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CLAYS AND SHALES OF MICHIGAN
AND
THEIR USES

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PART II. TESTS OF MICHIGAN CLAYS AND SHALES

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Chapter VIII. TESTS OF MICHIGAN CLAYS AND SHALES

EXPLANATORY STATEMENT

Maps. All of the surface clays of Michigan are of glacial or recent origin. Many deposits, particularly in the northwestern and eastern portions of the Northern Peninsula and along the eastern side of the Southern Peninsula, are true lake clays, at least at the surface, deposited as muds in the beds of former glacial lakes. They are fine grained and practically without pebbles. The rest of the clays are largely glacial till, a direct mechanical deposit by the ice sheet during the Ice Age,* and they contain more or less coarse sand and pebbles or boulders.

The mineral and chemical composition of these glacial clays, especially the boulder clays, generally varies rapidly vertically and horizontally. The properties of these clays vary correspondingly within wide limits, even in the same deposit. For these reasons it is practically impossible to indicate on the map (Fig. 67) areas containing clays of any particular kind or properties. A given area on the map indicates that a sample of clay of certain properties and possible uses was taken from that area and that similar clay may possibly be found elsewhere within it. Thus an area showing clay suitable for face brick means simply that a sample of clay taken from that area showed properties indicating that the sample might be used for face brick. It does not mean that the area is covered with clay suitable for face brick manufacture unless that statement is made definitely in the text.

The maps were prepared as an aid in understanding and summarizing the more accurate and detailed statements in the complete report, and must not be used except as subordinate to the text.

*Mon. LII, Pleistocene of Indiana and Michigan, by Leveret and Taylor, U. S. Geol. Surv., 1911
Pub. 25, Geol. Ser. 21, Surface Geology of Michigan by Frank Leverett, Mich. Geol. and Biol. Surv., 1916.

Description by Counties. Because it is impossible to describe intelligently the clays of Michigan in detail according to any geological classification, the State has been divided into its two natural subdivisions (The Northern and Southern Peninsulas) and the clay and clay industries described in detail according to counties. By the use of the maps and the index, which list all descriptions by number and kind, as well as by counties, any available information is readily accessible.

The location from which the sample was taken has been given in as definite and exact terms as possible. Peculiar local conditions, old and present workings, and encountered difficulties have been described so that the possible economic value of each deposit may be better estimated.

Sources of Information. Old records and reports have been consulted arid all important data included in the present report.

For general or preliminary information the following descriptions are essentially a complete record of all the available information. References have been given so that original sources may be consulted if desired.

Methods of Sampling. In taking samples the methods used were in general those outlined in chapter two on prospecting for clay. It is obviously impossible to sample and test every individual pocket of glacial clay, so an effort was made to sample so far as possible the representative clays of each district to obtain a general idea of the probable utility of the clays found in different parts of the State. The samples obtained by trenching, from the auger, or by other means were generally reduced to about 25 pounds in the field. The reduced sample was bound in a small, tightly woven sack of awning material, properly labeled, and carried in the car until a freight office was reached. The small sacks were then combined in larger sacks and shipped to the laboratory.

Methods of Testing. All tests were conducted in the Ceramic Laboratories (Plate XXXVI) of the Department of Chemical Engineering, University of Michigan, Ann Arbor, unless otherwise noted.

Because of the large number of tests necessary to indicate adequately the possible uses of Michigan clays, the testing was reduced to the simplest possible routine, and consisted simply of the drying and burning tests. These tests are adequate to determine fairly accurately the possible uses and value of the clay sample. The more specialized tests on plasticity, texture, warpage, transverse strength, etc., were omitted as unnecessary for the present purpose of indicating the possible uses of Michigan clays in a general survey of the entire State.

The clay samples as received at the laboratory were crushed and reduced to about three pounds. If the sample were of shale the sample was ground in the dry pan and screened to pass 40 mesh and then reduced by quartering as described in the second chapter.

The reduced sample was tempered with the requisite amount of distilled water to develop its maximum plasticity. The mixing was done thoroughly in small Werner & Pfleiderer mixers. The plasticity was judged by feel.

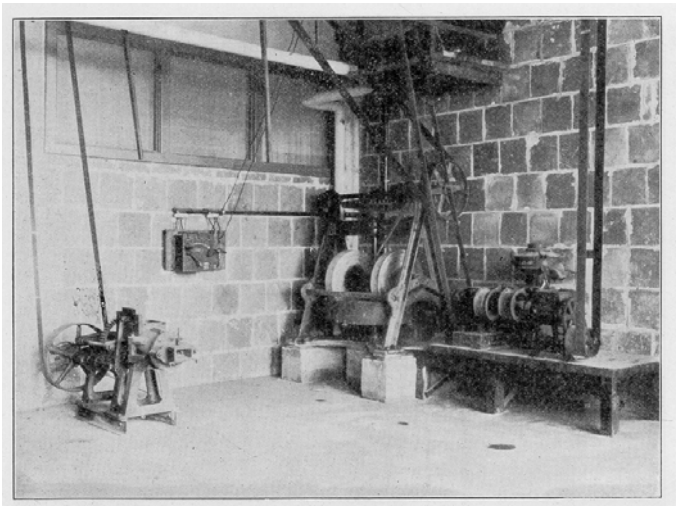

Plate XXXVI, Figure 1. Corner in clay preparation room. Department of Chemical Engineering, University of Michigan.

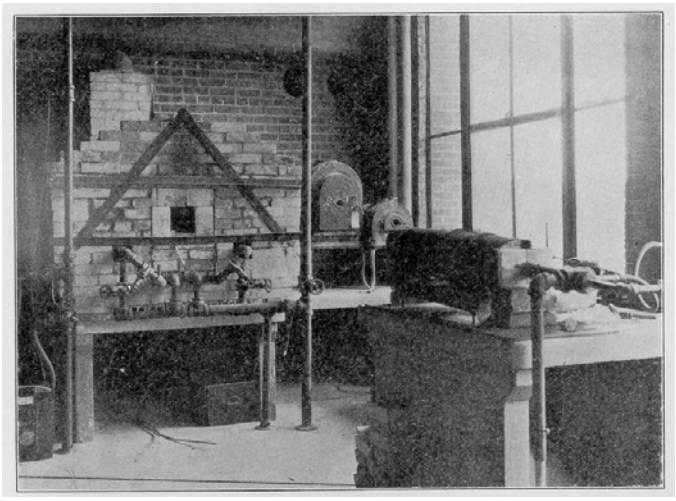

Plate XXXVI, Figure 2. Corner in kiln room. Department of Chemical Engineering, University of Michigan.

When properly tempered the clay was wedged into a cylinder and extruded in a screw press through a die of about 1 x ¾ inches. The column of clay was then cut into briquetts about two inches long which were numbered with the sample number and also given a serial number.

The plastic weight of the test brick was determined immediately. Then the plastic volume was determined in a volumeter filled with kerosene.

The bricks were then blotted dry of kerosene and allowed to dry at room temperature until air dry. They were then dried in an electric drying oven at 70°C. for five hours, and finally 110°C. to approximately constant weight. The dry bricks were weighed and then placed in a dessicator. Water of plasticity was determined as the number of grams of water evaporated per gram of dry clay.

The dry volume was determined by soaking the dry test bricks in kerosene as used in the volumeter for at least twelve hours, and then measuring the volume as before. The volume shrinkage was computed as a per cent of the dry volume. The drying shrinkage is reported for convenience as linear shrinkage in per cent of the dry length. The linear shrinkage = $\left(1-\sqrt[3]{1-\frac{b}{100}}\right)\times 100$ where b = volume shrinkage.

The bricks were then blotted dry and replaced in the drier to remove most of the absorbed kerosene. When this had been accomplished the test bricks were stood on end on the floor of the down draft testing kiln (Plate XXXVI). This kiln is a recuperative gas fired kiln with an effective space of about five cubic feet. It was built specially for this work and has proved very satisfactory. The samples were stacked in rows from front to back of the furnace with a row of pyrometric cones from 012 to 9 running down the center. In this way one brick from each row was removed as the corresponding cone went down and the next bricks to be removed were always in the front of the rows. In order to control the rate of heating a thermocouple with its hot junction adjacent to the row of pyrometric cones was always used.

Burning was done with an excess of air to aid in oxidizing the clay. Except in special cases of clays that had to be thoroughly oxidized at about 500°C. the temperature was raised about 100°C. an hour to 750°C. and held constant until the dark centers of drawn bricks were completely oxidized. Then the temperature was raised about 50°C. an hour until the clay melted. The above rates of heating are about twice those recommended in the standard method. Comparative burns at the slower rate showed no noticeable differences on cones or Michigan clays and the faster rate was used.

Test bricks were drawn at intervals of two cones, beginning at cone 010 and placed in the vestibule of the furnace to cool slowly until time to draw the next test specimens. The bricks were then removed from the vestibule and placed in hot sand to finish cooling. When

cool enough to handle the bricks were placed in a dessicator until weighed.

The burned bricks were then saturated with boiling water for four hours, and cooled under water. The saturated weight was then taken. The volume of the saturated brick was then taken in a volumeter containing water.

The apparent porosity is computed as the volume of water absorbed per unit volume of burned clay.

The apparent specific gravity is computed as the weight in grams per apparent unit net volume of burned clay. (Apparent net volume = fired volume minus volume of absorbed water).[1]

The color of the burned brick was compared against a chart and carefully noted.

Hardness of the brick was determined by a piece of rounded steel and reported as soft if easily scratched, and hard if not scratched. As porosity varies with hardness, porosity should also be considered in comparing hardness.

The above data were plotted as an aid in determining the possible uses of the sample of clay.

All sample numbers prefixed "R" are samples taken and tested or reported by Ries in the survey of 1900.[2]

The shrinkage reported by Ries is the total shrinkage or the shrinkage based on the length of the plastic clay instead of the dry clay as 100 per cent. The total shrinkage expressed as per cent of plastic length may be converted to dry and fire shrinkage as follows:

$$\text{D.s.d} = \text{D.s.p} \times \frac{100}{100 - \text{D.s.p}}$$

$$\text{F.s.p} = \text{T.s.p} - \text{D.s.p}$$

$$\text{F.s.d} = \text{F.s.p} \times \frac{100}{100 - \text{D.s.p}}$$

where

D.s.d. = Drying shrinkage expressed as per cent of dry length.
D.s.p. = Drying shrinkage expressed as per cent of plastic length.
F.s.d. = Fire shrinkage expressed as per cent of dry length.
F.s.p. = Fire shrinkage expressed as per cent of plastic length.
T.s.p. = Total shrinkage expressed as per cent of plastic length.

[1]See Chapter IV, Physical Properties.

[2]Mich. Geol. Survey VIII, Part I (1900).

Significance of Tests. It should be borne in mind that the following tests are simply preliminary tests to indicate the general possibilities, and that any particular deposit must be carefully sampled and tested before any plans are made to develop the deposit commercially. This report is intended simply to indicate the most promising localities where clay or shale of economic value may be found in Michigan, and not to prove up any deposit for any purpose. Lack of good raw material is the most general cause of failure of Michigan brick and tile plants. This can be prevented only by careful sampling and testing of the deposit by a competent engineer.

The results of the following tests indicate that the shales of the Southern Peninsula are generally much better ceramic material than the surface clays. The cement companies are aware of this fact, but thus far the shale resources of the State are not generally recognized by the brick and tile manufacturers. The idea seems prevalent that Michigan has no shale and that the surface clays are the only possible raw material for brick. This is far from true.

Michigan's shale (Fig. 68) resources are adequate to supply the State with face brick, tile, sewer pipe, and similar products for an indefinite period. There are also many surface clay deposits of much smaller extent that may be used for all forms of building brick and tile. A steady demand for the better grades of building material exists practically throughout the State. Yet most of our face brick and building tile is shipped in from Ohio and even as far south as St. Louis, Mo. The clay face brick plants in Michigan operated continuously through the coal shortage of 1922, one plant paying as high as ten dollars a ton at the mines for coal. A properly designed and operated plant making high grade products from a good deposit of suitable shale or clay near any of the larger markets should prove a profitable undertaking.

On the Northern Peninsula there are extensive deep deposits of lake clay that may be used for all forms of building brick and tile. The older shales of this peninsula are generally unsatisfactory and must not be confused with the shales of the Southern Peninsula.

THE SOUTHERN PENINSULA

GENERAL DESCRIPTION

In the Southern Peninsula the glacial deposits are generally much thicker than in the Northern Peninsula, the average thickness of the drift being about 300 feet. In places near the border of Lake Michigan the drift is known to exceed 600 feet, and near Cadillac it is over 1200 feet. The drift of this peninsula, like that of the northern, is the product of at least two separate invasions. The amount of weathering and cementation of the older drift that occurred before the deposition of the younger is much greater than the surface weathering and alteration in the uppermost or youngest drift. The great difference in the hardness of the older and of the younger drift leads well drillers to apply the term "hardpan" to the older and harder deposits, and is evidence of the much greater interval of time elapsed between glaciations, than since the last.

The main body of drift in Michigan seems to have been deposited in the Illinoian and Wisconsin stages of glaciation. Most of the surface deposits were laid down

by the Wisconsin glaciation, but frequently an older (Illinoian) till is found in cuts or cliffs, as near Avoca, St. Clair County; Fremont, Sanilac County; near Ypsilanti, Washtenaw County, and on the coast of Lake Huron on the east side of the "Thumb" and generally described as Pre-Wisconsin till.

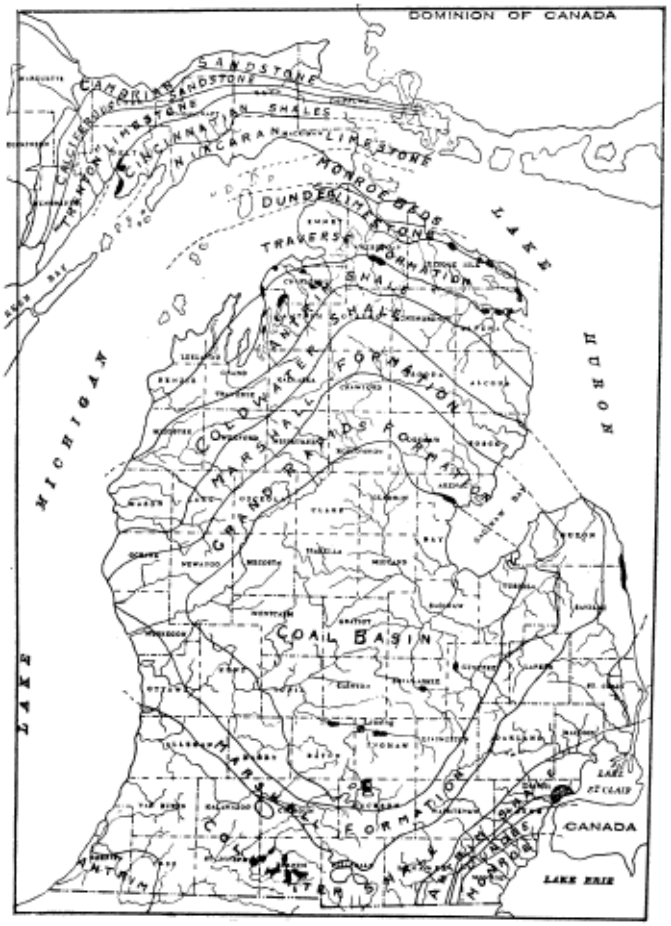

Figure 68. Sketch map showing the distribution of hard rock formations and the areas (solid black) in which exposures of shale occur.)

The lake deposits in the Southern Peninsula are confined almost entirely to a strip 40 miles wide running up from the Ohio line north along the east side of the Peninsula to the "Thumb" and around Saginaw Bay into central Alcona County.

On the west side of the peninsula the glacial Lake Chicago covered a very narrow strip of the present shore about one to two miles or less except from Holland north across Ottawa and Muskegon counties, where it extended 10 to 25 miles beyond the limit of Lake Michigan and included the Delta of the old Grand River. In this area the old lake bed is almost entirely fine sand.

As it is to be expected from the history of the northern counties, the lake clays deposited in this district by the glacial Lake Algonquin are very similar to the lake clays in Mackinac, Luce and Chippewa Counties, which were deposited by the same lake.

The rock formations in the southern Peninsula all lie in a nearly horizontal plain with a gentle dip toward the center of the peninsula. The formations range in age from the upper part of the Silurian, through the Devonian to the Carboniferous, arranged like the piling up of plates in a series of diminishing size, and diminishing amount of dishing, from bottom to top. The uppermost and youngest formation, although resting on those that precede it in age, does not stand above some of their outlying parts. These formations are sedimentary marine deposits that have been pressed to their present compact condition by the weight of the overlying rock, and are practically free from any metamorphism. Although the Pleistocene surface clays of the Southern Peninsula are probably less satisfactory than those of the Northern Peninsula, the many shales in the Devonian and Carboniderous Systems supply a wealth of material suitable for all kinds of heavy clay products.

The Bell shale, a soft blue shale usually about 50 to 80 feet thick, is the oldest number of the Traverse Formation, and outcrops in different places in Cheboygan and Presque Isle counties just above the Dundee limestone. The Bell shale is fine grained, plastic and seems to be suitable for brick and tile or possibly some pottery uses where a red burning clay is not objectionable.

The Antrim-Bedford shales of the Upper Devonian series are black at the bottom and generally blue at the top. They frequently contain concretions of siderite (iron carbonate) and pyrite (iron sulphide). When exposed to the weather the Antrim shale usually becomes very rusty due to its high iron content. The Antrim-Bedford shales vary from 150 to 575 feet in thickness and outcrop in many places through the northern counties where they form part of the bed rock, particularly in Antrim and Charlevoix Counties. The lower shale is bituminous and therefore must be carefully oxidized in burning. Both shales will burn to a hard red product suitable for all kinds of brick and tile. They may also be used as a raw material for Portland cement.

The Coldwater shales of the Lower Mississippian series are blue and gray shales with large concretions of siderite and lenses of sandstone known locally as "kidney rock" particularly near the top. In the western part of the State streaks of limestone and calcareous shale are common. The shale is 700 to 1000 feet thick and underlain in many places by the black Sunbury shale. The Coldwater shales are used as a raw material for Portland cement, but are not now used in making brick and tile although very suitable for that purpose.

The Coal Measure Shales are variable containing many different beds, but practically all of the beds are suitable for brick, tile and similar products where found in sufficient quantities.

The white shale ("fire-clay") of the Saginaw formation occurring with or without the coal seams in the Coal Measures is a semi-refractory clay, and suitable material for making all kinds of vitrified ware such as sewer pipe and paving brick.

The surface boulder or morainic clays in the central and north central parts of the Southern Peninsula do not as a rule contain excessive amounts of lime pebbles although they may be very stoney. The clays in the southern part of the state are very likely to contain large amounts of lime pebbles and are then practically useless.

In some areas that have been washed by the glacial lakes, lake clay of varying thickness may have been deposited. Some of these lake deposits contain very good brick or tile clay, particularly in the upper part of the deposit where the lime has been leached out and the clay is red burning; but these deposits generally run to lime concretions at depths of 3 to 12 feet and cannot be generally recommended. These deposits are also very variable as is evidenced by lake clays in Monroe, Wayne and Macomb Counties. The clays northwest of Lake Saint Clair are thoroughly leached and are very suitable for red brick to a depth of three feet, where lime concretions are found. In the Detroit district the lime concretions are not generally found above a depth of nine to twelve feet. Northwest of Lake Erie the clays may be good locally to a depth of three feet or they may contain lime pebbles from the very top.

River silts may be found in various parts of the state and in many places are suitable for common brick or tile.

At Harrietta, Wexford County, and near Harbor Springs, Emmet County, are deposits of a fine grained calcareous clay that, when properly prepared, seem as serviceable as Florida Fuller's Earth for clarifying oils.

Other special uses of Michigan clays may be developed by special study, but the surface clays of the Southern Peninsula are not generally to be recommended for ceramic materials. The shales found on the Southern Peninsula are generally far superior to the surface clays.

Description and Tests by Counties

ALCONA COUNTY

The bed rock of the county is largely shale. Upper Devonian Antrim shale underlies the northeast corner of the county. The Coldwater (Lower Mississippian) shales run diagonally NW-SE in a belt about 20 miles wide, across the county.

In drilling for water on the eastern shore of Hubbard Lake it is reported that 164 feet of blue (Antrim) shale were penetrated without any show of water.

The surface soil is largely landlaid moraine and sandy drift, with some bowlder clay areas. A lake deposit of clay from 6 to 60 feet thick extends from about 5 miles north of Harrisville south to the county line and about 3 to 8 miles in shore. The same clay is probably found in or under the AuSable delta to the southwest. The upper part of the deposit is red and the lower part blue clay. The latter is very heavy, ropey clay and is found at a depth of 20 feet at Mikado. About one or two miles north of Mikado the clay is thickest, about 60 feet.

A number of years ago the upper red clay at Mikado was used for the manufacture of common brick. Considerable trouble was caused by lime pebbles, which are found in small local areas scattered through the deposit, and the workings were abandoned.

About three miles southeast of Harrisville in sections 21 and 22, (T. 26 N., R. 9 E.) good red brick was made by the soft mud process about 1887.

Clay from Section 24, T. 25 N., R. 8 E., three miles south of Mikado, along the east bank of the creek has been used in Oscoda for setting brick in furnaces. But no clay possessing the necessary refractory properties to warrant its use for such purposes in modern practice could be found.

A sample of clay (166) from section 11, T. 25 N., R. 8 E., one mile south of Mikado and of the same general type as occurs through this deposit seems to be fair material for brick or tile.

Burning Test

Sample No. 166. Field Sheet No. 186.
Section 11, T. 25 N., R. 8 E.
Plasticity .315 gm. water per gm. clay.
Average linear drying shrinkage 11.7 per cent.
Average tensile strength about 116 lbs. per sq. in.
Apparent Sp. Gr. dry 2.67.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	950	.392	3.7 %	2.74	Soft burned..	Salmon
08	990	.402	3.0	2.70	Soft burned...	Cream
06	1,030	.404	2.0	2.70	Soft burned...	Cream
04	1,070	.422	3.2	2.83	Soft burned...	Cream
02	1,110	.405	4.8	2.84	Soft burned...	Cream
1	1,150	.266	9.9	2.74	Hard burned...	Light olive
3	1,190	.190	13.5	2.84	Hard burned...	Light olive
5	1,230	.022	15.7	2.48	Vitrified	Olive
7	1,270	.032	15.3	2.46	Vitrified.....	Olive
9	1,310	....	....	....	Viscous.	

Reddish brown clay. Easily molded.
Burned by H. W. Jackman.

ALLEGAN COUNTY

The Tyler Brothers made brick and tile at Saugatuck, Section 9, T. 3 N., R. 16 W., from a lake clay. They ceased operations in 1910 and the auger machine was later moved to Hamilton and is used by the Zeeland Brick Company.

This company has a plant about one mile south of Hamilton on the Allegan Road and the Pere Marquette Railroad in NW¼ section 8, T. 3 N., R. 14 W. The company owns a quarter section including about 50-60 acres of red lake clay. The plant is equipped with a steam shovel, skip cars, an auger machine with twin die for brick, dies for drain and building tile, and a steam heated intermittent drier.

Some brick is burned in oil fired scove kilns, but most of the product is burned in round downdraft kilns, 30 feet in diameter. The plant is equipped with six of these kilns and has a daily capacity of about 40,000 brick. Anthracite coal is added to the clay in the pug mill to aid in burning the brick to a good hard burned, dense product.

The clay is a red lake clay about 10 feet thick, covered by sand, which is used in tempering. The following test indicates that the sample is good material for brick or tile:

Burning Test

Sample No. 25. Field Sheet No. 24.
Section 8 NW¼, T. 3 N., R. 14 W.
Plasticity .327 gm. water per gm. clay.
Average linear drying shrinkage 11.4 per cent.
Average tensile strength about 137 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Hardness.	Color.
08	990	.382	0.7 %	Soft burned..	Salmon
06	1,030	.370	1.1	Soft burned....	Salmon
04	1,070	.349	1.9	Soft burned...	Salmon
02	1,110	.190	9.5	Hard burned...	Light red
1	1,150	.019	11.8	Vitrified.....	Dark brown
3	1,190	.025	8.3	Vitrified.....	Dark gray brown
5	1,230	....	....	Melted	

Molded easily. Suitable for brick and tile.

The Allegan Brick Company is operated by the Cadys, father and son, without other labor. The plant is just west of the road at the southwest corner of Allegan, about the center of Section 32, T. 2 N., R. 13 W. The clay (sample 24) is a river deposit about 5 to 6 feet deep. There is about one acre of this red clay left and another deposit of 10 acres near by. The clay is wheeled in from the pit, a distance of over 400 feet, on wheelbarrows, and molded in a six brick soft mud machine with vertical pugmill. The pugmill and molding machine is direct driven by a horse walking around above the machine on the charging platform. The brick is dried in open dicing racks and burned in wood fired scove kilns. A fairly good quality red brick is produced and sold locally. This plant is probably the most primitive of any plant in Michigan, at least so far as its power is concerned. The following burning test indicates that the sample of clay from this deposit could be used to make a higher grade product than soft mud common brick. It has a burning range of 10 cones, with uniform shrinkage, and could be used for hard burned front brick or tile, or possibly some vitrified products.

Burning Test

Sample No. 24. Field Sheet No. 23.
Section 32, T. 2 N., R. 13 W.
Plasticity .264 gm. water per gm. clay.
Average linear drying shrinkage 4.9 per cent.
Average tensile strength about 70 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Hardness.	Color.
06	1,030	.331	0.9 %	Soft burned.....	Salmon
04	1,070	.298	2.3	Soft burned.....	Light red
02	1,110	.202	6.0	Hard burned....	Deep red
1	1,150	.088	9.6	Hard burned....	Chocolate brown
3	1,190	.040	9.7	Hard burned....	Chocolate
5	1,230	.045	7.0	Vitrified.....	Chocolate
7	1,270	.028	6.0	Vitrified.....	Chocolate
9	1,310	.038	2.3	Vitrified.....	Dark chocolate

Molded easily and seems suitable for face brick and tile.
Burned by H. W. Jackman.

Northwest of Otsego on the southwest side of the Lake Shore and Michigan Southern Railroad, in Sections 9 and 10, T. 1 N., R. 12 W., there is a deposit of boulder clay on the property of the Cushman Brothers. Before the Civil War this clay was shipped and also used by the railroad, presumably for patching the fire boxes in the old wood burners. The old pit from which the clay was formerly obtained is now a small pond near the northern end of the deposit. At the request of the present owners this deposit was visited and tested. The following is taken from the report of this investigation:*

"The deposit was visited and drilled to determine the thickness and extent of the clay bed, and to obtain representative samples for testing. These samples were burned to determine the burning properties, and analyzed to determine the value of the clay as a raw material for Portland cement.

Sample No. 201 is from the upper ten feet of the deposit (reddish blue clay).

Sample No. 202 is from the lower twenty feet of the deposit (blue clay).

Drilling indicates that the deposit extends for at least 300 yards in a north and south direction and about 100 yards east and west and is approximately 28 feet thick.

Burning Test

Sample No. 201. Field Sheet No. 209.
Sample No. 201. Field Sheet No. 209.
Sections 9-10, T. 1 N., R. 12 W.
Plasticity .263 gm. water per gm. clay.
Average linear drying shrinkage 7.2 per cent.
Average tensile strength about 95 lbs. per sq. in.

Cone No.	Thermocouple Temp. °C.	Porosity.	Linear Shrinkage.	Hardness.	Color.
010	916	.404	0.0 %	Softer than steel...	Salmon
08	950	.448	1.2	Softer than steel...	Salmon
06	1,000	.468	2.2	Softer than steel...	Salmon
04	1,040	.445	3.5	Harder than steel..	Salmon
02	1,120	.309	5.5	Harder than steel..	Salmon
1	1,175	.181	10.8	Harder than steel..	Brown
3	1,220	.016	15.8	Vitrified.....	Dark brown
5	.....	....	....	Viscous (melting)	

Suitable for brick and tile.
Burned by Mark Huck.

Burning Test.

Sample No. 202. Field Sheet No. 209.
Section 9-10, T. 1 N., R. 12 W., Allegan County.
Plasticity .294 gm. water per gm. clay.
Average linear drying shrinkage 8.2 per cent.
Average tensile strength about 75 lbs. per sq. in.

Cone No.	Thermocouple Temp. °C.	Porosity.	Linear Shrinkage.	Hardness.	Color.
010	916	.400	0.6 %	Soft burned.....	Salmon
08	950	....	0.8	Soft burned.....	Salmon
06	1,000	.462	1.6	Soft burned.....	Salmon
04	1,050	.375	4.0	Soft burned.....	Salmon
02	1,120	.299	5.0	Hard burned....	Light brown
1	1,175	.043	8.8	Vitrified.....	Dark gray brown
3	1,220	.015	11.4	Vitrified.....	Chocolate brown
5	.....	....	....	Viscous	

Suitable for brick and tile.
Burned by Mark Huck.

Chemical Analysis

Sample No. 201. Field Sheet No. 209.
Sections 9-10, T. 1 N., R. 12 W., Allegan County.

			Av.
Loss on Ignition	14.08	14.10	14.09
Silica SiO_2	50.72	50.55	50.64
Alumina Al_2O_3	16.03	15.90	15.96
Titania TiO_2	0.32	0.32	0.32
Lime CaO	8.56	8.49	8.53
Magnesia MgO	4.95	4.99	4.97
Iron Fe_2O_3	2.60	2.53	2.56
Alkalies $Na_2O + K_2O$	4.12	4.02	4.06
			101.13

$$\frac{SiO_2}{R_2O_3} = \frac{50.64}{18.52} = 2.7$$

There are probably about 500,000 to 750,000 cubic yards of clay in the deposit which can be used for the manufacture of brick and tile."

[1]Report No. 202 of Clay Deposit of C. G. Cushman. Dept. of Eng. Research, University of Michigan.

ALPENA COUNTY

In the northern half of Alpena County the Traverse limestones and shales outcrop in many places near the shore of Lake Huron. The Antrim shale underlies the southern and southwestern portions of the county. It is exposed at several places from Partdridge Point west-northwest to and beyond Paxton.

The Antrim shale is quarried in sec. 30, T. 31 N., R. 7 E. on the D. & M. Railroad near Paxton about one-half mile east of Apple Orchard by the Huron Portland Cement Company. The shale is black in the upper strata except where discolored or rusted by weathering, and runs to bluish black shale in the lower strata. The shale contains dark purple and yellow concretions of pyrite and large concretions of lime-iron carbonate. The quarrying is done by drilling the bench, blasting, and loading the railroad cars by a steam shovel in the same manner as employed at Ellsworth. The shale is shipped to the plant in the eastern part of Alpena on the D. & M. Railroad. The following analyses of the different levels in the quarry were furnished by Mr. W. M. Smith, chief chemist of the Huron Portland Cement Company.

	Blue Black Low Level.	Rusty Upper.	Upper 5 Ft.
	%	%	%
Volatile	17.40	11.86	11.76
Silica (SiO_2)	54.52	62.32	60.22
Alumina (Al_2O_3)	13.46	16.48	14.44
Iron (Fe_2O_3)	5.12	4.44	7.60
Lime (CaO)	2.22	2.34	1.52
Magnesia (MgO)	2.15	2.33	2.20
Sulphur (S as SO_3)	2.50	2.04	2.21
K_2O	....	....	1.30
Na_2O	....	....	1.05
TiO_2	....	....	0.95

Burning Test

Sample No. 134. Field Sheet No. 144.
Section 30, (center), T. 31 N., R. 7 E.
Mixed sample of Antrim shale from quarry of the Huron Portland Cement Co.
Plasticity .282 gm. water per gm. clay.
Average linear drying shrinkage 5.7 per cent.
Heated for 5 hours to burn out carbon.

Cone No.	Cone Temp. °C.	Porosity.	Linear Drying Shrinkage.	Hardness.	Color.
08	990	.389	2.6 %	Soft burned	Light red
06	1,030	.359	4.0	Soft burned	Light red
04	1,070	.288	6.8	Hard burned	Red brown
02	1,110	.101	12.2	Hard burned	Chocolate
1	1,150	.118	12.7	Vitrified	Chocolate
3	1,190	.040	7.6	Vitrified	Dark chocolate
5	1,230	.056	−1.9	Vitrified	Dark chocolate
7	1,270	.146	−6.2	Vitrified	Dark chocolate

Last four samples cracked somewhat in cooling.
Burned by H. W. Jackman.

The shale is good material for brick and tile and will make a good dark brown or chocolate face brick. It should be ground in a wet pan or treated to develop its plasticity, and burned carefully. It is also good material for Portland cement and is preferred by the Huron Cement Company to the clay or shale of the Bell or lowest member of the Traverse Formation which was formerly used.

