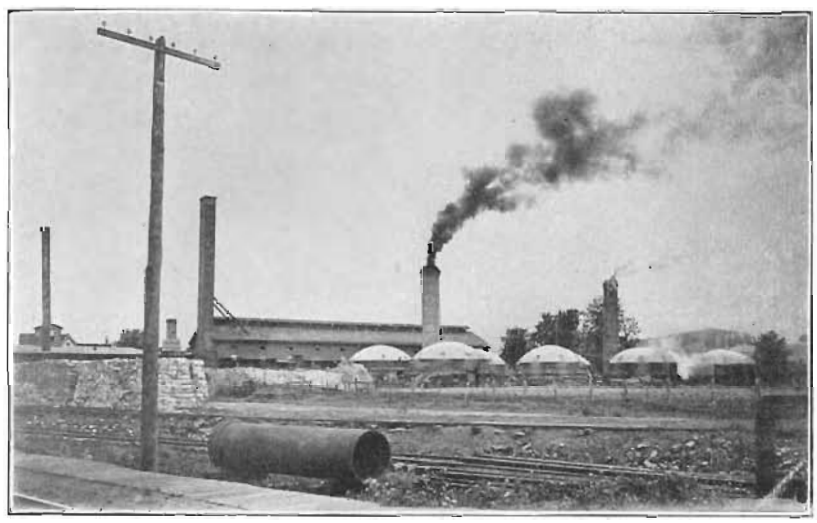


FIG. 58. Plant of the Davenport Brick and Paving Company, Buffalo, Iowa.

Common builders, paving brick, sidewalk and yellow ware constitute the manufactured products.

The next largest area in the county is situated about two miles southwest of LeClaire, directly on the river. At Island City the LeClaire Brick and Tile Company are using the shales in the manufacture of common brick and drain tile. The pit section is as follows:

	FEET.
7. Loess and drift, variable in thickness	
6. Cannel coal	2
5. Potter's clay	4
4. Coal	1
3. Fire clay	4
2. Shale, gray	2
1. Shale, blue-black, to bottom of pit	20

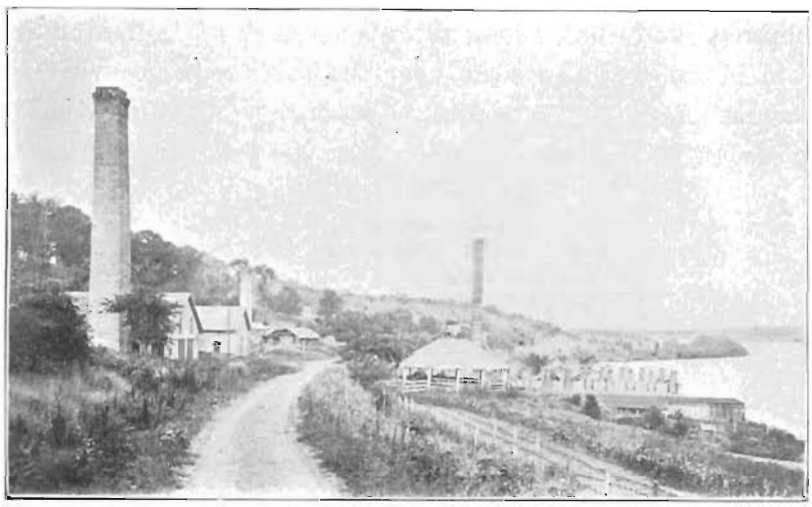


FIG. 59. Plant of the Le Claire Brick and Tile Company, Island City, Iowa.

Well borings in the immediate vicinity demonstrate that the shales continue down more than one hundred feet below the bottom of the pit, but no attempt has been made to utilize them.

Story County.—The county lies within the recognized limits of the Coal Measures, but owing to the great thickness of the glacial debris and the slight cutting of streams, shale exposures are comparatively rare. Pits have been opened and are being developed near Maxwell, Nevada and Roland. Shale outcrops along the Skunk river, near Story City, were formerly utilized to a limited extent. The pit at Maxwell is located about one mile east of town and shows the following beds:

	FEET.
4. Drift, weathered above, but calcareous below	6
3. Shale, gray, slightly arenaceous	8
2. Shale, variegated, much iron-stained along the joint and bedding planes; a limonitic, concretionary layer occurs about two feet from the base; iron concretions are common throughout	7
1. Sandstone	Exposed

Common building brick and hollow ware are the chief manufactured products. Along the west branch of Indian creek the Coal Measure shales come near the surface in the vicinity of Nevada. About one mile west of town they are being developed by Mr. S. M. McHose. The pit shows the following section:

	FEET.
7. Drift, bowldery, calcareous	5
6. Shale, blue, variegated; containing much ferruginous staining along the joint planes and known as "calico clay"	12
5. Sandstone, gray	½
4. Shale, gray-blue, jointed; containing some concretionary matter	3
3. Shale, carbonaceous	½
2. Fire clay	2
1. Shale, jointed, highly ferruginous; exposed	2

Common structural brick and drain tile are the chief products, although satisfactory paving brick and sidewalk block are made in varying quantities. With the exception of numbers 5 and 7, the entire section can be utilized. Sufficient iron is present to give a good color.

At Roland about eight feet of shales, light gray above and dark below, are available and are usually mixed with surface wash. Only the common wares are manufactured.

Taylor County.—The upper Coal Measures are supposed to form the superficial indurated rocks over the entire county. They comprise beds of hard limestone, bituminous and clay shales. Exposures of any note are practically limited to the western tier of townships, along the East Nodaway and West Fork rivers and their immediate tributaries. Coal has been

mined for some years along the East Nodaway, first by drifts and later by shafts. The shales and clays accompanying the coal seams are suitable for the manufacture of the common clay wares. They could not be worked extensively save by mining. None have been used up to this time.

Union County.—The upper Coal Measures extend over the entire county. Outcrops are rare save in the southeast quarter of the county. Along Grand river, below Afton Junction, sections showing shales and limestones are not uncommon, the former beds predominating. Some of the clay shales carry considerable calcareous matter, but many of the beds are pure enough, doubtless, for the common clay wares. No attempts have been made to develop them.

Van Buren County.—The Coal Measures present numerous outcrops along the Des Moines river and its tributaries, but have been but little developed. They consist essentially of various colored shales, with occasional thin seams of coal and friable sandstone. About one mile northeast of Douds Station, in Village township, the Findlay mine section is as follows:

		FEET.
12.	Concealed	20
11.	Shale, blue, argillaceous	10
10.	Coal	½
9.	Shale, arenaceous, filled with plant remains	1
8.	Coal	½
7.	Shale, becoming more argillaceous below	3
6.	Coal	½
5.	Sandstone, filled with plant remains	1
4	Fire clay	1 to 2
3.	Shale, black, fissile above, more compact below and filled with clay-ironstone concretions	4 to 5
2.	Coal, sometimes partially cut out by the nodular masses above	3 to 4
1.	Fire clay	2

The beds are quite variable, the coal seams often not appearing. The coal horizons are usually accompanied by beds of fire clay, some of which are suitable for the manufacture of pottery and

have been used to a limited extent for that purpose, as at Vernon and Farmington.

Wapello County.—The Coal Measures cover practically the entire county. The Saint Louis limestone appears along the Des Moines river and its immediate tributaries from Ottumwa to the northwest corner of the county, and the river has uncovered a small tract in the southeast corner. Representative shale sections may be viewed at numerous points, but have been developed only at Ottumwa. Along Bear creek, about two miles west of the city, near the Kansas City division of the Chicago, Milwaukee & Saint Paul railway, the following beds may be observed:

		FEET.
15.	Drift	20
14.	Shale, argillaceous, gray, sandy in upper part	20
13.	Shale, black carbonaceous, fissile	3
12.	Sandstone	3
11.	Shale, gray, argillaceous	2
10.	Shale, black, fissile, carbonaceous	5
9.	Coal, impure and bony, pyritic	1½
8.	Fire clay, filled with plant remains	1
7.	Shale, gray, argillaceous	5
6.	Shale, black	6
5.	Sandstone	½
4.	Shale, black	4
3.	Coal, bony, impure	1½
2.	Shale, black, carbonaceous, fissile, rich in plant remains	½
1.	Shale, gray, argillaceous, exposed to creek	20

In the above section the coal seams, sandstone layers and drift could not be used, and perhaps some of the bituminous shales would need to be rejected. The gray shales would undoubtedly yield a good grade of clay ware and are present in sufficient quantities to permit the safe use of much of the bituminous material which could not be used alone.

Near the limits of the city, to the northwest, the Ottumwa Brick and Construction Company have been in successful operation for a number of years. Their pit section is as follows:

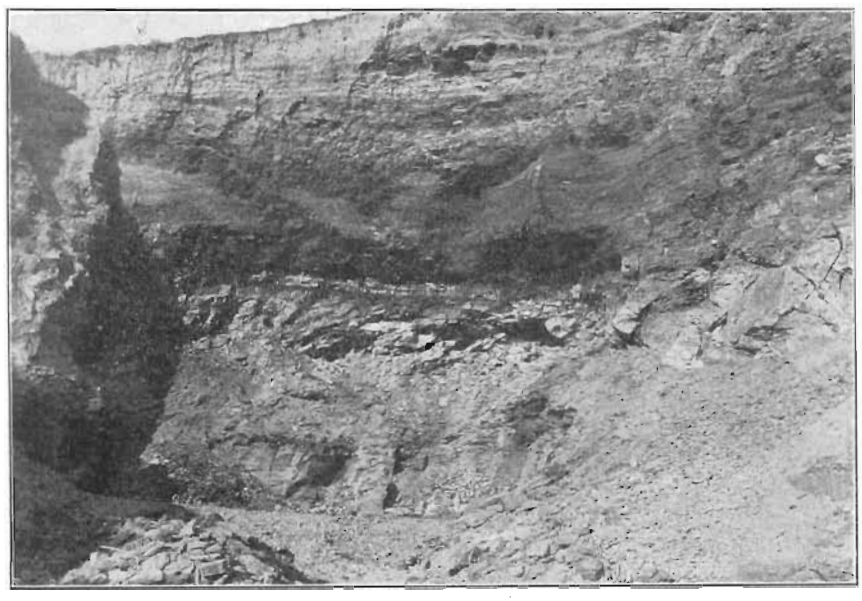


FIG. 60. Pit of the Ottumwa Brick and Construction Company, Ottumwa, Iowa.

		FEET.
12.	Drift	3
11.	Shale, argillaceous, gray	20
10.	Shale, black	4 to 10
9.	Coal	1
8.	Fire clay	1
7.	Sandstone, argillaceous	5 to 7
6.	Shale, black, fissile	2
5.	Sandstone, argillaceous, gray, in single ledge	4
4.	Shale, gray argillaceous	4
3.	Shale, black	1
2.	Coal	3 to 4
1.	Fire clay	6 to 8

The beds are exceedingly variable when traced laterally. All are used in the manufacture of clay wares save the coal seam, number 2, which has been used for fuel. The green brick hold their shape well in the drier and in the kiln, and vitrify with difficulty when numbers 5 and 7 are used. A good grade of vitrified products can be made from the gray, argillaceous shales. Common brick and hollow ware are successfully burned in a Dunn compartment continuous kiln.

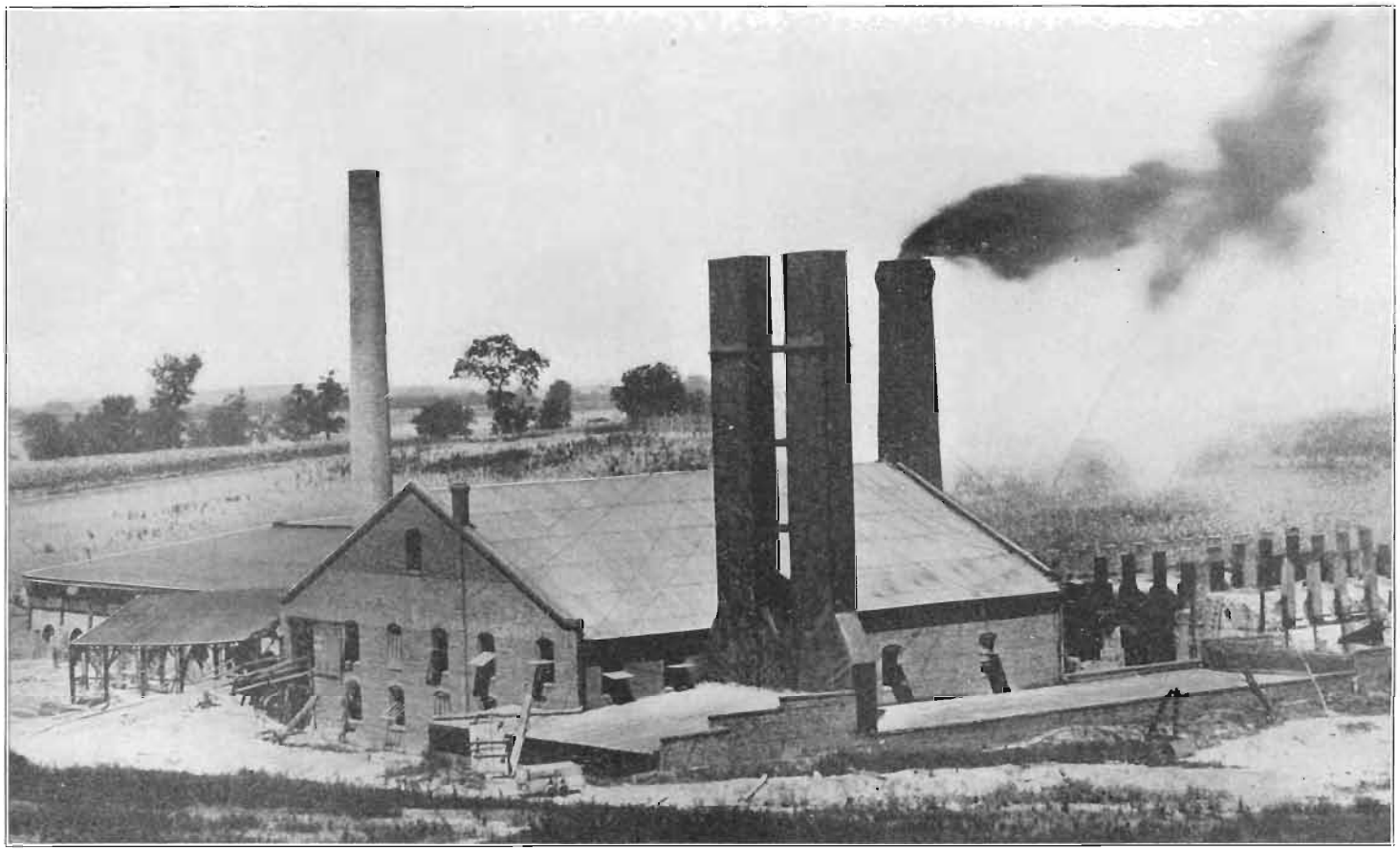


PLATE XXVII. A portion of the plant of the Ottumwa Brick and Construction Company, Ottumwa, Iowa.

About two miles southeast of Ottumwa on Sugar creek, near the bridge of the Chicago, Burlington and Quincy railway, the following section may be viewed:

		FEET.
9.	Sandstone	10
8.	Shale, black fissile	12
7.	Coal	2
6.	Fire clay	3
5.	Coal	2 to 4
4.	Fire clay and argillaceous shale	10 to 12
3.	Shale, black	15 to 20
2.	Obscured, probably shale	8 to 10
1.	Saint Louis limestone exposed in creek bottom	4

All of the beds above number 1 with the exception of the coal seams and a portion of number 9 could be used doubtless in the manufacture of clay goods. The coal seams afford an abundance of fuel.

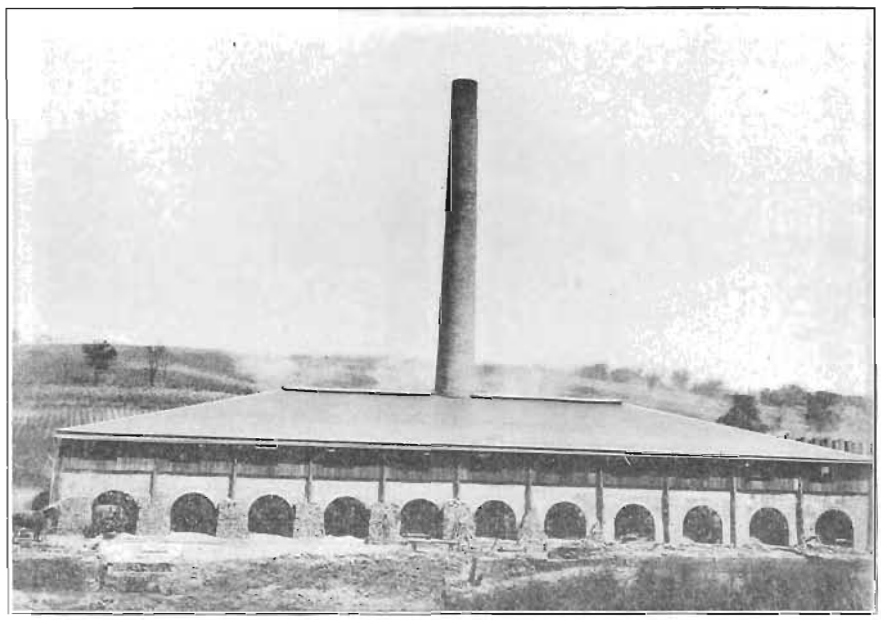


FIG. 61. Compartment continuous kiln, modified "Dunn" pattern; Ottumwa Brick and Construction Company, Ottumwa, Iowa.

Recently considerable exploratory work has been done about one and one-half miles northeast of the city along the head waters of Sugar creek. One of the most important test pits reveals the following section:

		FEET.
7.	Drift and surface wash; the lower portion charged with pebbles and bowlders	0 to 10
6.	Shale clay, yellow and clayey where weathered, gray where protected	6
5.	Coal, soft, impure	½
4.	Shale, dark, bluish-black, argillaceous	6½
3.	Shale clay, light colored, a putty clay when weathered	5
2.	Coal, bony	½
1.	Shale, compact, light gray, exposed	3

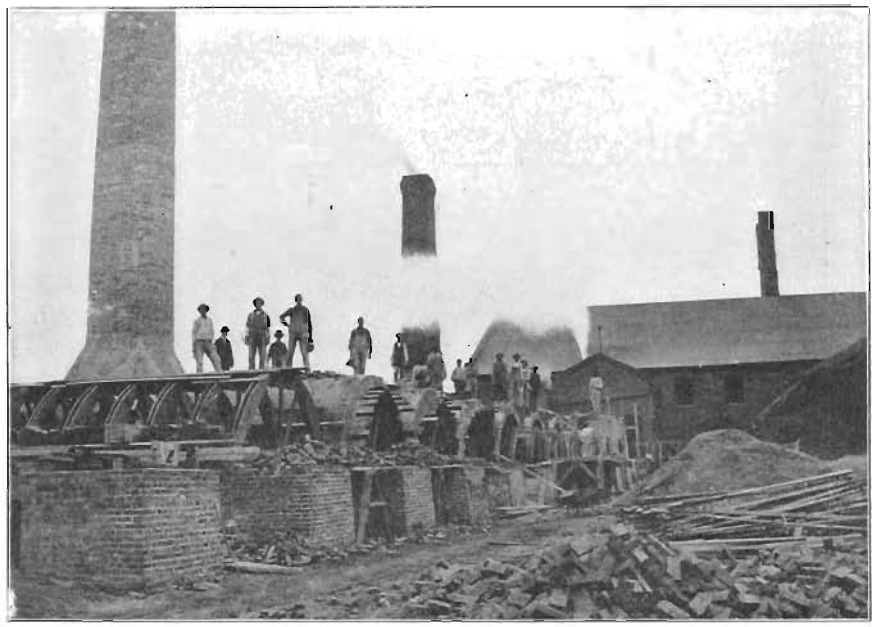


FIG. 62. Modified Dunn continuous kiln in process of construction; Ottumwa Brick and Construction Company, Ottumwa, Iowa.