The latter is somewhat pebbly blue clay obtained from section 18, T. 32 N., R. 9 E., east of Middle Lake, near the shore of Lake Huron, and shipped to their plant at Alpena. This clay has been analyzed as follows:

	I	II	III
	%	%	%
Volatile	7.69	5.13	....
SiO_2	56.17	61.09	57.96
Al_2O_3	17.23	19.19	20.44
Fe_2O_3	5.18	6.78	3.03
$CaCO_3$	6.03	....	9.12
CaO	....	2.51	.28
$MgCO_3$	2.62	....	5.02
MgO	....	.65	....
K_2O	....	1.8	3.40
Na_2O	....	1.36	
SO_3	.27	1.42	.72

I. W. M. Smith, Huron Portland Cement Company.
II. Ries, Michigan Geological Survey VIII, Pt. I, p. 48, analysis 17.
III. S. H. Ludlow, Alpena Portland Cement Co., I. C. Russell, Portland Cement Industry in Michigan, U. S. Geological Survey, 1902, page 665.

I. C. Russell* also includes as analyses of this clay, two analyses of the Antrim shale near E. Jordan and Chestonia given by Ries.** This is obviously an error.

*loc. cit.

**loc. cit., p. 46, Nos. 14, 15.

At Rockport about 2½ miles north of this old clay pit is the quarry of the Great Lakes Stone & Lime Company. The limestone is about 40 feet thick and belongs to the Long Lake series. The Bell shale directly underlies the limestone, and in this region appears to be about 50 feet thick. The shale is blue, very soft, and weathers to clay readily. It contains two or more thin limestone beds, one of which is about 6 or 8 feet below the top. This shale, reported by W. M. Smith, analyzed as follows:

	%
Silica (SiO_2)	38.48
Alumina (Al_2O_3)	14.04
Iron (Fe_2O_3)	5.0
Lime (CaO)	16.26
Magnesia (MgO)	2.6

With the exception of the high lime content this analysis is generally similar to the analyses of the clay in the cement company's old pit. This clay-shale at Rockport is similar to the clay found in the limestone at Petoskey, Emmet County, Charlevoix, Charlevoix County, and south of Bell, Presque Isle County. The shale or clay at the surface two and one-half miles south of Rockport is apparently an exposure of the lower Bell shale.

Some of the shales of the Upper Traverse or Thunder Bay series are markedly different from the Bell shale, but most of them are calcareous and are known to drillers as "soap rock." The Upper Traverse Shales are exposed in several places. Ries reported a deposit of a weathered shale at the end of Third Street in Alpena. A ten foot bed of shale is exposed along a prominent rock terrace on the south side of Thunder Bay River on the line between sections 17 and 18, T. 31 N., R. 8 E., and an 8 foot bed of blue fossile calcareous shale on the north side of the river in section 8. Thinner beds of shale are exposed in the southwest part of Alpena, at Fletcher dam, and near Orchard Hill. On the Potter farm in section 20, T. 31 N., R. 8 E. the rock section includes a 19 foot bed of blue fossiliferous shale. At the Upper or Four Mile dam there are 12 feet of shale-clay underlain by three feet of hard calcareous blue shale.

Ries reported that the smooth, unctuous clay at the end of Third Street, Alpena, effervesced freely with acid and was "too calcareous for many uses." It was noted that the clay appeared to come from under a, limestone and to have been a calcareous shale which had slacked in weathering. The main stratum is of thick, heavy, gummy blue clay (sample 133) and was formerly used to make brick. The plant was completely destroyed some years ago, apparently by fire. The product was a cream brick with slight red tint.

Burning Test

Sample No. 133. Field sheet No. 143.
Section 33 (NW), T. 31 N., R. 8 E.
Plasticity .211 gm. water per gm. clay.
Average linear drying shrinkage 4.9 per cent.
Average tensile strength about 60 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.425	0.8 %	1.58	Soft burned...	Cream pink
08	990	.419	0.8	1.58	Soft burned...	Cream pink
06	1,030	.419	0.6	1.55	Soft burned...	Cream
04	1,070	.431	0.2	1.52	Soft burned...	Cream
02	1,110	.435	−0.4	1.49	Soft burned...	Cream
1	1,150	.454	−0.2	1.49	Soft burned...	Cream
3	1,190	.456	0.2	1.50	Soft burned...	Very light olive
5	1,230	.094	12.0	2.20	Vitrified.....	Olive
7	1,270	....	....	....	Viscous	

Light blue shale and clay—chiefly shale. Easy to mold. Contains lime pebbles.
Burned by H. W. Jackman.

This material could be used for making porous brick or tile of a cream color only.

The Huron Portland Cement Company, organized August 9, 1899, was the first company in Michigan to use limestone and to operate on the dry process. The original wet process plant of six rotary kilns about six feet in diameter and 60 feet long, built in 1900-1901, was destroyed by fire. The second plant (dry process) equipped with eight kilns 8 feet in diameter and 110 feet long, was burned in the summer of 1923 but was completely rebuilt with modern equipment and machinery.

ANTRIM COUNTY

Antrim County is wholly underlain by shale formations—the Antrim, Bedford and Coldwater shales. The Antrim and Bedford shales are exposed in several places in the northwestern third of the county but the Coldwater is deeply buried by the glacial deposits. The Antrim shale is Upper Devonian in age, and is generally black, but the Bedford shale is blue, gray, or blue-gray and black, as at Ellsworth, near Chestonia, Eastport, and Central Lake. The same shale formations extend north into Charlevoix and eastward through the southern part of Cheboygan County and in the southwestern third of Alpena County.

The principal exposures are on the lake shore about a half mile south of Norwood, in the vicinity of Ellsworth, and Chestonia, East Port, and Central Lake. The exposures south of Norwood form bold cliffs along the lake. The shale is very black and pyritic. At some horizons the shale is so full of pyrite in crystals, masses, and stringers as to make it of doubtful value for any use. In the Ellsworth vicinity the shale deposits are very large and numerous. Shale forms the core of most of the hills and is exposed in many of the bluffs and hills around the north end of Intermediate Lake.

Shale also forms the core of many of the hills west of Chestonia and weathered shale is at or near the surface in the vicinity of Rocky three miles east. There are numerous exposures of shale, locally weathered clay, in the bluffs, ravines, and road cuts.

About one mile southwest of Eastport in sec. 12, T. 31 N., R. 9 W. there is a bluff or light colored shale reported to be 10 to 12 feet high along the lake shore.

The Antrim and Bedford shales are generally suitable for brick and tile, locally for face brick, and for the manufacture of Portland cement. In some places the shale has a wider range of vitrification and may be used for vitrified products. The shale near Eastport, however, contains considerale lime in some beds.

The Antrim-Bedford shale near Chestonia was investigated and the following facts reported by Ries:*

A shaft had been sunk to a depth of 105 feet in the shale on the property of J. H. Kocher about six miles south of East Jordan on the W½ of the NE¼ of Section 3, T. 31 N., R. 6 W. The shale is gray-black in color and near the bottom of the shaft contained small selenite crystals but

no pyrite was noticed. In testing the sample (R185) from shale it was found to have about 0.8% of soluble salts that formed a white coating on the surface during drying, which had to be carried on carefully as the sample had a tendency to crack. Burning had to be done carefully to oxidize the bituminous material. Tensile strength about 70-80 lbs. a sq. inch.

*Vol. VIII. Pt. I, Mich. Geol. Survey (1900).

Cone.	Shrinkage.	Hardness.	Color.
05	7 %	Soft burned	Red
01	...	Hard burned	
3	...	Vitrified	
6	...	Viscous	

This same locality was visited in 1921. Most of the hills near Chestonia are shale rather densely covered by vegetation. Sample 188 was obtained by stripping the shale in the hills in eastern part of section 17, T. 31 N., R. 6. W. about 1½ miles west of Chestonia. Care was taken to remove all the weathered shale. This sample of the dark shale without the characteristic rusty color which develops when the shale is exposed to the weather was tested as follows:

Sample No. 188, Sec. 17, T. 31 N., R. 6 W.
Chestonia, Antrim County.

Gray black shale containing organic matter which weathers to a light gray clay on exposure.

Chemical analysis:

Loss on ignition	8.23%
Silica (SiO_2)	60.61
Alumina (Al_2O_3)	20.84
Iron (Fe_2O_3 all the iron)	6.41
Lime (CaO)	.53
Magnesia (MgO)	2.14
Alkalies ($K_2O + Na_2O$)	1.24 (Approx)

Analysis by H. W. Jackman.

Burning Test

Water Plasticity. 0.25 gm. water per gm. clay.
Linear shrinkage. 4.7 per cent on drying.

If dried with reasonable care and slowly does not crack or warp.

Tensile strength of air dried brick between 80 and 100 lbs. a square inch.

In burning the clay must be heated very slowly until all the organic matter is thoroughly oxidized. About 5 hours were required to oxidize the testing briquettes, which were about one square inch in cross section.

Cone Temp. °C.	Cone No.	Linear Shrinkage.	Porosity.	Color.	Hardness.
880	014	2.1%	.30	Salmon buff	Soft burned
950	010	1.9	.31	Salmon	Soft burned
1,000	08	6.1	.171	Red (Wht. discoloration on surface).	Incipient vitrification (hard burned).
1,030	06	7.4	.121	Red (Wht. discoloration on surface).	Hard burned.
1,070	04	8.8	.0395	Dark red (discoloration gone).	Hard and dense
1,110	02	11.9	.0276	Dark red	Vitrified.
1,150	1	8.1	.0206	Chocolate red	Very hard.
1,190	3	....	.....	Chocolate brown	Some signs of over-burning.
1,230	5	....	.....	Chocolate	Viscous and bloated.

The sample seems very suitable for brick and tile, or for face brick and possibly for vitrified ware. Best product results when burned at about 1100° or cones 04 to 1. Burned by H. W. Jackman.

The chemical analysis shows the shale to be suitable for Portland cement, and the burning test shows it to be good material for all kinds of building brick, tile, and face brick. Some samples of the shale have been tested by the Bureau of Standards with very similar results.[1]

The American Clay Machinery Company, Bucyrus, Ohio, made a number of brick and tile from samples of this shale. When ground, screened, and pugged in a wet pan the mix extruded perfectly.

The white discoloration reported by Ries is not serious as it disappears at cone 04.

Ries[2] also reported shale outcropping along the road in section 13 between the old camp of the East Jordan Lumber Company and the town. Here the shale had weathered to a depth of 10 to 15 feet in many places. A sample (R177) of the weathered material, a tough reddish clay reported to be similar to the material used in the East Jordan brick yard, was very fine grained, slaked freely in water, and gave no effervescence with acid. It contained 0.8% of soluble salts which appeared on the surface in drying and burning. Air shrinkage 1%, hard burned at cone 05, vitrified at cone 01, with 13% shrinkage, and viscous at cone 2. It made a very smooth, deep red brick. Analysis (No. 14) of this sample:

Silica	55.95%
Alumina	17.43
Ferric Oxide (total iron)	7.67
Lime ($CaCO_3$)	2.14
Magnesium carbonate	1.55
Alkalies (K_2O)	2.86
Difference	12.40
	100.00
Ferrous iron (FeO)	.50

Analysis by A. N. Clark.

[1]Sample No. 1 Chestonia Shale.

This material appeared to be grayish brown in color and had the characteristics of a weathered shale. It seems to contain some organic matter. When worked up with water it showed excellent plasticity and good working properties. The amount of water of plasticity required was 24.61% and the linear drying shrinkage was 3.78%. It dried easily without checking and cracking. It showed some slight discoloration of a whitish color in burning which disappeared upon firing the clay to a higher temperature. In burning the clay to 1000°C. it showed a porosity of 22.4% and a salmon color. At the same time it was quite soft in structure. At 1030°C. the porosity was 14.95%, the color red and the structure hard and vitrified. At 1060°C. the porosity was reduced to 6.9% and the color became a chocolate red with a dense structure. At 1090 °C. the porosity was as low as .68% with a total burning shrinkage of 7.08%. The color at this point was of a very dark red and the structure exceedingly dense. At 1150°C. the material showed overburning and the color became dark brown. It would seem from these results that the clay is a very promising one for the manufacture of various kinds of brick and hollow tiles and it may even be considered in connection with the manufacture of paving brick."

"Sample No. 2, East Jordan shale.

This specimen consisted of lumps of shale in the partially weathered condition. It seems to contain some carbonate of lime. It

assumed fair plasticity upon grinding and tempering. It required 23% of water and showed a linear drying shrinkage of 3.2%. The drying took place without checking or cracking but showed slight warping. When burned to 1000°C. its porosity was 18.4% and its hardness such that it could hardly be scratched by steel. At 1030°C. the porosity was 12.5%, its color red and hardness considerable. At 1060° the porosity was 7.3%, the color chocolate and the structure dense and vitreous. At 1090°C. the porosity decreased to 3.56% and the burning shrinkage became 8.48%. The color was dark chocolate. At 1150°C. the clay was overburned and showed decided bloating. This clay is not quite as good as sample No. 1 although its burning behavior is very much like it. It is very likely that a mixture of the two would produce a satisfactory product. It is not so well suited for the manufacture of paving brick as would be sample No. 1.

Yours very truly,
(Signed) A. V. Bleininger,
For the Director."

2Mich. Geol. Survey VIII, Pt. I, 1900.

This analysis indicates that this part of the Antrim shale is also suitable as a raw material for the manufacture of Portland Cement. The burning tests show the shale to be suitable for all kinds of building brick and tile if carefully burned.

Ries* also reports an outcrop of the dark thinly bedded Antrim shale in extensive cliffs traversed by many joint cracks and extending south from Norwood along the lake shore. Sample R176 was taken from these bluffs about one-half mile south of Norwood and tested as follows:

Water of plasticity 24%
Air shrinkage 6%
Tensile strength of air dried bricks about 140 lbs. per sq. in.
Soluble salts 0.6%

Required careful drying and burning.

Cone.	Shrinkage.	Hardness.
02	12 %	Hard burned—Incipient Fusion.
1	14 %	Vitrified.
3	....	Viscous.

Shale on lake shore about 8 miles south of Norwood and one mile south of Eastport, Sec. 12 T. 32 N., R. 9 W., was formerly shipped to Elk Rapids and used by the Elk Portland Cement Company for a short time after completion of the plant in 1901. It was planned to use some of the clay found west of Torch Lake as well as this shale, with marl from the south end of Elk Lake. The company, organized March 3, 1900, built a plant in the village of Elk Rapids on Grand Traverse Bay, Section 20, T. 30 N., R. 9 W., where it was available to both lake shipping and the Pere Marquette Railroad.

The plant was driven by a 500 H.P. steam engine through rope drives. The marl was mixed with the clay slip in pug mills. The slurry ground in four tube mills was calcined in five kilns, 6 x 60 feet, fired with powdered coal. Four Griffin mills were used to grind the clinker.

Local clay first used was abandoned for Antrim shale from east ½ section 3, T. 33 N., R. 7 W., on Pine Lake, Charlevoix County, and from the more convenient deposit south of Norwood.

Farther south along the lake shore the blue Bedford shale in the Ellsworth horizon is exposed as weathered shale or clay in the bottom of some creeks.

*loc. cit.

The Bedford shale outcrops along Intermediate Lake for about one and one-quarter miles south of Ellsworth. Here the main body of shale is blue of undetermined depth at least 50 feet, and very hard. The section of the deposit is as follows:

6 inches to 3 or 4 feet yellow clay
20 feet yellow shale (sample 91)
2 to 3 inches sandstone
Over 50 feet hard blue shale (sample 92)

The shale is quarried just west of the P. M. Railroad in the eastern part of section 23, T. 32 N., R. 8 W. The bench is drilled and blasted a few yards behind the face to break up the hard shale which is then picked up by a steam shovel and loaded directly on railroad cars. At the time the quarry was visited in 1922 only the hard blue shale was being shipped. Usually 10 or 12 cars were loaded daily, more than half of which went to the Newaygo Portland Cement Company and the rest to the Petoskey Portland Cement Company.

Burning Test

Sample No. 91. Yellow Shale. Field sheet No. 97.
Sections 23 (E), 24 (W), 25 (NW), 26 (NE), T. 32 N., R. 8 W.
Plasticity .262 gm. water per gm. clay.
Average linear drying shrinkage 7.6 per cent.
Average tensil strength about 85 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.350	0.2 %	1.69	Soft burned.....	Salmon
08	990	.336	1.1	1.73	Soft burned.....	Light red
06	1,030	.323	1.1	1.75	Soft burned.....	Light red
04	1,070	.257	4.1	1.88	Hard burned.....	Red brown
02	1,110	.157	6.9	2.06	Hard burned.....	Red brown
1	1,150	.062	7.8	2.12	Vitrified.....	Dark brown
3	1,190	.044	5.9	2.00	Softening.....	Dark brown
5	1,230	....	...	....	Melted	

Light brown clay, easily molded. Contains small shaly lime lumps. Suitable for brick and tile.
Burned by H. W. Jackman.

Burning Test.

Sample No. 92. Blue shale. Field sheet No. 97.
Sections 23 (E), 24 (W), 25 (NW), 26 (NE), T. 32 N., R. 8 W.
Plasticity .208 gm. water per gm. clay.
Average linear drying shrinkage 5.6 per cent.
Average tensile strength about 65 lbs. per sq. in.
Heated for 5 hours to burn out carbon.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.362	0.2	1.72	Soft burned...	Light salmon
08	990	.355	0.4	1.73	Soft burned...	Light salmon
06	1,030	.358	0.4	1.72	Soft burned...	Tan
04	1,070	.379	0.8	1.72	Soft burned...	Tan
02	1,110	.327	2.5	1.81	Hard burned...	Light brown (speckled)
1	1,150	.134	6.5	2.06	Hard burned...	Dark brown (white spots)
3	1,190	.036	1.4	1.74	Vitrified.....	Very dark brown (white spots)
5	1,230	....	...	....	Viscous	

Blue shale. Easily molded. May be used for brick or tile. Burned by H. W. Jackman.

Analysis of shale from Ellsworth quarry by the Petoskey Portland Cement Company.

	Average Stock.	Hard Shale, similar to Sample No. 92.	Composite Sample.*
	%	%	%
Moisture (H_2O)	.....	.....	1.16
Carbon dioxide (CO_2)	.....	.....	9.78
Volatile matter	.....	.....	5.04
Ignition loss	11.40	16.76	.....
Silica (SiO_2)	49.57	46.48	46.86
Iron and Alumina ($Fe_2O_3 + Al_2O_3$)	23.48	15.36	15.81 (Al_2O_3) / 5.99 (Fe_2O_3)
Lime (CaO)	6.60	11.56	6.65
Magnesia (MgO)	5.87	8.22	3.76
Potash (K_2O)	.....	.....	3.89
Soda (Na_2O)	.....	.....	2.18

*Analysis by Prof. A. J. Patten, Chief Chemist, Exp. Sta., Mich. State College, East Lansing.

The main stratum of hard blue shale seems inferior to the upper yellowish shale as a raw material for cement, because the former contains a large amount of magnesia (8.22%). The yellow soft shale is good material for brick and tile, but for face brick it is inferior to the dark rusty shale found near Chestonia. The hard blue shale has a poorer color, a narrower burning range than the upper yellow shale, and develops white spots when hard burned.

There is considerable lake clay and weathered shale around Intermediate Lake and west of Torch Lake. This was used on an old brick yard on Wilson's farm 1½ miles south of Bellaire on Grass Lake in the east central part of section 31, T. 30 N., R. 7 W. Here the clay is blue containing some lime pebbles and is from 35 to 60 feet thick with no overburden for the first 80 rods back from the base of the mound. Here some sand covers the clay. This clay was probably considered by the Lake Shore and later by the Bellaire Cement Company as possible raw material for their proposed plant but it has not been worked since 1904, when some light colored salmon brick were made here.

Further north on the west side of Intermediate Lake just west of the road in the NW¼ of Section 2, T. 30 N., R. 8 W., on the property of William W. Johnston, clay very similar to that south of Bellaire, but containing fewer lime pebbles, was used to make hand molded brick about 1895. At that time the brick sold for $5.00 a thousand. The clay here is about 60 to 80 feet deep. It is very plastic and molds readily to a smooth even textured brick which burns as follows:

Burning Test.

Sample No. 90. Field Sheet No. 96.
NW¼ Section 2, T. 30 N., R. 8 W.
Plasticity .334 gm. water per gm. clay.
Average linear drying shrinkage 12.7 per cent.
Average tensile strength about 190 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.368	1.1%	1.60	Soft burned.....	Salmon
08	990	.377	0.9	1.60	Soft burned.....	Salmon
06	1,030	.373	0.9	1.62	Soft burned.....	Salmon
04	1,070	.331	2.6	1.70	Soft burned.....	Salmon
02	1,110	.174	7.2	1.97	Hard burned.....	Brown
1	1,150	.036	10.0	2.12	Vitrified.....	Chocolate
3	1,190	....	....	....	Viscous	

Brown clay. Molded easily. Suitable for brick or tile or some forms of pottery.
Burned by H. W. Jackman.

About one mile north of Johnston's property in section 35, T. 31 N., R. 8 W., James LaRue formerly made brick. The clay here is very similar to that on Johnston's place as is most all of the pleistocene clay in this district.

To the west along Grand Traverse Bay the clay burns to a darker color, making a deep red brick similar in color to that obtained from the Antrim shale.

ARENAC COUNTY.

One third mile northeast of Twining along the D. & M. Railroad, center of Section 19, T. 20 N., R. 6 E., the Cook Brick Company made bricks previous to 1912 from the red lake clay common in this district. The clay is generally similar to sample 137 and contains more or less lime pebbles.

Another deposit of very similar clay was worked from 1895 to 1912 by M. K. Perlberg one-half mile west and north of Standish in the SE¼ of Section 3, T. 18 N., R. 4 E. He operated a soft mud machine for bricks and also made drain tile, all of which was burned in scove kilns. At that time brick was sold profitably at $5.00 per thousand, and wood cost $1.00 a cord which was enough to burn 2500 to 3000 brick. The clay is a lake deposit as is most of the clay throughout the Saginaw Bay District, and contains lime pebbles particularly in the upper part. Only the upper 4 feet burn red. The lower member is the very fat, ropy, plastic pink clay that was laid down in one of the old lake beds in the Saginaw Basin. This clay is usually suitable for making brick and tile when the lime pebbles are absent or not too numerous.

On the south side of Rifle River about 3 miles northwest of Omer there is an outcrop of what appears to be a soft shale or clay of the Coal Measures. Sample 138 was taken from the river bank and represents the blue clay that may have been formed by weathering of the shale. At the point where the sample was taken in the south part of Section 5, T. 19 N., R. 5 E., the overburden is about 12-15 feet of sand and becomes thicker to the southwest and lighter to the northeast. The shale is not found near the surface on the northeast side of the river but is reported to have been found at greater depths. The shale contains lime pebbles and is generally a calcareous clay.

The Michigan Paving Brick Company's plant was located on the north side of the river across from the quarry where the sample was obtained. For about five years this company tried to make paving brick from this calcareous clay. Common brick and repressed brick

were also produced. The plant was equipped with eight down draft kilns. The venture consumed $160,000 and was abandoned in 1912.

The product was inconsistent as to size. Apparently no effort was made to keep the different strata of shales separate. As the different shales had different burning properties this practice added to the troubles caused by lime pebbles in a calcareous shale of narrow burning range. The following burning test of this clay explains a large part of the trouble experienced by the paving brick company. If the shale had a vitrification range of four to six cones beginning at about cone 5 or 7, it would probably make good paving brick, but a vitrification range of two cones or less does not allow enough range in which to produce vitrified ware, particularly when accompanied by sudden failure as in the case of the test sample. If a layer of this shale, practically free from lime, and having the required burning range, existed and had been used without mixing of the other clays, this plant might have had a different history.

Burning Test.

Sample No. 138. Field Sheet No. 148.
Section 5 (south), T. 19 N., R. 5 E.
Plasticity .236 gm. water per gm. clay.
Average linear drying shrinkage 7.6 per cent.
Average tensile strength about 125 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.402	0.2 %	1.55	Soft burned...	Salmon.
08	990	.410	0.4	1.55	Soft burned...	Cream salmon
06	1,030	.436	0.4	1.55	Soft burned...	Cream
04	1,070	.439	1.0	1.57	Soft burned ..	Cream
02	1,110	.445	1.0	1.56	Soft burned...	Cream
1	1,150	.408	2.5	1.65	Soft burned	Cream
3	1,190	.314	7.6	1.93	Hard burned...	Very light olive
5	1,230	.106	14.7	2.43	Hard burned...	Olive
7	1,270	.039	15.2	2.50	Vitrified	Olive
9	1,310	....	....	....	Viscous	

Gray brown clay containing lime lumps. Suitable for brick and tile. Easily molded.
Burned by H. W. Jackman.

BARRY COUNTY.

The Zeeland Brick Company formerly operated a brick plant at the northeast corner of Cloverdale in Section 26, T. 2 N., R. 9 W., on the Chicago, Kalamazoo, and Saginaw Railroad. The clay was about 6 feet thick and covered 10 acres. It made a good red brick that was sold in Kalamazoo. The freight rates were high, $4.00 a thousand to Kalamazoo, and the plant was dismantled in 1912 when the clay deposit ran out. There are about six acres of usable clay on the edge of Mud Lake that is probably similar to the clay formerly used by the Zeeland Brick Company.

At Delton the Leonard Brothers operate a soft mud brick yard about 400 yards north of the road and one-quarter mile east of the C. K. & S. Railroad in Section 5, T. 1 N., R. 9 W. The plant was just getting into operation in July, 1922. At that time the plant consisted of:

Steam power plant,
Rolls,
Pugmill,
Six brick soft mud molding machine,
Steam drier, drying bricks on pallets,
Kiln yard.

The brick is burned in coal fired scove kilns in preference to oil fired kilns. Operating with the above equipment the capacity was about 20,000 brick a day. A steam shovel was to be purchased as soon as the plant got under way.

The drier is similar to the driers used in the Detroit district and seemed to give trouble in cracking the brick, particularly that made from the upper red clay.

The clay covers 10 acres or more. The upper 3 feet is red clay underlain by 2 to 10 feet of blue clay, varying from 4 to 13 feet in total depth. The clay is a glacial clay fairly free from pebbles. Two gasoline driven pumps are required to keep the pit dry. Sample 48 was taken from an average sample obtained by trenching the side of the pit.

Burning Test.

Sample No. 48. Field Sheet No. 47.
Section No. 5, T. 1 N., R. 9 W.
Plasticity .259 gm. water per gm. clay.
Average linear drying shrinkage 8.3 per cent.
Average tensile strength about 162 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Hardness.	Color.
08	990	.384	−0.2 %	Soft burned.....	Salmon
06	1,030	.374	−0.5	Soft burned.....	Salmon
04	1,070	.380	0.0	Soft burned.....	Salmon
02	1,110	.370	0.8	Soft burned.....	Salmon
1	1,150	.246	5.7	Hard burned	Light olive
3	1,190	.079	7.6	Hard burned	Light olive
5	1,230	.024	7.6	Vitrified	Olive
7	1,270	.024	6.9	Vitrified	Olive
9	1,310	....	...	Melted	

Molded easily; may be used for brick and tile.
Burned by H. W. Jackman.

The Michigan Porcelain Company formerly made electrical porcelain at Hastings from clays obtained from New Jersey, Tennessee, and Florida. The company went out of business in 1918.

BAY COUNTY.

Bay County is almost completely covered with glacial lake deposited clay and sand. The clay is generally blue in color, contains lime, and frequently lime pebbles. This clay burns buff, becoming olive when hard burned. In some places the clay is locally red in color, comparatively free from lime and burns red. When fairly free from lime the clay is satisfactory material for brick and tile. The lake clay is generally 50 to 100 feet thick.

The Michigan Vitrified Brick Company was operated by Mr. Ed. Twining in the NW¼ Section 1, T. 13 N., R. 4 E. for a few years previous to 1916. Mr. Twining acquired the old coal mine of the Valley Coal Company and tried to make vitrified brick from surface clay found near the mine, using coal from the old mine as fuel. The surface clay is generally unsuited for vitrified ware and the attempt was unsuccessful.

Ries* mentions the so-called "fire clay" underlying the coal seam of the old Monitor shaft in Section 33, T. 14

N., R. 4 E. This clay was reported similar to that quarried at Flushing and suitable for paving blocks. It was reported to be 8 to 10 feet thick at this place. This old shaft as well as the adjacent Old Bay No. 1 shaft had been abandoned and filled before the present survey was undertaken. The "Black Diamond" shaft of the Robert Gage Company had been opened in the north central part of Section 30, T. 14 N., R. 4 E. about one and one-half miles east of Auburn, and one mile south of the Michigan Central railroad or two miles west of the old Monitor shaft. Here the coal seam, 156 feet below the surface, is covered with 20 feet of bituminous shale (sample 139) and underlain by "fire clay," (sample 140). This sample shows a wide burning range and is good material for making all kinds of brick and tile and even some vitrified ware, but cannot be classed as a refractory clay.

*Geol. Surv. Mich. VIII, Part I, p. 34 (1900-1903).

Burning Test.

Sample No. 140. Field Sheet No. 152.
Section 30 (North), T. 14 N., R. 4 E.
Plasticity .209 gm. water per gm. clay.
Linear drying shrinkage 3.0 per cent.
Average tensile strength about 175 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Fired Linear Shrinkage.	Hardness.	Color.
08	990	.612	−0.4	Soft burned	Pink
06	1,030	.659	0.0	Soft burned	Pink
04	1,070	.597	−1.0	Soft burned	Pink
02	1,110	.570	0.9	Hard burned	Pink
1	1,150	.544	3.0	Hard burned	Light brown
3	1,190	.543	4.1	Hard burned	Light brown
5	1,230	.538	3.9	Hard burned	Brown
7	1,270	.528	5.9	Hard burned	Brown
9	1,310	.478	7.8	Vitrified	Gray
11	1,350	.452	3.1	Vitrified	Gray
13	1,390	.480	1.1	Vitrified	Gray

Easily molded. Suitable for tile and brick or vitrified ware.
Burned by H. W. Jackman.

The Hecla Portland Cement Company, incorporated in West Virginia April 6, 1901, with a capital of $5,000,000, built a plant in Section 2, T. 13 N., R. 4 E., using the shale dumps from the old Hecla mine shafts as the source of shale. This company planned to use dry marl and Coal Measures shale as raw material and to use the heat in the kiln gases to evaporate salt solutions.

The following analyses of shale used by this company are taken from I. C. Russell.[1]

Silica SiO_2	61.13%	54.93%
Alumina and Iron $Al_2O_3+Fe_2O_3$	26.9	31.43
Lime CaO	1.12	.22
Magnesia MgO	.96	1.58
Water and Organic	6.47	7.44

Analyzed by Lathbury & Spackman.

These coal measure shales were carefully investigated by Ries.[2] For this reason and because they are so inaccessible, no further work was done on the coal measure shales in Bay County.

At the old shaft of the Central Coal Mining Company, SE¼ Sec. 25, T. 14 N., R. 4 E., the coal seam was 150 feet below the surface and was overlain by a brittle bituminous shale and underlain by a red to gray shale from 2½ to 4 feet in thickness. The under shale was homogeneous and similar to that of the old Standard Shaft near Saginaw.

It was stated that this clay (sample 228 Ries) was tried successfully as a raw material for bricks by the Saginaw Clay Manufacturing Company.

Burning Test.

Ries No. 228. Underclay. SE¼ Sec. 25, T. 14 N., R. 4 E.
150 feet below surface. Red to gray shale.
Water of plasticity 19%.
Air shrinkage 5%.
Tensile strength 50 to 60 lbs. per sq. in.
Soluble salts 0.3%.

Cone.	Total Shrinkage.	Burning.	Color.
05	6%		
1	7	Hard burned	Cream
4	9		Cream
5	...	Vitrified	Gray
8	...	Overburned	Gray
11	...	Viscous	Gray

This shale is not quite so good as sample 140 but has a wide burning range and is suitable for brick and tile.

The old shaft of the Michigan Coal and Mining Company was located about ½ mile north of the old Central shaft. Here the under shale was about two to three feet thick. It was rather soft when mined but hardened on exposure to the air.

[1]The Portland Cement Industry in Michigan, 22nd Ann. Rept. U. S. Geological Survey, Pt. III p. 670 (1902).

[2]Mich. Geol. Survey VIII, Pt. I, see also Pt. III, pp. 260-266.

Burning Test.

Ries Sample No. 187. Old shaft of Michigan Coal and Mining Co., Sec. 25, T. 14 N., R. 4 E.
Upper part of Under shale.
Water of Plasticity 25%.
Air shrinkage 6%.
Tensile strength 150-175 lbs. per sq. in.
Soluble salts 0.2%.

Cone.	Total Shrinkage.	Burning.
05	9%	Hard burned
1	...	Vitrified
5	...	Viscous

Chemical Analysis.

SiO_2	57.1 %
Al_2O_3	20.02
Fe_2O_3	8.18
$CaCO_3$	0.71
$MgCO_3$	1.47
K_2O	2.76
Difference	9.76

—A. N. Clark.

The lower part of the under shale running into a bluish-black shale was tested as follows:

Water of Plasticity 17%.
Granular, lean and easily dried.

Air shrinkage 4%.
Tensile strength 55-60 lbs. per sq. in.
Soluble salts 0.7%.
Hard burned at cone 06.
Vitrified at cone 2.

At the old Winona Coal Company's mine in NW¼ Section 4, T. 14 N., R. 5 E., the coal was 158 feet below the surface and underlain and overlain by shale. The under shale was very silicious. The over shale was similar to the shale used at Saginaw but had occasional streaks of bituminous brittle shale in it. This shale varied in thickness from two to ten feet. Ries reported that this shale gave no effervescence with acid, showed little or no pyrite, but some mica.

Ries, Sample 180. Winona Coal Mine, Section 4, T. 14 N., R. 5 E.
Over shale.
Water of Plasticity 18% (Low plasticity).
Air shrinkage 3%%.
Tensile strength 55 lbs. per sq. in.
Soluble salts 0.6%.

Cone.	Total Shrinkage.	Hardness.	Color.
2	4%	Hard burned	Red
6	...	Vitrified	....
8	...	Viscous	....

Chemical Analysis.

Silica (SiO_2)	52.45%
Alumina (Al_2O_3)	23.27
Iron (Fe_2O_3)	7.93
Lime ($CaCO_3$)	1.82
Magnesia ($MgCO_3$)	1.06
Alkalies (K_2O)	4.37
Difference (H_2O)+Organic	9.10

In the Consolidated No. 3 Mine SE¼ Sec. 17, T. 14 N., R. 4 E., the coal is 160 feet below the surface. Here the over shale is a bituminous material that spontaneously ignites when brought to the surface and burns to red powder that is used on the roads. In another mine in section 13, T. 14 N., R. 2 E., this same over shale is nearly white in color and burns in the mine.

BENZIE COUNTY.

Through Benzie County the clay is practically all morainic boulder clays. Most of it is light red clay running very high in lime and burning to a cream brick very similar to the sample from Leelanau. Northwest of the Ann Arbor Railroad between Frankfort and Beulah in Section 30, T. 26 N., R. 15 W., there is an outcrop of a bank of this red clay covering about 75 acres to a depth of 20 to 30 feet. The railroad swings around the face of the clay bank, some of which frequently slides down on the tracks. The following tests indicate this clay to be useful only for common brick.

Chemical Analysis.

Sample No. 37, Field Report Sheet No. 38.
Sec. 30, T. 26 N., R. 15 W.

Loss on Ignition	16.65%
SiO_2	54.19
Al_2O_3	9.11
Fe_2O_3	1.87
CaO	11.78
MgO	4.46
Na_2O—K_2O	1.94

Burning Test.

Sample No. 37. Field Sheet No. 38.
Section 30 (South) T. 26 N., R. 15 W.
Plasticity .183 gm. water per gm. clay.
Average linear drying shrinkage 3.8 per cent.
Average tensile strength about 55 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Hardness.	Color.
08	990	.407	−2.0%	Soft burned	Cream pink
06	1,030	.417	−1.4	Soft burned	Cream pink
04	1,070	.409	−1.6	Soft burned	Cream
02	1,110	.410	−1.6	Soft burned	Cream
1	1,150	.395	−0.2	Soft burned	Cream
3	1,190	.390	0.0	Soft burned	Cream
5	1,230	.379	0.9	Soft burned	Cream
7	1,270	.384	1.9	Soft burned	Cream
9	1,310	....	.....	Viscous	.....

Molded with difficulty; grainy.
Burned by H. W. Jackman.

BERRIEN COUNTY.

The surface clays of Berrien County are generally morainic boulder clays with some clay areas in the out wash plains.

Sample 183 was taken in Section 29, T. 7 S., R. 20 W., southeast of Lakeside. It is a brown boulder clay, containing pieces of shale. It is about 15 to 20 feet thick throughout this district, and is covered by a few inches of sandy loam. It is generally suitable for common brick and tile when fairly free from lime pebbles.

Burning Test.

Sample No. 183. Field Sheet No. 204.
Section 29, T. 7 S., R. 20 W.
Plasticity .300 gm. water per gm. clay.
Average linear drying shrinkage 9.7 per cent.
Average tensile strength about 128 lbs. per sq. in.
Apparent Sp. Gr. dry, about 2.52.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	950	.381	1.1	2.60	Soft burned	Salmon
08	990	.380	1.3	2.58	Soft burned	Salmon
06	1,030	.384	1.3	2.60	Soft burned	Salmon
04	1,070	.368	0.9	2.56	Soft burned	Light brown
02	1,110	.219	5.6	2.39	Hard burned	Light brown
1	1,150	.026	8.8	2.22	Vitrified	Olive brown
3	1,190	.019	12.6	2.38	Vitrified	Olive brown
5	1,230	....	....	....	Viscous	.....

Light brown clay. Few lime lumps. Molded easily.
Burned by H. W. Jackman.

Similar clay (sample 182) is found in Section 36, T. 7 S., R. 19 W. This clay occurs in ridges about 4 feet thick, overlying red sand.

The Mamer Brick Company formerly made brick from clay in Benton Harbor, near Paw Paw Avenue and the Pere Marquette Railroad. The deposit was exhausted in

1921 and the machinery sold. The former producers are now simply dealers in brick and building materials.

BRANCH COUNTY.

The Coldwater shales are probably the most important from the economic standpoint, at least, in the State. These shales outcrop and are quarried at several places in Branch County.

The shale at Coldwater, from which place the shale was named, is quarried by the Wolverine Portland Cement Company (formerly the Coldwater, and the Michigan Portland Cement Company, organized June 6, 1898, capital $2,500,000), and used at both the Coldwater plant, completed in 1898, and the Quincy plant, completed in 1900. This outcrop (Sec. 32, T. 6 S., R. 6 W.) was reported by Ries*. At that time only the upper weathered part of the bed was quarried. This material is mostly fine grained, containing but little grit, and slakes slowly in water. It does not effervesce with acid but contains siderite, (iron carbonate) concretions.

Sample, by Ries (unnumbered) of weathered shale at Coldwater.
Water of Plasticity 21%.
Can be dried rapidly.
Air shrinkage 7 %.
Tensile strength 125-139 lbs. per sq. in.
Soluble salts—trace.

Cone.	Total Shrinkage.	Burn.	Color.
03	14 %	Hard	Red
1	....	Hard	Deep red
2	16 %	Vitrified	.....
5	....	Viscous	.....

If heated too fast bricks warp.

Chemical Analysis (Ries 12).

Silica (SiO_2)	53.44%
Alumina & Iron Oxide (Al_2O_3+ Fe_2O_3)	24.80
Lime (CaO)	0.76
Magnesia (MgO)	0.25

*Mich. Geol. Survey VIII, Pt. I, p. 42 (1900).

The following range in composition of the Coldwater shale from the Coldwater quarry is given by Russell* as analyzed by H. E. Brown:

Silica (SiO_2)	57.26%	61.25%
Alumina (Al_2O_3)	18.12	21.59
Ferric Oxide (Fe_2O_3)	6.53	8.30
Lime (CaO)	1.25	1.50
Magnesia (MgO)	1.49	2.31
Sulphuric Oxide (SO_3)	.65	1.34
Carbon Dioxide (CO_2)	.95	1.18
Titania (TiO_2)	.82	1.12
Alkalies (Na_2O—K_2O)	2.25	3.45
Loss on Ignition	6.19	8.32

The following analyses were supplied by L. A. Hutchins, Chief Chemist of the Wolverine Portland Cement Company:

	Upper Yellow Clay. %	Lower Blue Shale. %
Loss on ignition	8.43	8.01
Silica (SiO_2)	65.62	57.68
Iron (Fe_2O_3)	6.72	7.52
Alumina	16.72	22.42
Lime (CaO)	Trace	0.60
Magnesia (MgO)	1.72	2.74
Sulphur trioxide (SO_3)	0.25	0.38
	99.46	99.35

When this quarry was visited in 1922, the main body of blue shale was well exposed. One to two feet of soil are removed above the brown clay (weathered shale), which is about 6 to 8 feet thick. The clay is underlain by a stratum of "kidney rock" (large iron carbonate concretions) and the main body of blue shale, which is very thick. These "kidney rocks" are also encountered in the blue shale. Sample 50 was taken from a railroad car at Quincy in 1922 and represents the main body of blue shale at the Coldwater quarry below the weathered part reported by Ries. Sample 185 is representative of the same shale but was taken directly from the Coldwater quarry in 1923.

*Twenty-second Annual Report U. S. Geol. Survey, Part III, p. 666 (1902).

Burning Test.

Sample No. 50. Field Sheet No. 49.
NW¼ Section 32, T. 6 S., R. 6 W.
Plasticity .323 gm. water per gm. clay.
Average linear drying shrinkage 8.0 per cent.
Average tensile strength about 47 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Hardness.	Color.
08	990	.325	0.5 %	Soft burned	Salmon
06	1,030	.329	0.7	Soft burned	Salmon
04	1,070	.273	3.2	Soft burned	Salmon
02	1,110	.159	7.5	Hard burned	Red.
1	1,150	.088	10.3	Hard burned	Dark red
3	1,190	.009	11.0	Vitrified	Chocolate
5	1,230	.009	12.0	Vitrified	Chocolate
7	1,270	.009	11.8	Vitrified	Chocolate
9	1,310	.144	3.7	Overburned	Dark chocolate

Molded easily. Good material for face brick, tile, sewer pipe, or vitrified ware.
Burned by H. W. Jackman.

Burning Test.

Sample No. 185. Field Sheet No. 206.
Section 32, T. 6 S., R. 6 W.
Plasticity .303 gm. water per gm. clay.
Average linear drying shrinkage 7.7 per cent.
Average tensile strength about 47 lbs. per sq. in.
Apparent sp. gr. dry 2.53.
Contains some carbon, burned out at 750°C. in 2½ hours.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	950	.343	0.0 %	2.56	Soft burned.....	Salmon
08	990	.331	1.9	2.61	Soft burned.....	Salmon
06	1,030	.298	4.5	2.77	Soft burned.....	Salmon
04	1,070	.214	7.4	2.67	Hard burned.....	Red
02	1,110	.081	8.9	2.44	Hard burned.....	Dark red
1	1,150	.017	11.5	2.43	Vitrified.....	Chocolate
3	1,190	.009	11.8	2.41	Vitrified.....	Chocolate
5	1,230	.009	11.5	2.37	Vitrified.....	Chocolate
7	1,270	.065	+5.6	2.09	Vitrified.....	Dark chocolate
9	1,310	.176	−0.6	2.04	Overburned.....	Dark chocolate

Blue shale. Molded easily, very plastic when ground. Excellent material for face brick and vitrified ware. Burned by H. W. Jackman.

The burning test shows this sample to have a wide burning range and a very satisfactory vitrifying range of about 5 cones over which the shrinkage is constant with uniform low porosity. It is excellent material for face brick, tile, or almost any vitrified product, as well as Portland cement.

In the quarry the shale and clay are dug by a steam shovel and loaded on dump cars, which are drawn by a gasoline engine to the plant in SW¼ section 20 on South Lake, just north of the Lake Shore and Michigan Southern Railroad. Here the shale is crushed and used in the Coldwater plant or shipped to the Quincy plant on the L. S. & M. S. Railroad.

The Coldwater plant uses marl from the lake with the shale in a wet process plant. The plant originally operated 14 small kilns, but is now equipped with three 182 foot bottle kilns having a total capacity of 1300 barrels a day. This plant burns about 175 pounds of coal in the kilns per barrel of cement produced.

The Quincy plant, just south of Quincy on Marble Lake, section 21, T. 6 S., R. 5 W., uses the same process. Marl is obtained from Marble Lake by two tugs, and shale from Coldwater. There are 7 kilns 120 feet long by 6 feet in diameter, having a combined capacity of 1200 barrels of cement a day.

An old brick yard in the southern part of Coldwater formerly used the brown clay for common brick.

Ries* investigated a shale deposit near Quincy and the following is a summary of his report:

"A sample (219) from the property of H. Bennett and representing the average of his deposit as exposed in the creek, gave the following results:

Sample Ries 219. Dense hard shale.
Weathers down to plastic tough clay.
Does not effervesce with acid.
Free from mica and pyrite.
Water of plasticity 19%.
Air shrinkage 4%.
Tensile strength 75-80 lbs. per sq. in.
Soluble salts 0.2 per cent.

Cone.	Total Shrinkage.	Burn.
05	6 %	Soft
03	8	Hard
3	12	Vitrified
6	..	Viscous

*Mich. Geol. Survey VIII, Pt. I, p. 42.

This material is similar to the shale quarried at Coldwater and may be used for hard burned brick or tile.

The weathered shale was formerly used by Reynolds four miles south of Quincy to make brick. The product was a good red brick used locally. The weathered shale was also used about 1870 in a brick yard in NE¼ section 19, T. 6 S., R. 5 W., two and one-half miles west of Quincy.

The Coldwater shales near Bronson were used by the Bronson Cement Company in section 6, T. 7 S., R. 7 W., just north of the Lake Shore & Michigan Southern Railroad. This company was organized on March 3, 1897, with a capital of $500,000. The plant was completed that year with seven kilns.[1] In 1911 this company was reorganized as the New Bronson Cement Company. The shale was formerly mined as it underlies the surface formations. Ries[2] reported a sample of the Bronson shale as "taken from the stock pile of the Portland Cement Works at Coldwater." This is probably a misprint as Bronson is meant and not Coldwater.

Sample (Ries) 230 (ground to 30 mesh).
Dark gray shale, dense but not very hard.
Slakes into a plastic clay when exposed to water.
Soluble salts 0.5%.
Water of plasticity 31% (very plastic).|Stands rapid drying without shrinking.
Tensile strength about 125 lbs. per sq. in.
Air shrinkage 6%.
Must be carefully oxidized because of a large amount of organic matter.

Cone.	Total Shrinkage.	Burn.	Color.
06	% 12	Hard	Red
02	15	Nearly vitrified.	Red
1	16	Vitrified	Deep red
2	..	Overburned	.....

Chemical Analysis[3]

Silica (SiO_2)	62.1 %
Alumina (Al_2O_3)	20.09
Ferric Oxide (Fe_2O_3)	7.81
Lime (CaO)	.65
Magnesia (MgO)	.96
Sulphur trioxide (SO_3)	.49
Water and Organic	7.90

[1]H. Lewis, Eng. Record XXXVII, 1898, pp. 470-472. Cement Industry, New York, 1900, pp. 33-14.

[2]Mich. Geol. Survey VIII, Pt. I, p. 43 (1900).

[3]Mineral Industry VI.

The Peerless Portland Cement Company, Union City, was organized August 23, 1896, with a capital of $250,000, and completed their plant of 19 intermittent vertical kilns that year. The marl and clay were mixed and molded into bricks which were dried and stacked in the kilns with alternate layers of coke. In 1900 Dietch Continuous Vertical kilns were installed. These kilns were later replaced with 9 rotary kilns having a combined capacity of 1500 barrels a day. Marl is now obtained

from Jackson County and shale from the local quarry about two miles south of the plant just west of Coldwater River, NW¼ section 15, T. 5 S., R. 7 W. The plant is just east of the main road going south and on the north side of the Michigan Central Railroad, on the west side of town, section 4, T. 5 S., R. 7 W. The wet process is used here as in all plants using marl.

The shale is very similar to that at Coldwater and Bronson. The upper 4 feet are yellow brown clay or weathered shale, then follows a layer of "kidney rock" (iron carbonate concretions). Under this there are 20-25 feet of blue shale, then another layer of "kidney rock" followed by more shale.

Ries* sampled this shale and reported it to be very similar to that found at Bronson.

Sample Ries 218.
Not effervesce with acid. Shows little pyrite.
Water of plasticity 25%.
Air shrinkage 5%.
Tensile strength 70-80 lbs. sq. in.
Soluble salts 0.4%.

Cone.	Total Shrinkage.	Burn	Color.
	%		
05	9	Hard	Bright red
2	13	Vitrified	.....
5	..	Viscous	.....

*Mich. Geol. Surv. VIII, Pt. I, p. 41 (1900).

Sample 49 was taken in 1922 and represents the main body of blue shale.

Burning Test

Sample No. 49. Main body blue shale. Field sheet No. 48.
SW¼ Section 15, T. 5 S., R. 7 W.
Plasticity .251 gm. water per gm. clay.
Average linear drying shrinkage 4.4 per cent.
Average tensile strength about 42 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.353	−1.2 %	1.61	Soft burned...	Salomn
08	990	.337	0.0	1.65	Soft burned....	Salmon.
06	1,030	.333	+1.1	1.68	Soft burned....	Salmon
04	1,070	.308	3.2	1.76	Soft burned....	Light red
02	1,110	.270	5.0	1.89	Hard burned...	Red
1	1,150	.195	7.8	2.07	Hard burned...	Dark red
3	1,190	.118	8.7	2.16	Hard burned...	Chocolate
5	1,230	.067	9.5	2.21	Vitrified.....	Dark brown
7	1,270	.015	9.3	2.21	Vitrified.....	Dark gray brown
9	1,310	.182	2.6	1.79	Vitrified.....	Dark gray brown
11	1,350	.163	0.0	1.56	Over burned..	Dark gray brown

Molded fairly easily. Cracks readily unless carefully cooled from high temperatures.
Suitable for brick, tile, and vitrified ware.
Burned by H. W. Jackman.

As used in the Peerless Portland Cement plant, stale from this quarry 2 miles south of Union City, NW¼ section 15, T. 5 S., R. 7 W., analyzed as follows:

Silica (SiO_2)	64.56%
Alumina (Al_2O_3)	22.00
Iron Oxide (Fe_2O_3)	2.96
Lime ($CaCO_3$)	.60
Magnesium ($MgCO_3$)	none
Sulphur (SO_3)	trace
Organic	9.88

Analysis by Peerless Portland Cement Co.

The Standiford Portland Cement Company was organized to use marl in the northwest corner of Branch County near Athens* but nothing came of it.

*Mich. Geo. Survey VIII, Pt. III, p. 301 (1900-3).

CALHOUN COUNTY

In Battle Creek Ed. Halsted formerly trucked clay from a glacial deposit to local foundries. The clay deposit is a typical glacial clay found in this district and was being graded into city lots in July, 1922.

The Alpha Portland Cement Company of Bellevue, Eaton County (formerly the Burt Portland Cement Company) obtains its clay by truck from a pit in SE*4 section 7, T. 1 S., R. 6 W., just west of trunk line road M-78 and 3½ miles south of the plant. The clay is blue, smooth, and comparatively free from lime pebbles. It is about 40 feet deep and covers about 47 acres. It runs to gravel on the east and quicksand on the west. So far the deposit has been worked to a depth of 20 feet over about 10 acres. The clay is excavated by a steam shovel and loaded on trucks which runs on a wooden track in the pit. The following analyses suggest that this clay is derived largely from the Grand Rapids or Michigan series shale as found under the limestone in the lime quarry at Bellevue:

	Average of upper 9 Ft. %	Stock Average. %
Silica (SiO_2)	48.87	49.30
Alumina (Al_2O_3)	11.84	11.70
Iron (Fe_2O_3)	5.26	4.60
Lime (CaO)	12.06	12.10
Magnesia (MgO)	4.07	4.30
Ignition loss	15.52	15.90

Analysis of hole in center of deposit SE¼ Sec. 7, T. 1 S., R. 6 W.

Depth.	3-9'	9-18'	18-27'	27-36'	36-45'
SiO_2	51.40 %	47.00 %	49.40 %	42.80 %	45.70 %
Al_2O_3	11.88	12.82	12.12	14.58	13.44
Fe_2O_3	4.42	5.78	3.88	3.32	4.66
CaO	14.06	.....	.....	.....	12.00
MgO	4.75	.....	.....	.....	4.86
Loss	12.80	.....	.....	.....	16.30

Clay or Michigan Series shale below the limestone in the pit at Bellevue.

SiO_2	52.42%
Al_2O_3	10.93
Fe_2O_3	4.01
CaO	14.06
MgO	1.65
SO_3	1.35
Loss	1.90

Analyses by C. H. Denman, Alpha Portland Cement Co.

Chemical Analysis

Sample No. 21. Field Sheet No. 18.
Depth 5-20 feet of deposit in Section 7, S. E. ¼, T. 1 S., R. 6 W.

Loss on Ignition	12.62%
Silica (SiO_2)	51.46
Alumina (Al_2O_3)	11.00
Iron (Fe_2O_3)	4.60
Lime (CaO)	12.43
Magnesia (MgO)	4.71
Alkalies (Na_2O, K_2O)	3.18

Analysis by H. W. Jackman.

Burning Test

Sample No. 1026. Field Sheet No. 1032 and 18.
Section 7, T. 1 S., R. 6 W.
Plasticity .252 gm. water per gm. clay.
Average linear drying shrinkage 7.2%.
Average tensile strength about 107 lbs. per sq. in.
Apparent Sp. Gr. dry, 2.56.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	950	.389	0.6 %	2.70	Soft burned...	Salmon
08	990	.381	1.1	2.70	Soft burned...	Cream
06	1,030	.381	1.4	2.72	Soft burned...	Cream
04	1,070	.362	1.0	2.59	Soft burned...	Cream
02	1,110	.354	6.0	....	Hard burned..	Verly light olive
1	1,150	.209	6.5	2.40	Hard burned..	Light olive
3	1,190	.055	14.2	2.69	Vitrified.....	Olive
5	1,230	....	....	....	Viscous	

Light brown clay containing lime pebbles. Molded easily.
Burned by H. W. Jackman.

The burning test shows this clay to have much the same burning properties as most of the surface clay found to the southwest through Cass and Berrien Counties.

In the southern part of the county the analyses* of some of the clays are very similar to the analyses of the Coldwater shale found south of Union City:

	East of Burlington Station.	One mile north of Athens.
SiO_2	67.02 %	70.97 %
Al_2O_3	14.95	17.25
Fe_2O_3	4.65	4.01
$CaCO_3$	.65	.96
$MgCO_3$	None	Trace
So_3	2.28	....
Organic	.....	7.77

*Kindly given by Mr. Sundteigen, chief chemist of the Peerless Portland Cement Company of Union City.

CASS COUNTY

The surface clays of Cass County are largely morainic or till plain clays with some silt clays in the outwash deposits. They are very similar to the clays found in Berrien County. Sample 184 taken from SE¼ section 31, T. 5 S., R. 15 W., just east of Dowagiac and west of the mill pond has properties very similar to sample 183 from west Berrien County. This clay is a smooth light colored clay found as a stratum in the glacial outwash of sand and gravel.

Burning Test

Sample 184. Field Sheet 205.
Section 31, T. 5 S., R. 15 W.
Plasticity .289 gm. water per gm. clay.
Average linear drying shrinkage 6.6 per cent.
Average tensile strength about 78 lbs. per sq. in.
Apparent sp. gr. dry 2.53.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	950	.406	0.2 %	2.57	Soft burned.....	Salmon
08	990	.420	0.6	2.66	Soft burned.....	Salmon
06	1,030	.418	+0.2	2.63	Soft burned.....	Salmon
04	1,070	.404	−0.2	2.61	Soft burned.....	Salmon
02	1,110	.318	+4.1	2.52	Hard burned....	Light brown
1	1,150	.037	14.7	2.50	Vitrified.....	Olive brown
3	1,190	.044	13.0	2.37	Vitrified.....	Olive brown
5	1,230	....	....	....	Viscous	

Light brown clay. Molded easily.
Burned by H. W. Jackman.

CHARLEVOIX COUNTY

The Antrim shale is found underlying the surface formations and outcropping in many places over the entire county except for a narrow strip about 2 to 3 miles wide along the shore of Lake Michigan and Little Traverse Bay. Here the Antrim shale has been removed by surface erosion exposing the Thunder Bay series (limestone and shale). The Antrim shale is about the only ceramic material in the county.

The Charlevoix Rock Products Company had its plant of 6 lime kilns and quarry on Lake Michigan about one mile west of Charlevoix in section 28, T. 34 N., R. 8 W. An old switch runs in from the P. M. Railroad and a steam shovel reposes in the quarry. It was formerly owned by Detroit parties and managed by R. S. Sloan. The company went into the hands of a receiver and the property covering about 500 acres was purchased by the Newaygo Portland Cement Company in 1918. The quarry section is as follows:

20 feet of limestone (some places less).
10 to 18 inches hard blue limestone.
9 ft. 10 in. of blue clay or soft shale (sample 94)
limestone.

The soft shale is full of fossils and contains some pyrite crystals. It resembles the shale found in the bottom of the Antrim Iron Company's limestone quarry near Petoskey. The sample of shale contains so many small lumps of lime that the bricks crumbled to pieces in water. The material is worthless for ceramic purposes but probably can be used for Portland cement.

Burning Test

Sample No. 94. Field Sheet No. 99.
Section 28, T. 34 N., R. 8 W.
Plasticity .296 gm. water per gm. clay.
Average linear drying shrinkage 8.0 per cent.
Average tensile strength about 80 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.388	0.0 %	1.59	Soft burned.....	Pink
08	990	.393	0.0	1.58	Soft burned.....	Pink
06	1,030	.399	1.0	1.54	Soft burned.....	Light pink
04	1,070	.412	−1.0	1.52	Soft burned.....	Light pink
02	1,110	.389	−0.8	1.53	Soft burned.....	Light pink
1	1,150	.414	−0.2	1.50	Soft burned.....	Light gray
3	1,190	.256	−0.4	1.75	Hard burned....	Light gray
5	1,230	.131	5.0	2.07	Vitrified.....	Gray green
7	1,270	....	9.6	....	Viscous	

Contains fossils and small shaly lime lumps, so that many of the bricks crumbled to bits in water. Molded easily.
Burned by H. W. Jackman.

A deposit of clay and clay shale occupies a synclinal basin in the limestone about two miles west of Charlevoix in the eastern part of see. 32, T. 34 N., R. 8 W, The deposit covers an area of at least 40 acres and varies in thickness from a feather edge to 20 feet. There is practically no cover on a considerable portion of the deposit. The upper portion of the shale has weathered into soft, fine grained clay. The clay and shale are calcareous, containing from about 25 to 30 per cent of lime. The high lime content probably would make it unsuitable for brick. Its analysis indicates that it could be used in the manufacture of Portland cement and as the deposit overlies extensive beds of pure limestone, the two raw materials may form a most favorable combination for the manufacture of cement if present in sufficient amount.

The brick plants at East Jordan, Boyne City, and Boyne Falls have been closed for some time, and the demand for building brick is so great that old brick buildings are being town down for the sake of the bricks contained in the walls.

The old plant at East Jordan, about one-fourth mile from E. J. & S. Railroad and one-third mile from D. & C. Railroad in the west central part of section 23, T. 32 N., R. 7 W. obtained its shale (sample 93) from the northwest corner of Section 24 and had about exhausted this outcrop. The old equipment consisted of two boilers, an engine, a dry pan, pug mill, American auger brick machine for making side cut brick which were burned in scove kilns.

The Antrim shale also outcrops in a ledge 50 to 60 feet thick on the north shore of Pine Lake and also along the road on the west side of the lake in sec. 30 T. 33 N., R. 6 W. On the point in the southern part of section 3, T. 33 N., R. 7 W. there is an old quarry from which the shale was formerly dragged across the ice in the winter and occasionally shipped in summer to Charlevoix. No shipments have been made since 1910. The quarry is on the property of Mr. D'Oge. Sample No. 96 from this quarry shows a, rather narrow burning range and cracked easily during cooling or on burning. The shale burns brown and could be used for all forms of building brick and tile if properly handled.

The shale contains zones of large concretions, chiefly of iron and calcium carbonate. In this deposit in section 30 noted above, the zone of concretions rises four or five feet above the lake. The upper section of the shale appears to be nearly free from concretions.

Burning Test

Sample No. 96. Field Sheet No. 103.
Section 3, T. 33 N., R. 7 W.
Plasticity 0.258 gm. water per gin. clay.
Average linear drying shrinkage 5.0 per cent.
Average tensile strength about 60 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.504	1.3 %	1.29	Soft burned	Light red
08	990	.472	3.5	1.38	Soft burned	Light red
06	1,030	.433	6.3	1.49	Soft burned	Light red
04	1,070	.344	10.4	1.72	Semi-hard burned.	Brown
02	1,110	.173	15.6	2.05	Hard burned	Chocolate brown
1	1,150	.111	17.1	2.16	Vitrified	Chocolate
3	1,190	.054	14.5	1.95	Vitrified	Chocolate
5	1,230	.140	3.5	1.38	Softening	Chocolate

Dark brown shale.
Burned by H. W. Jackman.

The plant of the Boyne City Brick Company was located at the northeast corner of Boyne City in the southwest ¼ of section 25, T. 33 N., R. 6 W. The plant seems to have been well laid out, built of concrete and brick, and equipped to make wire cut and dry pressed brick. The shale was dumped directly into a dry pan and when ground elevated to a dry mixer. From the mixer the ground shale was fed to a pug mill in which it was tempered for extruding side cut brick in a Canton auger machine, or fed to a Berg press for forming dry pressed brick.

The stiff mud brick were dried in a 6 tunnel fire gas drier. The kiln equipment was apparently some type of down draft kiln built in the rectangular form. The kiln is a wreck but the stack was still standing in 1922. The shale property has been taken over by the Boyne City Portland Cement Co. as a prospective source of shale for use in the manufacture of cement.

The shale pit shows a few inches of red clay over gravel covering the shale which outcrops in a ledge about 60 feet high just back of the plant. The shale is somewhat weathered and on the face of the ledge it is disintegrated. It is blue with a green and brown tint in the upper strata.

Burning Test

Sample No. 97. Field Sheet No. 105.
SW¼ section 25, T. 33 N., R. 6 W.
Plasticity .208 gm. water per gm. clay.
Average linear drying shrinkage 4.2 per cent.
Average tensile strength about 60 lbs. per sq. in.
Heated for 5 hours to burn out carbon.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.345	0.4 %	1.73	Soft burned	Salmon
08	990	.334	1.1	1.77	Soft burned	Salmon
06	1,030	.303	2.1	1.81	Soft burned	Salmon
04	1,070	.268	3.3	1.88	Hard burned	Salmon brown
02	1,110	.197	5.7	2.00	Hard bruned	Light brown
1	1,150	.107	5.1	1.97	Hard burned	Brown
3	1,190	.206	−9.5	1.34	Overburned	Dark brown
5	1,230	....	.....	....	Melted	

Blue gray shale. Molded easily. Suitable for brick and tile.
Burned by H. W. Jackman.

Sample No. 97 taken from this pit shows a rather narrow burning range but suitable for all types of building brick and tile. The color is brown rather than red, which is generally preferred for face brick, so that the other parts

of the Antrim shale are probably more suited for this purpose. This blue shale molds easily and does not crack on burning. This may be partly due to the fact that the shale is weathered to a greater extent than most of the rusty dark shale.

The dark rusty shale outcrops in many places throughout the county, some of which have been indicated on the map. An outcrop near Clarion at the corner of sections 9, 10, 15, 16, in T. 33 N., R. 5 W. was analyzed by the Petoskey Portland Cement Company:

Loss on ignition	13.88%
Silica (SiO_2)	66.72
Alumina + Ferric Oxide Al_2O_3, Fe_2O_3.	18.04
Lime (CaO)	2.03
Magnesia (MgO)	1.95

Ries* also reports a deposit of clay one and one-half miles southwest of Boyne Falls, on the property of J. F. May and of Mrs. Powers. A sample from this deposit showed a tendency to crack on burning.

Through the eastern part of the county from Clarion to Boyne Falls and around Pine Lake there is some lake and morainic red and blue clay. Some of this clay such as that described by Ries is probably derived from the shale and some is calcareous and buff burning.

About one-half mile south of the Boyne Falls station of the G. R. & I. in the west center of section 22, T. 32 N., R. 5 W. there are the remains of the Northern Brick Company's plant. The boiler, engine, rolls, pug mill, and Adrian auger machine for making brick are still intact but in bad repair. Local reports state that the plant ran for a few years until 1913 or 1914. The clay bank, about 500 yards back from the road, is of red and blue clay (sample 98) and contains some small boulders and lumps of shale. The clay is evidently boulder clay laid down by the glacier, and entirely different from the weathered shale which burns red. The burning test shows that it can be easily burned to make cream colored brick or tile as it molds easily and is free from bituminous matter.