With the exception of the thin coal seams and the drift the entire section could be utilized and a large variety of wares could be produced. The shales show considerable variations in the numerous outcrops exposed within a radius of a few hundred

yards. Two hundred yards east of the pit described, fifteen feet of gray shale are visible along a sharp gully. This shale quite closely resembles number 1 in the section but is more siliceous. Below are appended the analyses of numbers 1, 3, 4 and 6 in the section and a sample from the gully mentioned which is given as sample x.

	1	3	4	6	X
Silica	58.84	53.86	49.00	55.00	55.87
Alumina	21.70	26 28	29 31	24.63	23.79
Combined water	6.95	8.06	10 38	5.36	4 87
Clay and sand	87.49	88.20	88 69	84.99	84 53
Iron oxide	5.16	4.32	4.56	7 92	9 36
Lime	.91	.12	.57	.82	.46
Magnesia	.67	.43	.24	.71	.86
Potash	1.90	2.52	1.22	1.82	1 52
Soda	2.45	.43	.67	.98	1.06
Total fluxes	11.09	7.82	7.26	12.25	13.26
Moisture	.84	3.02	3.25	2.49	1.85
Sulfur trioxide	.45	1.22	.94	.16	.35

RATIONAL ANALYSES.

Clay substance	50.20	58.64	51.46	41 20	45.36
Feldspar	23.58	6.27	6.32	14.19	12 73
Quartz	26.22	35.09	42.22	44.61	41.91
Total	100.00	100.00	100.00	100.00	100.00

Sample number 1 is highly plastic, burns a light buff color and is comparatively free from impurities and would undoubtedly give excellent service as a potter's clay. It shows moderate shrinkage and could be used to advantage in the manufacture of face brick and fancy shapes. Number 3 burns a gray buff, while numbers 6 and x burn a deep red and vitrify easily. A mixture of all burns a deep red at a moderate temperature and readily takes on the blue-black hue at the point of vitrification, the color so much prized by manufacturers of paving brick. Actual kiln tests were made by the Barber Asphalt Company of Des Moines and gave excellent results.

Shales are exposed at numerous points in other portions of the county, but no attempt has been made to exploit them with the exception of small quantities of fire clay mined at some of the coal mines.

Warren County.—Warren county lies wholly within the Coal Measures and is deeply trenched by numerous streamways, thus exposing many sections. Shales, argillaceous to arenaceous, constitute the predominant type of rocks. Occasional thin bands of limestone and thicker beds of friable sandstone appear. Many of the outcrops are too far away from established lines of railway to be available at present for the shipping trade. The sections given below may be considered representative and do not in any way exhaust the possibilities.

RICHMOND TOWNSHIP, SEC. 24, S. W. QR. NE. ¼.

		FEET.
3.	Drift	12
2.	Shale, clayey to sandy, thinner banded above, heavier below	32
1.	Sandstone, red, heavy, cross-bedded, with pyritic concretions exposed	14

On the same side of the river, about one mile south of the above exposure, on section 25, the beds are as follows:

		FEET.
5.	Drift, variable in thickness.	
2.	Shale, bluish-gray, thinly laminated with sandstone below	40
1.	Talus to river	9

The shales in both sections would undoubtedly yield a fair grade of the common clay wares. Good sections continue to the southwest along South river, one of the best appearing on the southeast quarter of northeast quarter of section 3, in Union township, which is as follows:

		FEET.
10.	Drift	15
9.	Shale, black	2
8.	Coal	1
7.	Shale, argillaceous, gray	4
6.	Limestone, gray, fossiliferous	2
5.	Shales, argillaceous, gray	8
4.	Coal	3½
3.	Shale, bluish-gray, sandy below	34
2.	Coal	1
1.	Shale, exposed to river	2½

All of the members developed here could be used in clay manufactures, save the coal seams and numbers 6 and 10. The coal could be used to burn the wares and furnish heat and power for their manufacture. The beds dip gradually to the southwest. On section 9 a similar though less extensive section may be viewed. Good sections are also visible in sections 17 and 30.

South of Ackworth, near the Chicago, Burlington and Quincy railroad, a complicated series of beds are exposed. The section is given below:

		FEET.
13.	Loess, variable in thickness.	
12.	Limestone, compact, fossiliferous	1
11.	Shale, argillaceous, black	4
10.	Coal	¾
9.	Fire clay above, shale clay below	8½
8.	Sandstone, irregular, varying from shaly sandstone above, to true shale below	1½
7.	Sandstone, gray, friable	1⅓
6.	Shale, gray, thin irregular band, arenaceous	6½
5	Sandstone, reddish-brown	½
4.	Shale, argillaceous, gray above and dark below	6½
3.	Coal	⅛
2.	Fire clay and shale	1
1.	Talus to river (probably shale)	2

The above section could be used in its entirety, with the exception of number 12, and perhaps portions of 5, 7, 8, and 10 would need to be rejected. The beds assume a more arenaceous facies to the southwest, and while important seams of shale still persist, the outcrops are considerably obscured by the heavy sandstone talus and drift debris.

In the southeast corner of the county, along Whitebreast creek, a heavy sandstone appears near the top of the section and greatly obscures the beds below. Thick shale beds are known to be present but could only be developed by mining.

The Winterset branch of the Chicago, Rock Island and Pacific railway closely follows Middle river across the county and renders accessible commercially the numerous shale outcrops. South of Carlisle, above the wagon bridge in section 15, the following series of beds are exposed:

		FEET.
8.	Shale, argillaceous	1
7.	Coal	1/6
6.	Shale, clay	5
5.	Sandstone	1½
4.	Shale, argillaceous, dark below	3
3.	Coal	¾
2.	Fire clay and shale, containing nodular bands and thin seams of sandstone	14
1.	Shale, argillaceous, dark above, exposed to river	2

With the exception of numbers 3 and 5, the section in its entirety could be utilized. At Summerset the sandstone members come in more prominently near the base than in the preceding section. The sequence is as follows:

		FEET.
9.	Loess	14
8.	Sandstone, calcareous	⅜
7.	Shale, argillaceous	6½
6.	Coal	1
5.	Fire clay	4½
4.	Shale, sandy, gray	3½
3.	Sandstone, gray	1
2.	Shale, gray	2
1.	Sandstone, heavily bedded	2

About a mile and one-half southwest of Spring Hill a fairly clean section is exposed and presents only a moderate amount of stripping. The following beds may be observed:

		FEET.
10.	Loess	2
9.	Coal, badly weathered	½
8.	Coal, gray, with thick bands of sandstone	10
7.	Shale, blue above and black below	4
6.	Sandstone, concretionary, calcareous	½
5.	Shale, gray to black	2
4.	Coal	1
3.	Fire clay	4⅛
2.	Sandstone, gray, heavily bedded	1⅜
1.	Shale exposed	2½

The Coal Measures continue prevailingly argillaceous to the southwest, but the sections become more obscured with talus. Near Bevington, in Madison county, an excellent shale section may be seen and is noted in the description of the Coal Measures for that county.

The Coal Measure beds exposed along North river are prevailingly shales, but are less accessible at the present time than those of the Middle river district because of lack of railway facilities. One of the outcrops which is most easily accessible appears north of Greenbush, in section 30 of Greenfield township. The beds exposed are as follows:

		FEET.
6.	Loess and drift, variable in thickness.	
5.	Shale, argillaceous, light	½
4.	Coal, impure and weathered	½
3.	Shale, compact above and soft below	30
2.	Sandstone, gray	½
1.	Shale, argillaceous, blue exposed	20

A coal seam is said to lie just below the river bed. The entire section can be utilized save where the drift carries too many pebbles and bowlders. Numerous sections, less extensive than those given above appear along the tributaries of the principal streams, or occur within easy working distance of the surface inland, but sufficient have been given to demonstrate the bountifulness of the supply of raw materials which have been but sparingly developed. Small potteries in the vicinity of Carlisle and Hartford

have used the fire clays of the neighborhood for a number of years, but in amount so small as to be scarcely worthy of mention.

Wayne County.—Notwithstanding the fact that the upper Coal Measures cover the entire county, exposures are rare owing to the great thickness of Pleistocene deposits and the absence of large streams. Occasional much obscured outcrops appear in the vicinity of Confidence, in the northeastern portion of the county. Shales predominate and are usually accompanied by a thin coal seam. Near Seymour, thick seams of clay shales of good quality are known to exist, through exploratory work for coal. They could not be developed extensively, however, save through great expense by stripping or the adoption of mining methods. The argillaceous deposits are but little known and no attempts have been made toward their utilization.

Webster County.—With the exception of small isolated patches of Saint Louis limestone uncovered by the Des Moines river in the northern part of the county, and two detached areas in the inland portions of the county, the Coal Measures are believed to cover the county. The Des Moines river has cut a deep trench across the county and good shale sections are confined to the immediate vicinity of the river and a few of its larger tributaries. The heavy mantle of drift and the prevailingly steep slopes along the greater streamways have produced heavy deposits of talus which have obscured greatly the underlying Coal Measure series. Notwithstanding these drawbacks, the county possesses the compensating advantages of splendid location, thick shale beds of good quality and fuel close at hand. The shales have been developed at a number of points.

Webster county occupies a strategic position with reference to the great undrained area covered by the Wisconsin drift. The energies of all of the factories operating in the county are largely devoted to the manufacture of drain tile. Their closest competitors are the Mason City plants. In the vicinity of Fort Dodge the

pit at the Kime brickyard gives some idea of the extent and variability of the shales. The section is as follows:

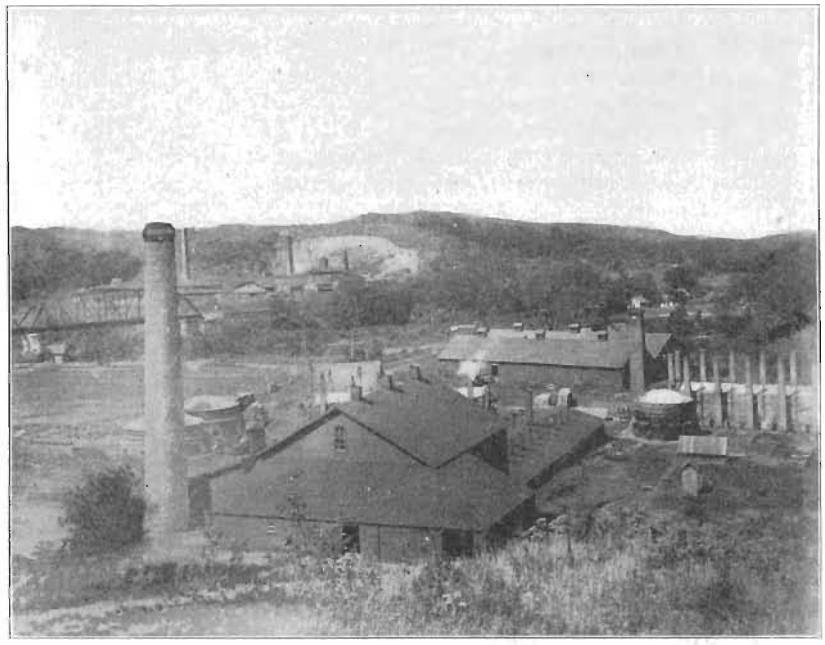


FIG. 63. Two of the Fort Dodge brick plants. In the foreground are the works of the Fort Dodge Brick and Tile Company; in the background the Fort Dodge Clay Works.

		FEET.
11.	Drift and soil	3
10.	Shale, black, bituminous	4
9.	Coal	1½
8.	Clay	3¼
7.	Coal	1½
6.	Sandstone, soft	⅔
5.	Fire clay	5
4.	Shale, dark colored, bituminous, fissile below	2½
3.	Shale, dark colored	2
2.	Shale, light colored	2½
1.	Shale, dark colored, exposed	10

Almost the entire section below the drift could be utilized in the manufacture of a wide range of clay wares.

The plant of the Fort Dodge Brick and Tile Company is located on the east bank of the river, north of the Illinois Central

railway bridge. The pit shows signs of slides and the various layers are somewhat irregular. The pit section is as follows:

		FEET.
7.	Surface wash and drift	4+
6.	Shale, coaly	⅜
5.	Shale, clayey, yellow to gray, pyritic	8
4.	Sandstone, impure	1
3.	Shale, argillaceous, gray	2½
2.	Shale, dark gray to black, fissile in the upper part	7
1.	Shale, argillaceous, light blue, exposed	18

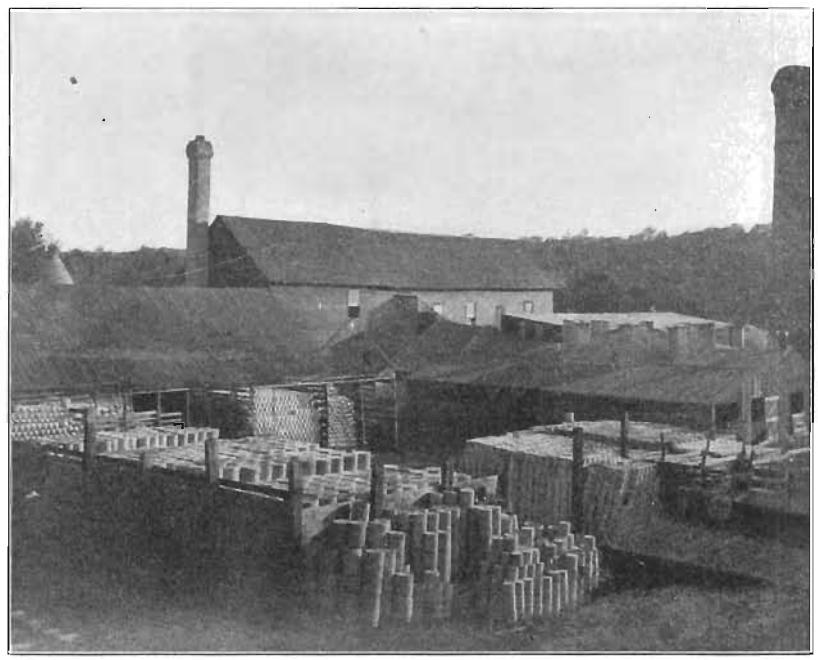


FIG. 64. A portion of the plant of the Fort Dodge Stoneware Company, Fort Dodge, Iowa.

Number 1 carries occasional calcareous concretions, pyrite and gypsum crystals. It is known locally as the potter clay and burns to a light gray or buff. The dark clay shales above the potter clay burn red. The entire section, with the exception of portions of the sandstone and drift, can be used. The various grades of brick, drain tile and sidewalk blocks are the principal manufactured products.

The shales are also being developed on the west side of the river. The plant of the Fort Dodge Clay Works is located south of the Illinois Central railway. The pit section shows the following beds:

		FEET.
5.	Drift ..... 5 to	20
4	Shale, clayey, variegated, siliceous in lower part.....	6
3.	Shale, impure, coaly.....	½
2.	Shale, argillaceous, light to dark gray	25
1.	Sandstone	1

Numbers 2 and 4 are the principal members worked. A Radford "Monarch" continuous kiln is used for burning the structural brick. It contains sixteen chambers and one chamber is burnt per day. The products are about the same as in the preceding. The company has opened a new pit recently farther up the Lizard and have secured a better shale section with less stripping.

Several other pits in and about Fort Dodge show sections of from thirty to fifty feet of shales suitable for the manufacture of the various grades of clay products, including paving brick. The overlying drift is of variable thickness and because of its large lime content must be carefully removed to insure high grade ware. The Bradshaw Brick Company has been in successful operation for a number of years. The product includes drain tile, building block, common builders, pavers and sidewalk block.

A potter's clay is obtained under one of the coal seams of the neighborhood from a small mine about one-half mile north of the city, on the west bank of the river. This clay has been used by the Fort Dodge Pottery Company and yields a good grade of stoneware. Analyses of the clay were made and are given below

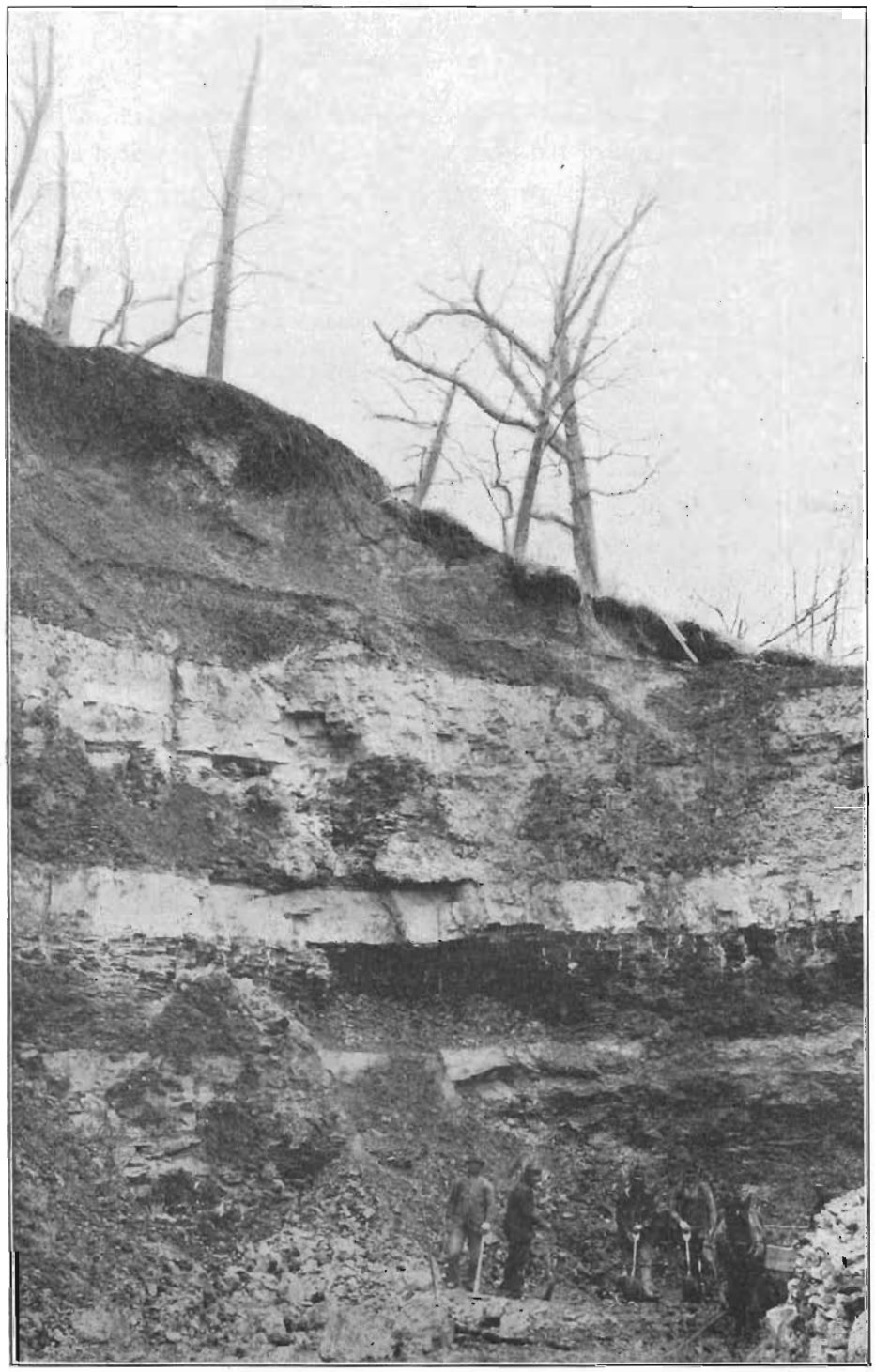


PLATE XXVIII. Pit of the Lehigh Brick and Tile Company, Lehigh, Iowa.