Burning Test

Sample No. 98. Field Sheet No. 107.
Section 22 (West Center) T. 32 N., R. 5 W.
Plasticity .280 gm. water per gm. clay.
Average linear drying shrinkage 8.8 per cent.
Average tensile strength about 110 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
08	990	.444	2.0%	1.53	Soft burned	Cream
06	1,030	.448	1.3	1.49	Soft burned	Cream
04	1,070	.454	1.3	1.51	Soft burned	Cream
02	1,110	.480	2.7	1.56	Soft burned	Cream
1	1,150	.389	4.9	1.68	Soft burned	Cream
3	1,190	.278	9.9	1.97	Soft burned	Cream
5	1,230	.116	14.7	2.32	Semi-hard burned	Light olive
7	1,270	.014	16.1	2.44	Hard burned	Light olive
9	1,310	....	....	....	Vitrified	
11	.....	....	....	....	Melted	

Pink clay. Molded easily. Burned by H. W. Jackman.

*Mich. Geol. Survey VIII, Pt. I (1900).

CHEBOYGAN COUNTY

The Antrim shale underlies the southern part of Cheboygan County in a strip about eight to twelve miles wide, and is probably the most valuable ceramic material in the county. The shale outcrops in an exposure over 25 feet thick in the bed of a small cascading stream flowing down a ravine in the SW¼ section 1, T. 34 N., R. 3 W., on the farm belonging to Mr. White, about one-third of a mile east of the Michigan Central Railroad and three miles south of Indian River. Many of the ridges in the timbered bluff are shale. An outcrop was found, about one and one-half miles farther east in section 6, T. 34 N., R. 3 W., on the hillside by the twin pines on the farm of Mr. Hatch. Exposures of share are reported to occur in cuts to the south along the Michigan Central Railroad. The shale has the characteristic rusty black appearance common to most of the Antrim shale. Drilling of this deposit shows large concretions of pyrite at certain horizons. Sample No. 130 from these exposures tests as follows:

Burning Test

Sample No. 130. Field Sheet 140.
Section 1, T. 34 N., R. 3 W.
Plasticity .255 gm. water per gm. clay.
Linear drying shrinkage 5.0 per cent.
Heated at 750°C. for 5 hours to drive out carbon.

Cone No.	Cone Temp. °C.	Porosity.	Absorption.	Fired Linear Shrinkage.	Hardness.	Color.
010	950	.439	.300	−0.7%	Soft burned	Salmon
08	990	.425	.298	−0.7	Soft burned	Salmon
06	1,030	.396	.258	+0.7	Soft burned	Salmon
04	1,070	.347	.210	3.2	Hard burned	Red
02	1,110	.256	.139	6.9	Hard burned	Dark red
1	1,150	.156	.076	....	Hard burned	Dark red
3	1,190	.082	.038	11.4	Vitrified	Chocolate
5	1,230	.058	.027	11.0	Vitrified	Chocolate
7	1,270	.056	.027	11.0	Vitrified	Chocolate
8	1,290	.014	.005	6.0	Vitrified	Chocolate.

Good material for face brick and vitrified ware. Contains carbon which burns out at 750°C. Slight white scum evident on burned bricks. This scum burns off before the brick become vitrified.

Burned by H. W. Jackman.

The burning test shows the shale to have a wide burning range of 10 cones with practically no further shrinkage from cone 2 to 7. The color is a good dark red. The sample indicates that the shale will make excellent face brick and tile, and can be used for vitrified products such as sewer tile, and possibly paving blocks for ordinary traffic. To obtain the best results the shale should be wet ground to develop plastic qualities, and carefully oxidized to burn out the bituminous material.

Shale is also exposed in a road cut near the center of section 14, T. 34 N., R. 2 W., and underlies the surface at shallow depth in a northwest-southeast belt for over a half mile. Diamond drill tests for the State showed depths of shale varying from 12 to 50 feet with alternating beds of shale and limestone below. The shale itself contains beds of limestone and concretions of calcium-iron and masses and stringers of pyrite. The

section and analyses are typical of the lithological and chemical composition of the deposit.

Shale Section

Diamond Drill Hole No. 2

Location: 3,809 ft. W. and 726 ft. N. of E. ¼ cor. Section 14, T. 34 N., R. 2 W. Cheboygan County.

Surface.	Thickness feet.	Depth feet.
1. Greenish gray very shaly limestone with occasional streaks of brown shale ($CaMgO$ 31.76 %)	14	17
2. Greenish brown shale with spots and bands of greenish gray (SiO_2 50.80 %)	6	23
3. Same but more calcareous ($CaMgO$ 9.73 %)	4	27
4. Brown shaly limestone ($CaMgO$ 35.84 %)	2	29
5. Very dark brown shale with pyrite (SiO_2 48 %)	10	39
6. Light greenish calcareous shale with streaks and spots of dark brown shale (SiO_2 32 %)	5-6	44-6
7. Gray calcareous shale (SiO_2 50.80)	5-4	50

Analyses of Afton Shale Samples

Diamond Drill Hole No. 2

Location 3,809 ft. W. and 726 ft. N. of E. ¼ Cor. Sec. 14, T. 34 N., R. 2 W. Cheboygan Co. Elevation 75.4 ft. Drillers, R. J. Longyear Co., A. Shepstedt in charge; Wm Hillman, night shift.

Hole.	Sample.	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	Loss	Total.	Ratio.
2	1	26.40	2.40	9.60	29.60	2.16	28.00	98.16	2.75
2	2	50.80	4.80	14.40	4.00	2.16	22.40	98.56	3.52
2	3	42.80	4.40	11.60	8.00	1.73	30.00	98.53	3.69
2	4	16.40	2.00	5.60	34.40	1.44	37.60	97.44	2.92
2	5	48.00	6.80	8.80	6.00	1.87	26.60	98.07	5.45
2	6	52.00	4.40	12.40	9.20	1.73	19.80	99.53	4.19
2	7	50.80	4.00	12.00	8.00	1.87	21.80	98.47	4.23

Analysis by Aetna Portland Cement Co., 1924.

In the Cheboygan and Mullet Lake district there is a total of about 85 square miles of lake deposited clay which runs about eight feet or more thick. About two miles northwest of Cheboygan on State highway M-10 in the southern part of Section 23, T. 38 N., R. 2 W. the clay is red in color with streaks of blue clay running through it. It has about the same physical appearance as similar lake clays in the Northern Peninsula. At this place the clay is about 15 or 20 feet deep and covers at least half of a section. Another ledge of the same clay is evident along the creek which crosses the highway in section 26.

Burning Test

Sample No. 127. Field Sheet No. 137.
Section 23, (south), T. 38 N., R. 2 W.
Plasticity .346 gm. water per gm. clay.
Average linear drying shrinkage 14.7 per cent.
Average tensile strength about 175 lbs. per sq. in.
Heated for 4 hours to burn out carbon.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.348	1.1	1.69	Soft burned.....	Salmon pink
08	990	.358	1.1	1.69	Soft burned.....	Salmon pink
06	1,030	.357	0.9	1.69	Soft burned.....	Salmon pink
04	1,070	.285	4.8	1.86	Hard burned.....	Salmon pink
02	1,110	.119	8.8	2.16	Hard burned.....	Red brown
1	1,150	.028	10.4	2.29	Vitrified.....	Dark brown
3	1,190	.040	4.3	1.87	Softening.....	Chocolate
5	1,230	....	....	....	Viscous.....	Greenish

Reddish brown clay. Molded easily.
Burned by H. W. Jackman.

This clay is good material for brick and tile but has a burning range too narrow for vitrified products. It is very similar to some of the lake clays found in the Northern Peninsula.

Smooth, plastic, fine grained, red clay is found underlying two or three feet of sand on both sides of the Black River in section 36, T. 37 N., R. 1 W. The section is as follows:

3 feet of sand and gravel.
8 feet of smooth red clay (sample No. 159).
4 to 5 feet of coarse gravel.
3 to 4 feet of clay or sand running into hardpan.

Burning Test

Sample No. 159. Field Sheet No. 180.
Section 36, T. 37 N., R. 1 W.
Plasticity 0.33.2 gm. water per gm. clay.
Average linear drying shrinkage 12.1 per cent.
Average tensile strength about 175 lbs. per sq. in.
Apparent Sp. Gr. dry, 2.64.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	950	.398	3.9 %	2.59	Soft burned.....	Light pink
08	990	.414	1.9	2.67	Soft burned.....	Light pink
06	1,030	.436	2.5	2.78	Soft burned.....	Light pink
04	1,070	.429	2.5	2.78	Soft burned.....	Cream white
02	1,110	.440	3.9	2.94	Soft burned.....	Cream
1	1,150	.373	5.9	2.81	Hard burned.....	Cream
3	1,190	.336	7.5	2.77	Hard burned.....	Cream olive
5	1,230	.072	17.1	2.88	Vitrified.....	Light olive
7	1,270	.046	17.3	2.72	Vitrified.....	Light olive
9	1,310	....	....	....	Viscous	

Bed clay. Easily molded. This clay is suitable for making a light cream colored brick or tile and seems to be suitable for some pottery purposes.
Burned by H. W. Jackman.

The Cheboygan Tile & Brick Company built a plant in 1919 about one-half mile south of Cheboygan, west of the Cheboygan river, and east of the Detroit & Mackinac railroad, in the north center of Section 7, T. 37 N., R. 1 W. The plant is equipped with a pug mill, auger machine for making tile or brick, a twelve track tunnel steam drier, and three round periodic down draft kilns of the Wheeler type (illustrated in Fig. 31) placed between four stacks. A siding runs into the plant from the D. & M. railroad. The plant ran for a short time in 1921. Dr. Gero, the president, died in 1922 and was succeeded by Mr. Fred Hunt, a wholesale grocer. The latter hired a superintendent for the plant and tried to get it running but was unsuccessful.

The market conditions are excellent, the plant is completely enclosed and the machinery in good condition. The kiln bottoms will probably need to be rebuilt before the ware can be burned efficiently, judging from the experience of the St. Louis Tile Company in Gratiot County with kilns of the same construction. The plant is said to have cost about $75,000. The capacity of the plant is probably about 30,000 brick or its equivalent in tile per day, and plants of this capacity can be erected for $30,000 to $40,000, depending on conditions.

The upper two feet of the clay used by the Cheboygan Tile Company is red. Below the red clay where the lime has not been leached out and the iron is not as well oxidized the clay is reddish blue in color. A sample from the deposit contains some pebbles which are not limestone, and seems to be fairly good material for brick or tile. It is very similar to sample 159.

Burning Test

Sample No. 128. Field sheet No. 138.
Section No. 7 (north center) T. 37 N., R. 1 W.
Plasticity .291 gm. water per gm. clay.
Average linear drying strength 10.1 per cent.
Average tensile strength about 122 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.414	1.2	1.58	Soft burned.....	Light pink
08	990	.417	1.8	1.60	Soft burned.....	Light pink
06	1,030	.432	1.8	1.60	Soft burned.....	Cream white
04	1,070	.400	1.1	1.58	Soft burned.....	Cream
02	1,110	.401	3.8	1.71	Soft burned.....	Cream
1	1,150	.294	8.3	1.96	Hard burned....	Very light olive
3	1,190	.178	12.0	2.23	Hard burned....	Light olive
5	1,230	.064	15.8	2.54	Vitrified.....	Light olive
7	1,270	.052	10.0	2.09	Viscous.....	Olive

Light red clay, containing some pebbles (not lime). Easy to mold.
Burned by H. W. Jackman.

There is a deposit of about 100 acres of pink clay along the banks and under the bed of the Pigeon river in the western part of Sec. 27, T. 35 N., R. 2 W. This clay molds easily and is reported to be a satisfactory potter's clay when white burning clay is not required. Sample 129 was taken from this deposit.

Burning Test

Sample No. 129. Field Sheet No. 139.
Pigeon river T. 35 N., R. 2 W., Section 27.
Plasticity .237 gm. water per gm. clay.
Average linear drying shrinkage 7.7 per cent.
Average tensile strength air dried bricks about 170 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Hardness.	Color.
010	950	.431	0.5 %	Soft burned.....	Light pink
08	990	.439	−1.1	Soft burned.....	Very light pink
06	1,030	.460	−1.9	Soft burned.....	Light cream
04	1,070	.459	−1.9	Soft burned.....	Light cream
02	1,110	.462	−0.9	Soft burned.....	Light cream
1	1,150	.407	2.5	Soft burned.....	Light cream
3	1,190	.397	3.7	Soft burned.....	Cream with green cast
5	1,230	.326	6.4	Hard burned.....	Cream with green cast
8	1,290	.030	13.6	Vitrified started to melt..	Light olive

Molded easily and might be used as pottery clay.
Burned by H. W. Jackman.

CLARE COUNTY

The Farwell Portland Cement Company organized in 1901 practically completed a plant at Farwell when it was auctioned to pay debts, and the property is now owned by J. L. Littlefield, the former president. This plant was considering the use. of some boulder clay formerly used to make brick on the property of Edward McKenna in the SE¼ of Section 24, T. 17 N., R. 5 W. The red clay covers about 12 acres to a depth of 12 to 17 feet. It is underlain by water bearing sand. The following tests indicate that so far as the analysis is concerned this clay is suitable for cement, but boulder clay is generally unsatisfactory for this purpose because of other considerations. On burning, the clay has a marked tendency to swell almost as soon as it becomes hard burned. The material molds easily and seems to be fair material for brick or tile but must be burned carefully.

Chemical Analysis

Sample No. 84. Field Sheet 89.
Red clay Section 24, T. 17 N., R. 5 W.

Loss on ignition	5.72
Silica (SiO_2)	67.70
Iron (Fe_2O_3)	5.51
Alumina (Al_2O_3)	19.19
Lime (CaO)	0.66
Magnesia (MgO)	0.19
Alkalies (Na_2, K_2O)	2.35
	101.32

Analysis by H. W. Jackman.

Burning Test

Sample No. 84. Field Sheet No. 89.
Section 24, T. 17 N., R. 5 W.
Plasticity .331 gm. water per gm. clay.
Average linear drying shrinkage 14.4 per cent.
Average tensile strength about 180 lbs. per sq. in.
Heated for 5 hours at 750°C.

Cone No.	Cone Temp °C.	Porosity.	Linear Shrinkage.	Hardness.	Color.
010	950	.28	1.1 %	Soft burned	Salmon pink
08	990	.227	3.0	Hard burned	Red
06	1,030	.134	3.0	Hard burned	Darker red
04	1,070	.081	2.9	Hard burned.....	Dark red brown

Bricks began to swell at cone 06. Molded easily
Burned by H. W. Jackman.

The Clare Portland Cement Company, organized in 1901 as a New Jersey corporation with a capital of $1,000,000, planned to use a very calcareous local boulder clay in sections 5, 8, 9, and 18, T. 17 N., R. 4 W., of the following composition:[1]

	Top.	20 ft. down.	30 ft. down.	Under marl.
	%	%	%	%
Volatile	1.04	2.91	3.13	2.98
Silica (SiO_2)	65.05	47.69	45.60	50.40
Alumina (Al_2O_3)	25.00	15.00	15.85	22.10
Iron (Fe_2O_3)	5.80			
Lime ($CaCO_3$)	2.05	28.29	28.82	24.00
Magnesium ($MgCO_3$)	0.40	6.00	8.60	00.52

The leaching action of surface waters is evident in the relatively low lime in the sample from the top (2.05 per cent) compared to the high lime in the main part of the deposit, (28.3 per cent).

[1]Mich. Geol. Survey Vol. VIII, Pt. III, p. 296.

CLINTON COUNTY

Clinton County is almost entirely boulder clay, generally stony and unsatisfactory. Sample 1002 was taken from the property owned by John Strause, seven miles north of St. Johns, section 9, T. 8 N., R. 2 W., by trenching the

side of a large drainage ditch. The clay is red to blue in color and contains some pebbles. In some places the clay is covered with a few feet of sand; elsewhere the clay is at the surface. A well driven on H. S. Rue's property, across the road from the Strause farm, went through 48 feet of clay and then entered gravel.

Burning Test

Sample No. 1002. Field Sheet No. 1002.
Section 9, T. 8 N., R. 2 W.
Plasticity .255 gm. water per gm. clay.
Average linear drying shrinkage 7.6 per cent.
Average tensile strength about 85 lbs. per sq. in.
Apparent Sp. Gr. dry 2.53.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	950	.370	0.0 %	2.62	Soft burned.....	Salmon
08	990	.367	0.2	2.61	Soft burned.....	Salmon
06	1,030	.379	0.2	2.70	Soft burned.....	Salmon
04	1,070	.390	0.2	2.60	Soft burned.....	Salmon
02	1,110	.299	3.5	2.64	Hard burned....	Tan
1	1,150	.122	7.2	2.35	Hard burned....	Olive brown
3	1,190	.225	7.3	2.68	Hard burned....	Olive brown
5	1,230	.....	.....	.....	Viscous	

Brown clay with lime pebbles. Might be used for brick or tile if pebbles do not spoil the product.
Burned by H. W. Jackman.

At St. Johns the boulder clay in the northern part of the town was formerly used to make light red brick in two different yards. A brick plant on Moore's farm, NE¼ Section 8, T. 7 N., R. 2 W., formerly produced a good common red brick that was used in many of the old buildings in the town. This yard went out of business about 1882. Another yard was started by a Mr. Houghton in Section 9 a short distance north of the Grand Trunk. Later Pulfrey and Ananias Pouch operated this yard, which also produced a good common brick. This yard went out of business in 1897.

EATON COUNTY

The most extensive natural exposure of the Coal Measures shales in the State is near Grand Ledge, just northwest of the town in the bluffs overlooking the Grand River.[1]

The Grand Ledge Sewer Pipe Company now the American Sewer Pipe Co. was the first to use these shales. A. C. Lane[2] described these shales "close to the Spiritualist Camp Meeting Grounds'" (Sec. 3, T. 4 N., R. 4 W.) as follows:

"The section is
13 ft. stripping of till.
4 ft. gray shale.
1 ft. black shale passing into coal.
2 ft. white shale, so-called fire clay. The lower line of this white shale undulates so as to indicate that it is merely an alteration of the shale below.
4 ft. blue shale. This and the shale above the coal both contain nodules of kidney iron ore, sometimes showing some zinc blende. This also shows traces of ferns (Sphenophyllum cuneifolium).
1 ft. darker shale, the floor of the quarry.

"Below in the bluff the section is continued by twenty feet of light and dark thin bedded sandstones and shales, readily checking or cracking and slaking on weathering, down to a foot and a half of coal."

[1]Rominger, Geol. Surv. Mich. III, Pt. I, p. 131.

[2]Mich. Geol. Surv. VIII, Pt. I, p. 37, 1900.

	Black Carboniferous Shale.	Gray Carboniferous Shale.
Silica (SiO_2)	44.3 %	57.20 %
Alumina (Al_2O_3)	33.72	18.95
Iron (Fe_2O_3)	7.68	8.31
Lime (CaO)	1.11	0.83
Magnesia ($MgO + Mn_3O_4$)	1.50	1.83
Alkalies ($K_2O + Na_2O$)	2.00	2.70
(H_2O +organic)	17.64	9.00
Carbon dioxide (CO_2)	2.36	1.32
Sulphur (SO_3)	.....	0.12
	100.31	100.26

A new pit has been opened by the Briggs Company, on the northeast side of Grand River, in Section 3, T. 4 N., R. 4 W. The shale is over 50 feet thick. Eight and one-half feet down from the top of the shale there is a six inch seam of coal and 24 feet from the top an 18 inch seam. Just over this lower coal seam there is a semi-refractory shale that burns to a light buff very hard brick and would make excellent paving blocks. It is very similar in burning properties to the shale found at Williamston, Ingham County. This stratum in the shale is very thin and it would be impractical to separate it from the main shale which is used by the Briggs Company to make the "Old Rose Mission" face brick.

This plant was originally built by the Baker Clay Products Company, to make tile, but the plant equipment is much better adapted for the present product, face brick. The shale is picked up by an Erie Steam Shovel loaded on narrow gage cars which are drawn up to the plant. The shale is then run through a roll crusher, two dry pans equipped with feeders, tempered in a pug mill, and extruded as side cut brick from an auger machine. The column of clay is scratched as it issues from the die to give the brick a, roughened surface which is very popular. The green brick are dried in an intermittent tunnel drier heated by separate fires. Burning is done in a 16 chamber Raymond Continuous Kiln with advanced heat for water smoking.* The kiln operates on a 120 hour cycle, with one chamber each, water smoking, oxidizing, burning, and cooling. Each chamber has a capacity of about 65,000 brick. The plant has a daily production of 40,000 to 43,000 brick. The product is an excellent brick, running from salmon through all shades to a dark vitreous color, that is always in demand. The plant was running to capacity in August, 1922, when many clay plants were down or at least on limited production, due to the coal shortage. Sample 76 represents the mixed shale as used at the Briggs plant. It has a wide burning range with a good color and is good material for face brick and tile.

*This kiln Installation is described under Continuous Kilns (see Chapter VII).

Burning Test

Sample No. 76. Field Sheet No. 76.
Section 3, T. 4 N., R. 4 W.
Plasticity .208 gm. water per gm. clay.
Average linear drying shrinkage 4.5 per cent.
Average tensile strength about 40 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Hardness.	Color.
08	990	.347	0.2 %	Soft burned.....	Salmon
06	1,030	.359	0.2	Soft burned.....	Salmon
04	1,070	.344	0.8	Soft burned.....	Salmon
02	1,110	.312	3.2	Soft burned.....	Salmon
1	1,150	.265	4.3	Hard burned	Dull red
3	1,190	.265	4.9	Hard burned....	Red brown
5	1,230	.211	6.1	Hard burned....	Red brown
7	1,270	.192	5.9	Hard burned....	Reddish brown
9	1,310	.148	2.2	Over burned....	Brown gray

Good material for face brick and vitrified tile.
Burned by H. W. Jackman.

Chemical Analysis

Sample No. 76. Field Sheet No. 76.
Shale, Section 3, T. 4 N., R. 4 W.

Loss on ignition	8.94%	8.94%	8.94%
Silica (SiO_2)	65.60	65.25	65.35
Iron (Fe_2O_3)	6.57	6.07	6.32
Alumina (Al_2O_3)	19.03	19.13	19.08
Lime (CaO)	0.68	0.77	0.72
Magnesia (MgO)	0.06	0.07	0.06
Alkalies (Na_2O, K_2O)			0.88
			101.35

Analysis by H. W. Jackman.

This shale quarry was carefully sampled and analyzed as a possible material for Portland cement. The following analysis of the different strata are given to show how the shale varies in analysis even in the same quarry:

Sample Shale, First Stratum, in a vein of about 30" above the coal:

Analysis of Shale		*Analysis of water soluble*
Silica	65.04%	Sulphates present; trace of chlorides present; no carbonate present.
Ignition loss	6.15	
Ferric oxide	5.67	
Alumina	18.47	*Metals*
Calcium carbonate	2.14	Sodium and some organic matter present.
Magnesium carbonate ...	2.07	
Water soluble	.06	
	99.60%	

Sample Buff Shale, 4 ft. stratum (2d stratum above coal).

Analysis of Shale		*Analysis of water soluble*
Silica	64.50%	Volatile chloride present.
Ignition loss	6.91	Non-volatile chloride present.
Ferric oxide	9.30	Sulphate present.
Alumina	15.90	Carbonate present.
Calcium carbonate	1.64	
Magnesium carbonate ...	1.69	*Metals*
Water soluble	.08	Sodium and organic matter present.
	100.02%	

Sample Shale, 20" stratum above buff strata (3d stratum above coal.

Analysis of shale		*Analysis of water soluble*
Silica	76.63%	Volatile chlorides present.
Ignition loss	2.13	Non-volatile chlorides absent.
Ferric oxide	3.32	Sulphate present.
Alumina	11.70	Carbonate.
Calcium carbonate	2.62	
Magnesium carbonate ...	2.57	*Metals*
Water soluble	.15	Sodium, potassium trace
		Organic matter present.
	99.72%	

Sample Shale, 4th stratum above coal, which goes to top of bank.

Silica	62.98%	Considerable volatile chloride present.
Ignition loss	5.07	
Ferric Oxide	6.86	Non-volatile chloride present.
Alumina	18.63	Sulphate present.
Calcium carbonate	3.74	No corbonate present.
Magnesium carbonate ...	2.42	
Water soluble	.09	*Metals*
		Sodium, trace potassium and organic matter present.
	99.79%	

Sample shale, Crop shale on same stratum as the last.

Silica	64.83%	Non-volatile chlorides present.
Ignition loss	5.54	Non-volatile chlorides present.
Ferric oxide	6.64	Sulphate present.
Alumina	19.42	No carbonate present.
Calcium carbonate	1.91	
Magnesium carbonate ...	1.00	*Metals*
Water soluble	.09	Sodium and organic matter present.
	99.63%	

Sample shale, blends in over 4th stratum above coal at different points of the quarry.

Silica	68.68%	Non-volatile chlorides present.
Ignition loss	4.43	Sulphates present.
Ferric oxide	4.43	No carbonate present.
Alumina	18.69	
Calcium carbonate	2.35	*Metals*
Magnesium carbonate ...	.94	Sodium present; trace potassium present.
Water soluble	.10	Organic matter present.
	99.62%	

Sample Scum.

Silica	84.97%	Ammonium chloride present.
Ignition loss	.26	Non-volatile chloride present.
Ferric oxide	3.32	Sulphate present.
Alumina	6.64	No carbonate present.
Calcium oxide	2.41	
Magnesium oxide	.70	*Metals*
Sulphate as SO_3.....	.42	Sodium present.
Water soluble	1.34	Trace potassium present.
	100.06%	Organic matter present.

The Grand Ledge Clay Products Company uses the same shale for making sewer pipe, conduits, flues, coping, etc. Their plant is just north of the Pere Marquette Railroad about one and one-fourths miles west of Grand Ledge. The sand overburden is removed by a gasoline tractor. The shale is blasted and picked up by hand. It is prepared in one dry pan and two wet pans, and extruded in an auger machine or a steam sewer pipe press. The ware is dried in the factory on steam heated, wood slatted floors, and burned in downdraft kilns. The kiln yard includes 14 thirty foot

kilns, and one forty foot kiln. The plant was down in 1922 during the coal shortage.

The American Sewer Pipe Company south of the Pere Marquette Railroad, about one mile west of Grand Ledge was burned in November, 1924. It is part of the American Vitrified Products Company as is the plant at Jackson. This organization has about 30 plants throughout the country, with headquarters in Akron, Ohio. This plant was the oldest plant at Grand Ledge and is the same plant mentioned by Lane as the Grand Ledge Sewer Pipe Company. The plant was equipped with one steam press and one auger tile machine and 14 kilns. The products are similar to those made by the Grand Ledge Clay Products Company, sewer pipe, drain tile, coping, and flues. This plant was also closed in 1922 due to the coal shortage.

Sample 8 was obtained from the property of G. F. Blacksten, two and one-half miles north of Potterville on the Grand Ledge road. This clay is found under one foot of muck and thirty inches of marl, over an area of about 40 acres. It is evidently a lake clay and seems to be suited for brick or tile. Being located in low ground recovery of this clay would probably present a serious drainage problem.

Burning Test

Sample No. 8. Field Report Sheet.
G. F. Blacksten, Potterville, R. F. D. No. 1.
Water of Plasticity .271 gm. per gm. clay.
Average linear drying shrinkage 6.2 per cent.
Sample held at 750°C for 4 hours.
Tensile strength of air dried samples, about 145 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Fired Linear Shrinkage.	Hardness.	Color.
010	950	.445	0.2 %	Sfo6 burned.....	Pink
08	990	.432	−1.1	Soft burned.....	Light pink
06	1,030	.466	−0.18	Soft burned.....	Pink cream
04	1,070	.452	0.0	Soft burned.....	Light cream
02	1,110	.450	−1.1	Soft burned.....	Cream
1	1,150	.402	2.7	Hard burned....	Light brown
3	1,190	.352	5.1	Hard burned....	Brown
5	1,230	.213	Cracked	Vitrified.....	Brown
7	1,270	.024	Cracked	Vitrified.....	Olive brown
8	1,290	melted		.....	.....

Easily worked and molded. Air dried brick is bluish gray and cracks easily at higher temperatures.
Burned by H. W. Jackman.

Sample 73 is also from a lake clay found at the northeast corner of Narrow Lake, nine miles southwest of Eaton Rapids, on the property of F. C. Hunt, in the SW¼ Section 27, T. 1 N., R. 4 W. The clay is 8 feet or more in thickness, plastic, and has an extent of 10 acres or more. It is covered by a few inches of sandy gravel and lies at about the lake level. The sample represents the upper 3 feet of the deposit. Some marl was reported on the west side of the lake.

Burning Test.

Sample No. 73. Sheet No. 73.
Plasticity .235 gm. water per gm. clay.
Average linear drying shrinkage 4.7 per cent.
Average tensile strength 130 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Hardness.	Color.
010	950	.330	2.1 %	Soft burned.....	Salmon
08	990	.364	1.3	Soft burned.....	Dull salmon
06	1,030	.372	1.0	Soft burned.....	Cream
04	1,070	.333	1.9	Soft burned.....	Cream brown
02	1,110	.288	3.2	Hard burned....	Light brown
1	1,150	.086	12.0	Hard burned....	Gray brown
3	1,190	Very low	14.7	Vitrified.....	Olive brown
5	1,230	....	....	Melted.....	Olive brown

Clay contains lime lumps which show up white in burned product. Molded easily.
Burned by H. W. Jackman.

Chemical Analysis.

Sample No. 73. SW¼ Sec. 27, T. 1, N., R. 4 W., Eaton Rapids.
Field Report Sheet No. 78.
Upper 3 feet of clay NE end Narrow Lake, Section 27, T. 1 N., R. 4 W.

Loss on Ignition	15.99
Silica SiO_2	50.15
Alumina Al_2O_3	13.66
Iron Fe_2O_3	4.84
Lime CaO	12.10
Magnesia MgO	1.27
Na_2O K_2O	1.99
Total	100.00

Analysis by H. W. Jackman.

The morainic clay was formerly used by the Olivet Brick & Tile Company, just west of Olivet, in SE¼ Section 30, T. 1 N., R. 5 W. Nothing is left of the old yard but an old boiler, a hole in the ground, and a pile of disintegrating brick. The clay deposit is about 5 to 10 feet thick over about 15 acres. It is red with some blue clay intermixed. There is a large amount of similar clay throughout the district. There is no overburden and the clay is underlain by fine sand.

Burning Test.

Sample No. 20. Field Sheet No. 17.
SE¼ Section 30, T. 1 N., R. 5 W.
Plasticity .287 gm. water per gm. clay.
Average linear drying shrinkage 10.5 per cent.
Average tensile strength about 124 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Hardness.	Color.
08	990	.351	0.0 %	Soft burned.....	Salmon
06	1,030	.342	0.0	Soft burned.....	Salmon
04	1,070	.342	0.0	Soft burned.....	Salmon
02	1,110	.242	4.8	Hard burned....	Pale red
1	1,150	.008	9.3	Vitrified.....	Chocolate
3	1,190	.017	8.4	Vitrified.....	Chocolate
5	1,230	....	...	Melted	.....

Molded easily. Suitable for brick and tile.
Burned by H. W. Jackman.

The Alpha Portland Cement Company plant is just southwest of Bellevue, east of the road to Battle Creek, near the Grand Trunk Railroad, NE¼ Section 7, T. 1 N., R. 6 W. The clay is obtained from SE¼ Section 7, T. 1 S., R. 6 W., Calhoun County.

The plant uses the dry process in 8 kilns 6½ x 60 feet. The clay and limestone are mixed and crushed, dried, and ground by preparatory mills. This mixture is then

stored, sampled, and analyzed, and properly proportioned or "corrected," mixed and reground and calcined. The daily capacity is 2,000 bbls., with an average coal consumption of 109 pounds per barrel of clinker.

EMMET COUNTY.

Emmet County is generally sandy and seems to contain practically no workable deposits of Pleistocene clay.

The Antrim shale formation underlies the southern 5 or 6 miles of the county and is the most promising ceramic material to be found therein. This shale outcrops on the north side of Walloon Lake as a rusty dark brown shale running black in streaks, under about 3 feet of moraine and glacial drift composed of five inches of soil and two or three feet of sand and gravel. The upper 30 inches of the shale is weathered to a plastic clay. The exposure was opened by the digging of a road patrol who used it as road material. The shale extends all around this side of the lake in cliffs about 30 feet above the level of Walloon Lake, which is about 96 feet above Lake Michigan. Sample 95 was taken from this formation in section 36, T. 34 N., R. 6 W.

Chemical Analysis.

Sample No. 95. Field Report Sheet No. 102.
Reddish dark brown shale, Section 36 (southern edge), T. 34 N., R. 6 W.

Loss on Ignition	10.37%
Silica (SiO_2)	60.50
Iron Oxide (Fe_2O_3)	5.77
Alumina (Al_2O_3)	21.93
Lime (CaO)	0.48
Magnesia (MgO)	0.13
Alkalies (Na_2—K_2O)	0.60
	99.78

Analysis by H. W. Jackman.

The chemical analysis shows a ratio of silica to alumina and ferric oxide of 2.18 and a very low content of magnesia, both of which indicate that the Antrim shale at this place is suitable for use in the manufacture of Portland cement.

Burning Test.

Sample No. 95. Field Sheet No. 102.
Reddish dark brown shale, section 36 (southern edge), T. 34 N., R. 6 W.
Water of plasticity .275 gm. water per gm. clay.
Average linear drying shrinkage 5.4 per cent.
Samples held at 750°C. for 5 hours to burn out bituminous material.

Cone No.	Cone Temp. °C.	Porosity.	Fired Linear Shrinkage.	Hardness.	Color.
010	950	.356	3.0%	Soft burned....	Salmon
08	990	.199	8.9	Hard burned....	Light red
06	1,030	.125	11.1	Hard burned....	Brick red
04	1,070	.056	13.2	Hard burned....	Dark red
02	1,110	.034	12.1	Vitrified.....	Dark red
1	1,150	.019	9.9	Vitrified	Dark red brown
3	1,190	.017	4.4	Vitrified	Dark red brown
5	1,230	.025	1.0	Over burned....	Chocolate
8	1,290	.163	−20.2	Over burned....	Chocolate.

Brown shale. Vitrifies between cones 02 and 1. Burning test by H. W. Jackman.

The burning test shows the shale to have a wide burning range of over 6 cones, developing a uniform red brown color in a hard burned brick of uniform size from cone 06 to cone 1. The dry ground shale does not mold easily, so that for extruding brick or tile in an auger machine it would probably be necessary to grind the shale in a wet pan or allow the shale to weather thoroughly to develop the desired plasticity. If treated in some such manner to develop its plasticity, the Antrim shale at this place would make excellent face brick or tile. The Antrim shale is always bituminous and must be carefully oxidized to avoid early failure in burning. The small testing briquettes were completely oxidized in about 5 hours when heated at 750°C. in a strong oxidizing atmosphere.

The analysis of this shale shows it to be practically free from the common fluxing agents—lime, magnesia, and the alkalies—and it seems probable that, if the iron could be removed, the remaining aluminum silicate would be more refractory than the original shale. An interesting experiment was conducted on this sample of Antrim shale by Mr. H. W. Jackman while testing the Michigan shales at the University of Michigan. The following is quoted from his report of the experiment:

"Treatment.

In order to remove the iron and the small amount of other fluxing agents from the shale it was thought best to treat the shale with hydrochloric acid.

Three batches of the shale were treated, the first with concentrated hydrochloric acid at room temperature, the second with concentrated hydrochloric acid heated to about 80 to 90 degrees C., and the third with dilute acid made by mixing half and half concentrated hydrochloric acid and water and heated to the same temperature. All three batches were treated for 7 days, but it is quite probable that a shorter treatment would have accomplished the same results. At the end of this period the acid was filtered off, the clay washed free of acid, and made up into small bricks about 2 inches long, and one square inch in cross section. The water of plasticity and drying shrinkage were determined. The bricks were then fired in the laboratory down-draft, testing kiln, to determine the shrinkage, porosity, and melting point.

Results of Firing.

Most of the samples began to slag with the brick on which they were supported. Two samples were saved, however, and these were carried to the higher temperatures.

The batch that was treated with hydrochloric acid in the cold was not much improved. By the time the furnace had reached 1300°C. the samples had swelled and soon afterwards they melted.

The bricks made from the shale treated with concentrated hydrochloric acid, and with dilute acid,

at 80 to 90 degrees centigrade, behaved practically the same. Samples taken between cones 8 and 15 had the following properties:

Sample heated with concentrated hydrochloric acid at 80° to 90°C.

Cone.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Hardness.	Color.
8	1,290	.347	15.2 %	Hard burned....	Cream (brown cast)
11	1,350	.342	13.6	Hard burned....	Cream (brown cast)
14	1,410	.331	12.7	Hard burned....	Cream (brown cast)
15	1,430	.326	12.1	Hard burned....	Cream (brown cast)

Sample heated with dilute hydrochloric acid at 80° to 90°C.

Cone.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Hardness.	Color.
8	1,290	.338	15.8 %	Hard burned....	Cream (brown cast)
11	1,350	.319	14.6	Hard burned....	Cream (brown cast)
14	1,410	.331	14.0	Hard burned....	Cream (brown cast)
15	1,430	.299	12.6	Hard burned....	Cream (brown cast)

It is seen that over this range of 120 degrees C., at a higher temperature than that at which the untreated shale failed (cone 8) the samples treated with hot acid were still standing up well. They seemed to be swelling slightly but were not nearly vitrified, as shown by the high porosity.

The two bricks that did not slag with the improper support were heated to Seger Cone No. 23 or about 1600°C. The bricks showed some signs of vitrification between cones 20 and 21. After they had remained at a temperature corresponding to cone 23 down for some time, the interior of the bricks were still firm and hard although the surface was soft and glazed. At this point the bricks had nearly reached the limit of their firing range.

A sample of each batch was analyzed and compared to the analysis of the original shale. The three analyses are given and compared below:

	Original.	Treated with HCl cold.	Treated with HCl at 80-90 degrees C.
Loss on Ignition	10.37 %	11.01 %	9.87 %
SiO_2	60.50	67.02	83.65
Fe_2O_3	5.77	2.70	0.58
Al_2O_3	21.93	16.10	5.57
CaO	0.48	0.35	0.33
MgO	0.13	0.10	Trace
Na_2O and K_2O	0.60	.....	.....

The cold acid removed half of the iron, and nearly one-third of the alumina. The hot acid removed nearly all of the iron and three-fourths of the alumina. Silica, lime, magnesia, and the material which came off as "Loss on Ignition" were not affected much in either case. Silica appears to have increased because, of the large loss of alumina and iron.

Conclusions. As these two constituents, alumina and iron oxide, are the only ones which were removed, and as small percentages of iron oxide are known to be quick fluxing agents, it seems quite probable that the removal of the iron caused the change. The samples treated in the cold had a part of the iron extracted and stood up better than the original material, but there was still enough iron oxide present to cause them to fail at cone 9. The removal of alumina probably had little to do with the change, as the Al_2O_3—SiO_2 equilibrum diagram shows little difference in the melting points over the range of composition indicated by the above analyses."

The treated shale should probably be classed as a class one fire clay because of its burning properties, although it would probably fail below cone 30. This experiment indicated that the Antrim shale in Emmet County is unfitted for use as a refractory material probably because of its iron content. It is obviously impracticable to remove the iron for the purpose of using the shale as a refractory material, but this experiment is of scientific interest as indicating that the high iron content of the Upper Devonian shales is probably the one factor which spoils them as refractory material.

The Petoskey Portland Cement Company has its plant two miles west of the city of Petoskey on the P. M. Railroad, between Little Traverse Bay and State Highway M-11, in section 3, T. 34 N., R. 6 W.

This plant commenced operation in March 1921, and was the first cement plant designed and built with waste heat boilers to supply all the power necessary for plant operation.* Since that time many plants have installed waste heat boilers. About 85 to 90 per cent of the power requirements are supplied by the waste heat boilers.

As the power for grinding is available only when the kiln is running, the clinker must be ground as produced. At Petoskey large silos are used for storing the ground clinker during the winter months of light demand. These silos have a capacity of about 225,000 barrels or about 3½ months' production.

This plant uses the wet process, feeding a slurry containing 33 per cent moisure to two kilns 150 feet long and ten feet in diameter. The daily capacity of the plant is about 2300 barrels. At the time the plant was visited in the summer of 1922 the plant was not running at full capacity due to the coal shortage at that time.

Limestone obtained from the local quarry is loaded on 10-ton side dumping quarry cars and hauled to the crushing plant by a 40-ton saddle-back locomotive. The limestone is first crushed in a No. 12 Gates Gyratory crusher and screened. The oversize (over 2½ inch) is crushed in three No. 5 gyratory crushers, and screened. Large quantities of limestone are available for shipment in addition to that used by the cement mill. The crushing plant is driven by one 400 H.P. three phase motor. Crushed limestone is stored in the raw storage building over an 8 x 8-foot tunnel.

Shale is brought in on railroad cars from Ellsworth, dumped into a hopper and conveyed to the dry disintegrator. From the disintegrator the shale is conveyed to the raw storage building.

The shale and limestone are drawn out of storage through gates in the roof of the tunnel into separate hoppers feeding a 24-inch belt conveyor. This conveyor discharges to a bucket elevator which carries the shale and limestone to bins over the ball mills. As the raw material is fed to the mills the proper amount of water (32-33 per cent) is added.

*Chem. and Met. Eng. 31 N. 15, p. 570, October 13, 1924.

The mills are Allis-Chalmers "com-peb" mills 7 feet in diameter and 22 feet long having 10 tons of chilled steel balls 2½ to 5 inches in diameter in the preliminary grinding compartment and 30 tons of 1¼-inch balls in the finishing compartment.

The mills are continuous in operation, rotating at 20 r.p.m. The slurry from these mills is finely ground (96 per cent through 100 mesh and 91 per cent through 200 mesh).

The slurry is then pumped to four correcting concrete tanks 20 feet in diameter and 38 feet high. To prevent settling each tank is agitated once an hour by air admitted through six or eight pipes near the bottom. The slurry in these tanks is sampled, analyzed, and corrected for composition by adding limestone or shale as may be necessary. The corrected slurry is pumped to the "mud" tanks by means of an automatic blow case. From these tanks it is fed to the kilns through an orifice in a trough. This gives very poor feed control and it is planned to synchronize the feed with the operation of the kiln.

The kilns are insulated with "silocel" brick between the steel shell and the refractory lining. The hot clinker discharged from the kilns is passed through an air cooler 6 feet in diameter and 60 feet long. As the clinker leaves the cooler the proper amount of gypsum is added to bring the total sulphur trioxide (SO_3) up to 1.9 to 2.1 per cent. The clinker passes immediately to the compartment ball mills as the clinker must be ground as made.

As the clinker leaving the ball mills is hot a screw conveyor is necessary to convey the ground clinker to the storage silos (a belt conveyor might burn up).

The coal crushing plant is at the opposite end of the plant from the raw storage building. The coal is crushed, then dried in a coal fired muffle drier which consumes about one per cent of the coal. The drier is supplied with a dust collector and cyclone which discharge into the elevator lifting the dry coal to hoppers feeding the Fuller Lehigh mills. These mills are centrifugal roll mills which use large balls held in sockets as rollers. These balls are rolled at high speed around the inside surface of the grinding ring. The coal is fed into a center cage and thrown against the ring. Attached to the rotating cage is a series of fan blades which elevate the finely ground coal and force it against the screen directly above the fan. The fine coal passes through the screen and the coarse coal falls back into the center and is again thrown between the balls and ring.

From the four Lehigh mills the coal is elevated to a storage bin and screw conveyed to the hoppers feeding the kiln burners. These burners consist simply of a pipe through which the primary air is blown and into which coal is fed at a regulated speed. Secondary air is drawn through the clinker cooler and is considerably preheated.

The plant is well located with respect to transportation facilities, which is really the most important consideration in locating a cement plant, and also in respect to raw material. The plant, however, had not taken full advantage of the nearby deposits of shale, apparently preferring to ship in shale from the Ellsworth quarry to using the local Antrim shale.

The analysis of the stock average of Ellsworth shale used at the plant as given by the company's chemist is as follows:

Ignition loss	11.40%
Silica (SiO_2)	49.57
Iron Oxide + Alumina	23.48
Lime (CaO)	6.60
Magnesia (MgO)	5.87
	96.92

The ratio of silica to alumina plus iron oxide in the Ellsworth shale (2.11) is about the same as that in the sample of Antrim shale (No. 95) taken from Walloon Lake and the latter has the decided advantage of much less magnesia. If the Antrim shale is sufficiently uniform in composition it would seem to be a somewhat better material for the Petoskey Cement Company not only because of its locality but also in the low magnesia content. Large ball-like concretions, however, in the Walloon Lake shale deposits might be numerous and cause serious quarrying difficulties. The exact safe limit of magnesia is not known but it is generally stated to be not over 4 per cent in the clinker. Of course this company can keep well within this limit using the Ellsworth shale and a pure limestone.

The lime burning plant of the Antrim Iron Company is in the south central part of section 1, T. 34 N., R. 6 W. In the lime quarry under 6 feet of blue shale containing many fossils and some small pyrite crystals are found 30 to 32 feet of limestone. This shale has the same appearance and is found in the same formation as that noted in the bottom of the lime quarry at Charlevoix. The shale is some member of the Traverse formation underlying the Antrim shale, probably the Upper Traverse or Thunder Bay member, and should not be confused with the Bell shale, an older member of the same formation.

GENESEE COUNTY.

In northwestern Genesee County the surface or glacial deposits are thin, allowing the economic working of the Coal Measures shales.

The quarry of the old Saginaw Clay Products Company is located about a mile and a half north of Flushing on the Flint river in Section 22, T. 8 N., R. 5 E. This quarry was described by Ries*. The shale is very similar to that

worked by the New Corunna Brick Company east of Corunna. The upper shale (R222) is dark gray, fine grained, and somewhat brittle. This is covered by about five feet of soil and underlain by a thin seam of coal. It contains some sand often in the form of thin seams.

*Mich. Geol. Survey VIII, Pt. I, p. 29.

Burning Test.

Sample (Ries) 222. Ground to pass 30 mesh.
Section 22, T. 8 N., R. 5 E.
Water of plasticity 20 per cent.
Air shrinkage 3 per cent.
Tensile strength 35-40 lbs. sq. in.
Soluble salts 0.3 per cent.

Cone.	Total shrinkage.	Burns.	Color.
05	5 %		
1	7 %	Hard	Red
6	9 %	Vitrified	Deep red
8		Viscous	

The lower shale (R183) underlying the coal has a lighter color, is softer and has a more open texture. It is more plastic and also more refractory than the upper shale.

Burning Test.

Sample (Ries) 183. Ground to pass 30 mesh.
Section 22, T. 8 N., R. 5 E.
Water of plasticity 20 per cent.
Air shrinkage 5 per cent.
Tensile strength 60-65 lbs. sq. in.

Cone.	Total Shrinkage.	Burn.	Color.
1	10 %	Hard	Gray Buff
5	11 %		
7	....	Vitrified	
11	....	Viscous	

Clay contains some iron carbonate concretions and considerable fine mica.

The same sample ground to pass a sixty mesh screen tested as follows:

Burning Test.

Sample (Ries) 183. Ground to pass 60 mesh.
Section 22, T. 8 N., R. 5 E.
Water of plasticity 22 per cent.
Air shrinkage 5% per cent
Average tensile strength 55-60 lbs. sq. in.

Cone.	Total Shrinkage.	Burn.
1	10 %	Hard
5-6	....	Vitrified
10	....	Viscous

Chemical Analysis

Sample (Ries) 222.
Section 22, T. 8 N., R. 5 E.

	Upper Shale	Lower Shale* (Burned?)
	%	%
Silica (SiO_2)	54.50	70.55
Alumina (Al_2O_3)	30.73	21.20
Iron (Fe_2O_3)	3.50	3.20
Lime (CaO)	1.05	1.90
Magnesia (MgO)	1.69	1.50
Soda (Na_2O)	.8	.74
Potash (K_2O)	2.2	.90
Water (H_2O)	5.51	

*Eighteenth Annual Report U. S. Geol. Survey, Pt. V, p. 68 from Saginaw Clay Man. Co. H. and W Heim, analysts.

The lower shale is very similar to that found in Williamston, Ingham County, and is suitable material for the manufacture of paving block. Mixed with about an equal amount of the upper shale it was formerly shipped to Saginaw and used for this purpose. The shale bench was blasted and the broken pieces loaded on narrow gage cars. These cars were drawn to the base of an incline by horses, and drawn up the incline by a wire cable to above the railroad siding where they were dumped into the railroad cars.

The quarry ceased operations about 1916 when labor became scarce. The owners made money in other ventures and have lost interest in the quarry, which has produced nothing since the war. It is now flooded.

The surface clays have been worked at a number of places throughout the county. For some years Stewart and Kirby ran a tile plant at Otter Lake, ceasing operations in 1915. Leonard and Charles Scholl made brick near Clio.

At Duffield, T. 6 N., R. 5 E., J. J. Middlesworth tried to make brick from the thin boulder clay. The attempt was unsuccessful and the machinery was removed by the manufacturers. Similar clay was used to make tile by Fred W. McCann at Gaines just south of the Grand Trunk Railroad in SW¼ section 32, T. 6 N., R. 5 E. Here the boulder clay lies under the village to a depth of 4 to 8 feet and could not be obtained for tile making when the small pit was exhausted in 1911.

The same kind of boulder clay (sample No. 153) was also used by Frank Sharp to make tile three miles north of Linden, SE¼ section 31, T. 6 N., R. 6 E. Here in section 31 are about 40 acres of good clay free from stone. The better clay lies toward the west of the deposit where it is 10 to 12 feet deep. Generally the clay runs from 4 to 10 feet thick and is yellow to brown in color except for the lower 12 to 18 inches which are blue. The following burning test indicates that the clay is good material for brick and tile and could be used successfully to make a dark red or chocolate hard burned or face brick.

Burning Test.

Sample No. 153. Field Sheet No. 171.
Section 31, SE¼, T. 6 N., R. 6 E.
Plasticity .294 gm. water per gm. clay.

Average linear drying shrinkage 11 per cent.
Average tensile strength about 125 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.331	0.4 %	1.70	Soft burned	Salmon
08	990	.331	0.0	1.69	Soft burned	Salmon
06	1,030	.318	1.1	1.72	Soft burned	Salmon
04	1,070	.304	2.1	1.76	Soft burned	Light red
02	1,110	.216	4.7	1.93	Hard burned	Red
1	1,150	.102	8.7	2.16	Hard burned	Brown
3	1,190	.017	8.7	2.17	Vitrified	Dark brown
5	1,230	.016	6.9	2.07	Vitrified	Chocolate
7	1,270	....	---	....	Viscous	.....

Olive brown clay. Good material for brick and tile.
Molded easily.
Burned by H. W. Jackman.

This clay was tempered with water in the pit and allowed to stand overnight in a bin before working. The clay was fed into a 9A Brewer auger tile machine, equipped with automatic cut-off for making drain tile up to 18 inches in diameter. The tile were dried in a closed drying shed and turned end for end to promote even drying. One down-draft kiln was used for burning. This plant made an excellent tile from the clay described above, until it was shut down in 1917, because no help could be obtained at that time. The equipment was in good condition in 1922.

Clay near Grand Blanc on the Pere Marquette about six miles south of Flint was formerly used until it was all consumed. The equipment was then purchased by the Flint Clay Products Company of 629 East Third Street, Flint. This company went bankrupt. Neither of these clays is as good as that used by Frank Sharp north of Linden. The Atlas Clay Products Company (Fred Goodrich) made good brick and drain tile from boulder clay near Atlas on the D. U. R. about eight miles southeast of Flint.

The Detroit Portland Cement Company organized March 7, 1900, with a capital of $1,000,000, and the Egyptian Portland Cement Company organized June 29, 1900, with an equal capitalization, built cement plants near Fenton. The Twentieth Century Company (organized Feb. 2, 1901) plant never materialized. The two former were later reorganized as the Aetna and New Egyptian Cement Companies respectively. These plants formerly obtained their clay from local lake deposits. The following analysis is representative of the local clays:*

	%
Loss on Ignition	15.55
Silica (SiO_2)	49.34
Alumina (Al_2O_3)	14.50
Iron (Fe_2O_3)	5.37
Lime (CaO)	9.75
Magnesia (MgO)	4.77
Sulphur (SO_3)	0.13

*Analysis by E. D. Campbell, Bull. 522, U. S. Geol. Surv., p. 222 (1913).

At present these plants get their clay from the clay pit northeast of Corunna via the Grand Trunk R. R. They are still using marl obtained from Marl Lake and Silver Lake south of the plants.

The Aetna Cement Company is located just north of the Grand Trunk railroad in NW¼ Section 27, T. 5 N., R. 6 E. The plant is equipped with two 175 foot kilns 10 feet in diameter, with a combined capacity of about 1600 bbls. per day. The slurry fed to the kilns contains about 50% of water. About 200 pounds of coal are required to burn a barrel of cement under these conditions.

The New Egyptian Cement Company is south of the railroad about opposite the other plant. This plant is equipped with nine 60-foot kilns about 6 feet in diameter having a combined capacity about equal to that of the two larger kilns of the Aetna Cement Company (1600 bbls. per day). The New Egyptian plant feeds a slurry of about 47-48 per cent water content which requires about 230-250 pounds of coal per barrel of cement. No wash mills are used on the clay.

Detroit or Aetna Cement Company at Fenton. The marl is dredged from the lakes and loaded into cars which are drawn up an inclined trestle and dumped into a hopper over the stone separator. The separator removes stones, grass, sticks, etc., from the marl which is then run into storage tanks. The clay received on cars is disintegrated, pugged, washed, and mixed with the marl in proper proportions in a mixing pit. From these pits the mix is pumped to iron tanks which feed into the tube mills. The slurry is then fed to the kilns at constant pressure.

The clinker falls into regenerative cooling pits. Two pits are supplied for each kiln. As one pit received clinker from the kiln cold air is drawn up through the pit cooling the clinker and becoming preheated before entering the kiln as secondary air, and the other pit is discharged into cars running in a tunnel below the pits. These cars are drawn out of the tunnel, elevated and discharged into bins. From these bins the clinker is ground successively in ball mills and tube mills.

The Aetna Portland Cement Company at Fenton (the old Detroit Portland Cement Company) uses clay from Kirby near Corunna and Marl from Silver Lake. The marl is transported on scows and pumped to the mill by compressed air. The following analysis of the clay was supplied by Mr. Dibble, Chief Chemist:

Loss on ignition	14.00%
Silica (SiO_2)	50.00
Alumina (Al_2O_3)	16.78
Iron (Fe_2O_3)	5.22
Lime (CaO)	7.60
Magnesia (MgO)	4.35

The clay is ground in a dry pan, mixed with marl, and the slurry then finely ground in tube mills and run to storage bins.

The plant is equipped with two Allis-Chalmers Rotary Kilns 175 feet long and 10 feet in diameter, having a combined capacity of 1500 barrels, using 165 to 170 pounds of coal per barrel. The same size kiln at the Bay City Plant using limestone will produce one and one-half times as much cement using 130 pounds of coal per barrel.

At Flint the Titan Spark Plug Co. imports high grade clays and refractory mineral materials for the manufacture of spark plugs.

GLADWIN COUNTY

Christ Korkoske made brick for a few years previous to 1912 from boulder clay west of Gladwin. The clay covers about 30 acres in the hills. The upper two to three feet is red burning. Under this red clay there are from two to twelve feet of clay that burns cream. This difference in color of the burned clay from the upper part of the bed is noticed with nearly all of the glacial clays of the State, and is due to the action of surface water which leaches the lime out of the upper part of the clay, allowing the red color to develop on burning. The low content of lime in the upper weathered part of a clay bank of calcareous clay is very evident in the analysis of the clay reported by the Clare Portland Cement Company.

Korkoske made stiff mud brick and tile using Brewer conical rolls, a Kellogg (Adrian) auger machine driven by a 40 H. P. steam engine. The green ware was dried in a shed which is now used as a barn. At the time the plant was closed labor was hard to obtain and the demand for brick and tile was limited. At the present time market conditions are improving.

The weathered upper part of the clay is better than the lower stratum. The following test is of a sample from the lower cream burning clay, and indicates that the clay is fairly good material for brick and tile.

Burning Test

Sample No. 88. Field Sheet No. 93.
Section No. 3, T. 18 N., R. 2 W.
Plasticity .284 gm. water per gm. clay.
Average linear drying shrinkage 9.5 per cent.
Average tensile strength about 140 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.390	2.1 %	1.62	Soft burned.....	Salmon
08	990	.396	1.8	1.61	Soft burned.....	Cream
06	1,030	.410	1.8	1.60	Soft burned.....	Cream
04	1,070	.399	2.3	1.63	Soft burned.....	Cream
02	1,110	.371	3.8	1.70	Soft burned.....	Cream
1	1,150	.228	8.4	1.98	Hard burned.....	Very light olive
3	1,190	.049	13.2	2.34	Hard burned.....	Olive
5	1,230	.020	14.1	2.39	Vitrified.....	Olive
7	1,270	.041	8.7	1.99	Over burned.....	Olive

Brownish red clay. Molded easily. Suitable for brick and tile.
Burned by H. W. Jackman.

About three and one-half miles north and six miles east of Gladwin, in Section 13, T. 19 N., R. 1 W., on the banks of the river there is an outcrop of red clay apparently a lake deposit. The clay is 30 to 40 feet deep and extends under the sand in all directions. About three miles south of this place where sample 168 was taken, the clay is covered by about two feet of sand. About six miles further south in section 1, T. 17 N., E. 1 W., sample 169 was taken. Here the clay is covered by 10 to 14 inches of sand and carries water at a depth of five feet.

Burning Test

Sample No. 168. Field Sheet No. 188.
Section 13, T. 19 N., R. 1 W.
Plasticity 0.287 gm. water per gin. clay.
Average linear drying shrinkage 5.15 per cent.
Average tensile strength about 139 lbs. per sq. in.
Apparent sp. gr. of air dried sample 2.38.

Cone No.	Thermo-couple Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	910	.415	2.5 %	2.60	Soft burned.....	Salmon
08	952	Lime pop	....	....	Soft burned.....	Creamy white
06	1,015	.435	3.0	2.74	Soft burned.....	Creamy white
04	1,070	.426	4.6	2.74	Soft burned.....	Creamy white
02	1,110	.417	....	2.68	Hard burned.....	Cream
1	1,150	.219	11.0	2.57	Hard burned.....	Light olive
3	1,195	Lime pop	....	....	Hard burned.....	Light olive
5	1,220	Lime pop	....	....	Hard burned.....	Olive
7	1,250	.033	14.5	2.49	Vitrified.....	Olive

Reddish yellow clay containing lime pebbles. Easily molded.
Burned by M. C. Huck.
This clay is suitable for brick or tile if the lime pebbles can be removed.

Burning Test

Sample No. 169
Section 1, T. 17 N., R. 1 W.
Plasticity 0.272 gm. water per gm. clay.
Average linear drying shrinkage 4 per cent.
Average tensile strength about 155 lbs. per sq. in.
Apparent Sp. Gr. of Air Dried samples 2.24.

Cone No.	Thermo-couple Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	910	.465	2.0 %	2.79	Soft burned.....	Salmon pink
08	952	.456	5.3	3.04	Soft burned.....	Pinkish white
06	1,015	.433	3.0	2.78	Soft burned.....	Cream
04	1,070	Cracked	on firing	....	Soft burned.....	Cream
02	1,110	.372	−4.2	2.38	Soft burned.....	Cream
1	1,150	.320	2.1	2.47	Soft burned.....	Cream
3	1,195	.196	12.0	2.67	Hard burned.....	Pale olive
5	1,225	.103	14.6	2.74	Hard burned.....	Pale olive
7	1,250	.054	16.5	3.02	Vitrified.....	Olive

Blue clay with yellowish red clay intermixed. No pebbles. Effervesces with HCl. Difficult to mold.
Burned by M. C. Huck.

This sample is better than 168 in that it is free from lime pebbles but the burned bricks crack readily and are brittle.

GRAND TRAVERSE COUNTY

Grand Traverse County is almost completely covered by the glacial moraine and drift. Just east of Traverse City, straight out Front Street about half way between the East Arm of Grand Traverse Bay and where the concrete highway turns southerly on Edward's property, there are about nine acres of blue clay. This clay seems to be a lake deposit and very calcareous. Some clay has been removed to put on the race track and the pit is now a pond. Sample 35 was taken from this area in Section 1, T. 27 N., R. 11 W. The land is too low and the deposit too poor to be of much commercial value.

About five miles south of Traverse City on the G. R. & I. just northeast of Keystone Station, there is a mound of

red and blue drift clay covering about 25 acres to a depth of about 15 feet. The top red clay is covered with sand and the lower blue clay runs into sandy gravel. Some years ago this clay was used to make brick. The brick yard is reported to have shut down because of poor market conditions and is now a wreck. At the present time market conditions in this part of the State are good and this pit is well located on the railroad. The product appears to have been soft burned cream and salmon brick. Sample 36 from the old pit indicates that this clay is good material for brick and tile, having a burning range of four cones so that a hard burned product can be produced. The clay is very plastic and molds easily to a smooth fine grained brick. It may be useful for some pottery purposes.

Burning Test

Sample No. 36. Field Sheet No. 37.
NE¼ Section 3, T. 26 N., R. 11 W.
Plasticity .335 gm. water per gm. clay.
Average linear drying shrinkage 13.5 per cent.
Average tensile strength about 150 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Hardness.	Color.
08	990	.389	.02 %	Soft burned.....	Salmon
06	1,030	.382	1.1	Soft burned.....	Salmon
04	1,070	.388	1.0	Soft burned.....	Salmon
02	1,110	.322	6.2	Hard burned....	Salmon brown
1	1,150	.029	11.4	Hard burned....	Brown
3	1,190	.019	11.4	Vitrified.....	Brown
5	1,230	.025	6.7	Over burned....	Olive
7	1,270	....	....	Melted	.....

Very plastic. Molded easily. Suitable for brick and tile. Burned by H. W. Jackman.

GRATIOT COUNTY

Gratiot County is similar to Ionia County in having over 80 per cent of its surface covered with clay. But east of a line drawn through St. Louis, North Star, and Pompeii the surface is largely clay deposited in the bed of a glacial lake which formerly filled the Saginaw basin and is similar in form to the clay found in Saginaw and Midland Counties. West of this line the clay is largely boulder clay, morainic and till clays, similar to those in the counties to the south and southwest.

The St. Louis Tile Company is located about one mile west of the center of St. Louis, one quarter mile west of Pine River, and about three-quarters of a mile northwest of the P. M. R. R., in NW¼ Section 25, T. 12 N., R. 3 W. The plant was poorly built and badly located in low wet ground near a poor deposit of otherwise good clay. The plant originally cost about $50,000 as equipped, with an American Clay Crusher, a, pug mill, one Wallace Tile Auger machine, one American Tile Machine, an eight track tunnel fire heated drier, and five down-draft kilns. Twenty-seven men were employed to produce about 7,000 tile a day. The Wheeler kilns, built in low wet land where the kiln bottoms are certain to be moist if not actually flooded (sometimes six inches of water were found in these kilns when a burn was started), consumed 30 to 50 tons per burn. As might be expected, considering all these unfavorable factors, the plant lost money from the start.

In 1922 the plant, after losing $35,000 in operation, was in the hands of O. E. Buchanan of Alma as receiver; Mr. Parcher, the manager, was rebuilding the kiln bottoms in the manner described on another page and generally repairing and rebuilding the plant with the object of getting it back into operation in 1923.

In August, 1923, the plant was again visited. The company had reorganized and was owned by Messrs. J. Allen, Mort Lake, O. C. Buchanan, and Dave Acker.

Two of the four 30 foot kilns had been rebuilt and were turning out a fairly satisfactory product on about 12 tons of coal instead of 50 but the drainage problem was still very serious. The drying tunnels had been rebuilt and each equipped with 900 feet of steam pipe to supersede the fire drying. Steam was supplied by two 75 H. P. Atlas boilers which were also required to run a 125 H. P. engine to drive the machinery. Labor conditions were favorable and the local market would absorb all the tile that could be produced, at $30 to $90 a thousand. The clay pit lies to the south of the plant and seems to be a deposit of boulder clay. The clay covers about 15 acres and is locally considered usable to a depth of two to three feet. It is full of lime pebbles in places and contains sand pockets. Because of these variations in the deposit it must be carefully dug to prevent spoiling the product by the inclusion of lime pebbles or excessive sand. Sample 81 represents the good clay from this pit.

Burning Test

Sample No. 81. Field Sheet No. 85.
Section 25, T. 12 N., R. 3 W. St. Louis Tile Company.
Plasticity .267 gm. water per gm. clay.
Average linear drying shrinkage 10.9 per cent.
Average tensile strength about 150 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.306	−0.4 %	1.81	Soft burned.....	Salmon
08	990	.294	+0.4	1.86	Soft burned.....	Deep salmon
06	1,030	.291	0.9	1.88	Soft burned.....	Light red
04	1,070	.278	2.0	1.92	Soft burned.....	Light red
02	1,110	.191	5.0	2.13	Hard burned....	Red brown
1	1,150	.082	6.9	2.27	Hard burned....	Red brown
3	1,190	.016	6.3	2.21	Vitrified.....	Chocolate red
5	1,230	.019	4.1	2.06	Softening.....	Chocolate
7	1,270	.014	2.7	1.98	Viscous.....	Chocolate brown

Yellowish brown clay. Molds easily. Suitable for face brick, tile, etc., when free from lime pebbles and sand. Burned by H. W. Jackman.