	FIRST QUALITY.	SECOND QUALITY.
Silica	66.00	63.83
Alumina	19.32	17.55
Combined water		
Clay and sand	85.32	81.38
Iron oxide	0 80	2.75
Lime	2.85	2.94
Magnesia	0.54	0.57
Potash	1.15	0.67
Soda	2.49	0.79
Total fluxes	6.83	7.72
Moisture and undetermined	6.84	8.54
Carbon dioxide		2.36
Insoluble in sulfuric acid and sodium carbonate	58.55	68.69

The first quality clay compares favorably with the clay used at Zanesville, Ohio, and other clays equally well known.

South of Fort Dodge the Coal Measure shales outcrop at numerous points and have been quite extensively developed near Coalville and Lehigh. Northwest of Coalville, west of the Des Moines, Johnson Brothers are operating a plant located on the Minneapolis and Saint Louis railway. Their pit shows the following section:

		FEET.
6.	Alluvium on the 70 ft. terrace. Mainly fine sand, silt and clay; few pebbles present. Imperfectly stratified; varies up to	4
5.	Drift, bowldery, blue-gray to yellowish along the seams, varies from 1 to	2
4.	Drift residuum, composed chiefly of limonite concretions, rotten granite bowlders, greenstone and limestone pebbles. The pebbles rarely exceed 3 inches for greatest diameter. The upper portion is a peaty brown of putty-like consistency. The layer bears evidence of age and varies from 1 to	1½
3.	Shale, variegated, sandy, "Calico rock", body color bluish-gray, cracks and seams stained red, often a bright red	7
2.	Sandstone, yellowish-gray, forms an indurated ledge up to	1½
1.	Shale, bluish-gray, the principal bed in the pit, light bands appear occasionally; exposed	12

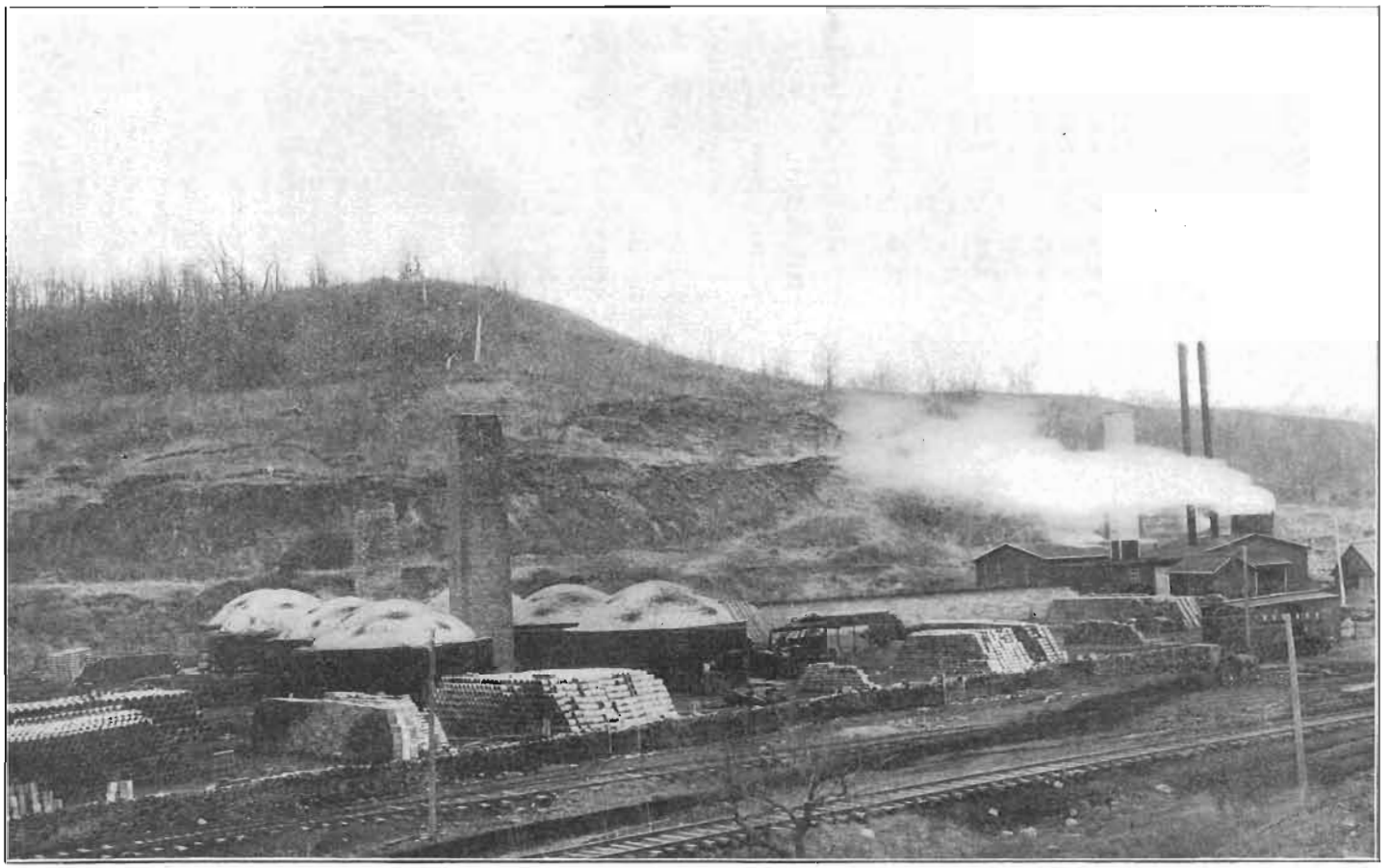


PLATE XXIX. Plant of the Lehigh Brick and Tile Company, Lehigh, Iowa.

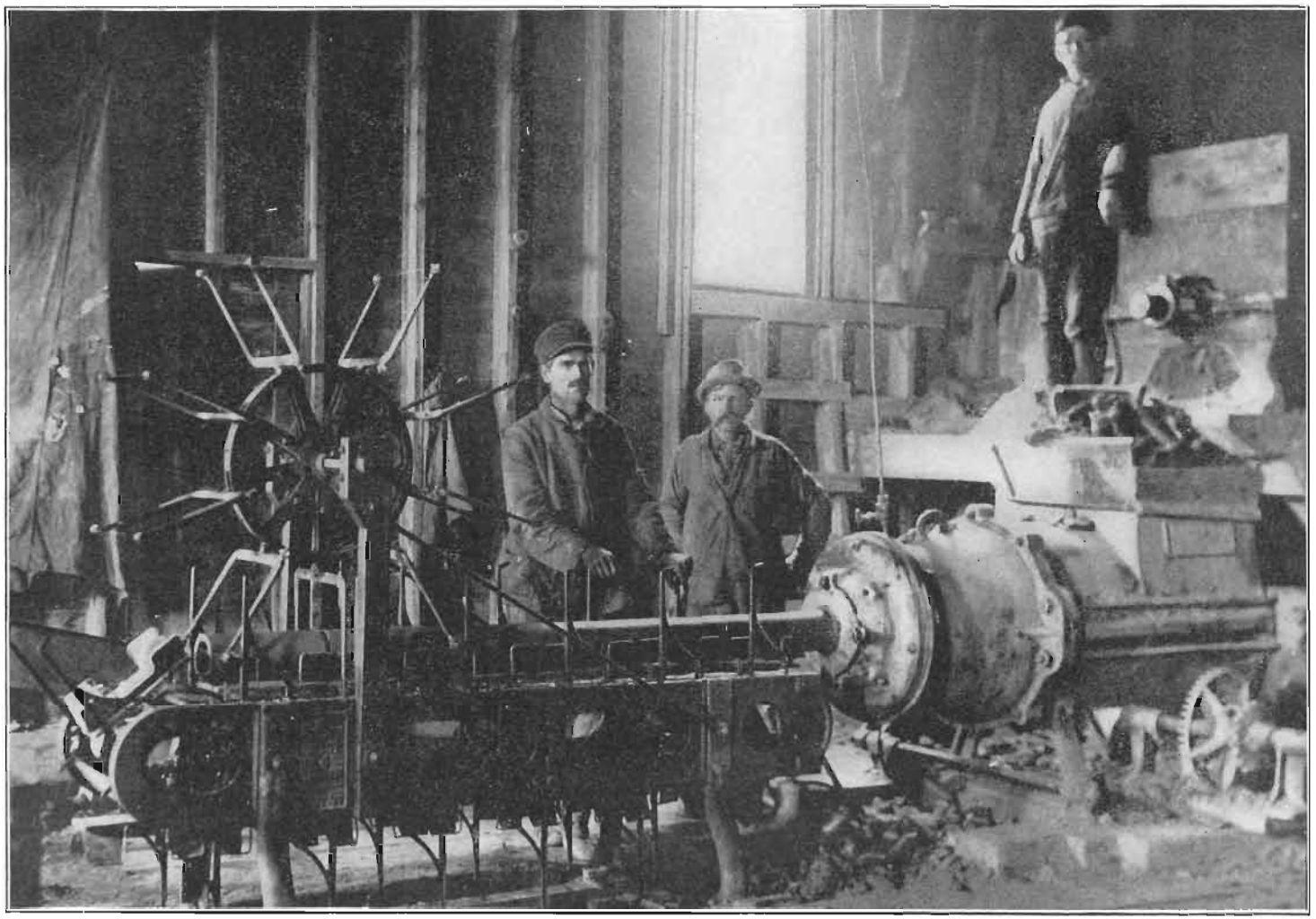


PLATE XXX. Reel cutting table for hollow ware, Lehigh Brick and Tile Company, Lehigh, Iowa.

A seam of cannel coal lies about five feet below the base of the section and is mined and used to burn the ware and furnish heat and power. Hollow ware is the chief manufactured product at present. A chemical analysis was made of number 3 with the following results:

Silica	70.20
Alumina	16.70
Combined water	3.70
Clay and sand	90.60
Iron oxide	4 00
Lime	0.28
Magnesia	0.63
Potash	1.75
Soda	1.39
Total fluxes	8.05
Moisture	0 53
Sulfur trioxide	0.82

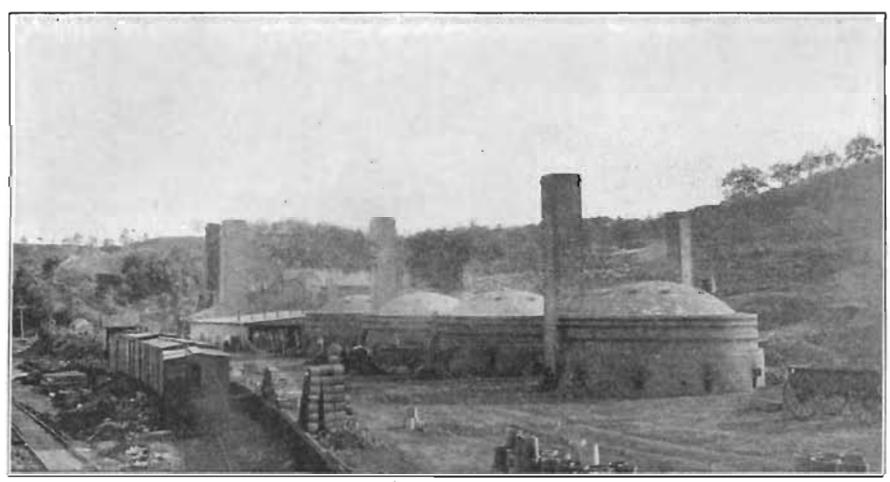


FIG. 65. Plant of the Kalo Brick and Tile Company, Kalo, Iowa.

With the exception of the drift and hard ledges, the entire section is utilized. The pit is above the plant and the clay is transferred from pit to dry pan largely by gravity.

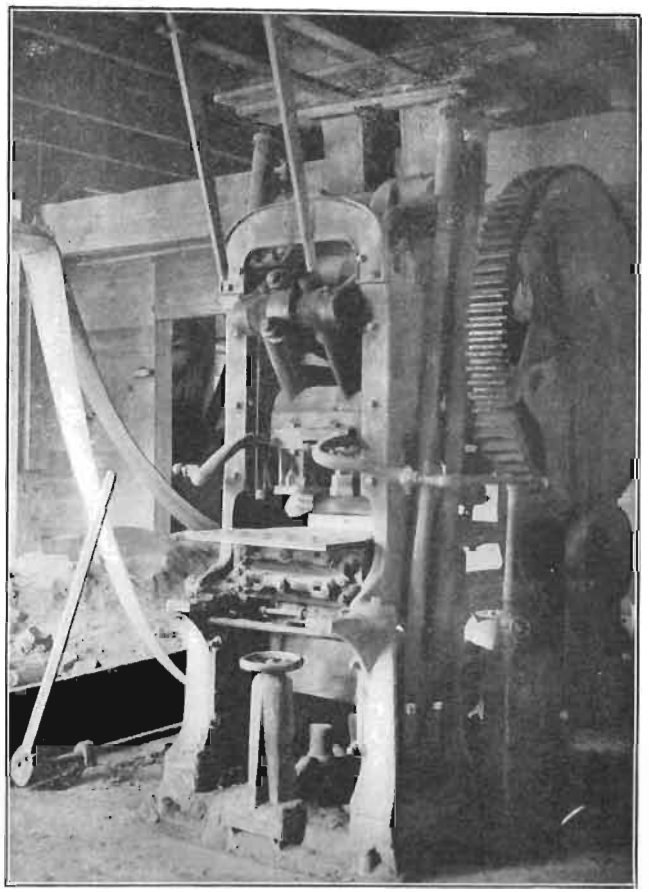
The plant of the Kalo Brick and Tile Company, owned and operated by Schnurr Brothers, is located almost directly west of Coalville, also west of the Des Moines river. The shales developed here are a little higher in the Coal Measures series and are rather more variable. The section is as follows:

	FEET.
8. Drift and wash about the level of the "70-foot" terrace	5
7. Shale, bluish-gray to yellowish-gray above, jointed below	8
6. Coal blossom, brown to black and earthy	
5. Shale, sandy, weathers out soft and is of an ash color, contains plant impressions	8
4. Sandstone, argillaceous, projecting ledge in places, lower portion often variegated light and dark bands	2
3. Coal	½
2. Sandstone, argillaceous, when weathered forms a hard ledge; contains leaf impressions	1
1. Shale, blue-black, pyritic above and gypseous below; pyrite aggregates vary from one-half inch up to three inches, flattened clay-ironstone concretions up to eight inches are also present	4

A small fault crosses the face of the pit. The strike is northeast-southwest and the hade is about 50°. The hanging wall is to the northwest, the throw being about two feet. Here as at the Johnson plant, hollow ware is the chief manufactured product. With the exception of the hard ledges, the entire section is used with satisfactory results. A branch of the Minneapolis and Saint Louis railway gives an outlet and nearly the entire output is shipped.

Lehigh rivals Fort Dodge as the most important clay working center in the county. Four factories are doing business on a large scale and all are using very similar raw materials. In addition to the clay used locally, a considerable amount of raw clay is supplied the plants at Fonda and Webster City.

The works of the Lehigh Brick and Tile Company are located on a stub of the Crooked Creek railway. The beds exposed in the pit are as follows:



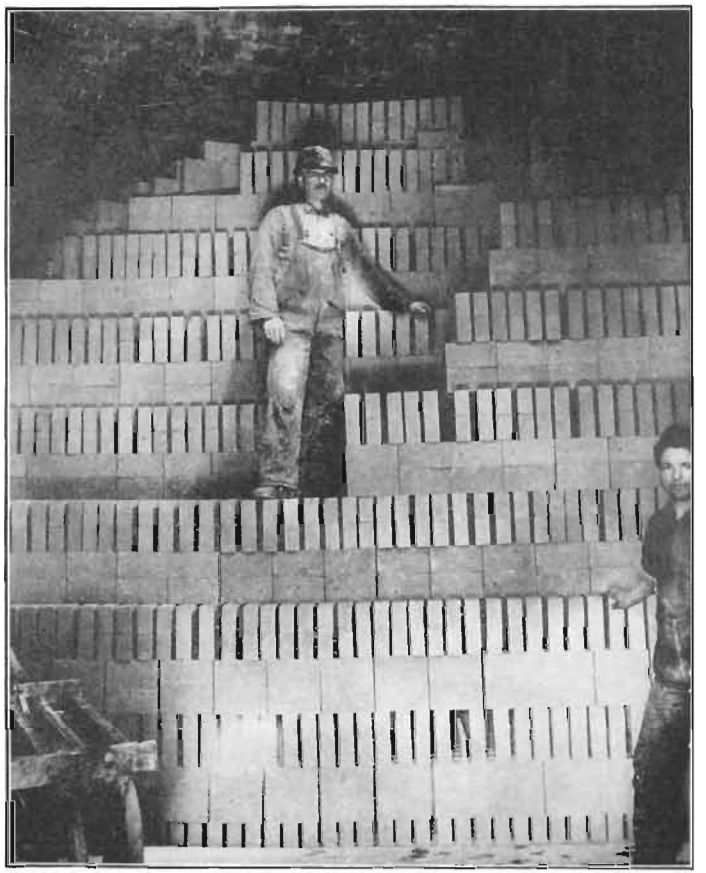


PLATE XXXI.

Dry press, shape machine. Method of facing dry press brick in a round, down draft kiln.
Corey Pressed Brick and Coal Company, Lehigh, Iowa.

		FEET.
7.	Drift	4
6.	Shale, clayey, blue	5
5.	Shale, variegated	10
4.	Sandstone, friable	2
3.	Shale, argillaceous, red and yellow	3½
1.	Shale, dark, unctuous, exposed	4

With the exceptions of portions of the sandstone ledges and the drift, the entire sequence is used.

An average sample from the pit of the Lehigh Clay Works was analyzed and gives some idea of the variation in the composition of the shales of the district. The analysis is as follows:

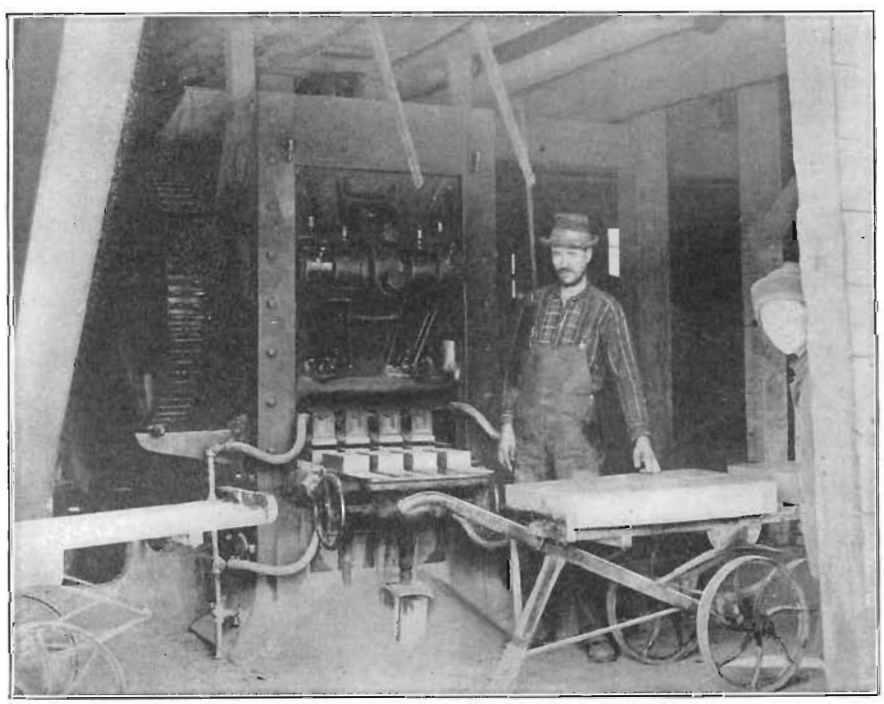


FIG. 66. Boyd four mold, dry press machine; Corey Pressed Brick and Coal Company, Lehigh, Iowa.

Silica	53.08
Alumina	17.71
Combined water	9.30
Clay and sand	80.09

Iron oxide	8.64
Lime	4.05
Magnesia	0.94
Potash	1.25
Soda	3.70
Total fluxes	18.58
Insoluble in sulfuric acid and sodium carbonate	71 55

The Corey Pressed Brick Company is situated on the north side of Crooked creek, a short distance northeast of the Lehigh Brick and Tile Company and is one of the pioneers in the district. The dry press process only is used and face and fancy brick and special shapes are manufactured with excellent success. Two seams of clay are being developed, the upper seam, occurring above the upper coal vein and averaging about 4 feet in thickness, burns buff; and the lower seam, some 15 feet below and averaging 15 feet in thickness, burns a deep red. Both seams can be developed economically only by mining. Analyses of these clays were made and the results are given below:

	Red Burning.	Buff Burning.
Silica	58.05	58.68
Alumina	23.05	23.89
Combined water	8.10	6.13
Clay and sand	89.17	88.70
Iron oxide	3.83	3.83
Lime	0.30	0.96
Magnesia	2.04	1.70
Potash	0.90	0.84
Soda	2.04	2.19
Total fluxes	9.11	9.52
Moisture	0.96	0.79
Sulfur trioxide	0.86	1.16
RATIONAL ANALYSES.		
Clay substance	68.20	54.62
Feldspar	5.99	11.18
Quartz	25.81	23.23
Calcium sulfate		1.97
	100.00	100.00

PLATE XXXII. Pit of the Campbell Brick and Tile Company, Lehigh, Iowa.

The pits of the Campbell brickyard and of the Webster City Brick and Tile Company are located near the point of the hill between the Des Moines river and Crooked creek, about one-half mile below the wagon bridge in Lehigh. The sections exposed in the two pits are practically identical. The beds exposed are as follows:

		FEET.
10.	Drift and surface wash ..... 1 to	3
9.	Sandstone, clayey, to sandstone shale	5
8.	Coal, impure, to bituminous shale	1+
7.	Fire clay, impure, sandstone and shale	10
6.	Coal, impure, to bituminous shale	1+
3.	Fire clay, somewhat arenaceous	3
4.	Shale, blue, dense, shows slight fissility	15
3.	Coal blossom	½
2.	Shale, clayey	3
1.	Sandstone, argillaceous, soft, almost wholly unindurated, exposed	3

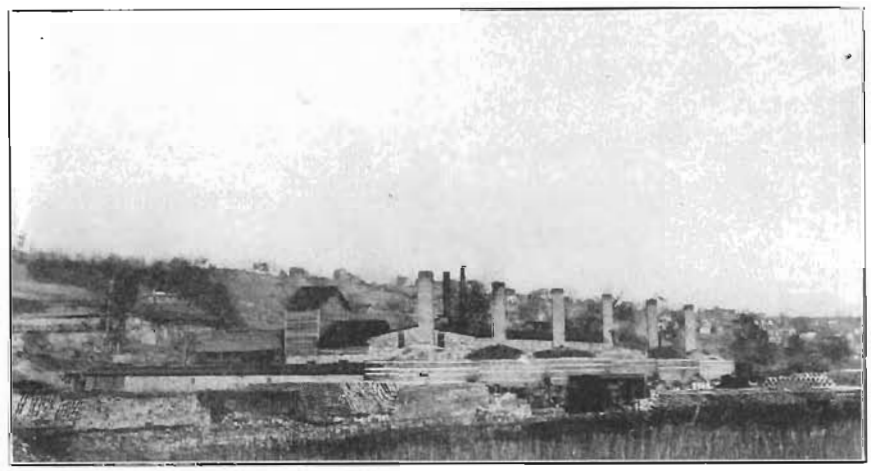


FIG 67. Plant of the Campbell Brick and Tile Company, Lehigh, Iowa.

With the exception of the sandstone ledges and the larger coal seams, the entire section is utilized. The buff burning shale exposed in the Corey pit is cut cut at this point. Number 4 in the section is believed to correspond to the red burning shale at the Corey pit. Drain tile and hollow block are the leading manufactured products.

Chemically the two clays are remarkably similar, and yet one burns a strong red and the other buff. Both give excellent satisfaction as face brick or for inside finish.

The principal manufactured product is hollow ware for all save the Corey plant and almost the entire output of the district is shipped, mainly to the north and northwest. The Chicago and Great Western and the Webster City and Crooked Creek railways afford the rail outlets.

Shales are exposed at numerous other points but the outcrops are not readily accessible at present.

THE CRETACEOUS.

The Cretaceous as represented in Iowa may be divided readily into two divisions, a lower sandstone and shale series, the Dakota, and an upper series of interbedded sandstones, shales and marly limestones. In the upper series the argillaceous beds greatly predominate. Near the top marls and marly limestone of the Niobrara Chalk appear. Rocks referable to the Cretaceous are supposed to cover the larger portion of the northwestern one-third of the state. The limits, however, can not be determined definitely. Cretaceous shale beds are known to exist in Sioux, Plymouth, Woodbury, Sac, Calhoun and Montgomery counties. In most of these some attempts have been made to develop them. It is probable that the shales extend as far east as the Emmet, Calhoun, Guthrie tier of counties, as far south as Montgomery and west to the Missouri bottom lands. The shales have essentially the same range texturally and in composition as those of the Coal Measures but are prevailingly more siliceous and less plastic. The best known deposits are, considered alphabetically by counties:

Calhoun County.—The Cretaceous shales have been developed near Lake City for a number of years. At present but one fac-

tory is in operation, the Lake City Clay Works. The pit is located on Lake creek, a tributary of the Raccoon river, about a mile northwest of the town. The pit section is as follows:

	FEET.
5. Drift and wash, the upper portion of which contains much gravel in places	10
4. Shale somewhat fissile, grayish-blue to dark blue; when dry, a light gray	4
3. Sandstone, friable, in three ledges of about equal thickness, indurated in places; the lower ledge highly ferruginous and often contains concretions; the middle layer unindurated and white, top layer stained a very light yellow	2
2. Shale, clayey, massive, variable texturally and structurally	7
1. Sandstone, concretionary, much iron-stained, exposed	5

A short distance north of the pit the sandstone members become very prominent and constitute the major portion of the section. Near the base of the section a red stratum appears and is associated with an almost pure white putty clay. The sandstone shows various stages of induration, and clay balls and lenses occur throughout the entire mass. A light shale comes in above this sandstone. Good shale sections are reported to occur along the Raccoon river three or four miles to the southwest. The same shale also occurs near Grant City, in Sac county. An analysis of the principal shale bed was made with the following results:

Silica	74.83
Alumina	12.20
Combined water	5.15
Clay and sand	92.18
Iron oxide	1.24
Lime	2.22
Magnesia	1.08
Potash	.32
Soda	1.08
Total fluxes	5.94
Moisture, carbon dioxide and sulfur trioxide	2.58

RATIONAL ANALYSIS.

Clay substance	42.00
Feldspar	8.44
Quartz	46.16
Calcium sulfate	3 40
	100.00

A casual inspection of the analysis will show that the clay is highly siliceous, comparatively low in alumina and low in the fluxing constituents. It is also low in iron and burns a light color, and shrinks but little during the process of drying and burning. Where it has been used the practice has been to mix with it the surface wash and alluvial material which run much higher in iron and give a good color. Clay shales have not been utilized at any other point in the county.

Montgomery County.—The Cretaceous deposits represented in the county are usually arenaceous and have been referred tentatively to the Dakota stage. Although sandstones prevail near the top of the series in certain places certain argillaceous deposits are of importance. The clay beds are somewhat irregularly distributed and are not persistent. The most important clays of this age known in the county are found near Red Oak. The beds have been developed for a number of years by the Red Oak Pottery Company.

The pit section is as follows:

		FEET.	INCHES.
11.	Loess, impure in lower portion	6	6
10.	Sandstone, light yellow, soft	3	
9.	Shale, light gray, used for pottery		11
8.	Sandstone, white to yellow	1	6
7.	Shale, light gray, for pottery	2	
6.	Shale, gray, siliceous; for fire brick	1	1
5.	Shale, dark to light gray; for pottery	1	6
4.	Shale, gray, siliceous; for fire brick		2
3.	Shale, light to dark gray; for pottery	2	2
2.	Shale, grayish; for fire brick		6
1.	Shale, siliceous, gray, impure, exposed		6

The principal shale in the pit attains a thickness in some places of 15 feet and apparently rests unconformably upon a very siliceous shale. Near the east end of the pit it is replaced by friable sandstone. Loess covers the entire section. A sample of the purest clay was analyzed and the results are given herewith:

Silica	69.75
Alumina	18.68
Combined water	3 85
Clay and sand	92.28
Iron oxide	1.94
Lime	1.07
Magnesia	.95
Potash	2.32
Soda	.64
Total fluxes	6.92
Moisture	1.33

White stoneware is manufactured from the best grades and a few fire brick have been made which give fair satisfaction. It is believed that certain layers if freed from impurities by washing could be made into a superior quality of glass pots and crucibles. At this time the Cretaceous clays have not been developed at any other point in the county.

Plymouth County.—The shale clays in Plymouth county are not very accessible at the present time for open pit work. They are present in considerable quantity and of good quality within easy mining distance. A representative section may be viewed near the site of the old Crill mill on section 32, in Sioux township. The beds of indurated rocks visible at this point are as follows:

	FEET.
6. Limestone, thin, leafy texture, fossiliferous	90
5. Shale, buff, sandy, with layers of sandstone and ferruginous concretions	30
4. Shale, dark blue to drab, fine-grained, argillaceous	10
3. Sandstone, fine-grained, calcareous, light buff to white	15
2. Lignite	1½
1. Fire clay, white to light gray, only slightly exposed, found in digging	6

The fire clay contains very little grit, is quite plastic and apparently would be easily worked. The sandstone above the lignite seam would afford a good roof and the bed would yield readily to mining operations. An analysis of the fire clay was made with the following results:

Silica	67.42
Alumina	19.43
Combined water	5.59
Clay and sand	92.94
Iron oxide	2.39
Lime	0.55
Magnesia	0.25
Potash	0.25
Soda	0.58
Total fluxes	4.47
Moisture	2.98

The fire clay compares favorably in composition with some of the standard fire clays of the country. Numbers 4 and 5 in the section would also be available and could be used separately or by blending with number 1, and the possibilities of manufacture be increased greatly. Also the surface clays could be brought into service. At present no serious attempt has been made to develop the shales, although similar beds are used extensively at Sioux City and Sargents Bluff.

Pottawattamie County.—Shales and sandstone of Cretaceous age are known to cover portions of Pottawattamie county. The arenaceous beds predominate in the outcrops known. Along the western line of the northeast quarter of section 36, in Wright township, there is a long escarpment of sandstone running nearly due north and south for more than a quarter of a mile, facing the river and forming its western bluff. South of the escarpment, near the north line of section 1, in Waveland township, the sandstone exposed in the river rises only a few feet above the water. On top of the sandstone rests forty feet of light gray clay

or shale in which there are occasional seams of fine sand. The shale is variable in color, ranging from light to dark, and weathers yellow. In addition to the sand layers, it contains occasional carbonaceous seams and concretions of siderite. The clay is known to outcrop at other points and is believed to be suitable for all of the grades of common brick and hollow ware. No attempts have been made to develop it commercially.

Sac County.—The clay shales exposed along the Raccoon river and Lake creek in Calhoun county continue into Sac county and

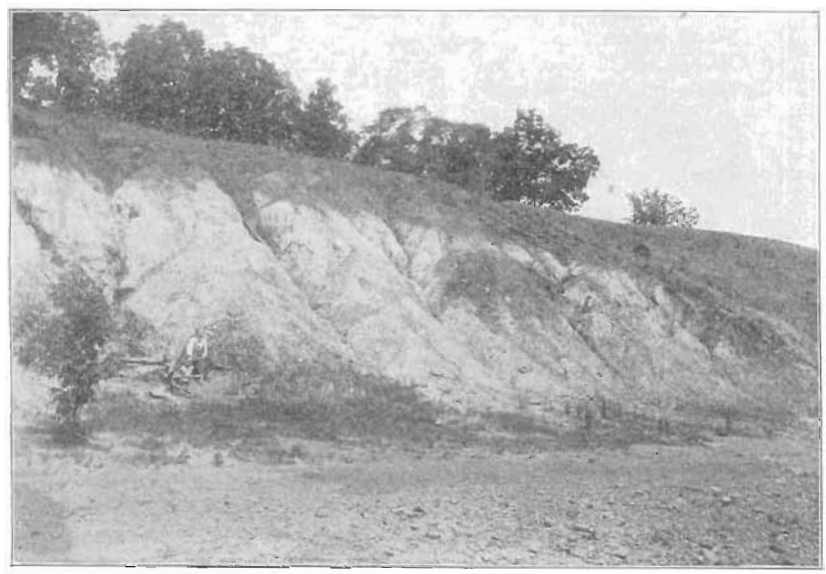


FIG. 68. Clay shales with concretions of clay-ironstone. Sec. 36, Wright township, Pottawattamie county, Iowa.

appear in the bluffs near Grant City. They appear to be of excellent quality, but little has been done toward their utilization commercially.

Sioux County.—Shales presumably belonging to the Benton stage of the Cretaceous appear in the railway cut about four miles south of Hawarden. The section is given below.

		FEET.
2.	Shale, drab to blue, argillaceous in part, containing numerous crystals of gypsum	25
1.	Limestone, fossiliferous, thinly bedded, with chalky layers	20

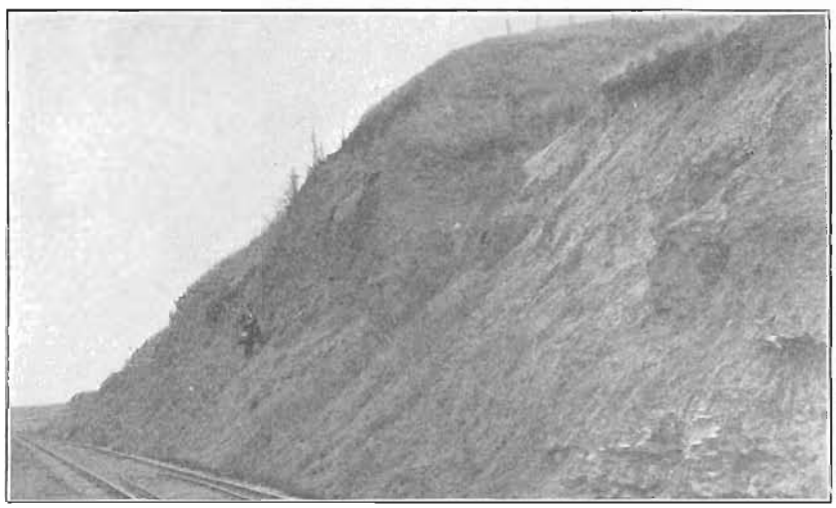


FIG. 69. Benton shales exposed in railway cut three miles south of Hawarden, in Sioux county, Iowa.

Formerly the shales were used in the manufacture of brick and common hollow ware with somewhat indifferent results. The plant burnt down some years ago and has not been rebuilt. So far as known the shales do not present any other outcrops readily accessible in the county, although they are undoubtedly within easy mining range over a considerable area.

Woodbury County.—Shale beds referable to the Cretaceous are abundantly exposed in the western portion of the county, especially in the vicinity of Sargents Bluff and Sioux City. At both points they have been developed extensively in the manufacture of clay goods. In general the shales are highly siliceous, and comparatively low in clay substance and the fluxes. As a consequence they are not so well adapted to the manufacture of hollow ware as the shales of the Coal Measures and Devonian.

They are especially adapted to the manufacture of shapes because of their low shrinkage and would give good results when treated by the dry press process. At present the stiff mud process only is used.

At Sargents Bluff, about seven miles below Sioux City, one of the standard sections of the county may be viewed. The sequence of beds is as follows:

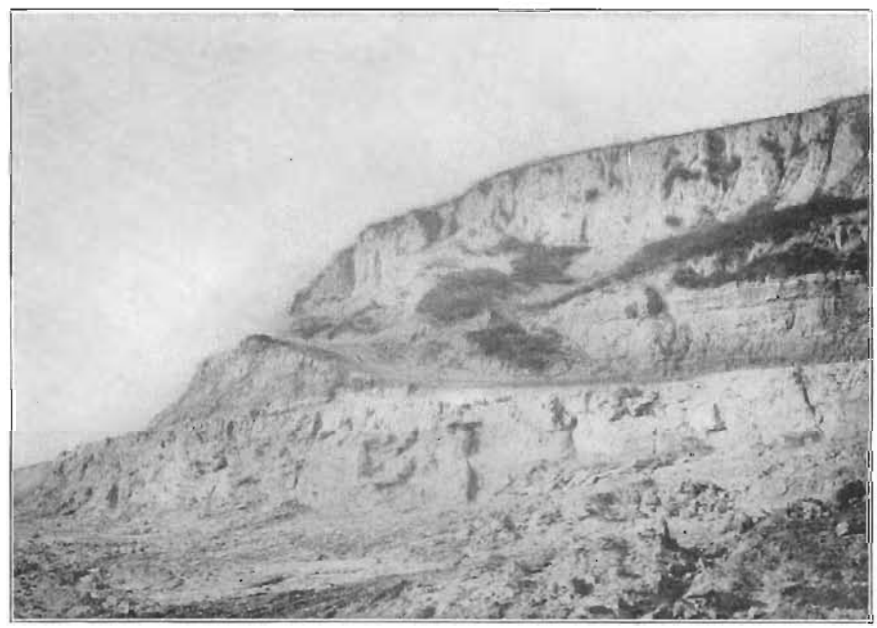


FIG 70. Pit of Holman and Brother Brick Plant, Sargents Bluff, Iowa.