J. O. Thomas formerly made brick and tile from a deposit of morainic boulder clay about three-quarters of a mile north of the center of Ithaca in the NE¼ section 36, T. 11 N., R. 3 W. The clay is very high in lime, contains lime pebbles, and burns nearly white. Mr. Thomas owned seven acres of the clay. The old pit is forty feet deep, covering little more than a acre, and is filled with water. The last brick were made in 1909 and all production ceased in 1915. The plant employed eight men and was equipped with the following machinery which is still in the old plant.

Eighty H. P. Boiler.
Forty H. P. Engine.
Double roll crusher for dry clay.
Pug mill (Fate & Co., Plymouth, Ohio).
Auger machine equipped with automatic cut off for extruding tile.
Auger machine for extruding side or face cut brick.
80' x 100' shed drier for tile.
Covered open air drying for brick.
Two 20 ft. down-draft kilns about 12 feet high in the crown.

The production was never large enough to warrant the Ann Arbor Railroad running a three-quarter mile siding to the plant. All the fuel was teamed in from Ithaca and the product carried back and shipped from the same point.

The plant was shut down because Mr. Thomas' health was failing, the lime pebbles caused trouble, and poor shipping arrangements made a very small margin for profit. His son found the pit could be used for cutting ice which is sold in Ithaca. This venture has proved more profitable than the brick yard.

The Elverside Brick and Tile Company operated by the Duffield Brothers is located three-quarters of a mile southeast of Simmer on the Pine River in west center of Section 33, T. 11 N., R. 4 W. The main bed of clay is found under the glacial moraine and outwash. The section through the deposit is as follows:

4 to 6 feet of yellowish red clay.
4 feet of blue clay.
1 to 4 feet of compact sand.
75 to 100 feet of blue clay.

It covers at least 50 acres eastward down the river and runs back to the north one-fourth mile or more. Sample 80 represents the blue clay which forms most of the deposit. It is high in lime, has a narrow burning range and cannot be used for a hard non-porous product although suitable for common brick and tile.

Burning Test

Sample No. 80. Field sheet No. 84.
Section No. 33, T. 11 N., R. 4 W.
Plasticity .248 gin. water per gm. clay.
Average tensile strength about 125 lbs. per sq. in.
Average linear drying shrinkage 6.9 per cent.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.422	0.8 %	1.51	Soft burned.....	Light salmon
08	990	.436	0.2	1.49	Soft burned.....	Cream
06	1,030	.455	0.2	1.48	Soft burned.....	Cream
04	1,070	.461	0.4	1.48	Soft burned.....	Cream
02	1,110	.485	0.6	1.49	Soft burned.....	Cream
1	1,150	.479	0.8	1.50	Soft burned.....	Cream
3	1,190	.454	3.2	1.6	Soft burned.....	Very light olive
5	1,230	.331	8.9	1.92	Hard burned.....	Light olive
7	1,270	.162	14.8	2.34	Partially vitrified	Olive
9	1,310	....	....	....	Viscous	

Molded easily. Suitable for common cream or buff brick and tile.
Burned by H. W. Jackman.

The Riverside plant is equipped with a steam power plant (fired with wood) and a Brewer Tile Machine equipped with a vertical pug mill. Some brick and hollow tile are made with this equipment but the main product is drain tile. There are two open air drying sheds, one of which is practically wrecked, and one wood fired, down draft, twenty foot kiln with a capacity of 12,000 four inch tile. Employing three or four men this plant can turn out 7,000 tile per day, or more than can be burned in the single kiln.

When this plant was visited in August, 1922, market conditions were excellent and an additional new boiler was being installed to operate a new steam drier so that the plant could operate during the winter season.

At North Star, on the edge of the lake washed area, one-third of a mile southeast of the center of the village, on the Ann Arbor Railroad, in the NW¼ Section 22, T. 10 N., R. 2 W., the Kennett Company operates a brick yard with the following equipment:

Steam power and boiler.
Double roll crusher for dry clay.
Pug mill.
Auger machine for making side cut brick or tile.
12 track steam drier.
One 25 foot down draft kiln.
One 30 foot down draft kiln.

The plant has a capacity of about 18,000 brick a day, which is the main product. Hollow building tile is made on order.

The clay deposit covers about 20 acres of blue clay, varying in depth from three to sixteen feet and covered by 12 to 16 inches of red clay. The clay (sample 79) is high in lime and similar to that at Sumner except that it has a somewhat wider burning range. It seems to be fairly good material for common brick or tile of a cream or buff color.

Burning Test

Sample No. 79. Field sheet No. 82.
Section No. 22, T. 10 N., R. 2 W.
Plasticity .265 gm. water per gm. clay.
Average linear drying shrinkage 8.2 per cent.
Average tensile strength about 100 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.409	0.0 %	1.53	Soft burned.....	Salmon
08	990	.415	0.0	1.51	Soft burned.....	Cream Salmon
06	1,030	.422	0.4	1.50	Soft burned.....	Cream
04	1,070	.416	1.0	1.53	Soft burned.....	Cream
02	1,110	.406	2.3	1.60	Soft burned.....	Cream
1	1,150	.353	6.0	1.79	Hard burned.....	Light olive
3	1,190	.186	11.5	2.14	Hard burned.....	Olive
5	1,230	.030	15.5	2.48	Vitrified.....	Olive
7	1,270	.000	14.5	2.48	Vitrified.....	Olive
9	1,310	....	....	....	Melted	

Clay molded easily but contains some lime lumps.
Burned by H. W. Jackman.

In the lake washed area, east of North Star, C. D. Peet formerly made stiff mud brick at Sickles, Section 8, T. 10 N., R. 1 W. Here the surface red clay is two feet thick and then runs to lime pebbles. Mr. Peet sold his equipment to Chas. Lee of North Star and it is now being used by the Kennett Company.

A. E. Fuller operates the Ashley Tile Company about one-half mile southeast of the center of Ashley on the Ann Arbor Railroad, in Section 7, T. 9 N., R. 1 W. The clay covers a large area through this district. There are about five feet of brownish red clay, then two feet or less of clay and lime pebbles, underlain by about five feet of reddish blue clay. Sample 78 was taken from the stock pile at the plant and represents the upper five feet of clay above the lime pebbles, as used by Fuller. The burning test shows this sample to be good material for all kinds of hard burned or vitrified building brick or tile. It has a burning range of about eight to ten cones and a vitrification range of four to six cones which is very unusual in Michigan surface clays.

Burning Test

Sample No. 78. Field Sheet No. 81.
Section 7, T. 9 N., R. 1 W.
Plasticity .326 gm. water per gm. clay.
Average tensile strength about 140 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.325	0.0 %	1.74	Soft burned.....	Salmon
08	990	.303	1.0	1.80	Soft burned.....	Light red
06	1,030	.278	1.9	1.85	Soft burned.....	Light red
04	1,070	.242	3.1	1.94	Hard burned....	Red
02	1,110	.165	6.0	2.11	Hard burned....	Red brown
1	1,150	.080	7.9	2.24	Vitrified.....	Red brown
3	1,190	.052	7.7	2.22	Vitrified.....	Chocolate
5	1,230	.049	4.8	2.06	Vitrified.....	Chocolate
7	1,270	.047	3.3	1.95	Vitrified.....	Chocolate

Molded easily. Suitable for red brown face brick, tile, and possibly vitrified ware. Good material but demands careful firing for thorough oxidation.
Burned by H. W. Jackman.

Mr. Fuller makes an excellent hard burned drain tile from this clay, which has sufficient strength to be used for road culverts. His plant is equipped as follows:

Conical rolls to crush dry clay and throw out pebbles.
Combined pug mill and auger extrusion machine.
Two storied, closed, air drying shed.
Three 24 foot down draft kilns.

When visited on August 26, 1922, Mr. Fuller reported the market conditions were the poorest he had seen in 32 years. He was practically unable to get rid of his tile, though having the advantages of good clay, railroad transportation, and supposedly good local markets. By building a short spur to the Ann Arbor railroad other markets could be readily reached. The plant is adjacent to the railroad right of way; therefore the spur could be built at a minimum of cost.

HILLSDALE COUNTY.

The surface clays of Hillsdale County are chiefly morainic clays similar to those found in Washtenaw, Cass, and St. Joseph Counties.

The Omega Portland Cement Company, organized Feb. 1899, with a capital of $300,000 completed their factory of five 6 x 60-foot kilns at Mosherville, section 15, T. 5 S., R. 3 W., in 1900. This company found the local clays so unsatisfactory that they imported clay from the lake deposits of Ohio near Milbury and Bryan.* This plant failed a number of years ago.

The Jerome Brick and Tile Company on the northwest side of the Lake Shore and Michigan Southern Railroad in SE¼ section 18, T. 5 S., R. 1 W., used a boulder clay of high lime content and narrow burning range. Sample No. 186 was taken by trenching in the side of the old pit. The deposit worked by this company is about 30 feet thick and covers 20 acres or more.

*Russell, U. S. Geol. Survey, 22d Ann. Rept., Pt. III, p. 673 (1902).

Burning Test.

Sample No. 186. Field Sheet No. 207.
Section 18, T. 5 S., R. 1 W.
Plasticity .259 gm. water per gm. clay.
Average linear drying shrinkage 7.1 per cent.
Average tensile strength about 120 lbs. per sq. in.
Apparent sp. gr. dry. 2.57.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	950	.400	+0.6 %	2.62	Soft burned	Salmon
08	990	.372	−2.0	2.40	Soft burned.....	Salmon
06	1,030	.374	−0.2	2.46	Soft burned.....	Salmon
04	1,070	.385	+0.6	2.56	Soft burned	Salmon
02	1,110	.314	3.1	2.54	Hard burned....	Light brown
1	1,150	.089	9.8	2.29	Hard burned....	Light olive
3	1,190	.086	8.9	2.22	Vitrified	.....
5	1,230	....	...	....	Viscous	.....

Brown clay containing lime lumps. Molded easily.
Burned by H. W. Jackman.

The Jerome Brick and Tile Company has changed hands at least three times. Mr. Walker first operated the plant, then Douglas Harvey and W. Branch. The plant next passed into the hands of Edward Potter, et al, of Jackson, and is now owned by Detroit interests. The plant equipment includes rolls, Brewer pugmill, Brewer No. 10 tile and brick auger extruder, making side cut brick, and a four track tunnel drier. The plant is gradually becoming a wreck.

On the Parks farm, north of the brick yard, across the road, and between the N. Y. C. R. R. (Hillsdale-Ypsilanti Div.) and Moscow road, in Sec. 18, T. 5 S., R. 1 W., there is a deposit of blue clay from 20 to 30 feet deep and covering about 10 acres in area. West and north of this deposit the surface for 5 feet or more in depth is a mixture of clay, sand, gravel, and muck. This deposit was sampled* where the overburden was less than 5 feet. One small vein of quicksand was found in the blue clay deposit.

Analyses of blue clay.

	%	%	%	%
Silica (SiO_2)	42.10	43.04	49.46	43.74
Alumina (Al_2O_3)	12.52	13.78	13.60	12.00
Iron (Fe_2O_3)	5.26	5.68	5.12	6.68
Lime (CaO)	16.75	15.54	12.25	14.74
Magnesia (MgO)	4.49	4.70	5.00	4.01
Ignition Loss				19.01
Sulphur				.03

Soluble and Insoluble tests* on a sample of above clay.

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO
	%	%	%	%	%
Insoluble part	43.32	13.02	4.68	2.16	1.55
Soluble part	1.22	.76	.99	13.29	1.34
Total	44.54	13.78	5.67	15.45	2.89

About three miles northeast of Jerome along the railroad there is a deposit of morainic clay mixed with limestone pebbles, gravel, and traces of sand. It is of unknown depth and extends from the New York Central track north to the road, with indications that it may extend one-half mile farther north. Its width is about one-quarter mile.

*Kindness of Mr. Kane, Chief Chemist, Peninsular Portland Cement Co., Cement City, Lenawee County.

	No. I Sample taken in woods near road. Near cemetery. Depth of sample 8 feet.	No. II Sample taken in ravine, west of No. 1. Near road at east edge of pond.
	%	%
Silica (SiO_2)	61.00	46.10
Iron and alumina ($Fe_2O_3 + Al_2O_3$)	25.30	18.00
Lime (CaO)	1.50	13.00
Magnesia (MgO)	5.87	6.96
Color	Yellow	Blue

Kindness of Mr. Kane, Chief Chemist, Peninsular Portland Cement Co., Cement City.

A number of years ago a good red brick was made in Gay's yard in SW¼ Sec. 19, T. 5 S., R. 2 W., north of the road, and in section 36, T. 5 S., R. 3 W. Most of the houses in Jonesville were made of these brick. Buff brick was formerly produced just east of Hillsdale and immediately north of the railroad about section 30, T. 6 S., R. 2 W.

In the southern part of the county one mile north of Prattville just east of the Cincinnati Northern railroad on the section line 2-11, T. 8 S., R. 1 W., there is a deposit of red clay formerly worked by J. B. Keiser and Son. The brick were of good red color.

Near Waldron in sections 20 and 29, T. 8 S., R. 1 W., west of St. Josephs of the Maumee River there are 30 to 50 acres of red clay running about 4 to 5 feet deep. It was formerly used to make a good red brick.

East of the river in section 21 blue clay is found under the muck. This clay contains lime pebbles and makes a poor quality of buff brick.

HURON COUNTY.

North of the angle formed by Gagetown (Tuscola County), Bad Axe and Ruth, Huron County is practically covered with lake clay similar to that found elsewhere in the Saginaw Bay district. This clay is generally red in color and red burning for the upper two or three feet, and then runs into a blue clay containing more lime and burning buff. Lime pebbles are generally found in quantity sufficient to cause serious trouble.

Ernest Reinhold operated a soft mud brick plant just east of Sebewaing, (SW¼ Section 9, T. 15 N., R. 9 E.) for over 20 years until a sand lime brick plant started up about 1907. When the site of the old yard was visited in September, 1922, some of the open drying racks were still standing. The clay is a river or lake clay overlain in places by sand. The upper few feet of the deposit are red burning and the lower part, high in lime, burns buff. Both strata contain large quantities of lime pebbles especially at the juncture of the two clays.

Ries* has described the method of washing the clay formerly employed at this yard to remove lime pebbles and sand. The clay was worked up to a thin slip with water in a blunger made of cylindrical sheet iron tank and stirred by arms attached to a vertical shaft. In this operation the clay goes into suspension while the sand and pebbles tend to settle to the bottom of the tank. The clay slip was then passed through a half-inch mesh screen and run into a trough about 50 feet in length. In flowing through this trough most of the sand was dropped and the clay slip was passed through a quarter inch mesh screen into the settling tanks which were made of wooden sides and a sand bottom. In these settling tanks the excess water evaporated leaving the washed clay in a layer about six inches thick in the bottom of the tank. With this crude equipment two men were able to wash enough clay for a daily production of 16,000 brick.

If this yard was able to operate successfully for 20 years washing its clay for the manufacture of common brick, it seems reasonable to expect that a modern plant using modern methods could profitably wash its clay particularly when used for the manufacture of the higher grade products such as face brick, tile, and vitrified ware. Although such a procedure is generally unnecessary when using a good clay or shale free from lime, there are many surface clays in Michigan that are very suitable for hard burned brick or vitrified products if the lime pebbles could be economically removed. Efficient washing is probably the solution to the problem of the best use of these clays.

At the old Sebewaing yard the washed clay was molded in a Quaker soft mud machine, dried on pallets in open racks, and burned in scove kilns. Some pressed brick were also made.

The clay near Elkton in the Pinnebog River valley, sections 10-15, T. 16 N., R. 11 E., was formerly used for common brick. The clay has much the same properties at that used at Sebewaing and also contains lime pebbles.

At Bad Axe both the upper and lower strata were worked. The lower blue clay, particularly when fired in the center part of the kiln where the temperature may have been higher and the gases less oxidizing burned buff and upper red clay burned red. Some trouble was experienced by soluble salts, but lime pebbles seemed to have caused little trouble. Two and a half miles southwest of Ubly on the county line south center of section 38, T. 15 N., R. 13 E., the river or lake clay has about two or three feet of red burning clay on top, underlain by blue, buff-burning clay. This clay was formerly used by Wyers and later by John Ruddy to make common brick. In 1910 the plant stopped production because of the scarcity of wood fuel.

*Michigan Geo, Surv. VIII, Pt. I, p. 59 (1900).

East of E. 14 E. and along the lake shore north to Grindstone City, the bed rock is composed of the Coldwater shale. This shale is generally good material for the manufacture of hard burned brick, tile, and for Portland cement; in some cases it may also be used for face brick or vitrified products. This shale outcrops along the lake shore south of White Rock and north of Forestville.

This outcrop was sampled (R179) and reported by Ries as follows:

> "Excellent exposures of Coldwater shale occur along the shore of Lake Huron between White Rock and Forestville, but they have not thus far been utilized.
>
> The shale forms a line of cliffs and when fresh appears brittle and gritty; in places, however, it has been mellowed down to a tough clay.
>
> The rock is thinly laminated shale (R179) which contains much sand of a very fine nature and slakes slowly along the layers."

Sample R179.
Water of Plasticity 19 per cent.
Total air shrinkage 4 per cent.
Tensile strength 36 to 42 lbs. per sq. in.

Cone.	Burned.	Total Shrinkage.	Color.
03	Hard		
3	Vitrified	11 %	Deep red
6	Viscous		

Chemical Analysis.

	%
Silica (SiO_2)	58.7
Alumina (Al_2O_3)	18.31
Ferric Oxide (Fe_2O_3)	7.19
Lime Carbonate ($CaCO_3$)	1.80
Magnesium Carbonate ($MgCO_3$)	0.98
Alkalies ($Na_2O + K_2O$)	3.67
Water and Organic (Difference)	9.35
	100.00
Ferrous Oxide	2.73

In September 1922 this outcrop, still unused, was visited and sampled (sample No. 147) about ¾ mile south of White Rock, two miles north of Forestville, east of the highway, where the shale outcrops in the bed of a stream in the eastern part of section 32, T. 15 N., R. 16 E. The shale is over 50 feet thick and is covered by gravel, sand, red and blue clay, 30 feet thick in places. The upper two or three feet of the shale runs dark gray or black. The main body of shale is blue black with a few ledges about an inch thick of reddish brown shale. When weathered the shale becomes blue or covered by rust.

Burning Test.

Sample No. 147. Field Sheet No. 161.
Section 32 (eastern), T. 15 N., R. 16 E.
Plasticity .247 gm. water per gm. clay.
Average linear drying shrinkage 6.4 per cent.
Average tensile strength about 50 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage	Bulk Sp. Gr.	Hardness.	Color.
010	950	.322	−0.2 %	1.77	Soft burned	Salmon
08	990	.269	0.8	1.82	Soft burned	Salmon
06	1,030	.228	3.9	1.97	Semi-hard burned	Light red
04	1,070	.147	7.2	2.18	Hard burned	Light red
02	1,110	.046	8.9	2.30	Hard burned	Red brown
1	1,150	.024	10.0	2.37	Vitrified	Red brown
3	1,190	.031	9.6	2.32	Vitrified	Choc!.late
5	1,230	.040	8.6	2.27	Vitrified	Chocolate
7	1,270	.086	6.2	2.12	Vitrified	Chocolate
9	1,310	.174	1.8	1.85	Vitrified	Chocolate brown

Blue shale, easily molded, suitable for face brick, tile, vitrified ware, etc.
Burned by H. W. Jackman.

This shale burns to a slightly lighter color than the weathered clay derived from the shale (sample No. 146), and the vitrified bricks from the shale are somewhat more brittle.

It is hard to understand why attempts are persistently made in Michigan to use the inferior pebbly clays while unlimited amounts of good shale material, readily accessible, are ignored, unless the value of shale is not recognized.

The Michigan Standard Coal Company had a shaft at the southern end of Sebewaing. The shales associated with the coal were sampled and reported upon by Ries.*

"The shale over the coal is a brittle black bituminous shale with numerous nodules of pyrite, while that under the coal is gray and sandy. On exposure to the air it slakes readily to lumps the size of a hazel nut, but to get it finer requires grinding."

*Mich. Geol. Survey VIII, Pt. I, p. 37.

"The sample collected (182) gave no effeverscence with acid and slaked very slowly in water. It contained 0.25 per cent of soluble salts.
Water of plasticity 17 per cent.
Air drying shrinkage 5 per cent.
Average tensile strength 100 lbs. per sq. in.

Cone.	Total Shrinkage.	Hardness.	Color.
1	8 %	Hard burned	Buff
5	13 %	Vitrified	
9		Viscous	

INGHAM COUNTY.

The Coal Measures shales are near the surface in and about the village of Williamston, and along the banks of Cedar River. They were exposed in a number of shallow coal mines, now abandoned. The chief area of thinly covered shale comprises apparently about 80 acres in the eastern part of the village between Cedar River and the Pere Marquette Railroad.

The shale beds in the vicinity of Williamston are known to have a thickness of over 100 feet and in an area between trunkline highway M-16 and the railroad have been penetrated in numerous test holes to depths varying from 18 to over 60 feet. The upper shales are a series of dark gray and black, locally containing a thin

coal seam, which was formerly mined on a small scale. The lower shales of the drilled section are light gray and very uniform in color, and apparently in general chemical and physical properties.

The elevation of the shale tract varies from 20 to about 30 feet above Cedar River. The relatively low elevation of the land above the river and the very considerable overburden locally will necessitate careful engineering to avoid excessive stripping and pumping costs. The location along a paved trunkline highway and the Pere Marquette Railroad affords very favorable transportation and marketing facilities.

The Williamston Clay Products Company is now utilizing the shale to make face brick. The plant is located in the southeastern part of the village on a tract of about 14 acres on the north side of the railroad. The plant is near the railroad and the shale pit is on the north side of the tract on the site of a former shallow coal mine. The overburden is from four to six feet thick in the vicinity of the pit. It is chiefly sand and gravel clay with a thin patchy capping of rotton sandstone over the shale. Apparently the sandstone capping thickens to the south.

The shale is dug and loaded on small cars by hand and hauled up an incline to the plant. It is ground in a dry pan, pugged and extruded by an auger machine making rough textured side cut brick. The green brick are dried in a tunnel drier and burned in a coal fired rectangular down draft kiln.

Part of the shale is black, very bituminous, and requires careful oxidation in burning. Some of the beds are light colored. A thin coal seam occurs in the shale at a depth of 12 to 15 feet. This has been partially mined out through a shallow slope shaft near the present pit. Sample 157 was from a so-called "fire-clay," a light colored shale associated with the coal in this mine. It nearly justifies its name as it is a true semi-refractory clay. It vitrifies at about cone 10 or 11 and does not fail until cone 17 is down, but it cannot be used for refractory purposes as such clay should stand cone 30 or at least cone 27. It is high grade material, however for making vitrified products for which purpose it may be mixed with less refractory clay or used unmixed. It has a wide burning range of 14 cones and is somewhat similar to shale quarried north of Jackson by the American Vitrified Products Co.

Burning Test.

Sample No. 157. Field Sheet No. 177.
Section 1, T. 3 N., R. 1 E.
Plasticity .166 gin. water per gm. clay.
Average linear drying shrinkage 3.1 per cent.
Average tensile strength about 45 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk.	Hardness.	Color.
010	950	.240	+0.4 %	1.85	Soft burned.....	Cream salmon
08	990	.282	−0.8	1.82	Soft burned.....	Cream Salmon
06	1,030	.283	−0.4	1.83	Soft burned.....	Cream salmon
04	1,070	.267	+0.4	1.87	Soft burned.....	Cream salmon
02	1,110	.253	1.3	1.92	Soft boiled.....	Light brown
1	1,150	.245	1.5	1.92	Soft burned.....	Light brown
3	1,190	.226	2.1	1.96	Hard burned.....	Light brown
5	1,230	.191	3.0	2.01	Hard burned.....	Light brown
7	1,270	.185	2.8	2.02	Hard burned.....	Gray brown
9	1,310	.126	5.0	2.15	Hard burned.....	Gray
11	1,350	.079	6.1	2.20	Vitrified.....	Gray
13	1,390	.055	4.9	2.16	Vitrified.....	Gray
15	1,430	.124	−1.3	1.78	Vitrified.....	Gray
17	1,470	.159	−2.1	1.74	Vitrified.....	Light brown

Light gray clay shale. Hard to mold unless ground. Excellent vitrifying shale. The clay becomes soft and unworkable if the amount of water added exceeds about 17 per cent.
Burned by H. W. Jackman.

In 1917 the Central Michigan Clay Products Company was organized to exploit a 70-acre shale property adjoining on the east the properties

of the present Williamston Clay Products Company. Four scattered drill holes were put down to depths varying from 36 to 65 feet. The enterprise did not materialize.

In 1925 thirteen more test holes were drilled but to the west of those previously drilled. The holes ranged in depth from 35 to 70 feet. These disclosed an upper thin group of dark gray and black shales with an included thin patchy seam of coal, as on the property to the west, and a much thicker lower group of lighter colored shales, very uniform in color and general appearance. The coal seam is apparently replaced by black shale over considerable areas.

On the northwest portion of the property the overburden is generally between 4 and 15 feet; on the east and south from 20 to 30 feet. The overburden on the higher ground is composed of 8 to 10 feet of clay, sand, and gravel, and a capping of "rotten" sandstone over the shale from a foot or two up to 20 feet or more in thickness. The drillings indicate an area of quarryable shale on the property ample to maintain large scale operations for a long period. This area extends to the north and west across M-16 to other properties, but these are in part occupied by residences and other buildings.

The Michigan Clay Products Company has been organized to develop the deposit for the manufacture of face brick and other vitrified products.

Numerous burning tests were made of the material obtained from the drill holes. These tests show that the shale has a wide burning range and good vitrifying properties. It burns to light red and red brown colors and is suitable for face brick, sewer pipe, and probably for paving block since it does not appear to develop the full vitrified structure before cone 5. Sample 198 was an average of the top 20 feet of variable shale beds in hole 2.

Sample No. 198.
NE¼ Sec. 1, T. 3 N., R. 1 E.

Plasticity .176 gm. water per gm. clay.
Average linear drying shrinkage 2.71 per cent.

Cone No.	Cone Temp. °C.	Perosity Per cent.	Apparent Sp. Gr.	Linear Shrinkage.	Hardness.	Color.
010	950	36.10	2.82	.....	Soft burned.....	Flesh pink
08	990	35.78	2.82	.....	Soft burned.....	Flesh pink
06	1,030	.....	....	.....	Soft burned.....	Light red
04	1,070	19.55	2.01	−2.70	Hard burned....	Red
02	1,110	.....	2.75	−2.24	Hard burned....	Red
1	1,150	15.76	2.15	0.65	Hard burned....	Red
2	1,170	15.47	2.33	.....	Hard burned....	Red
3	1,190	10.04	2.46	.....	Hard burned....	Red brown
5	1,230	11.95	2.64	11.45	Vitrified.....	Red brown
9	1,310	10.62	2.69	13.70	Vitrified.....	Red brown

Suitable for face brick.
Burned by Beatty.

Burning and other tests were also made at the laboratory of E. Lovejoy, Consulting Engineer, Columbus, Ohio. Sample No. 1 comprised 75 pounds of drill sludge from test hole No. 6 from 3 to 17 feet, and sample No. 2 a similar quantity from 18 to 32 feet. Sample No. 1 was from the upper darker shale beds and Sample No. 2 from the lower lighter colored beds.

According to the report on the results of the test, the prepared shale gave no trouble in machine operation. Both shales formed smooth bars and ran fast through the dies, but there was some lamination. The plasticity measured by the wet test was very high but by the dry strength test was just between weak and strong. The clays dry rapidly without cracking. The results of the burning test are shown below:

Burning Test.

No.	Cones.	Shrinkage.		Temp. °F.
		Sample No. 1.	Sample No. 2.	
1	07	1.4%	2.5%	1,850
2	04	5.0	6.0	1,958
3	02	5.4	6.2	2,030
4	1	6.0	6.5	2,102
5	3	6.2	6.8	2,174
6	5	6.6	6.7	2,246
7	7	7.0	6.1	2,318

Burning range, sample No. 1, cones 04 to 7 or ten cones; sample No. 2, cones 04 to 3, or eight cones.

The shrinkage for sample No. 1 was small and practically at a uniform rate for 10 cones. In sample No. 2 the shrinkage was also small and uniform for about 8 cones. Since the heat variation in factory kilns should not exceed 4 cones, sample No. 1 gave a margin of safety of six cones, and sample No. 2 of four cones. The wide burning range permits much higher temperatures to get color effects.

The range in hardness was eleven cones for sample No. 1 and eight cones for sample No. 2. The color ranged from salmon and light brown to dark brown.

Love joy reports that both samples scummed, making necessary the use of barium salts.* Because of the carbon, the upper shales require careful oxidation as in the case with the dark Coal Measures shales at Jackson, Grand Ledge, and Corunna.

*No scumming was noticed on sample 198 or others from this deposit prepared with distilled water.

At the Clippert & Spaulding, now the Briggs Company, brick yard in Lansing a short distance north of East Michigan Avenue and about one-quarter mile east of the city limits, in NW¼ section 14, T. 4 N., R. 2 W., a morainic clay* is used for making common brick. The deposit is practically solid clay from the surface down. At the bottom of the bed some lines of stratification are noticable but they seem entirely lacking in the main mass of the bed.

Surface—slightly stony.
3 feet—red burning clay.
1 foot—pink burning clay.
10-11 feet—blue clay burning buff (R30).
1 foot—"shaly" clay with layers of fine blue sand, red sandy clay, and sandy gravel.

The main body of blue clay is of practically the same composition as that used at the Ionia pottery.

Sample (Ries analysis No. 30).

Silica (SiO_2)	41.86
Alumina (Al_2O_3)	10.70
Iron Oxide (Fe_2O_3)	5.02
Lime (CaO)	14.33
Magnesia (MgO)	2.81
Alkalies	2.80
Loss on Ignition	22.56
Carbon Dioxide (CO_2)	14.56

Sample No. 77 represents the mixed clay as used in the brick yard.

Burning Test.

Sample No. 77. Field Sheet No. 79.
Section 14, T. 4 N., R. 2 W., Lansing Township.
Plasticity .252 gm. water per gm. clay.
Average linear drying shrinkage 7.5 per cent.
Average tensile strength about 125 lbs. per sq. in.
Average apparent Sp. G. (dry) 2.93.

Cone No.	Thermo-couple Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	905	.504	7.0%	4.28	Soft burned.....	Salmon red
08	945	.495	0.2	3.36	Soft burned.....	Salmon pink
06	995	.428	−0.2	2.94	Soft burned.....	Pinkish white
04	1,045	.420	+0.6	2.93	Hard burned....	Pinkish white
02	1,090	.418	1.0	3.00	Hard burned....	Pinkish white
1	1,130	.413	1.5	3.24	Hard burned....	Cream
3	1,170	.031	9.0	2.37	Vitrified.....	Dark cream
5	1,210	.033	12.5	2.40	Vitrified.....	Light olive cream
7	.....	....	....	....	Melted	.....

Yellow clay. Molded easily. Free from lime pebbles.
Burned by M. C. Huck.

*Ries, Mich. Geol. Surv. VIII, Part I, p. 56 (1900).

About 20 acres of the deposit were left in 1922. The plant was equipped with one soft mud brick unit and one stiff mud unit for extruding brick or tile. Each of these units had a daily capacity of about 35,000 brick.

The plant equipment comprises the following:

Soft mud unit	Stiff mud unit
Dry mixer	Dry mixer
Rolls	Rolls
2 pugmills	2 pugmills
6-Brick old style molding machine	Triple die end cut auger machines
Open air drying on pallets	Steam heated drier
Scove kilns	Scove kilns

The soft mud brick are preferred and demand a higher price than the stiff mud brick. During the coal shortage in the summer of 1922 an attempt was made to burn the kilns with wood, but the attempt was not very satisfactory.

Sample 9 represents a surface boulder clay found near Mason on the property of Seth Jubb, who reports it to be three to six feet deep over a rather wide area. Similar clay containing pebbles and sand and of a reddish color is found east of Dansville, in section 13, T. 2 N., R. 1 E., and probably extends over most of this district in the central part of the county.

Burning Test.

Sample 9, Seth Jubb, Mason.
Plasticity .377 gm. water per gm. clay.
Average linear shrinkage 10.0 per cent.
Average tensile strength about 218 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Hardness.	Color.
010	960	.470	1.2 %	Soft burned	Salmon
08	990	.450	0.7	Soft burned	Cream salmon
06	1,030	.470	0.5	Soft burned	Cream
04	1,070	.484	1.0	Soft burned	Cream white
02	1,110	.461	1.6	Soft burned	Cream
1	1,150	.337	15.7	Hard burned	Light olive
3	1,190	.144	14.0	Vitrified	Light olive
5	1,230	....	....	Melted	Light olive

Easily molded.
Burned by H. W. Jackman.