		FEET.
5.	Loess, thickening back from the river and forming bold bluffs, 100 to 150 feet high	40
4.	Sandstone, fine-grained, light buff to white above, coarse, orange-yellow below	25
3.	Lignite, more or less earthy, usually of a dark purplish hue	1½
2.	Shale, variegated, brilliant orange to dark olive green, with interstratified beds of fine white sand and thin bands of ferruginous concretions containing plant remains	18
1.	Shale, sandy, reddish, becoming drab to orange below, and containing large ferruginous sandy masses with plant remains	25

The shale members have been developed on a large scale for a number of years. At present two plants are in operation, C. J. Holman and Brother, and C. W. Ritz. The former yard is the pioneer in the district. The Holman pit shows the following details.

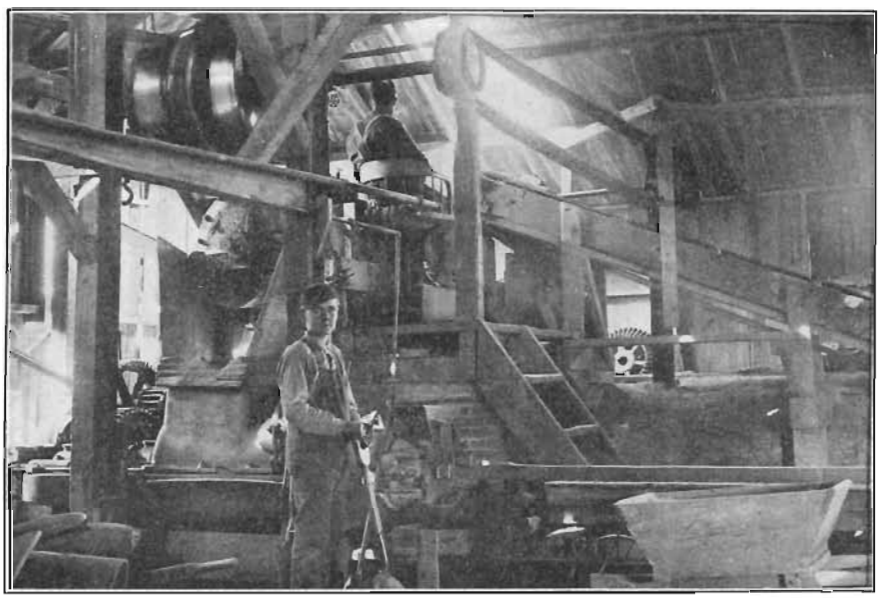


FIG. 71. Interior view of machinery building, Holman and Brother Brick Plant, Sargents Bluff, Iowa

		FEET.
7.	Loess of variable thickness up to	40
6.	Sandstone, unevenly indurated (exposed)	10
5.	Shale, lignitic to argillaceous	1½
4.	Shale, argillaceous to sandy	5
3.	Shale, unctuous, dark to light gray in color	8
2.	Shale, light colored, somewhat arenaceous	6
1.	Shale, buff to yellow and gray	16

All of the beds are usable save the sandstone and lignite seam. The loess, however, is not generally used, although it would undoubtedly make a good quality of builders either alone or blended with the clay shales. The sandstone is usually quite friable and breaks down easily when exposed to the weather. It

furnishes an abundant supply of clean sand for sanding the ware in the kilns. Analyses were made of the principal shale seam and of a seam of fire clay. The results are given below:

Silica	71.63	75.85
Alumina	14.17	10.73
Combined water	5.16	6.38
Clay and sand	90.96	92.96
Iron oxide	2.39	1.43
Lime	2.15	1.00
Magnesia	.86	.49
Potash	.50	.24
Soda	1.15	.70
Total fluxes	7.05	3.86
Moisture, sulfur trioxide and carbon dioxide	2.30	3.18

RATIONAL ANALYSES.

Clay substance	49.69	41.28
Feldspar	3.13	6.55
Quartz	47.18	52.17
Total	100.00	100.00

Both clays are highly siliceous and comparatively low in fluxes. In fact the entire assemblage of beds are somewhat arenaceous and work "short." The ware, when properly burnt, is strong and resists the weather well. Common and face brick, paving brick and sidewalk brick and block are the chief manufactured products. The sidewalk block and brick have gained great favor and the demand is growing rapidly.

The ware shrinks but little in drying and burning. The Holman type of kiln is used and the brick are successfully burnt when set 48 brick high.

The Ritz pit presents some local variations but the beds worked belong to essentially the same horizons as those just described.

At North Riverside, a suburb of Sioux City, the Cretaceous shales are being developed extensively. Two up-to-date plants

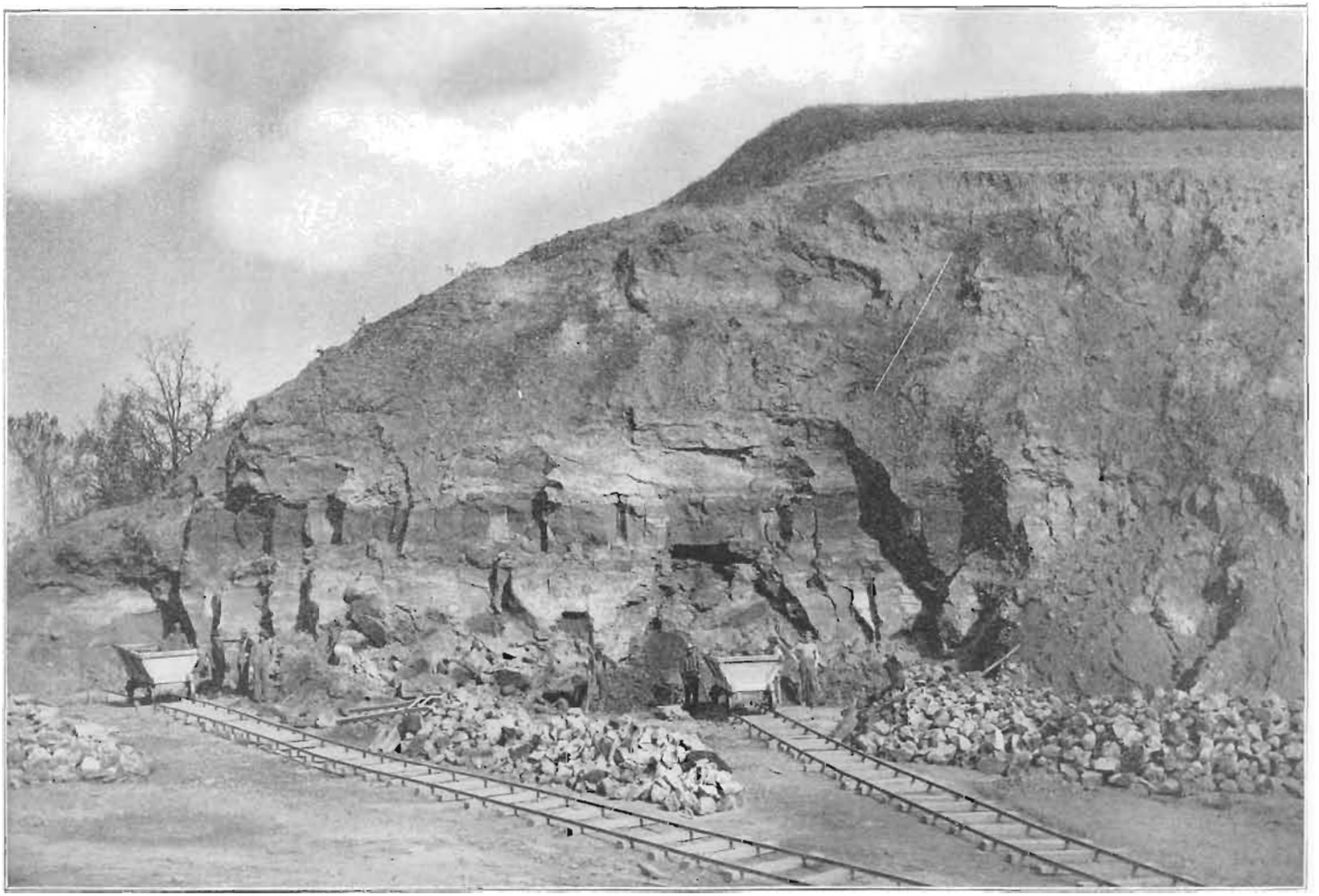


PLATE XXXIII. Pit of the Sioux City Brick and Tile Company at North Riverside, Sioux City, Iowa.

are in operation, the Sioux Paving Brick Company, successors to the old Sioux Paving Brick Company and the Lower Brick Company, and the Sioux City Brick and Tile Works. The beds developed at the various plants in this vicinity are not very different and are essentially stratigraphic equivalents. The pit of the Sioux Paving Brick Company is perhaps the most extensive and shows the greatest diversity. The details are given below:

		FEET.
13.	Loess, up to	10
12.	Shale, very arenaceous, with gypsum in veins	14
11.	Shale, light to drab-gray, in part sandy, with gypseous seams	15
10.	Shale, with impure limestone in irregular bowlder-like masses	3
9.	Shale and sand, ferruginous, in alternating layers	4
8.	Shale, gray, non-siliceous	10
7.	Shale, grayish to drab, with four-inch rock ledges about the middle	6
6.	Sandstone, calcareous, in part shaly	4
5.	Shale, gray, fissile	2½
4.	Shale, gray, very finely siliceous, with ferruginous masses near middle, also in upper part	5½
2.	Sandstone, light colored	7
1.	Shale	1

Nearly all of the beds are used save the hard ledges and strongly calcareous bands. For ordinary builders the loess can be used freely. Some attempts have been made to manufacture vitrified brick, but with rather indifferent success.

About one-half mile south is the pit of the old Northwestern Sewer Pipe and Tile Company. The pit shows some variations and is given below:

		FEET.
7.	Shale, gray to white, siliceous	15
6.	Lignite, impure	1
5.	Sandstone, marly, white	2½
4.	Shale, gray to white, with ferruginous colorings; also layers of siliceous bowlders	12
3.	Shale, drab to white, arenaceous	2
2.	Sandstone, white to red	7
1.	Shale, gray, sandy, especially below; exposed	7

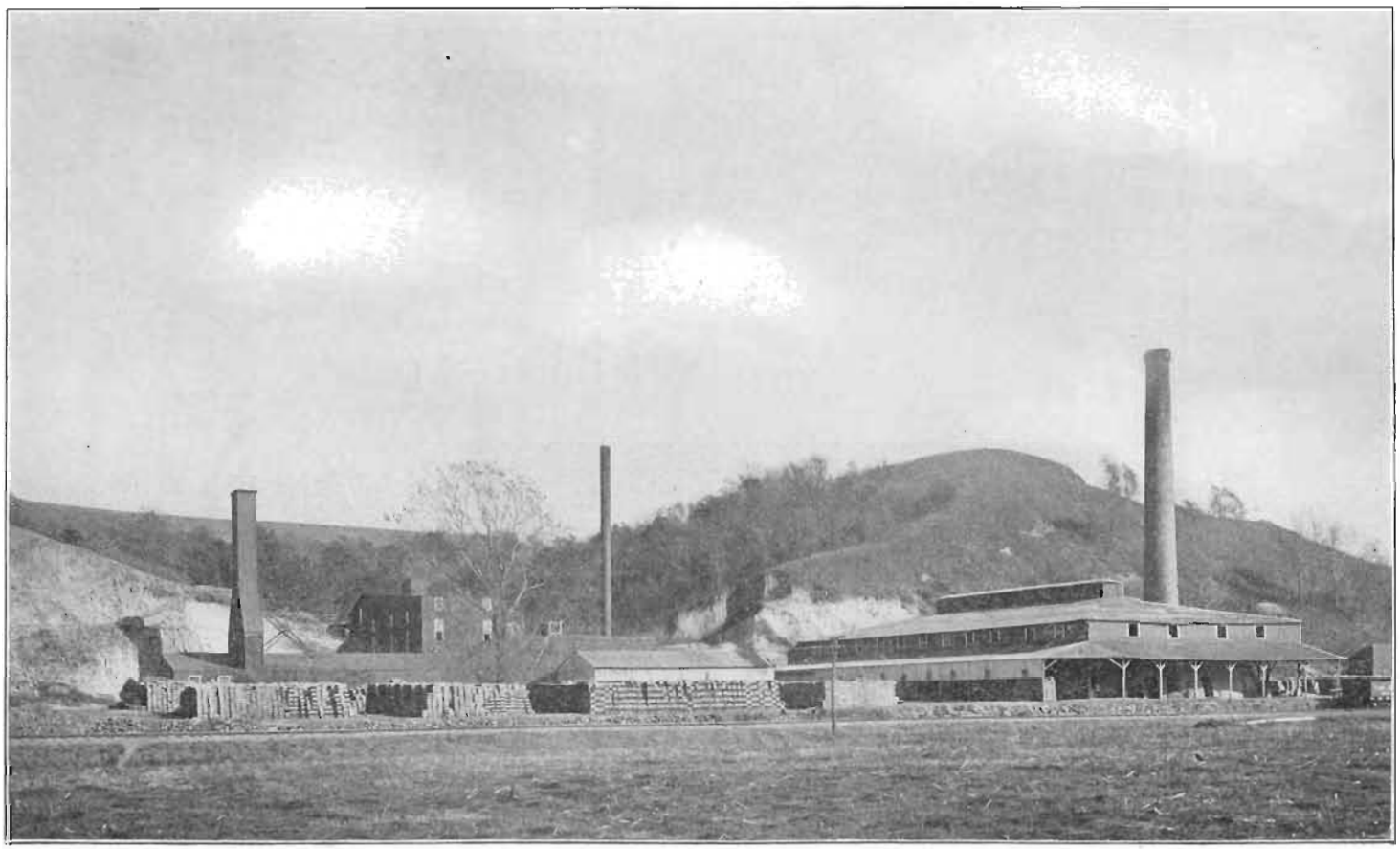


PLATE XXXIV. Plant of the Sioux City Brick and Tile Company at North Riverside, Sioux City, Iowa.

Formerly sewer pipe was manufactured, but no pipe has been made for some years.

The manufactured products comprise common building brick, paving brick and fire brick and sidewalk brick. The shale blended appears to be especially adapted to the manufacture of first-class sidewalk brick. The process of manufacture consists of running the ware stiff mud and then passing the end cut brick through a repress in which they are shaped and a pattern stamped upon them.

The Sioux City Brick and Tile Company has recently installed a modern plant between the above mentioned plants and are doing business on a large scale. Their pit is shown in the accompanying cut. In addition to common builders and face brick, a large number of tile and building block are produced annually. Most of the ware is burnt in a Haigh continuous kiln, which gives eminent satisfaction. Here, as at Sargents Bluff, the shales are highly siliceous and but little loss is experienced in drying and burning. Higher temperatures are required to secure a good burn than for any other series of shales in the state.

Some of the shale and clay seams are highly plastic, fairly free from impurities, yield readily to the potter's art and burn a satisfactory color. Potteries have been in operation from time to time both at Sioux City and Sargents Bluff but none are in business at present.

Shale crops continue northward along the Big Sioux but become more and more intimately associated with calcareous and arenaceous beds so that their extensive development would only be possible by drifting or shafting. Nothing has been done toward their utilization in the manufacture of clay goods at any other point in the county.

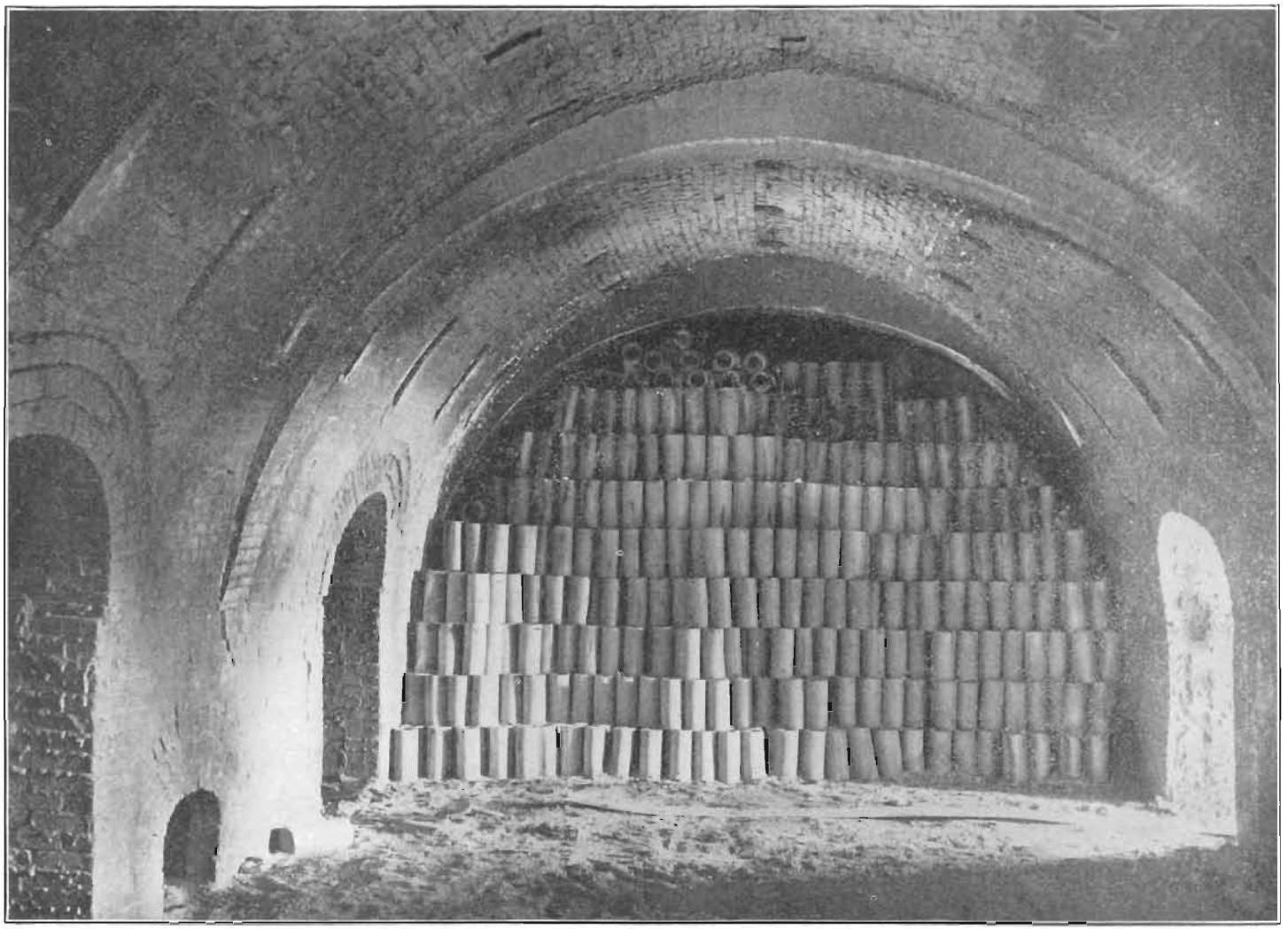


PLATE XXXV. Interior view of Haigh continuous kiln showing method of setting hollow ware. Sioux City Brick and Tile Company, Sioux City, Iowa

FIG. 72 Interior view of Haigh continuous kiln showing method of setting brick; Sioux City Brick and Tile Company, Sioux City Iowa.

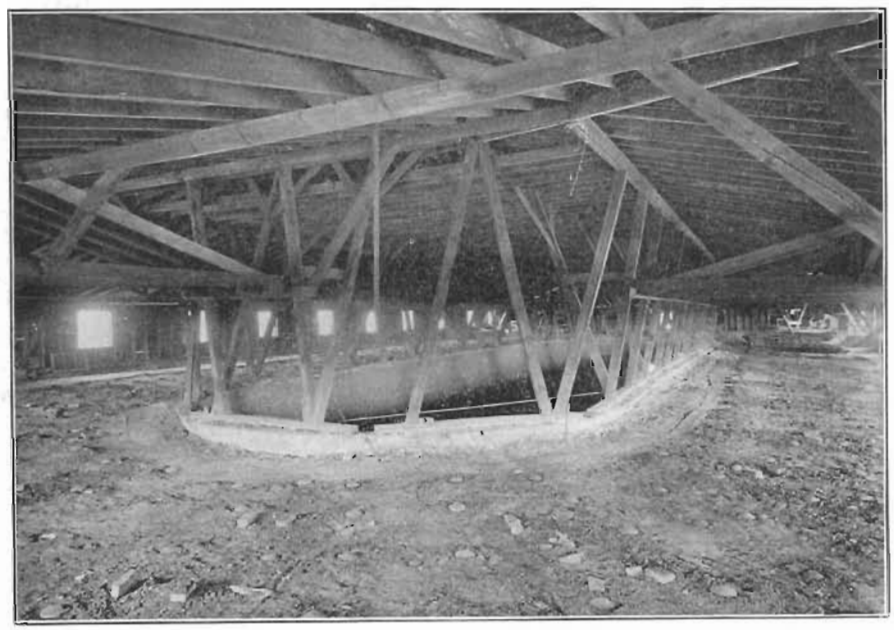


FIG. 73. Top view of Haigh continuous kiln showing arrangement of fire holes and open court.

The Pleistocene

With the exception of a small area in the northeast corner of the state the older rocks are covered by a thick mantle of glacial debris which varies from total absence up to two and even three or four hundred feet in thickness. Only the larger streams and their immediate tributaries have cut through the drift. The detailed features of the landscape are moulded in it. Only the larger features are in any way the result of the older rocks. The drift is composed of a most heterogeneous series of materials comprising bowlder beds, gravel trains and the more or less sorted over-wash. Intimately associated with the drift sheets are the massive structureless deposits of loess. The loess is composed of fairly well sorted finer sands, silts and clays. It covers about two-thirds of the superficial area of the state and affords an inexhaustible supply of raw material ready prepared for the clay worker. It varies from a thin veneer to deposits many feet in thickness. Of the drift sheets themselves but little has been done toward their utilization in the clay working industries. The greater portion of the various drift sheets contains numerous pebbles and bowlders, many of which are calcareous in character and make the use of drift expensive or impossible to the brick-maker. In addition to the pebbles and bowlders, the unaltered drift contains a high percentage of lime, both in the form of concretions and in the widely disseminated form throughout their entire mass. Lime concretions must be eliminated or finely pulverized in order that the clay may be used safely. Many of the drift clays, even when fairly free from the deleterious impurities mentioned, still fail to give satisfaction on account of excessive shrinkage and consequent great loss due to checking in drying and burning. However, several of the drift sheets present deposits which have been slummed or washed naturally through the processes of weathering, transportation and sedimen-

tation and have been partially prepared for the brick maker. Such deposits occur about some of the present or recent lake beds, along ravines and draws and on second bottom land, merging insensibly into alluvial deposits, and are used to a limited extent and give fairly satisfactory results.

In Iowa five drift sheets are recognizable and will be discussed in the order of their age. All save one are shown on the accompanying map.

PRE-KANSAN OR ALBERTAN.

The glacial deposits supposed to be the equivalent of the Albertan of the Canadian geologists, have been observed at a number of points in the state. The best known sections may be viewed at Afton Junction in Union county, at Albion mills in Marshall county and in the cut along the Great Western railway near Oelwein in Fayette county. The Albertan is not known to appear at the surface, save in natural or artificial cuts, and is of no practical importance to the clay worker. It has been observed at numerous other points and is usually separated from the overlying drift sheet by peat beds, forest remains, old soils and gravel beds.

THE KANSAN.

The ice invasion which produced the Kansan drift marks the extreme ice advance for the Mississippi Valley. It is the only glacial sheet which was known to cross the Missouri river into Kansas and hence the name. It is not only the most extensive areally in Iowa but also averages the thickest. A glance at the map will show that it extended over practically the whole of the state and is at present the superficial drift sheet of more than half of the state. It ranges in thickness from zero to more than 100 feet. In places it is believed to reach a maximum thickness of nearly 300 feet and averages nearly 100 feet for the entire

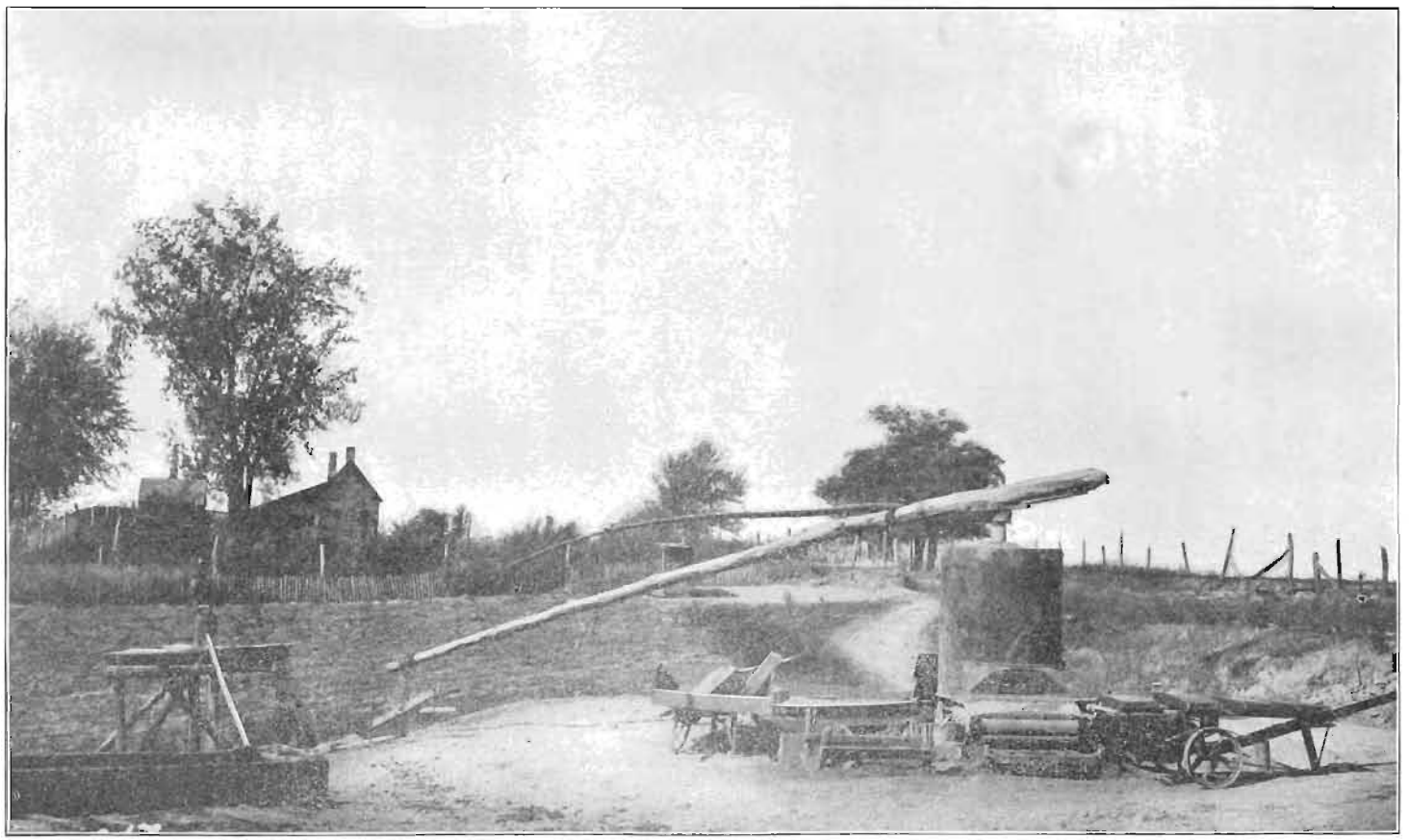


PLATE XXXVI. Plant near Moravia, Iowa, showing method of manufacturing surface clays.

state. The upper portion of the Kansan is more or less completely oxidized to a red-brown or yellow-brown and is thoroughly leached of its lime in the widely disseminated form and as concretions. It may still contain some lime pebbles and bowlders. The thickness of the oxidized portion varies from a few feet to 20 or 30 feet and when fairly free from gravel and bowlders can be used for the manufacture of common brick and tile. Some attempts have been made to utilize the unoxidized Kansan drift, with unsatisfactory results. Topographically, the Kansan drift area is characterized by being much stream dissected. The drainage lines are mature, and generally the small tributaries have almost perfectly drained the divides. No ponds or lakes are to be found away from the immediate vicinity of the larger streams. The land comprised in this area is considerably broken.

THE ILLINOIAN.

The drift produced by the Illinoian ice invasion is limited to a comparatively small area and constitutes considerable portions of Scott, Muscatine, Louisa, Des Moines and Lee counties. The drift materials are not very different from those which constitute the Kansan and possess the same advantages and the same disadvantages when viewed from the standpoint of the clay worker. They have not been developed to any extent in Iowa, yet the oxidized, leached portion could undoubtedly be successfully used in the manufacture of the common clay wares.

THE IOWAN.

The Iowan drift occupies about 10,000 square miles of the northeast quarter of the state. It is bounded on the west by the Altamont moraine, which passes in a southerly direction through the western portions of Worth, Cerro Gordo and Franklin counties, east of the middle of Hardin county, and on the south by a series of finger-like loops, the various fingers extending into

Poweshiek, Johnson, Cedar, Scott and Clinton counties. The eastern boundaries are also irregular, lobes extending into Jones, Dubuque and Clayton counties, a more or less even line across the northwest corner of Fayette, southwest corner of Winneshiek, cutting the northeast corner of Howard county to the state line. The Iowan drift is characterized by large numbers of red and gray granite bowlders, many of which are of gigantic size. The finer materials rarely exceed 10 or 15 feet in thickness and when unweathered contain a considerable amount of lime. The weathered portion of the Iowan and the wash from the Iowan is often sufficiently free from lime to be serviceable in the clay industries. It has not been developed to any extent along those lines. Topographically, the Iowa drift surface is but slightly broken and presents an even, monotonous plain known as the "Iowan drift plain."

Delaware County.—The Iowan drift covers the major portion of the county and in places is sufficiently free from lime and other impurities to be used in the manufacture of common brick and tile. At Manchester the brickyard of C. H. Mattox, located on top of the hill in the eastern part of the city, has been operating for more than one-third of a century. The clay bank developed shows the following materials:

		FEET.
3.	Soil, very sandy in parts	1
2.	Clay, sandy and pebbly, yellow	3
1.	Clay, yellow to brown	6

Number 1 contains sharp sand disseminated throughout and in pockets, and occasionally a pebble. Below the base of the cut there is about sixty-five feet of blue drift clay; limey in the upper portion. The Niagara limestone lies below the heavy till. Common brick only are manufactured at the present time.

THE LOESS.

Beyond the borders and overlapping some of the drift sheets, a fine, evenly sorted material has been deposited. Such deposits

appear to be almost structureless and while easily eroded or removed by running water, possess the property of maintaining vertical embankments, even assuming the magnitude of cliffs as may be seen facing the Missouri river. When examined closely, it is found that the materials composing such deposits are clay, silt and fine sand, exactly identical with those materials found in the unassorted bowlder clays which preceded them. Sometimes one

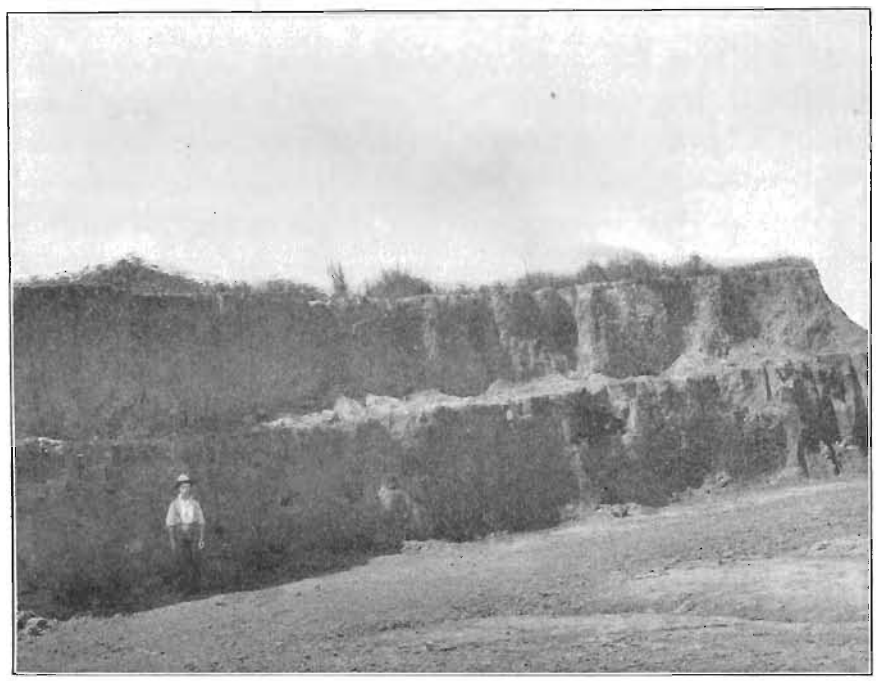


FIG. 74. Pit of the Muscatine Pressed Brick Company, Muscatine, Iowa.

and sometimes another of these constituents predominate. As a general rule there is a gradual increase in the sand element from the surface downward, the deposit often terminating in a bed of fine sand. This material is known as the loess. The distribution of the loess appears to be independent of the local topography. It is usually thickest near the brow of the hills and bluffs, along the principal water courses, especially those bluffs which face

west, and thins gradually toward the divides. The deposits also become less arenaceous in character toward the water sheds. The loess often contains the well preserved remains of arid region gastropods, root casts and lime concretions. Some of the last assume curious and fantastic shapes, the Germans calling them Loess-Püppchen and Loess-Männchen because of their fancied resemblance to dolls. The lime balls when present usually occur in a zone some feet from the surface and can generally be avoided when the clay is used in the clay industries. The loess covers more than one-half of the surface of the state, and varies from

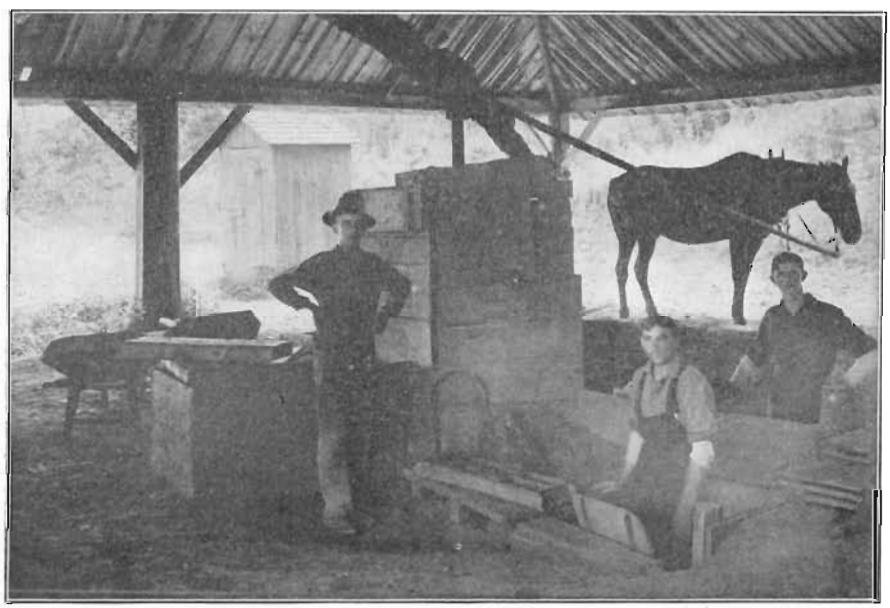


FIG. 75. Brick machine used in the manufacture of soft mud brick. William Samuels yard, Muscatine, Iowa.

total absence to twenty or thirty feet and exen exceeds one hundred feet in thickness along the Missouri river. It affords an exhaustless supply of material suitable for the manufacture of brick by the soft mud, stiff mud or dry press process, drain tile and burnt clay ballast. It is the cheapest of clays to work, requiring neither dynamite nor pick in the pit and often receiving no pre-

liminary grinding, crushing or pugging before being introduced to the brick machine. A large majority of the brick plants in the state draw their raw material from the loess.

The Red Clay.—Several fairly distinct types of loess have been recognized in Iowa, but all are believed to be genetically related. The most important deposits are known to be younger than the Kansan drift and are older than the Wisconsin. Perhaps the oldest type occurs in the southwestern portion of the state and is known as the red clay or "gumbo" and has been quite fully described by Udden in his report on the Geology of Pottawattamie County.* The red clay quite closely resembles physically the younger phase of loess which covers it, but is less porous, and has been thoroughly oxidized and leached. On drying it resembles a joint clay, breaking into a number of angular fragments. Occasionally, but not commonly, it contains drift pebbles in the lower portion. Its impervious character appears to be due to a slightly higher percentage of clay particles but more especially to the interstitial deposition of fine ferruginous material through the agency of the ground water. So far as known it is free from organic remains and its origin and taxonomic relations are not well understood. Exposures are not common and the red clay has not been developed in the clay industries. The close relationship between the red clay and the younger loess is clearly shown by an inspection of the following table, which is taken from Professor Udden's report. It is estimated that the loess constitutes 95 per cent of the red clay.

*Iowa Geological Survey, Vol. XI. pp. 255 to 258.

TABLE SHOWING PERCENTAGES OF MATERIALS OF DIFFERENT GRADES OF COARSENESS IN SAMPLES OF LOESS AND GUMBO.