The Michigan State plant at Onondaga uses clay that is very similar to this boulder clay. The plant is about one mile southeast of Onondaga on the Michigan Central railroad in NE¼ Section 33, T. 1 N., R. 2 W. The blue clay, covered by about 2 feet of yellow-red clay, extends to the south and west of the plant in a bank over 30 feet thick covering 25 acres or more. The clay contains a high percentage of lime and lime pebbles, has a narrow burning range, and must be considered as poor material even for the purpose for which it is used. Even so, the plant produces a first class hard buff brick that is in demand throughout this part of the State. It is of particular interest because it is the best example in the State showing how a good product can be produced from poor material containing many lime pebbles, if care is taken to adapt the machinery to the clay. In this respect L. G. Smith, former superintendent of the plant, was a successful pioneer.

The clay is dug by a steam shovel, drawn up into the plant and dumped into a bin over the machinery, in the usual manner. From this bin the clay is run through a pug mill used as a dry mixer, then through conical rolls which tend to throw out a large number of the lime pebbles and to crush those pebbles passing through. The dry clay then passes through a pair of cylindrical rolls to insure that all the lime pebbles not thrown out by the conical rolls are crushed. After this thorough preliminary dry preparation, the clay is tempered in a pug mill, and finally extruded in a Brewer auger machine. This is equipped with a four-pitch screw propeller to aid in eliminating laminations, which are conspicuously absent in the brick from this plant. This machine making side cut brick has made a high record of 100,500 brick in one day of nine hours, and has an average capacity of about 80,000 brick a day. The brick are dried in a 20 track intermittent tunnel drier heated by exhaust steam.

Twelve 30-foot down draft kilns are available for burning the brick. Burning is done very carefully and thoroughly; the brick are burned hard and the kiln is given a soaking heat to carry the burning to completion at the bottom of the kiln and to cause the lime to go into combination with the other oxides thus becoming inactive to moisture. In this way the loss due to lime pops is negligible and then only in the softer brick, which are generally red in color.

Sample No. 75 was taken from the mixed clay at the plant, samples 218, 219, and 220 from test holes 10 feet deep on the floor of the present pit. Samples 218 and 219 were from holes 2 and 5 and sample 220 was a composite of holes 1 to 10 inclusive.

Burning Test.

Sample No. 75. Field Sheet No. 75.
NE¼ Section 33, T. 1 N., R. 2 W.
Placticity .239 gm. water per gm. clay.
Average linear drying shrinkage 8.3 per cent.
Average tensile strength about 98 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
08	990	.370	1.0	1.62	Soft burned	Cream
06	1,030	.412	0.6	1.59	Soft burned	Cream
04	1,070	.378	1.1	1.61	Soft burned	Cream
02	1,110	.338	3.6	1.75	Hard burned	Cream brown
1	1,150	.083	10.9	2.21	Hard burned	Olive brown
3	1,190	.043	11.3	2.23	Vitrified	Olive brown
5	1,230	....	....	....	Viscous	.....

Molded easily. Contains lime lumps.
Burned by H. W. Jackman.

Burning Test

Sample 218. From Hole No. 5, west side of pit.
NE¼ section 33, T. 1 N., R. 2 W. State Prison Brick Plant, Onondaga. Plasticity .249 gm. water per gm. clay.

Cone No.	Thermo-couple. Temp. °C.	Porosity.	Apparent Sp. Gr.	Linear Shrinkage.	Hardness.	Color.
010	860	37.10 %	2.61	0.46	Soft burned	Flesh pink
08	895	38.70	2.62	0.27	Soft burned	Flesh pink
06	920	36.30	2.49	0.07	Soft burned	Flesh pink
04	1,054	Cracked*	....	....	Soft burned	Cream
02	1,075	32.80	2.46	0.06	Hard burned	Cream
01	1,090	13.90	2.41	0.72	Hard burned	Olive
1	1,110	0.49	2.42	11.95	Vitrified	Olive
3	1,125	Cracked*	....	....	Vitrified	Olive
4	1,135	Cracked*	....	....	Vitrified	Olive
5	1,145	Cracked*	....	....	Viscous	Olive

Burned by Beatty.

*Had small lime lumps.

Burning Test

Sample No. 219. From Hole 2, northeast part of pit.
NE¼ section 33, T. 1 N., R. 2 W. Prison Brick Plant.

Onondaga.
Plasticity .246 water per gm. clay.
Average linear drying shrinkage 4.83 per cent.

Cone No.	Thermo-couple Temp. °C.	Porosity Per cent.	Apparent Sp. Gr.	Linear Shrinkage Per cent.	Hardness.	Color.
010	860	....	....	....	Soft burned.....	Flesh pink
08	895	38.8	2.03	2.0	Soft burned.....	Flesh pink
06	920	37.2	2.00	1.4	Soft burned.....	Flesh pink
04	1,054	37.7	2.61	1.4	Soft burned.....	Cream
02	1,075	41.4	3.11	3.5	Hard burned....	Cream
01	1,090	....	....	....	Hard burned....	Olive
1	1,110	19.3	2.47	11.8	Vitrified.....	Olive
3	1,125	0.8	2.93	18.1	Vitrified.....	Olive
4	1,135	Cracked	....	....	Vitrified.....	Olive
5	1,145	Cracked	....	....	Viscous.....	Olive

Burned by Beatty.

Sample No. 220. Composite of Holes 1 to 10 inclusive, on floor of pit, NE¼ section 33, T. 1 N., R. 2 W, State Prison Brick Plant, Onondaga.
Plasticity .255 gm. water per gm. clay.
Average linear drying shrinkage 5.94 per cent.

Cone No.	Thermo-couple Temp. °C.	Porosity Per cent.	Apparent Sp. Gr.	Linear Shrinkage Per cent.	Hardness.	Color.
010	860	....	....	...	Soft burned.....	Flesh pink
08	895	37.2	2.59	1.2	Soft burned.....	Flesh pink
06	920	37.0	2.57	1.2	Soft burned.....	Flesh pink
04	1,054	36.5	2.56	...	Soft burned.....	Cream
02	1,075	32.3	2.62	1.4	Hard burned....	Cream
01	1,090	0.91	2.19	5.6	Hard burned....	Olive
1	1,110	0.35	2.25	8.1	Vitrified.....	Olive
3	1,125	0.39	2.20	7.8	Vitrified.....	Olive
4	1,135	Cracked*	....	...	Vitrified.....	Olive
5	1,145	Cracked*	....	...	Viscous.....	Olive.

Burned by Beatty.

South of Dansville on Taylor's farm in the central part of section 2, T. 1 N., R. 1 E., the clay is red burning and has a wider burning range than the highly calcareous clays mentioned above. The clay is very sandy and runs In streaks through the low hills. This clay was used about 1885 for making common brick but the project was abandoned because of poor transportation and exhaustion of the deposit. Another deposit of similar clay was worked about 1885 on the Densmore place about 2½ miles south of Dansville. Sample 1001 was taken just north of Taylor's place in what seems to be the old clay pit. It is very sandy clay and is not thick, but it seems to have been derived in part from the coal measure shales beneath.

*Had lime spots.

Burning Test.

Sample 1001. Field Sheet 1001.
Section 35, T. 2 N., R. 1 E.
Plasticity .203 gm. water per gm. clay.
Average linear drying shrinkage 3.3 per cent.
Average tensile strength about 97 lbs. per sq. in.
Apparent sp. gr. dry, 2.38.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	950	.325	−0.8	2.56	Soft burned.....	Salmon
08	990	.322	−1.1	2.54	Soft burned.....	Salmon
06	1,030	.322	−0.5	2.60	Soft burned.....	Salmon
04	1,070	.301	+1.1	2.53	Soft burned.....	Light red
02	1,110	.249	2.1	2.52	Hard burned....	Red brown
1	1,150	.206	4.1	2.50	Hard burned....	Dark red brown
3	1,190	.152	4.6	2.45	Hard burned....	Chocolate
5	1,230	.112	6.4	2.40	Hard burned....	Chocolate
7	1,270	.093	+7.0	2.36	Vitrified.....	Chocolate brown
9	1,310	.298	−9.9	1.93	Overburned.....	Gray
11	1,350	.251	−3.6	2.03	Melting.....	Brown

Gray sandy clay. Very grainy and hard to mold. Good burning range and suitable for face brick.
Burned by H. W. Jackman.

About 1½ miles east of Stockbridge, one-quarter mile southwest of the Grand Trunk Railroad in Section 24, T. 1 N., R. 2 E., Gay Sperry operated a brick yard about 1888. The machine molded 7 brick at a time which were dried 8 to 10 days before firing. Sperry abandoned the yard and went to Ludington where he made brick for a time. The clay is red to blue, apparently free from pebbles, and burns to a light red brick. It covers about 100 acres to a depth of 10 to 30 feet. In places the clay is mixed with sand as in the deposit south of Dansville.

The brick made at this yard were used for many of the buildings in Stockbridge.[1] Drainage is good and the clay seems to be suitable material for common brick.

Clay from near Stockbridge, probably this same deposit, was analyzed by Prof. E. D. Campbell and reported by Russell[2] as follows:

	%
Loss on Ignition	15.31
Silica SiO_2	46.22
Alumina Al_2O_3	15.02
Ferric Oxide Fe_2O_3	5.49
Lime CaO	10.85
Magnesia MgO	4.52
Sulphur Trioxide (SO_3)	Trace
Sand	1.20

[1]F. Isbell, Bert Morgan, or Walter Michols, Stockbridge.

[2]22d Ann. Rept. U. S. Geo. Surv. Pt. III. 671 (1902).

Sample 1000 taken from the old clay pit shows some lime pebbles or lime lumps that may not cause trouble. The following burning properties show the sample to be suitable for brick or tile.

Burning Test.

Sample No. 1000. Field Sheet No. 999.
Section 23, T. 1 N., R. 2 E., Stockbridge Township.
Plasticity .266 gm. water per gm. clay.
Average linear drying shrinkage about 8 per cent.
Average tensile strength about 102 lbs. per sq. in.
Average apparent sp. gr. (dry) 2.90.

Cone No.	Thermo-couple Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	905	.379	1.0 %	3.05	Soft burned.....	Salmon red
08	945	.382	1.9	3.24	Soft burned.....	Salmon red
06	995	.396	2.8	3.24	Soft burned.....	Salmon red
04	1,045	.331	2.9	2.75	Hard burned....	Salmon red
02	1,090	.307	3.0	2.65	Hard burned....	Salmon red
1	1,130	.189	3.5	2.56	Hard burned....	Light brown
3	1,170	.027	8.5	2.41	Vitrified.....	Brown
5	1,210	.045	−0.5	1.88	Over burned....	Chocolate brown
7	1,255	....	...	....	Melted	.....

Blue clay. Lime pebbles present. Easily molded.
Burned by M. C. Huck.

IONIA COUNTY.

Ionia County includes about 80% of morainic and boulder clay. In some places the clay is locally free from stone and of economic value.

In Saranac, about the center of section 1, T. 6 N., R. 8 W., on the Grand Trunk about 120 feet north of State Highway M-16, there is a deposit of about 50 acres of blue clay running about 25 feet deep. The blue clay is covered by a few inches of reddish clay in places, and gravel in other places. It contains some pebbles in limited quantity and is calcareous. This deposit was formerly worked by Albert Brown until his death in 1920, and soon after that the yard burned. Sample 45 was taken from the old clay pit.

Burning Test.

Sample No. 45. Field Sheet No. 44.
Section 1, (S. Center) T. 6 N., R. 8 W.
Plasticity .352 gm. water per gm. clay.
Average linear drying shrinkage 12.0 per cent.
Average tensile strength about 136 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Hardness.	Color.
08	990	.407	2.6 %	Soft burned.....	Pink
06	1,030	.436	2.0	Soft burned.....	Cream
04	1,070	.420	1.8	Soft burned.....	Cream
02	1,110	.424	2.7	Soft burned.....	Cream
1	1,150	.248	9.4	Hard burned.....	Light olive brown
3	1,190	.035	10.6	Vitrified.....	Olive
5	1,230	.033	14.8	Vitrified.....	Olive
7	1,270	.033	14.9	Vitrified.....	Olive
9	1,310	....	....	Melted	

Molded easily. Suitable for brick, tile, and hard burned olive brick such as sewer brick or possibly sewer tile. Color probably unsuited for face brick.
Burned by H. W. Jackman.

A somewhat similar deposit, also on the south side of the Grand river, about one and one-half miles west of Ionia, just beyond the Asylum, in SW¼ Section 25, T. 7 N., R. 7 W., and directly south of the State Highway, is used by the Michigan Porcelain Tile Works or the Ionia Pottery Company. In 1900 Ries* reported this deposit as follows:

"The pottery at Ionia is operated by Sage and Dethrick, and the product consists of earthen ware, flower pots, and saucers. The clay used is found on the opposite side of the valley from, the town at the base, of the hill near the penitentiary. It is a fine grained, highly plastic, blue clay, leaving very little grit so that most of it passes through a 150 mesh sieve. In water it slakes moderately fast to a flocculent mass. It needed 28 per cent of water to work it up, yielding a mass of high plasticity, and with no grit. The air shrinkage amounted to 8½ per cent and the air dried briquette had an average tensile strength of 150 to 170 pounds per square Inch. The clay contained 0.2 per cent of soluble salts.

"In burning incipient fusion occurred at 05 and vitrification at cone 1 to 2. The clay burns cream white and at Incipient fusion is still quite porous."

"In manufacturing the earthenware at Sage and Dethricks the clay is brought from the bank and stored in bins ready for use, and then put through a pair of rolls, from which it passes to a pug mill. At the discharge end of the latter there is fastened a heavy wire netting with meshes about one-quarter inch, and forcing the clay through this tends to give an additional amount of tempering and also to destroy any lumps that may be in it. From the pug mill the tempered clay goes to the molding room."

"The larger sized pots and saucers are jollied but the small ones are 'pressed' in steel molds."

"The kilns are updraft and fired by wood, and the ware is commonly cream colored, being burned at about cone 05."

*Mich. Geol. Survey VIII, Pt. I, p. 51 (1900).

When visited in July, 1922, the clay pit was about 300 feet above the river bed, on the south side of the highway, just west of the asylum. The clay covers 25 acres or more and runs about 20 feet of red clay (sample 46) with some quicksand pockets, underlain by 50 to 75 feet of blue clay (sample 47). The clay is free from pebbles, fine grained, and very plastic. The clay and sand are dug by hand and teamed into the plant in the southern part of Ionia on the Grand Trunk.

In the old plant flower pots from one to sixteen inches in diameter are made. Formerly milk jars were made but this line was discontinued some time ago. The cellar of the plant is completely equipped for preparing the clay. Storage bins receive the clay and sand from the pit. The clay slip is prepared in blungers, filtered through fine screens or cloth and run into cisterns. The slip is pumped from the cisterns to the filter press. The pressed clay is then run through a pug mill and cut into lumps which are delivered to the molders in the upper part of the factory. The larger pots are jollied in molds and the common smaller pots "pressed" by steel plungers in a revolving mold. About 40 men are employed in making flower pots.

The main factory building includes three 30 foot round down draft kilns for burning flower pots. In this way the heat given off from the kilns aid in drying the green ware and in heating the factory.

A later addition to the old plant was built to contain the glazed tile plant. The clay used for glazing is imported, but the local glacial drift clay prepared as outlined above is used to make the body of the tile. The tile are formed by extrusion through a die and in some cases by pressing. The addition is fully equipped for forming tile and glazing. The tile are burned in a small down draft kiln in the old factory. A small test kiln is provided in the tile department for testing the glazes.

About a quarter of a mile east of the old plant is a modern new plant containing two 30 foot down draft kilns, for the manufacture of tile. This plant was under construction in 1922 but was in full operation in 1923.

This plant is of particular interest for two reasons. For 40 years it has successfully made earthenware from Michigan boulder clay. Recently it has expanded its facilities and is doing a very active business in making high grade glazed tile, using the same boulder clay for the tile body.

The following tests show the clay to be buff burning with a high lime content, which is partly counteracted by the magnesia, giving a burning range of six cones:

Burning Test

Sample No. 46. Field Sheet No. 45. SW¼ Section 25, T. 7 N., R. 7 W.
Plasticity .323 gm. water per gm. clay.
Average linear drying shrinkage 11.2 per cent.
Average tensile strength about 135 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Hardness.	Color.
010	950	.391	2.9 %	Soft bruned.....	Salmon
08	990	.384	2.9	Soft burned.....	Salmon cream
06	1,030	.366	2.9	Soft burned.....	Cream
04	1,070	.296	2.5	Soft burned.....	Cream
02	1,110	.239	8.1	Hard burned.....	Dark cream
1	1,150	.043	14.0	Vitrified.....	Light brown
3	1,190	.022	14.1	Vitrified.....	Light gray brown
5	1,230	.012	15.2	Vitrified.....	Light olive
8	1,290	....	....	Melted	.....

Pottery clay. Easily molded.
Burned by H. W. Jackman.

Burning Test

Sample No. 47. Field Sheet No. 45.
Michigan Porcelain Tile Works, SW¼ Section 25, T. 7 N., R. 7 W.
Plasticity .309 gm. water per gm. clay.
Average linear drying shrinkage 10.9 per cent.
Average tensile strength about 115 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Hardness.	Color.
010	950	.378	2.3 %	Soft burned.....	Pink
08	990	.391	1.3	Soft burned.....	Cream white
06	1,030	.400	3.0	Soft burned.....	Cream white
04	1,070	.382	3.6	Soft burned.....	Cream white
02	1,110	.325	5.9	Hard burned.....	Cream
1	1,150	.086	14.1	Hard burned.....	Light brown
3	1,190	.023	15.8	Vitrified.....	Light brown
5	1,230	.012	17.1	Vitrified.....	Light olive brown
8	1,290	....	....	Melted	

Easily molded; used as pottery clay.
Burned by H. W. Jackman.

Chemical Analysis

Red and blue clay of deposit in SW¼ Section 25, T. 7 N., R. 7 W.

	Red clay Sample No. 46		Blue clay Sample No. 47	
Loss on ignition	18.15%	18.73%	18.67%	18.70%
Silica (SiO_2)	39.66	42.38	43.20	42.79
Iron (Fe_2O_3)	2.78	4.82	4.38	4.60
Alumina (Al_2O_3)	21.95	15.74	16.24	15.98
Lime (CaO)	13.60	13.95	13.66	13.80
Magnesia (MgO)	1.54	3.50	3.10	3.30
Alkalies (Na_2O, K_2O) ...	2.61	....	....	2.11
	100.29%			101.28%

Analyzed by H. W. Jackman.

F. H. Van der Heyden formerly operated a brick yard at Ionia. Ries* visited this yard and reported the deposit as follows:

"Sand	2 ft.
Fat clay	6 ft.
Gravel	2 ft.
Sandy clay	12 ft.

A mixture of the upper and lower clay is commonly used as it gives the best results. A sample of this was tested (R. 181).

Its fineness is shown by the fact that when washed but few grains are retained on the 100 mesh sieve. "In tempering only 18 per cent of water was required, but this yielded a mass of high plasticity. This shrinks in the air 6 per cent and at cone 05 incipient fusion was just about reached, with a total shrinkage of 7 per cent, and the color creamy white. At cone 1 the total shrinkage was 12 per cent and the color buff. Vitrification took place at cone 2 and viscosity between cones 3 and 4.

The clay is used for making brick, and owing to its high plasticity tends to laminate when molded in a stiff mud machine. The yard is equipped with two different brick machines, viz. a Wallace stiff mud auger machine with a triple die and a Creager soft mud machine. The latter is used for the lower sandy clay, while the mixture of the upper and under clay is molded in the auger machine. The soft mud bricks, it is said, stand the weather much better. The Creager machine has the clay prepared for it in a six foot pug-mill and a pair of rolls.

The yard is also equipped with a hand power repress and the product includes some tile."

For purposes of comparison chemical analyses of the brick clays sample 22 and the pottery clay, sample 23, by A. N. Clark are here given.

Analysis No.	22	23
Silica	44.15%	40.15%
Alumina	10.00	11.25
Ferric Oxide	4.08	4.88
Lime carbonate	24.68	21.43
Magnesium carbonate	1.50	8.93
Alkalies	1.55	2.06
Organic matter	1.95	2.05
Water by difference.....	12.13	9.25

*Mich. Geol. Survey VIII, Pt. I, p. 52 (1900).

IOSCO COUNTY

Iosco County is largely covered by the Old Au Sable River Delta and is generally sandy. Just west of Tawas City running north for about 10 miles and south for a greater distance there is a strip of morainic and lake clays containing some pebbles that may be suitable for common red brick. From Tawas City west for about six or eight miles there is a wide strip of lake clay with morainic clay on the north side. This lake clay runs generally less stony toward the southwest where it may be suitable for a brown colored face brick. The clay is generally red, about 60 feet deep, and covered in places with two or three feet of sand. Sample 136 is from the eastern part of this strip in the southwest corner of Section 21, T. 22 N., R. 7 E. Sample 137 is from the western part and is excellent material for brick and tile.

Burning Test

Sample No. 137. Field Sheet No. 146.
Section 24 (s.), T. 22 N., R. 6 E.
Plasticity .270 gm. water per gm. clay.

Average linear drying shrinkage 18.0 per cent.
Average tensile strength about 210 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.283	1.0 %	1.78	Soft burned.....	Light red
08	990	.279	1.5	1.82	Soft burned.....	Light red
06	1,030	.187	4.0	1.94	Hard burned.....	Red
04	1,070	.120	5.8	2.04	Hard burned.....	Red
02	1,110	.028	7.4	2.18	Vitrified.....	Dark brown
1	1,150	.024	2.7	1.88	Vitrified.....	Chocolate
3	1,190	....	...	....	Viscous	

Reddish brown clay. Easily molded. Vitrified bricks swelled slightly and cracked. Suitable for brick and tile.
Burned by H. W. Jackman.

ISABELLA COUNTY

Just northeast of Mt. Pleasant there is an old delta of the Chippewa River which marks the western limit of the glacial lakes in the Saginaw basin. Northeast of Mt. Pleasant there is a large area of lake clay that is an extension of the adjoining area in the northwestern part of Midland County. It has the same general qualities. East of Mt. Pleasant the clay is covered with sand.

About 1900 DePotty made brick from a deposit of boulder clay three miles south of Clare, near Russell, in section 12, T. 16 N., R. 4 W. Some good brick and poor brick were made. Sample. No. 83 was taken from the side of a cut on State Highway M-14 about four and one-half miles south of Clare in sections 26 and 27, T. 16 N., R. 4 W. This sample is representative of the red boulder clay in this district which is found in the plains and drumlins mixed with gravel. It is from six to fifteen feet or more in depth.

Burning Test

Sample No. 83. Field Sheet No. 87.
Section 26-27, T. 16 N., R. 4 W.
Plasticity .241 gm. water per gm. clay.
Average linear drying shrinkage 10.1 per cent.
Average tensile strength about 129 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.334	−0.2 %	1.70	Soft burned.....	Pink
08	990	.348	−0.2	1.71	Soft burned.....	Pink
06	1,030	.344	−0.4	1.71	Soft burned.....	Pink
04	1,070	.334	0.7	1.74	Soft burned.....	Light tan
02	1,110	.202	0.7	1.85	Soft burned.....	Tan
1	1,150	.236	4.3	1.96	Hard burned.....	Tan
3	1,190	.123	6.7	2.13	Hard burned.....	Light olive
5	1,230	.032	7.4	2.16	Vitrified.....	Olive
7	1,270	.016	6.0	2.05	Vitrified.....	Olive
9	1,310	....	...	....	Melted	.....

Lime pebbles. Molded fairly easily but somewhat grainy. Suitable for common brick.
Burned by H. W. Jackman.

About 1880 soft mud brick was made from red burning boulder clay just south of Mount Pleasant. This brick was used in the older buildings of the town and seems to have been a fairly good product. Similar clay containing some lime pebbles and sand extends south through Shepherd to St. Louis, .Gratiot County.

Thompson and Gere formerly operated brick yards, using the lake clay about one to two miles northeast of Mount Pleasant along the Chippewa River. These plants are dismantled and torn down.

Wademan owns a plant about one and one-half mile northeast of Mount Pleasant in Section 2, T. 14 N., R. 4 W. The plant is located just east of the Pere Marquette Railroad and is equipped with a Fate tile auger machine, a drying shed, and two 20 foot round down draft kilns. The clay runs about three to 12 feet deep and is covered by three feet of sand and gravel. The same kind of blue clay is found north of the Salt River up to Coleman and the Clare County line. Sample 82 was taken from the pit of Wademan's yard. The tests of this clay indicate that it may be used for cream brick and tile and possibly for some pottery purposes as it is very fine grained and molds readily to a very smooth product.

Burning Test

Sample No. 82. Field Sheet No. 86.
Section 2, T. 14 N., R. 4 W. Wademan's yard.
Plasticity 0.230 gm. water per gm. clay.
Average linear drying shrinkage 6.9 per cent.
Average tensile strength about 125 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.386	1.1 %	1.60	Soft burned.....	Pink cream
08	990	.381	1.0	1.59	Soft burned.....	Cream
06	1,030	.400	0.6	1.59	Soft burned.....	Cream
04	1,070	.418	0.2	1.55	Soft burned.....	Cream white
02	1,110	.427	1.0	1.58	Soft burned.....	Cream white
1	1,150	.430	2.1	1.63	Soft burned.....	Cream white
3	1,190	.361	5.0	1.80	Hard burned.....	Buff
5	1,230	.127	13.0	2.34	Hard burned.....	Olive
7	1,270	.059	15.2	2.51	Vitrified.....	Olive
9	1,310	....	.....	....	Melted	.....

Molded easily.
Burned by H. W. Jackman.

Chemical Analysis

Sample No. 82. Field Sheet No. 86.
Clay in Section 2, T. 14 N., R. 4 W.

			Average
Loss on Ignition	20.00%	19.75%	19.87%
Silica (SiO_2)	41.60	42.82	42.22
Iron (Fe_2O_3)	3.17	3.48	3.32
Alumina (Al_2O_3)	11.30	12.32	11.81
Lime (CaO)	14.89	15.01	14.95
Magnesia (MgO)	6.22	6.42	6.32
Alkalies ($Na_2 + K_2O$)			2.34
			100.83%

Analyzed by H. W. Jackman.

West of Mount Pleasant there is morainic boulder clay, generally containing lime pebbles and sand, and of little value. A few years ago the National Portland Cement Company was contemplating the erection of a cement plant on Coldwater Lake, section 30, T. 15 N., R. 5 W. The plan was to use marl from the lake and some of the adjacent boulder clay as raw material. The following tests of two samples of clay taken from the deposits proposed as raw material for cement indicates that the clay contains a ratio of about 4:1 silica to iron and alumina, which is near the maximum limit permissible in cement mixtures. This fact, taken in consideration with the generally unsatisfactory nature of boulder clays, should make it an object of suspicion as a raw material for cement. The burning tests indicate that it might be used for common brick or possibly tile, but a first class

product could not be produced due to the lime pebbles and high lime content.

Chemical Analysis.

Sample No. 18.
15-20 acres at south end of Coldwater Lake.
SE¼ Sec. 30, T. 15 N., R. 5 W.

H_2O and organic matter	13.53%
Silica (SiO_2)	56.15
Total iron as Fe_2O_3	3.66
Alumina (Al_2O_3)	11.04
Lime (CaO)	11.43
Magnesia (MgO)	1.45
Alkalies (K_2O — Na_2O, Approx.)	2.74

Analyzed by H. W. Jackman.

Burning Test

Sample No. 18. Section 30, T. 15 N., R. 5 W.

Cone No.	Cone Temp. °C.	Linear Shrinkage.	Porosity.	Hardness.	Color.
014	870	−1.2 %	.381	Soft burned	Salomn
010	950	−0.5	.384	Soft burned	Salmon
08	990	−0.7	.383	Soft burned	Pale salmon
06	1,030	0.6	.381	Soft burned	Pale salmon
04	1,070	3.4	.340	Hard burned (Incipient fusion)	Salmon gray White spots (lime)
02	1,110	3.3	.296	Hard burned	Blue gray
1	1,150	4.5	.283	Hard burned	Blue gray
3	1,190	6.3	.220	Hard burned	Blue gray, showing green
5	1,230	...	....	Overburned, (viscous)	

Burning range 04 to 1.
Burned by H. W. Jackman.

Sample No. 19. Sec. 30, T. 15 N., R. 5. W.
North end of Coldwater Lake, 20 acres on Henry Cook and Mat Schaeffer's farms.

Chemical Analysis

H_2O and organic matter	10.92%
Silica (SiO_2)	57.65
Iron (Fe_2O_3)	4.20
Alumina (Al_2O_3)	12.54
Lime (CaO)	9.89
Magnesia (MgO)	2.54
Alkalies (K_2O — Na_2O)	2.26

Analyzed by H. W. Jackman.

Burning Test

Cone Temp. °C.	Cone No.	Linear Shrinkage.	Porosity.	Color.	Hardness.
870	014	1.0 %	.368	Salmon	Soft burned
950	010	0.5	.374	Salmon	Soft burned
990	08	0.4	.368	Pale salmon	Soft burned
1,030	06	1.1	.353	Salmon buff	Soft burned
1,070	04	7.1	.159	Violet gray, White spots (lime)	Hard burned
1,110	02	7.5	.148	Violet gray, White spots (lime)	Hard burned
1,150	1	8.3	.110	Violet gray, White spots (lime)	Hard burned
1,190	3	7.4	.615	Cream, showing green	Beginning to soften
1,230	5	...	....	.....	Viscous

Burning range 04 to 1.
Burned by H. W, Jackman.

JACKSON COUNTY

The Coal Measure shales are very near the surface in Jackson County, outcropping In the Grand River valley north of Jackson, where they are quarried by the American Vitrified Products Company and used for sewer pipe at the Jackson plant. The plant is in the north center part of Jackson just east of the Grand Trunk railroad on Porter Street, about 1,000 feet west of Cooper Street, SE¼ Section 27, T. 2 S., R. 1 W.

The shale is brought in on a narrow gage railroad. It is prepared by grinding in a dry pan and then tempering in a wet pan. These operations have a capacity of about 130 tons of shale a day. The tempered clay is then conveyed from the wet pan to the cylinders of the extrusion presses.

The plant is equipped with two steam presses for extruding sewer pipe and tile. The steam piston is 42 inches in diameter and operates under a steam pressure of 120 pounds per square inch. In this way 70 to 80 tons pressure are exerted on the die during extrusion. The combined capacity of the two presses is equivalent to 4½ miles of 6 inch tile per day, or about 1,500 carloads of finished ware per year. The extruded pipe issuing from the bottom of the press is cut off and carried on a truck to a suitable place on the drying floor. This is a slatted wood floor overlying steam pipes. The ware is burned in 19 round down draft kilns about 28 to 30 feet in diameter.

The present quarry is about four miles north of the plant in NE¼ section 11, T. 2 S., R. 1 W., just east of the Grand River. The old pits in section 15 and the southern part of section 11 have been exhausted. The low hills back from the river are capped by limestone. The Coal Measures containing the shale beds lie in the depressions between the hills. The shale is exposed along the banks of the river where it is quarried. The shale section contains one or more lenses of sandstone. Quarrying is done in a rather crude fashion, all of the picking, and loading being done by hand.

Sample 74 was taken from the ground shale as discharged from the dry pan at the plant. The analysis and burning properties are very similar to the shale found at Grand Ledge. Quarry conditions are unfavorable in many ways and the Grand Ledge shale is considered more suitable material. Other deposits farther north and west of the present quarry may contain better material and should be investigated.

Burning Test

Sample No. 74. Field Sheet No. 74.
Section 10, T. 2 S., R. 1 W.
Plasticity .223 gm. water per gm. clay.
Average linear drying shrinkage 7.0 per cent.
Average tensile strength about 56 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Hardness.	Color.
08	990	.285	−0.2 %	Soft burned	Salmon
06	1,030	.278	0.4	Soft burned	Salmon
04	1,070	.258	0.9	Soft burned	Salmon
02	1,110	.224	2.1	Hard burned	Salmon
1	1,150	.196	3.2	Hard burned	Red brown
3	1,190	.195	3.2	Hard burned	Red brown
5	1,230	.168	4.4	Hard burned	Red brown
7	1,270	.157	3.5	Hard burned	Red brown
9	1,310	.073	3.1	Vitrified	Gray

Molded easily,—good material for face brick and tile.
Burned by H. W. Jackman.

Chemical Analysis

Sample No. 74. Field Report Sheet No. 74.
NE¼ Section 11, T. 2 S., R. 1 W.