DIAMETER OF FRAGMENTS. (IN MILLIMETERS)	GUMBO.									LOESS.											Averages.	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
	Northwest corner section 22, Minden township.	Three miles west of Avoca, 5 feet above bowlder clay.	Two and one-half miles east of Walnut.	Railroad cut, section 13, Layton township.	Railroad cut, section 13, Layton township.	Railroad cut, section 13, Layton township.	Railroad cut, section 14, Layton township.	From a well, 5 miles north of Walnut	Braddyville, Iowa.	Light yellow loess, section 33, Boomer township.	Council Bluffs, base of bluffs	Council Bluffs, 20 ft. above base.	Council Bluffs, 40 ft. above base.	Council Bluffs, 60 ft. above base.	Council Bluffs, 20 ft. from top of bluff.	Council Bluffs, 15 ft. from top.	Council Bluffs, 8 ft. from top.	Council Bluffs, 2 ft. from top.	Council Bluffs, 10 in. from top.	Council Bluffs, top soil.	Average composition of Gumbo.	Average composition of Loess.
8–4	5	.		....		.		....	....		.....	......	......	......	.....			......	......	.....	tr.	.....
4–2	.9	.1	.	...		....	....	......	.....	....	.....	......		......	....	....	....			.....	.1	.....
2–1	.9	.1	tr.			.		....	....	....	.....		....	....	....	......		......	....	.....	.1	.....
1–$\frac{1}{2}$	3.3	.4	tr.	tr.	......	tr.		tr.	.1			......	....	......	....	..	......		.	....	.4	.....
$\frac{1}{2}$–$\frac{1}{4}$	2.7	.9	.4	.5	tr.	tr.	tr.	tr.	2		tr.	......	....	.....	......	tr.	tr.	......	.	tr.	.5	
$\frac{1}{4}$–$\frac{1}{8}$	8.8	3.2	1.0	3.5	.2	tr.	.1	2	3.3	tr.	1.0	1.9	.7	.3	.1	.2	.1	tr.	tr.	.1	2 2	.4
$\frac{1}{8}$–$\frac{1}{16}$	6.5	8.3	7.5	5.0	2.5	20.6	4.0	5.6	14.9	2.3	12.8	8.9	18 0	2 8	.8	5.2	6.5	6.0	1.1	5 8	8.3	6 2
$\frac{1}{16}$–$\frac{1}{32}$	52.9	53 3	56.7	45.4	59.0	47.3	62.5	52 5	54.2	69.2	66 0	62 4	65.1	65.0	56 2	66.9	64.0	66 0	61.8	66.0	54.9	64.4
$\frac{1}{32}$–$\frac{1}{64}$	15.1	22 1	20.8	31.9	25.1	19.3	22.5	30.6	17.4	19.9	17.9	19 6	13.0	26.0	34 2	20.9	19.4	22 1	29.6	21.3	22 5	22.2
$\frac{1}{64}$–$\frac{1}{128}$	5.0	9.9	9.0	8.9	8.8	9.1	8.0	6.4	6 5	7.5	1.8	5.7	2.5	5 0	7.0	5.7	7.9	4.9	5 9	5.9	3.9	5.4
$\frac{1}{128}$–$\frac{1}{256}$	1.4	1.3	1 8	2.5	2.5	1.5	1.1	2.0	1.5	1.0	.4	1.1	.2	.6	.5	1.0	1 3	.8	.7	1.4	1 8	.8
$\frac{1}{256}$–$\frac{1}{512}$	.9	.5	1.4	.7	.6	.5	.3	8	.4	.1	.1	.3	.1	.2	tr.	.3	.3	.3	.2	.2	.7	.2
$\frac{1}{512}$–$\frac{1}{1024}$	1 0	.4	.	1.2	1.2	1.3	.9	.8	.8	.....	.....	tr.	tr.	tr.	tr.	.1	.2	.1		tr.	9	tr.
$\frac{1}{1024}$–$\frac{1}{2048}$	tr.	tr.	....	tr.	tr.	tr.	......	tr.				....		.....	....		.. .				tr.	

The Gumbo.—In the southern portion of the state, away from the great rivers, the gumbo is gray to drab in color, and while believed to belong stratigraphically with the loess, it is more plastic and less porous than the loess which covers it. When damp, but not wet, it presents a mealy appearance which is quite deceptive as to its real character. As in the case of the red clay, it rarely carries pebbles. Small lime balls are often present, but are usually not so large or so numerous as those in the loess. The inland type of gumbo rests directly on the ferretto zone of the Kansan and attains a thickness of ten feet. It is possible that the red clay and the inland gumbo may be phases of the same deposits.

Burnt Clay Ballast.—The red clay and gumbo are not of practical interest to the brick maker because of their excessive shrinkage. The gumbo, with the close-textured loess which covers it in a number of counties in southern Iowa, has been developed quite extensively at a number of points for the manufacture of burnt clay ballast. Two companies are actively engaged in this work at the present time. The Davy Burnt Clay Ballast Company, whose home office is in Kenosha, Wisconsin, and the Western Ballast Company, with home office at Aurora, Illinois. The first company has pits at Selection and Corning, while the second is operating at Nodaway, Adams county. The methods used are essentially the same. The material used ordinarily consists of the superficial loess with the gumbo below. Occasionally an alluvial clay is used, as was the case near Cuba, in Iowa county. Whatever the material used certain physical properties are essential to insure satisfactory results. The excessive shrinkage mentioned which is fatal to success in the manufacture of ordinary clay goods is not only a desirable quality but is essential to the economic manufacture of burnt clay ballast. The extraordinary shrinkage causes the gumbo masses scooped out by the ballast machine to partially disintegrate under fire, at once facilitating an

equable distribution of heat, which makes uniformity in burning possible and prevents the overheating and consequently the production of unwieldy glassy bowlders and clinkers. The product when successfully burned consists of fragments fairly uniform in size and requires no further treatment preparatory to use. A second quality, while not so important as the first, contributes

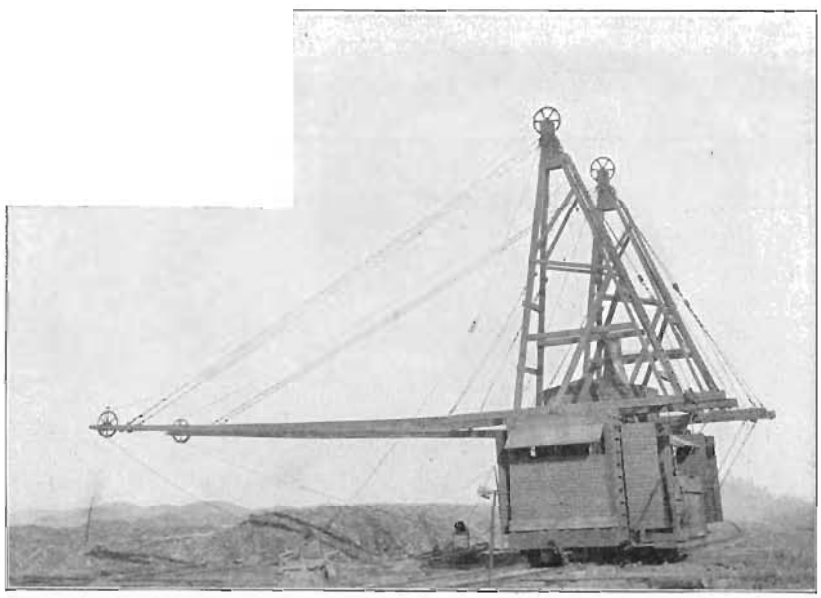


FIG. 76. Burnt clay ballast machine used by the Davy Burnt Clay Ballast Company.

very largely to economical production. The clays best adapted to the manufacture of burnt clay commonly contain high percentages of fluxes. The upland gumbos in particular, which yield the best results, are, on account of their impervious nature, almost wholly unoxidized and unleached. The high percentages of fluxes and the extremely fine textures of the gumbo lower the fusibility and obviously reduce the cost of burning.

The upland type of gumbo has a wide distribution over the southern half of Iowa. It is commonly present on the divides between nearly all of the more important drainage lines and

varies in thickness from a thin veneer or total absence to twenty or even thirty feet. The superficial portion is charged generally with humus and stained a gray-black in color when wet, to lighter shades when dry, and grades downward into an ash-gray to blue-gray, pebbleless and almost gritless deposit. The monotony of the lower portions is broken occasionally by almost white blotches of lime.

The methods used by the Davy company in the manufacture of burnt clay are very simple and very effective. Some five or six

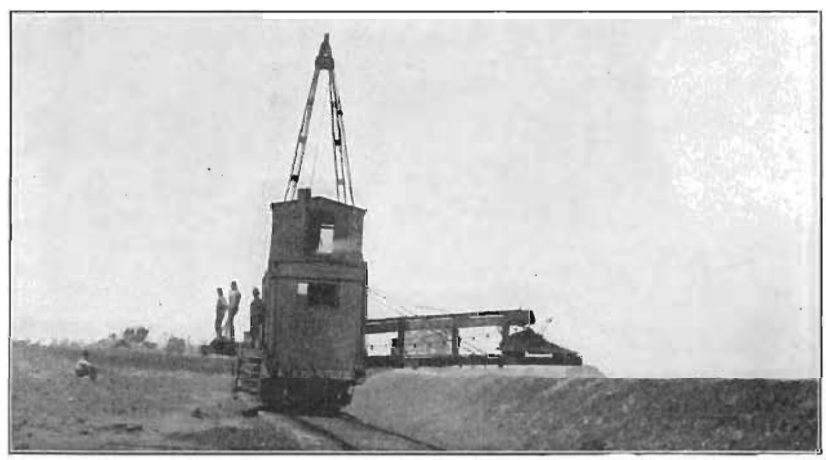


FIG. 77. Coaling machine used by the Davy Burnt Clay Ballast Company.

feet of the surface materials are used. A car mounted on trucks and equipped with a pair of steam shovels working from two extra long booms extending out at right angles to the car constitute the excavating or ballast machine. In opening a pit a windrow of combustible material, usually old ties, bridge material and other refuse, is placed at the margin of the area which it is proposed to exploit. A track is laid in front upon which the ballast machine operates. The steam shovel cuts a trench as it moves ahead, depositing the removed materials on the row of wood on the opposite side of the trench by the scoop running out on the

boom and dumping. The excavating car is followed by a coaling car which consists of a traveling scoop or dredge much on the same principle as the steam shovel which brings the coal to a belt conveyor, which in turn deposits a thin layer of coal evenly over the fresh clay ridge. The track is set back from the trench and the steam shovel cuts a new swath transferring the material across the trench and depositing it evenly over the preceding layer. This in turn is followed by the coaling machine and the process is repeated over and over again. The first layers are fired and the fire passes from one layer to another, the process being continuous when once well under way. The amount of coal added is intended to be sufficient to burn all or nearly all of the clay, but not to fuse it. The value of the ballast depends very largely upon the perfection of the burning. If underburnt the clay slakes and becomes slippery when wet. If completely fused it adds to the expense of distribution. The product of a successful burn consists of fragments more or less uniformly sized, and may be considered an artificial gravel. The usual way of handling the ballast when sufficiently cooled is to lay a track on the opposite side of the pit from the ballast machine and coaler and use a steam shovel. Flat cars are loaded in this way or may be loaded by hand. Thus when the plant is in full blast loading and removal follow closely trenching and coaling. Steam coal, slack and mine waste only are used for burning after the initial kindling. For economical working the pit usually ranges from one-half mile to a mile in length. The methods used in the distribution of the ballast along the right-of-way are the same as those practiced in the distribution of gravel and crushed stone. In addition to the use of burnt clay for railway ballast, it bids fair to serve as a substitute for cinders and gravel in filter beds, and for gravel and crushed stone in concrete and highway work. When the "good roads" movement assumes a more practical form the wealth of raw materials suitable for the manufacture of burnt clay may receive the attention their importance merits.

The Iowan Loess.—The most important loess deposit is known as the Iowan loess. It closely fringes and is supposed to be closely contemporaneous with the drift sheet of that name. The Iowan loess forms a veneer over the older silt and clay deposits mentioned and has the greatest superficial extent of any deposit in the state.

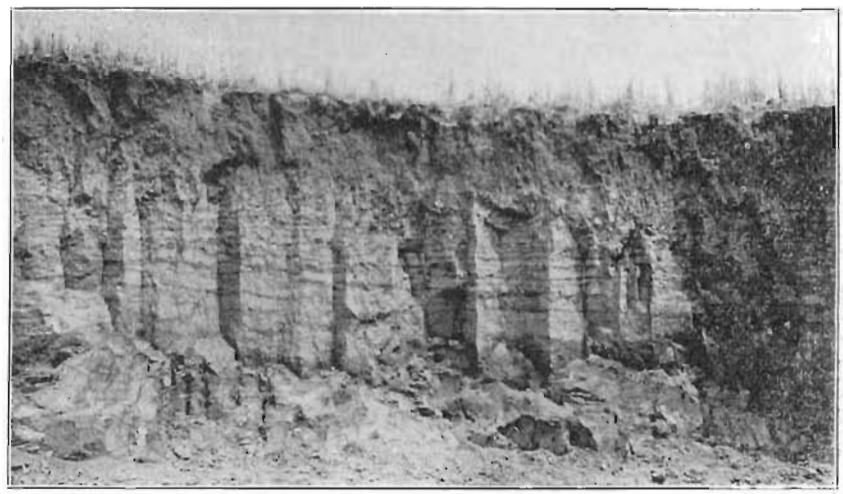


FIG. 78. Stratified loess, in clay pit of Sieg and Size, west of Marshalltown.

The Iowan loess forms an uninterrupted deposit from Lyon and Osceola in the northwest around the Wisconsin lobe to Jasper and Marshall counties, closely fringing the front of the Iowan drift to Johnson and Cedar counties. The Iowan loess also margins the Iowan lobe on the east. While its continuity is unbroken, the Iowan loess presents quite different phases for the different portions of the state. The Missouri river type carries more fine sand and silt than is characteristic of the inland and the Mississippi types. The first type has been developed most extensively at Council Bluffs and Sioux City. The Besley pit at the former place exposes some fifty feet of loess usable in the clay industries. The bulk of the deposit is made up of particles varying from one-sixteenth to one-thirty-second of a millimeter

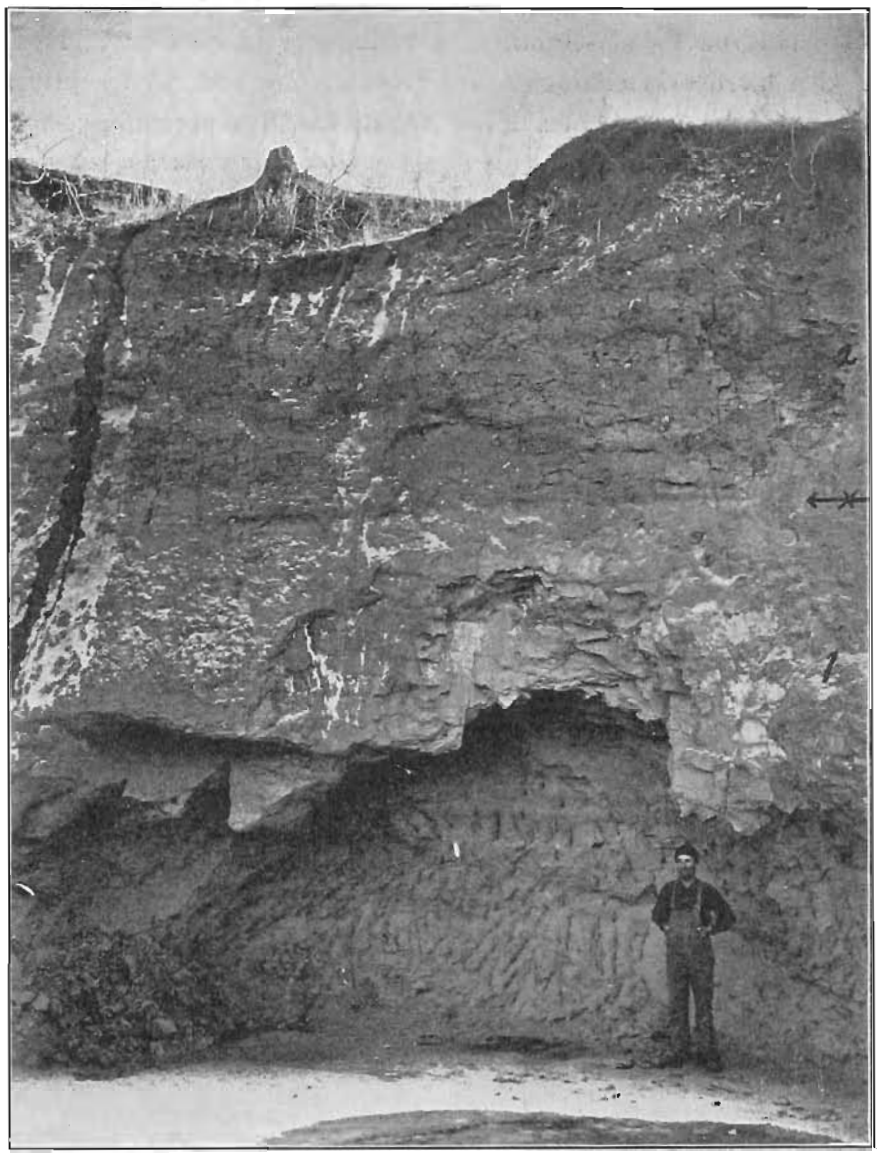


PLATE XXXVII. Clay pit of the Kelly Brick and Tile works. 1, represents the loess, and 2, the Wisconsin drift.

in diameter, less than two per cent consisting of fragments exceeding one-eighth of a millimeter in diameter or smaller than one-one hundred twenty-eighth of a millimeter in diameter. It is highly porous in character and breaks along vertical fractures, rarely showing any traces of bedding planes. The prevailing color is a grayish-yellow to a pale straw yellow. It does not possess sufficient plasticity to work well in the manufacture of hollow ware. It yields a fair grade of brick manufactured by soft mud, stiff mud or dress press process. Considerable difficulty is experienced in drying the ware to prevent air checking. Considerable lime is present in the widely disseminated state and as gastropod shells but few concretions are present. Local exceptions are numerous where lime occurs in sufficient amount to render the deposit useless. Three samples were selected from the Besley pit, believed to be representative of the top, middle and lower portions. Complete chemical and rational analyses are given below:

	TOP.	MIDDLE.	BOTTOM.
Silica	67 15	68.22	71.76
Alumina	6.55	10.21	10 12
Combined water	2.03	1.52	2 94
Clay and sand	75 73	79 95	84 82
Iron oxide	3.83	2.87	2.40
Lime	7.36	3.90	2.52
Magnesia	3.15	3.16	3.29
Potash	.55	.58	.47
Soda	1 89	1.68	1.59
Total fluxes	16 78	12.19	10 27
Moisture	1.05	.62	1.52
Sulfur trioxide	0.90	1.45	1.76
Carbon dioxide	5.53	5.86	1.86
RATIONAL ANALYSES.			
Clay substance	26.51	19 72	27.37
Feldspar	28.34	25.74	19.32
Quartz	32 77	40.29	46.09
Magnesium carbonate	6 15	6.63	
Calcium carbonate	4.70	5.16	4 25
Calcium sulfate	1.53	2 46	2 97
	100.00	100 00	100.00

It will be noted that all are highly siliceous, ranging from 67.15 to 71.76. It is also apparent that they run low in alumina and comparatively high in lime and magnesia. Sufficient iron is present to give a fair color and the high percentage of fluxes causes the ware to melt at a reasonable temperature, notwithstanding the high silica contained and the comparatively coarse material.

Council Bluffs is the largest user of surface clays in the manufacture of brick. The Sioux City material is essentially the same although analyses have not been made. Practically every county in the state where the Iowan loess occurs contains one or more clay plants using it, which have developed it. At Council Bluffs most of the ware is made by the soft mud process although a limited number are turned out as stiff mud brick. In Guthrie county the usual inland type of the Iowan loess prevails over the southern and eastern portion of the county; northeasterly it passes under the Wisconsin drift. It has been worked at a number of points. At Guthrie Center the pit opened by Mr. W. E. Berry may be taken as fairly representative for the district. It is adapted to all of the common processes of brick making and would undoubtedly yield a good face brick. An analysis is given below.

Silica	68.62
Alumina	14 98
Combined water	3.55
Clay and sand	87.15
Iron oxide	4.16
Lime	1.48
Magnesia	1.09
Manganese oxide	.64
Potash	1.50
Soda	1.86
Total fluxes	10.73
Moisture	2.78

It is obvious from a casual inspection of the above analysis that the Guthrie county type is less siliceous, contains a lower

percentage of lime and magnesia and is considerably higher in alumina and iron. It burns a pale color and is much more plastic than the Missouri river type and gives good results in the manufacture of hollow ware. In this region the loess varies from total absence, where it has been removed along stream ways, to fifteen or twenty feet thick near the hill fronts and becomes gradually thinner as the divides are approached.

In Adair county the loess is even more siliceous than the Council Bluffs type. The loess covers the entire county save where it

FIG. 79. Loess occurring over stratified drift in the pit of the Le Mars Brick and Tile Company, Plymouth county, Iowa.

has been removed by the streams. It varies from a few feet to thirty feet in thickness and is used at a number of points in the manufacture of clay wares. It is usually quite homogeneous and free from impurities. Occasionally it carries small calcareous concretions and a few gastropod remains. At Bridgewater the Gillette brickyard, located just south of the pit, is developing the loess. Under the soil, which is usually removed, lies a gray joint

clay which is used in the manufacture of common brick. An analysis of the clay shows the following constituents:

Silica	77.13
Alumina	10.75
Combined water	2.22
Clay and sand	90.10
Iron oxide	2.38
Lime	2.08
Magnesia	0.83
Potash	1.73
Soda	0.60
	7.62
Moisture	1.45

Although the amount of iron runs lower than for most of the inland loess, yet sufficient is present to give a good color to the burnt ware. The clay is also suitable for making drain tile.

The Iowan loess has also been extensively developed in and around Des Moines, in Polk county. In many cases the loess has been somewhat modified by drift wash and alluvium. It has been manufactured by all of the well known processes of brick making. Modified loess has been used quite extensively by the Dale Brick Company. An analysis of the average material taken from the pit is as follows:

Silica	73 69
Alumina	9.68
Combined water	3.88
Clay and sand	87.25
Iron oxide	5.36
Lime	1.53
Magnesia	1.01
Potash	1.27
Soda	2.72
Total fluxes	11.89
Moisture	.71

RATIONAL ANALYSIS.

Clay substance	31.30
Feldspar	12.47
Quartz	56 23
	100.00

It may be noted that the Dale clay runs exceptionally high in silica and quartz sand and is comparatively low in alumina and magnesia. It also runs high in the stronger fluxes, soda and potash, and notwithstanding its high siliceous percentage burns at a reasonable temperature. It also runs high in iron and assumes a deep cherry red when burnt. The ware gives good satisfaction as face brick and is used extensively as a trimming for interior finish and has been adopted as a veneer for many railway buildings along the Rock Island and the Northwestern railways.

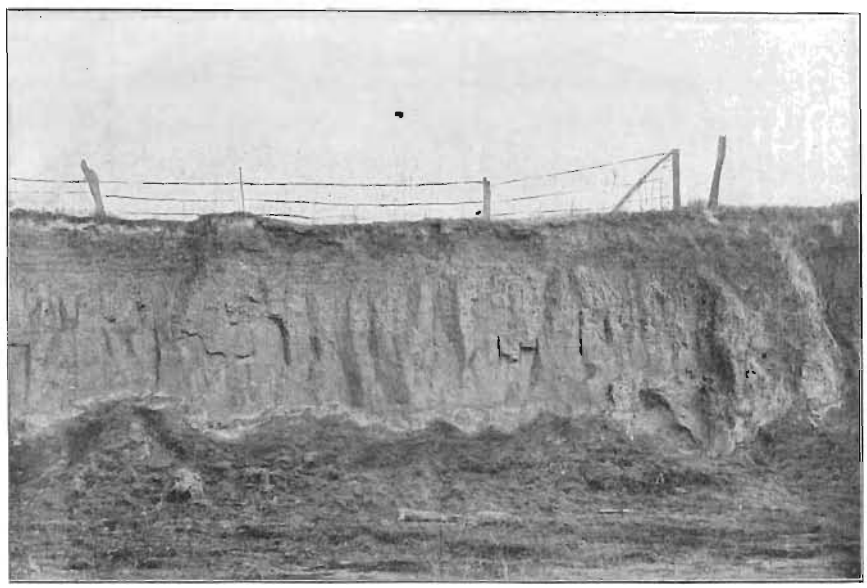


FIG 80. Pit of C. B. Bentley & Son, one mile east of Tama, Iowa.

In the manufacture of dry press brick the Iowan loess has been most extensively developed near the Iowan drift margin at Gladbrook, in Tama county. Two large factories have been using it at this point for a number of years. The loess area varies from ten to twenty feet in thickness and while all the inland type carries a higher percentage of the coarser materials than the loess in the southern tier of counties, it contains a sufficient amount of

flux to insure burning at moderately low temperatures, and is high enough in iron to yield a good color. An analysis of the loess selected from the pit of the Gethmann Brothers is as follows:

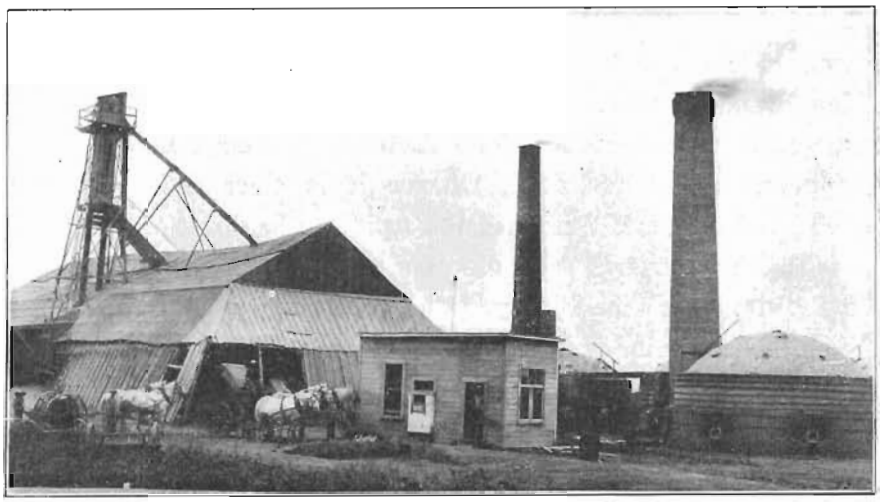


FIG. 81. Plant of Gethmann Brothers Pressed Brick Company, Gladbrook, Iowa.

Silica	67.92
Alumina	11.76
Combined water	5.36
Clay and sand	85.04
Iron oxide	6.72
Lime	1.63
Magnesia	1.18
Potash	1.87
Soda	1.92
Total fluxes	13.32
Moisture	1.49

RATIONAL ANALYSIS.

Clay substance	39.90
Feldspar	19.80
Quartz	40.28
	99.98

Certain portions of the loess contain a higher percentage of the finer constituents and are sufficiently plastic to be used in the manufacture of drain tile. As in practically all of the loess, considerable care must be used in drying to prevent undue loss by air checking. Both of the Gladbrook factories gather the clay and dry it in the same way. The pit covers quite an extensive area, is plowed and permitted to weather a few days; is then collected by automatic loaders, hauled to the factory by teams, dumped into a hopper-shaped chute, from whence it is elevated into storage sheds and kept until most of the moisture has been evaporated. It is then put through rolls, elevated and screened, and conducted to the dry press machinery. The product is uniform in character, of good color and gives good service as face brick and structural brick.

The loess in Warren county is of the inland type and is being used at a number of points for common building brick and drain tile. Two samples selected from the pit of the Indianola Brick and Tile Company were analyzed by Professor G. E. Patrick. The first sample was taken near the surface, just below the soil, while the second is dark gray in color and is found below the upper yellow loess. The results of the analyses are given below:

	No. 1.	No. 2.
Silica	72.24	63.31
Alumina	12.58	16.51
Combined water	3.33	6.89
Clay and sand	88.15	86.71
Iron oxide	4.02	4.06
Lime	1.40	1.11
Magnesia	.99	1.10
Manganese oxide		0.49
Potash	1.54	.96
Soda	2.60	2.20
Total fluxes	10.55	9.92
Moisture	1.70	3.76

It will be noted that the upper loess is more highly siliceous and is poorer in aluminum than the lower. The lower clay is slightly poorer in the fluxing constituents but slightly more plastic. The chief output of the plant is common building brick.

THE WISCONSIN.

The Wisconsin drift forms a tongue-shaped lobe whose apex extends well down past the middle of the state, Capitol Hill, in Des Moines, marking its southern extension. The lobe loops to the westward to the middle branch of the Raccoon river, in Dallas and Guthrie counties, continues diagonally across Carroll, through Sac, Buena Vista, Cherokee and O'Brien counties, looping back to the middle of O'Brien and Osceola county line and then northwesterly across the corner of Lyon county to the Minnesota line. The eastern limits have already been given as the Altamont moraine. The Wisconsin is characterized by large numbers of bowlders of various sizes, many of which are calcareous in character. The drift carries a large quantity of gravel, lime concretions and lime in the widely disseminated form. In the vicinity of some of the old lake beds and some of the draws and ravines, the wash from the drift has accumulated to depths of several feet and is fairly free from the bowlder and lime impurities, and is easily wrought into the cheaper grades of clay wares. The Wisconsin has been developed with varying degrees of success at a number of points. While it is no better adapted for the manufacture of clay products than materials derived from the other drift sheets, the demand for clay goods has been greater because of the scarcity of shales in the district and because of the great demand for drain tile, owing to the undrained character of the surface. A casual inspection of the map will show the great scarcity of drainage lines. The larger systems only being outlined, and the map shows a remarkable scarcity of the smaller tributaries. The Wisconsin area is the region of the Iowa lakes,

and a line so drawn as to take in all of the lakes and ponds of mapable size will approximately coincide with the limits of the Wisconsin drift. Because of the great demands and the relative scarcity of suitable material for the manufacture of clay goods, more persistent efforts have been made to utilize the Wisconsin than have been made toward the utilization of any other drift sheet.

Buena Vista County.—Russell Brothers of Storm Lake are developing modified Wisconsin drift. Their plant is located about one-half mile east of the Illinois Central railway depot, north of the railway track. The clay is obtained in the immediate vicinity and consists of a surface wash of silt and clay, free from gravel, and limestone concretions are not common. Below the black loam the yellow clay bears a blotchy appearance due to the presence of partially weathered pyrites. The clay averages five to six feet in thickness and resembles a gumbo. It is very similar to the material used in the manufacture of brick and tile at Dysart, in Tama county. A chemical analysis was made and the results are given below:

Silica	66.44
Alumina	12.64
Combined water	5.83
Clay and sand	84.91
Iron oxide	4.00
Lime	4 02
Magnesia	1.80
Potash	1.14
Soda	1.90
Total fluxes	12.86
Moisture	2.33

RATIONAL ANALYSIS.

Clay substance	38.80
Feldspar	24.84
Quartz	36.36
	100.00

It will be noted by a casual inspection of the analysis that the clay is relatively high in silica and lime and low in alumina. In this respect it closely resembles the loess. It is also high in feldspar, another character common to the loess. Drain tile is the principal product, although a few common building brick are manufactured.

Clay County.—The Spencer Brick and Tile Works is located about a mile and one-half north of the station of the Chicago, Milwaukee & St. Paul railroad, between the Little Sioux river and the Spirit Lake Branch of the railroad. Formerly brick were made by hand, but at the present time a stiff mud machine is used. Great care is required to prevent checking in drying. The pit section is as follows:

		FEET.
4.	Soil, black grading into brown and calcareous below	3⅜
3.	Clay, gray to yellow, clouded	2⅜
2.	Clay, grayish, plastic, jointed	1½
1.	Clay, drab, sandy in lower part	19

With the exception of a thin layer of soil, the entire section is utilized. Considerable care is exercised in the removal of lime concretions which are present in small quantity throughout the section. Number 2 is decidedly loess-like and the entire series resembles altered upland material. The loess-like member was analyzed and the results are as follows:

Silica	52.42
Alumina	13.04
Combined water	4.06
Clay and sand	68.52
Iron oxide	6.24
Lime	7.98
Magnesia	2.24
Potash	1.41
Soda	2.67
Total fluxes	20.54
Moisture	2.67
Carbon dioxide	7.51

The analysis does not show any marked loess-like affinities save in the low percentage of alumina. It is much lower in silica and carries more of the carbonates than is usual in the loess. During wet seasons some difficulty is experienced in keeping the pit dry enough to work the entire section.

Pocahontas County.—The Wisconsin drift has been most extensively used at Fonda at Straight Brothers. The raw clay is obtained from a pit immediately west of the factory, which is located opposite the Illinois Central depot. The pit shows typical Wisconsin drift with its characteristic gravels, bowlders, lime concretions and all. The clay has been worked to a depth of over twenty feet, pumping being necessary to keep the pit dry during certain seasons of the year. The soil and partially oxidized yellow bowlder clay comprise about two-thirds of the section, the gray blue to blue clay making up the lower one-third. The material is plowed, allowed to weather and dry out more or less; is then loaded into cars by means of horse scrapers, after which it is drawn to the factory by a tail rope. The clay is carried by means of a belt conveyor to the clay working machinery, which consists of a nine-foot Eagle dry pan in which the mullers are suspended so as not to pulverize the gravel and lime concretions too fine. The gravel is removed by a shovel and thrown into an elevator which conveys it to a slumming box fitted with an auger pugger and screens. The finer clay and soot particles rise and float off into a chute, are elevated and sent back to the pug mill. The part which passes through the dry pan is elevated and passes from a fine mesh inclined screen. Screenings are led directly to the combined brick and tile machine. Tailings pass into the slumming box as is the case with the tailings from the dry pan. Both brick and drain tile up to eight inches in diameter are manufactured, the ware giving good satisfaction. It burns a pale red, quite similar in color to the product from the Devonian shales at Mason City. It is strong and little loss is sustained through air and fire checking.

Numerous attempts have been made to develop the Wisconsin at other points but usually without taking the precautions of removing the gravel and lime concretions. The results have been variable, never wholly satisfactory and numerous failures have been recorded.

Clay works using modified Wisconsin drift have been in continuous operation at Jewell Junction, Hamilton county; Manson and Lohrville, in Calhoun county; Sioux Rapids, Buena Vista, Eagle Grove, in Wright county; Livermore, in Homboldt county; and Spencer, in Clay county. The methods used are very similar to those at Storm Lake. Unaltered Wisconsin drift can not be used with a reasonable chance of success unless the same precautions are observed as those at Fonda in its use. Numerous areas can be found, doubtless, of Wisconsin drift where the pebbles, bowlders and lime concretions have been largely removed, as is the case at Storm Lake and Jewell Junction, and in such cases the clays will respond satisfactorily to the treatment ordinarily accorded surface clays. Considerable loss may be expected during the process of drying and some loss perhaps during burning, but the great demand with the consequent high prices ought to stimulate the growth of the industry in the counties covered by the Wisconsin drift. Large plants have been established recently at Estherville, in Emmet county, and at Britt, in Hancock county. Others will be organized in the near future. In addition to the deposits which have accumulated in the depressions of the lake bed type, as at Storm Lake, less important deposits may be found along small ravines and draws, along the larger drainage lines, as alluvium and the so-called "white oak" soil which face some of the more important streamways. The first will be described here, while the latter will be described under the head of Post-Wisconsin deposits.

It is a well known fact that the finer particles from hilltops and slopes slowly gravitate toward lower levels. This change of

position may be initiated and doubtless is accentuated in times of freshets, but even gentle rains facilitate the downward movement until eventually these finer materials find lodgment on the lower hillslopes and ravines, where they are in more or less stable position. This is a natural slumming process, the coarser materials being left behind. They often show some evidence of sorting and stratification, proving that running water has had something to do with their deposition, while in other places no structural features are apparent. They are always of heterogeneous character both chemically and mineralogically, showing their descent from several different kinds of rocks and also evidencing their temporal character. Such clays yield readily by the soft mud process and have been used stiff mud at Eagle Grove and Iowa Falls, both for brick and drain tile.

POST-WISCONSIN.

Deposits of clays and silts, younger than the Wisconsin drift, are found along the larger streamways and on many of the bluffs facing the larger streams. The former are known as alluvial deposits, while the latter are believed to have been accumulated through the agency of the wind. Both are very heterogeneous in character both mineralogically and chemically and are composed of fine sand, silt and clay, the first two oftentimes comprising more than half of the entire bulk. Alluvium is found along all those streams which have built flood plains for themselves and varies in thickness from a few inches to a number of feet. It is easily obtained and yields readily to the simplest processes of the clay worker. In Iowa the alluvium affords the raw materials for the manufacture of soft mud brick only. On account of the high percentage of fine sand, it is usually short, dries easily and shrinks but little where the clay and silts greatly predominate. The alluvial deposits can not be used alone, because of the high shrinkage during drying and the attendant loss through check-

ing. The short alluvial clays when blended with more plastic materials may be used by the stiff mud process in the manufacture of common brick and hollow ware. The older alluvial deposits are usually found on terraces or benches above the present stream flood plain and are often known as the second bottom deposits. They are very similar in character to the modern alluvial deposits and are treated in the same way in the manufacture of clay goods.

The wind deposits flank most of the larger streams of the state, usually on the opposite side from which the prevailing winds blow. They are commonly quite highly arenaceous to silty, gray-brown deposits and are devoid of pebbles and bowlders. They are of mixed chemical and mineralogical compositions but are highly siliceous. The deposits obtain a thickness from five to ten feet, often not exceeding one to three feet. They attain their maximum thickness on the brow of the bluffs and thin quite rapidly inland, rarely being recognizable more than a mile from the bluffs' scarp. They are often known locally as white oak soils because that very well known and desirable species of oak finds in them a congenial host. The deposits are thoroughly oxidized and leached and structural or bedding planes are absent. The coarsest materials which enter into their composition are found nearest the flood plain and the size of grain diminishes gradually as the deposit feathers out away from the river. The source of materials and the transporting agent are not difficult to apprehend. The process of accumulation is going on today. Winds sweeping across the broad flood plain gather up such material as can be transported and move it towards the restraining bluffs. Only the very finest materials are given continuous passage for any considerable distance, but through successive short excursions the coarsest silt particles and fine sand grains eventually reach the brow of the bluffs and are deposited in the reverse order of their fineness. The position of these deposits is determined essentially

by surface contours. When crossing the valley the wind impinges against the hill flanks, is deflected upward and coming in contact with the still air above, loses velocity and being unable to carry its load further, deposits it over the brow of the hill. In this location its position is reasonably secure, although the entire assemblage of deposits possesses proclivities of the sand dune and may progress bodily inland. This process of wind transport and accumulation of materials may readily be witnessed during early spring and late autumn, when large tracts of bottom land are unprotected by vegetation. Dust storms are common and often during a single storm a measureable deposit is accumulated. If this be true now, how much greater must have been the efficiency of the winds which blew across the wide flood plains before vegetation had time to reclaim the valleys so recently vacated by the various ice sheets. The prevailing winds in Iowa during spring and fall are from the west, and hence the greater accumulation of aeolean deposits are an the eastern flank of the streams. Structurally, texturally and in composition and distribution, there is a remarkable resemblance between these wind accumulated deposits and the loess. Both are essentially devoid of stratification planes, possess similar compositions and textures and are highly siliceous, and bear the same relationships to the chief water courses along which they attain their maximum development. The wind deposits have been used at a number of points for the manufacture of common soft mud brick. These deposits with alluvium may be counted on as a source of raw materials suitable for the manufacture of clay wares in the Wisconsin drift area. The supply, however, is somewhat limited and in this territory the deposits rarely exceed more than two or three feet in thickness. Outside of the Wisconsin the deposits attain much greater thicknesses and have been accumulating, doubtless, for a much longer time than since the retreat of the Wisconsin ice.