			Average
Loss on Ignition	6.67%	6.67%	6.67%
Silica (SiO_2)	66.51	65.25	65.88
Iron (Fe_2O_3)	3.80	4.01	3.90
Alumina (Al_2O_3)	22.50	21.79	21.90
Lime (CaO)	0.37	0.52	0.44
Magnesia (MgO)	0.46	0.86	0.66
Alkalies (Na_2O, K_2O)			1.77
			101.22%

Analysis by H. W. Jackman.

Many of the surface clays of Jackson County are derived in considerable part from the Coal Measure shales. Ries* gives the following report concerning the surface clays:

"There occurs a bed of potters' clay five miles west of Jackson, while at the Adler Brick Company, three and one-half miles west, a soft plastic surface clay is employed which burns red in parts and buff in others. The bricks are molded by the soft mud process and come into competition with the Detroit ones."

"The Bennett Tile Co. is located one and one-half miles east of town and utilizes a plastic clay, making drain tile and paving brick. They have a clay deposit seven miles from Jackson and a narrow gage road connects it with the works."

"The following is the composition of a clay from G. H. Wolcott's yard, Springport township, from Mineral Resources for 1896, p. 61. Analyzed by Mariner and Haskins:

Silica SiO_2	52.26%
Alumina Al_2O_3	22.95
Iron Oxide Fe_2O_3	8.15
Lime CaO	4.48
Magnesia MgO	1.32
Water, etc.	10.56
	99.72%

"This analysis indicates a more or less direct derivation from a coal measure shale."

*Mich. Geol. Survey VIII, Part I, p. 60 (1900).

The Zenith Portland Cement Co., organized July 17, 1900, with a capital of $700,000, planned to use marl and clay as found near Grass Lake. The plant site was located at the southeast end of Grass Lake.

A sample of clay from this location was analyzed by F. S. Kedzie* as follows:

Silica (SiO_2)	49.86%
Iron and Alumina ($Fe_2O_3 + Al_2O_3$)	21.22
Lime (CaO)	6.32
Magnesia (MgO)	2.75
Carbon Dioxide (CO_2)	5.44
Organic and water	7.14
Difference	7.21

About two and one-half miles southwest of Concord and the Michigan Central Railroad in SW¼ section 1, T. 4 S., R. 3 W., is an exposure of stony yellow clay in a cut in the road. The clay is about 20-25 feet thick under one to two feet of stony yellow sand, and is represented by sample 1027.

On the Wittenberg farm about one mile north of Cement City in SE¼ Section 32, T. 4 S., R. 1 E., there is a deposit of yellow and gray clay, about 15 feet thick, over 15 acres. The clay contains considerable sand and gravel. It was carefully drilled and analyzed by Mr. Kane of the Peninsular Portland Cement Company.

Silica	Iron and Alumina	Lime	Magnesia
68.60%	20.50%	2.10%	1.66%
62.88	23.00	1.60	1.77
68.60	21.70	1.80	1.48
69.86	18.30	1.00	.79
66.76	20.90	1.50	2.00
68.50	20.90	2.00	1.99
67.16	20.58	1.00	1.73

The above represents a set of holes covering about 15 acres which is the extent of the deposit. Unsuitable for cement.

Analysis of a composite of the entire deposit

	SiO_2	R_2O_3	CaO	MgO	Total
Insoluble part ..	64.88%	13.05%	.80%	1.15%	79.88%
Soluble part	1.56	6.29	.70	.50	9.05
Total of the two.	66.44	19.34	1.50	1.65	88.93

Wm. Kane, Penin. Ptld. Cement Co.,
Cement City.

*Mich. Geol. Survey VIII, Part III, p. 288 (1900-3).

KALAMAZOO COUNTY

In the vicinity of Kalamazoo there are several small deposits of surface clay, that have been used for the manufacture of common brick. One of these deposits was formerly worked at Waits' yard on the western edge of the town.* This clay bank is a shallow deposit surrounded and underlain by sand. The clay burns red.

A larger deposit was formerly worked at Leonard's yard about six miles from the city on the South Haven branch of the M. C. railroad. Here the clay is about 14 feet thick, composed of an upper sandy clay and a lower fat clay. The two clays were mixed, tempered in ring pits, and molded in soft mud machines. The brick were dried on pallets and burned in scove kilns. A sample of these mixed clays was tested by Ries as follows:

Sample (Ries) 223.
Water of plasticity 23%,
Air shrinkage 6%.
Tensile strength 135-150 lbs. sq. in.
Soluble salts 0.7%

Cone.	Total Shrinkage.	Burn.	Color.
04	14 %	Hard	Bright red
1	15 %	Hard	Brown red
2	17 %	Vitrified	.....
4	....	Viscous	.....

The clay is very plastic and seems to be good material for making face or pressed brick, and tile.

Kalamazoo is the site of the old Eagle Portland Cement Company. This plant was equipped with four vertical kilns, two of which were built in 1872, and produced a total of 300,000 barrels of cement before it was abandoned in 1882.

The Kalamazoo Sanitary Products Company makes washbowls and closets from imported clays.

Shields Brothers formerly operated a brick yard at Williams, about five miles beyond the Leonard yard on the South Haven branch of the Michigan Central Railroad. The yard is just south of the railroad in NE¼ section 30, T. 1 S., R. 12 W. The clay is about 30 inches thick over 10 acres. No brick has been produced since 1907. The reason given is that the brick could not be sold. The plant was still in good condition in 1922.

*H. Ries, Mich. Geol. Survey VIII, Pt. I, p. 56.

Sample 22 was taken from the pit and seems to be good material for face brick or tile.

Burning Test

Sample No. 22. Field Sheet No. 19.
Section 30, NE¼, T. 1 S., R. 12 W.
Plasticity .363 gm. water per gm. clay.
Average linear drying shrinkage 13.7 per cent.
Average tensile strength about 210 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.334	0.3 %	1.63	Soft burned.....	Salmon
08	990	.315	1.5	1.69	Soft burned.....	Salmon
06	1,030	.225	5.0	1.89	Semi-hard burned.	Light red
04	1,070	.066	10.1	2.24	Hard burned.....	Red
02	1,110	.004	10.4	2.28	Vitrified.....	Chocolate red
1	1,150	.038	8.3	2.07	Vitrified.....	Chocolate red
3	1,190	.127	−4.7	1.48	Viscous.....	Chocolate

Light brown clay, molded easily; suitable for face brick and tile.
Burned by H. W. Jackman.

KENT COUNTY

Kent County has a considerable area, probably over 40 per cent, covered by boulder and moraine clays.

At Sparta The Clay Manufacturing Company works a ten acre deposit of reddish clay that seems to lie in the glacial outwash plain. The plant is located in the northeast corner of Sparta, just east and south of the intersection of the Grand Trunk and Pere Marquette Railroads in the center of Section 14, T. 9 N., R. 12 W. The clay runs about 11 feet deep and then goes to quicksand, at least in places. Digging is done by a steam shovel which loads the skip cars directly. The cars are drawn up from the pit by a power driven drum, and dumped into a pug mill where the clay is tempered. The clay is then passed through rolls into the auger extrusion machine. Drain tile and building tile are manufactured. The drier is heated by separate fires and by steam coils supplied from the steam power plant. Burning is done in four thirty foot round downdraft kilns.

When the plant was visited in July, 1922, it was closed. Local information reported the shut down was due to the difficulty of obtaining labor. Rather hasty observation of some tile on the property indicated that the clay was dug in a rather careless manner, i. e., quick sand and top soil was included in the clay to the detriment of the product. The tile were generally buff to salmon, with some red tile around the bag walls where the fire gases first struck the ware. Sample 29 was taken from the clay pit.

Burning Test

Sample No. 29. Field Sheet No. 28.
Section 14 (center) T. 9 N., R. 12 W.
Plasticity .331 gm. water per gm. clay.
Average linear drying shrinkage 12.1 per cent.
Average tensile strength about 100 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Hardness.	Color.
010	950	.394	1.3 %	Soft burned.....	Salmon
08	990	.388	1.3	Soft burned.....	Salmon pink
06	1,030	.400	2.0	Soft burned.....	Cream
04	1,070	.401	2.8	Soft burned.....	Cream
02	1,110	.333	4.0	Soft burned.....	Cream
1	1,150	.143	9.7	Hard burned.....	Olive
3	1,190	.075	11.1	Hard burned.....	Dark olive
5	1,230	.040	13.0	Hard burned.....	Dark olive
7	1,270	.035	8.1	Over burned.....	Olive

Molded easily; suitable for brick and tile.
Burned by H. W. Jackman.

The Grand Rapids Clay Products Company operates a modern brick plant at the eastern edge of Grand Rapids about one-fourth mile south of the Grand Trunk Railroad in the NW¼ Section 28, T. 7 N., R. 11 W. This plant has had a rather checkered history. When the clay pit was first opened the overburden of fine sand was not removed properly and became mixed with the clay. This practice made the production of a first class brick impossible, and the poor quality product could not be sold. The plant then changed hands and was heavily mortgaged. A second failure placed the property in the hands of the present owners, the Federal Life Insurance Company, who are sparing no pains or expense to make it a first class plant.

The clay deposit was originally about 40 acres in extent, one-half of which has been dug over. The heavy blue clay is covered by about five feet of fine sand and soil which must be removed before the clay is dug. Under the clay, which runs about 20 feet thick there is a somewhat coarser sand that is used to temper the clay. Sample No. 28 was taken from the clay pit.

Burning Test

Sample No. 28. Sheet 27.
Section 28, (NW Corner) T. 7 N., R. 11 W.
Plasticity .257 gm. water per gm. clay.
Linear drying shrinkage 6.7 per cent.
Average tensile strength about 102 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Fired Linear Shrinkage.	Hardness.	Color.
08	990	.445	2.6 %	Soft burned.....	Pink
06	1,030	.453	1.4	Soft burned.....	Cream
04	1,070	.465	0.7	Soft burned.....	Cream
02	1,110	.454	1.8	Soft burned.....	Cream
1	1,150	.428	4.3	Hard burned.....	Cream
3	1,190	.328	8.2	Hard burned.....	Tan
5	1,230	.291	10.0	Hard burned.....	Olive
7	1,270	.045	16.5	Vitrified.....	Olive
9	1,310	....	....	Melted	

Cracked slightly at the higher temperatures. Easily molded, good material for cream or buff tile and brick.
Burning test by H. W. Jackman.

The clay is dug by a steam shovel and loaded with a small amount of sand into narrow gage cars which are drawn to the plant by a small gasoline engine. The clay is dumped directly into a pug mill and tempered with water and some ground burned clay that is prepared by grinding bats in a dry pan. The tempered clay then passes through rolls into the auger machine equipped with a twin die for extruding brick. The green brick are stacked on trucks and pushed through a continuous tunnel drier which is heated directly by the hot gases from the boiler furnace. These stack gases are drawn from the boiler through a large flue along the side of the drier and blown into the exit end of the drier by a fan. The hot gases enter near the floor of the drier and come into contact with the nearly dry brick, ready to be removed, and do not reach the wet brick at the charging and until the gases have become more nearly saturated and cooled by their passage through the drier. At the charging end of the drier these gases escape through wooden stacks. The drying tunnels are also equipped with steam coils for auxiliary heating. This drying equipment cost $30,000 in 1921 and has increased greatly the capacity of the plant.

The dried brick as they leave the drier are covered with soot from the furnace gases, but this burns off in the kilns and causes no difficulty. The brick are burned in eight scove kilns of about 65,000 brick each. The product is a buff building brick of good quality. In 1923, when the plant first produced a good brick, the hard dark brick were being sold as sewer brick, but it would be impossible to produce satisfactory vitrified brick from this clay as a main product.

Under good conditions the capacity of the plant will approach 80,000 to 100,000 brick a day with a force of 55 men or more.

A sample of clay (189) submitted by the Ponce de Leon Water Company from Section 9, T. 6 N., R. 11 W., near East Paris, is red burning and would be good material for brick and tile if the pebbles it contains can be satisfactorily handled. It has a good commercial color and a burning range of 6 cones

Burning Test

Sample No. 189.
Section 9, T. 6 N., R. 11 W.
Plasticity .270 gm. water per gm. clay.
Average linear drying shrinkage 9 per cent.
Average tensile strength about 125 lbs. per sq. in.
Average apparent Sp. Gr. (dry) 2.47.

Cone No.	Thermo-couple °C. Temp.	Porosity.	Linear Shrinkage.	Hardness.	Color.
08	950	.386	1.0 %	Soft burned.....	Salmon
06	1,000	.388	1.4	Soft burned.....	Salmon
04	1,050	.354	2.0	Hard burned.....	Salmon
02	1,120	.275	6.5	Hard burned.....	Salmon
1	1,175	.092	9.8	Hard burned.....	Dark brown
3	1,220	.057	14.2	Vitrified.....	Chocolate brown
5	.....	....	....	Viscous	

Good material for brick and tile except for pebbles which may cause trouble.
Burned by Mark Huck.

The blue shales of the Grand Rapids Series associated with the gypsum were investigated by Ries* in 1900. His report includes samples taken at the shaft of the Powers Plaster Company (R216) and at the quarry of the Alabastine Co. (R227).

The shale from the Powers Plaster Co. (R216) was a dense, brownish gray shale, containing but little mica and no pyrite. It slaked very slowly, and mellowed slowly when simply exposed to the air.

Soluble salts, 0.9%.
Water of plasticity, 26%.
Air shrinkage, 6%.
Tensile strength, 130-155 lbs. sq. in.

Cone.	Total Shrinkage.	Burned.	Color.
05.....	12 %	Hard.....	Red
2.....	....	Vitrified	.....
6.....	....	Viscous	.....

*Mich. Geol. Survey VIII, p. 39, Pt. I.

The sample from the Alabastine Co. (R227) was taken from a shale bed seven feet thick overlying the gypsum. The shale itself was covered by three feet of drift. This shale was formerly used in the manufacture of common brick by the stiff mud process. The shale was spread out under a shed to dry and slake, then ground in a dry pan, tempered, and extruded. This shale is similar to that from the Powers Plaster Co.

Sample R227 ground to 30 mesh.
Water of plasticity, 32%.
Air shrinkage, 6%.
Tensile strength, 105 lbs. per sq. in.
Soluble salts, 0.9%.

Cone.	Total Shrinkage.	Burned.	Color.
05.....	12 %	Hard burned.....	Red
01.....	16 %	Vitrified	
3.....	....	Viscous	

In drying a white scum was formed on the surface by the soluble salts.

Chemical Analysis (Sample R227)

Silica (SiO_2)	56.50%
Alumina (Al_2O_3)	19.31
Iron (Fe_2O_3)	5.89
Lime ($CaCO_3$)	1.00
Magnesia ($MgCO_3$)	1.85
Alkalies (K_2O)	5.98
Difference	9.47
Ferrous Iron (FeO)	1.34

By A. N. Clark.

Compare this analysis with the following analysis of surface clay from Grand Rapids by S. P. Sharpless.*

Silica (SiO_2)	58.70%
Alumina + Iron ($Al_2O_3 + Fe_2O_3$)	25.95
Lime (CaO)	1.00
Magnesia (MgO)	.74
Alkalies	5.54
Water, etc.	8.07

Generally the shale is found in a stratum about 23 inches thick overlying the gypsum at a depth of 95 feet for an area of about 50 square miles. Sample 27 was taken from this stratum in section 3, T. 6 N., R. 12 W., about one mile southwest of Grand Rapids city limits on the Pere Marquette railroad.

*16th Ann. Rept. Director U. S. Geological Surv., Part IV, p. 566.

Burning Test

Sample No. 27.
Section 3, T. 6 N., R. 12 W.
Plasticity .325 gm. water per gm. clay.
Average linear drying shrinkage 10.6 per cent.
Average tensile strength about 66 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Hardness.	Color.
010	950	.295	1.1	Soft burned	Light red
08	990	.231	2.0	Soft burned	Light red
06	1,030	.192	3.8	Hard burned	Red
04	1,070	.058	7.6	Hard burned	Red
02	1,110	.068	4.6	Vitrified	Red brown
1	1,150	.329	−28.4	Over burned	Dark brown

Molded easily. Samples swelled at cone 03.
Burned by H. W. Jackman.

This blue shale is very suitable for brick or tile, but it is relatively inaccessible and thin.

LAKE COUNTY

Lake County is covered with morainic boulder clay, most of which is useless but may be locally usable for brick and tile. It is very similar to the clay near Branch, Mason County, (sample 1017). The Great Northern Cement Company, organized in 1899 as a New Jersey corporation, with $5,000,000 capitalization, built a plant of 24 kilns just south of Baldwin in Marlboro. This company was to use the clay bank in section 10, T. 17 N., R. 12 W., which covers some 400 acres of a glacial deposit about 80 to 120 feet high. It is reported to be free from grit.

LAPEER COUNTY

The boulder clay near Elba was used for some time by the Elba Tile Company. The lake clay near Lapeer was formerly used to make common red brick.

About four miles north of Almont on Mark Parley's farm along the south side of the Belle River in Section 34, T. 7 N., R. 12 E., there is about six to eight feet of sandy yellow clay overlying about 25 feet of blue clay. This deposit covers 40 or 50 acres. Farther east and north of the river the blue clay is exposed on the surface. The clay is a lake clay similar to that found down the river to the east. Sample 151 was taken from the brown surface lake clay south of the Belle River.

Burning Test

Sample No. 151. Field Sheet 168.
Section 34, Southern, T. 7 N., R. 12 E.
Plasticity .234 gm. water per gm. clay.
Average linear drying shrinkage 6.3 per cent.
Average tensile strength about 97 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.339	−0.4 %	1.65	Soft burned	Pale salmon
08	990	.347	−0.2	1.65	Soft burned	Pale salmon
06	1,030	.349	−0.2	1.65	Soft burned	Pale salmon
04	1,070	.333	+0.6	1.68	Soft burned	Pale salmon
02	1,110	.149	6.3	2.02	Hard burned	Light brown
1	1,150	.094	7.9	2.13	Hard burned	Brown
3	1,190	.029	6.7	2.04	Vitrified	Dark brown
5	1,230	....	...	....	Viscous	

Light brown clay. Burned samples at Cones 02 and 1 have white edges, suitable for brick and tile.
Burned by H. W. Jackman.

LEELANAU COUNTY

Leelanau County is completely covered with glacial drift and sandy lake deposits. About three miles north of Traverse City and just west of the lake shore road in section 28, T. 28 N., R. 11 W., there is a ten acre deposit of blue clay about 20 to 25 feet deep in the form of a mound, covered in places by two to five feet of fine sand and underlain by a coarser sand. The deposit was formerly worked by James W. Markham, making good quality, stiff mud brick, of cream color. The plant is a total ruin and all of the machinery removed.

Chemical Analysis

Sample No. 34. Field Sheet 35.
Sample is a mixture from 5, 10, 15, 20 feet diggings in face of a clay bank in section 28. T. 28 N., R. 11 W.

Loss on Ignition	20.08%
SiO_2	34.95
Al_2O_3	14.05
Fe_2O_3	3.50
CaO	18.60
MgO	6.66
$Na_2O + K_2O$	2.16

Analysis by H. W. Jackman.

Burning Test

Sample No. 34. Field sheet No. 35.
Sections 28, 33, T. 28 N., R. 11 W.
Plasticity .286 gm. water per gm. clay.
Average linear drying shrinkage 9.2 per cent.
Average tensile strength about 130 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Hardness.	Color.
08	990	.452	0.9 %	Soft burned.....	Cream
06	1,030	.464	1.3	Soft burned.....	Cream
04	1,070	.474	2.0	Soft burned.....	Cream
02	1,110	.464	2.4	Soft burned.....	Cream
1	1,150	.457	2.4	Soft burned.....	Cream
3	1,190	.372	7.7	Hard burned.....	Light olive
5	1,230	.103	15.9	Hard burned.....	Olive
7	1,310	....	....	Melted	

Molded easily. Suitable for brick or tile.
Burned by H. W. Jackman.

The analysis and burning test of this clay are very suggestive of the clay in the Long Lake series or Thunder Bay Series of the Traverse Formation* which forms the bed rock of the northwestern part of Leelanau and Benzie Counties. It seems probable that this glacial clay may have been derived at least in part from these shales.

*See sample 133 Alpena County and analysis of clay in limestone at Rockport, Alpena County.

LENAWEE COUNTY

Many of the clays of Lenawee County seem to have been derived in considerable part from the Coldwater and other shale formations which underlie the major part of the county. Lake clay is found east of Macon, Tecumseh, and the Detroit, Toledo & Ironton R. R.

The American Brick & Tile Company (B. A. Claypole) and M. F. Fairbanks operate tile plants at the western limits of Morenci in Section 6, T. 9 S., R. 2 E. The clays are practically identical lake clays in both pits and make a first quality red tile.

The American Brick and Tile Company is on the south side of the L. S. & M. S. Railroad. The section of the clay bank is as follows:

6 to 8 feet of red clay.
3 feet of blue clay.
1 in. sandstone.
Coarse sand

About two acres have been dug over so far and little more seems available as the village occupies the land surrounding the pit. The plant was apparently closed in 1922 because of exhaustion of its clay deposit. This yard is quipped with

Steam power.
Steam shovel.
Pug mill.
Rolls.
Auger tile machine making drain tile and building tile.
Small air drying shed.
Fire drier and
Four 30 foot down draft kilns.

M. F. Fairbanks' plant is just north of the L. S. & M. S. Railroad. Here the clay section is reported as

8 ft. red clay.
1 in. sandstone.
60 feet blue clay (sample 61).

The plant is run by electric power and consists of:

Pug mill.
Brewer tile, auger machine, with cut off.
Open shed air driers.
One 20-ft. and one 30-ft. coal fired down draft kiln.

Mr. Fairbanks turns out a first class tile of salmon color. He claims to be able to dry the clay very rapidly by placing it in the sun without injury to the tile.

Sample 61 is representative of the blue clay used in both plants at Morenci. The red clay burns to a deeper color but is otherwise similar.

Burning Test.

Sample No. 61. Field Sheet No. 67.
Section 6, T. 9 S., R. 2 E.
Plasticity .320 gm. water per gm. clay.
Average linear drying shrinkage 9.8 per cent.
Average tensile strength about 126 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.385	0.0 %	1.52	Soft burned.....	Salmon
08	990	.426	1.4	1.57	Soft burned.....	Cream salmon
06	1,030	.405	1.0	1.55	Soft burned.....	Cream salmon
04	1,070	.405	2.0	1.50	Soft burned.....	Cream salmon
02	1,110	.289	4.5	1.76	Hard burned.....	Very light brown
1	1,150	.020	13.6	2.32	Vitrified.....	Olive brown
3	1,190	.037	12.0	2.16	Vitrified.....	Olive
5	1,230	....	....	....	Viscous	

Easy to mold. Suitable for common brick or tile.
Burned by H. W. Jackman.

About 1887 in the neighborhood of two miles east of Packard, Section 13, T. 8 S., R. 2 E., north of the river, lake clay was used to make brick.

Lewis Ruff operated a brick and tile plant some years ago about ¾ mile south of Jasper, just east of the main road (M-52) in NW¼ section 14, T. 8 S., R. 3 E. All the machinery has been dismantled and removed. All that is left is the wrecked down draft kiln, the drying shed, and the two stacks. The clay pit lies to the south of the yard in a bank of red clay about 12 to 15 feet deep at the greatest depth, and covering 15 acres or more. The clay is somewhat pebbly, particularly in the upper red strata, and grades to blue clay at the bottom. The brick and tile were of good quality and had a good red color.

Sample 60 was taken from the old pit. The analysis and burning properties suggest that this clay was derived from the shale formations which underlie this part of the State.

Burning Test.

Sample No. 60. Field Sheet No. 65.
Section 14, T. 8 S., R. 3 E.
Plasticity .264 gm. water per gm. clay.
Average linear drying shrinkage 9.6 per cent.
Average tensile strength about 155 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.308	−0.4 %	1.73	Soft burned.....	Salmon
08	990	.321	0.0	1.74	Soft burned.....	Salmon
06	1,030	.336	+0.8	1.76	Soft burned.....	Salmon
04	1,070	.301	1.4	1.81	Soft burned.....	Light red
02	1,110	.227	3.8	1.94	Hard burned....	Red
1	1,150	.117	6.5	2.14	Hard burned....	Dark red brown
3	1,190	.045	6.5	2.12	Vitrified.....	Chocolate
5	1,230	.038	5.1	2.06	Vitrified.....	Chocolate
7	1,270	....	...	....	Viscous	

Brown clay containing lime and other pebbles. Suitable for face brick and tile if trouble from pebbles can be overcome. Molded easily.
Burned by H. W. Jackman.

Chemical Analysis.

Sample 60. Sheet 65.
Section 14, T. 8 S., R. 3 E.

Ignition Loss	9.80%
Silica SiO_2	58.90
Ferric Oxide Fe_2O_3	4.26
Alumina Al_2O_3	17.24
Lime CaO	5.60
Magnesia MgO	2.57
Sulphur Trioxide So_3	Trace
Alkalies	1.25
Total	99.64

Analysis by Wm. Kane, Penin. Portland Cement.

C. H. Wilt made tile at Ogden Center, Section 21, T. 8 S., R. 4 E., until his death in 1920. The plant is fairly intact and owned by Mrs. Wilt of Blissfield. The clay is a somewhat stony red clay, apparently similar to that used near Jasper, (sample 60).

A Mr. Rupp made brick some years ago from the lake clay just north of Riga in sections 3-4, T. 8 S., R. 5 E., just north of the L. S. & M. S. Railroad. The property now comprises part of Snyder's farm.

A Mr. Bliss operated a brick yard just east of Blissfield in NE¼ section 32, T. 7 S., R. 5 E., about 1-3 mile north of the railroad about 1890. The clay is very similar to that used by J. S. Saxton & Son until 1907, in SE¼ section 36, T. 7 S., R. 5 E., just northwest of the four corners three miles east and ¾ mile north of Riga. At the latter yard the clay is light gray in color and about 8 to 10 feet thick under four feet of black loam and lime pebbles, and covers about 20 acres. They made a fairly good brick and tile of a salmon color. Saxton & Son stopped operations apparently because of labor troubles.

Just north of the Raisin River at the river bend about the central part of section 21, T. 7 S., R. 5 E., there is a deposit of blue clay covered by a little sand. The river bed is also clay. This blue clay was used by W. T. Atkins until about 1915 to make soft mud brick and drain tile. The clay made first class buff brick and tile, but according to reports, it is exhausted.

Two and one-half miles northeast of Adrian on Bailey's farm SE¼ section 24, T. 6 S., R. 3 E., a number of clay samples were taken. South of the D. T. & I. R. R., and just north of the creek in the south central part of the section there is a knoll which was drilled on the south and north sides with the following results:

South Side.	North Side.
4 ft. top soil.	8 ft. sand.
2 ft. red brown sand.	14 ft. sand.
18 inches light brown sand.	Water.

4 feet light brown boulder clay. (Samples 301 and 302).
Blue boulder clay possibly Pre-Wisconsin till. (Sample 303).

Analysis.

Sample 303. Sheet 210. Section 24, T. 6 S., R. 3 E.

Loss on Ignition	15.10%	15.21%	15.16%
Silica (SiO_2)	46.26	46.38	46.32
Alumina (Al_2O_3)	10.01	10.01	10.01
Titania (TiO_2)	0.36	0.36	0.36
Lime (CaO)	5.97	6.06	6.03
Magnesia (MgO)	4.85	4.81	4.83
Iron (Fe_2O_3)	1.47	1.46	1.47
Alkalies (Na_2O, K_2O)	14.76	14.98	14.87

Analysis by Sutton.

Burning Test.

Sample No. 302. Field Sheet No. 210.
Section 24, T. 6 S., R. 3 E.
Plasticity .189 gm. water per gm. clay.
Average linear drying shrinkage 6.0 per cent.
Average tensile strength about 85 lbs. per sq. in.
Dry porosity .228.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Hardness.	Color.
010	916	.416	0.8 %	Soft burned.....	Salmon
08	950	.392	−0.4	Soft burned.....	Salmon
06	1,000	.323	−0.8	Soft burned.....	Salmon
04	1,050	.313	−0.2	Hard burned.....	Salmon
02	1,120	.308	5.0	Hard burned.....	Cream salmon
1	1,175	.206	7.3	Hard burned.....	Olive
3	1,220	.082	12.2	Hard burned.....	Olive
5	.....	....	....	Viscous	

Yellow brown clay with lime pebbles causing lime pops.
Burned by Mark Huck.

Burning Test.

Sample No. 303. Field Sheet No. 210.
Section No. 24, T. 6 S., R. 3 E.
Plasticity .163 gm. water per gm. clay.
Average linear drying shrinkage 4.6 per cent.
Average tensile strength about 85 lbs. per sq. in.
Dry porosity .246.

Cone No.	Temp. °C. by Thermocouple.	Porosity.	Linear Shrinkage.	Hardness.	Color.
010	916	.380	0.0 %	Soft burned.....	Salmon
08	950	.421	1.8	Soft burned.....	Cream salmon
06	1,000	.433	4.6	Soft burned.....	Cream salmon
04	1,050	.356	8.0	Hard burned.....	Cream salmon
02	1,120	.270	9.2	Hard burned.....	Gray
1	1,175	.236	12.4	Hard burned.....	Olive
3	1,220	.100	14.8	Hard burned.....	Olive
5	.....	....	....	Viscous	

Blue clay with lime pebbles, lime pops.
Burned by Mark Huck.

On the northwest side of the railroad about the center of section 24 there are 20 acres of brown clay running about 3 to 5 feet deep. Samples 304, 305, 306, and 307 were taken at various points in the deposit, mixed and tested.

Burning Test.

Samples No. 304, 305, 306, and 307.
Section No. 24, T. 6 S., R. 3 E., Lenawee County.
Plasticity .227 gm. water per gm. clay.

Average linear drying shrinkage 8.5 per cent.
Average tensile strength about 110 lbs. per sq. in.
Dry porosity .236.

Cone No.	Temp. °C. by Thermocouple.	Porosity.	Linear Shrinkage.	Hardness.	Color.
010	916	.414	0.2 %	Soft burned.....	Light red
08	950	.360	−0.4	Soft burned.....	Light red
06	1,000	.356	1.0	Soft burned.....	Light red
04	1,050	.357	1.6	Soft burned.....	Light red
02	1,120	.357	5.0	Hard burned.....	Red
1	1,175	.160	6.9	Hard burned.....	Chocolate brown
3	1,220	.149	10.2	Vitrified.....	Chocolate brown
5	.....	....	....	Viscous	

Good material for brick and tile and might be used for face brick.
Burned by Mark Huck.

The Peninsular Portland Cement Company, organized June 24, 1899, with a capital of $875,000, completed their plant of 6 kilns, located at Cement City at the intersection of the C. N., L. S. & M. S. Railroads, section 5, T. 5 S., R. 1 E., in 1901. At that time marl from Silver Lake and clay from Millbury, Ohio, were used as the raw materials. The wet process is used.

The present plant is equipped with 3 bottle kilns 9 ft. in diameter in the lower section, 7 feet in diameter in the upper section, and 205 feet long, with a, combined capacity of 2400 barrels a day. Limestone from Alpena and lime refuse from Wyandotte has superseded the marl.

Clay is obtained from a pit on the Deo farm 1½ miles south of Rollin and 12 miles south of the plant on the Cincinnati & Northern Railroad in NE¼ section 5, T. 7 N., R. 1 E. The clay bank is about 12 to 15 feet thick with compact coarse gravel and sand at the bottom.

Five samples from the lower four feet of the deposit:

Silica SiO_2	44.90%	48.90%	46.60%	43.60%	47.20%
Iron Fe_2O_3	5.39	4.97	5.11	5.11	5.08
Alumina Al_2O_3 ..	15.31	18.93	17.09	15.69	17.72
Lime as CaO ...	13.00	10.10	10.60	10.90	10.50
Magnesia MgO..	3.67	3.90	3.83	3.62	3.11
Ignition Loss ..	16.65	14.85	15.05	15.10	14.75
Total	99.92	99.65	98.18	94.02	98.96
Color.....	Blue / White	Yellow Blue	Yellow Blue	Yellow Blue	Yellow Blue

Analyses by W. Kane, Peninsular Portland Cement Co.

The average analysis of the upper 8 to 10 feet is as follows:

Loss on Ignition	9.5 %
Silica (SiO_2)	59.44
Alumina (Al_2O_3)	14.6
Ferric Oxide (Fe_2O_3)	6.02
Lime (CaO)	6.56
Magnesia (MgO)	2.91

Burning Test.

Sample 187 from the lower part of this deposit.
Section No. 5, T. 7 N., R. 1 E.
Plasticity .306 gm. water per gm. clay.
Average linear drying shrinkage 5.5 per cent.
Average tensile strength about 132 lbs. per sq. in.
Average apparent Sp. Gr. 2.74.

Cone No.	Thermo-couple Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	905	.431	0.5 %	2.95	Soft burned.....	Salmon
08	945	.431	0.9	2.89	Soft burned.....	Salmon
06	995	.425	1.2	2.90	Soft burned.....	Salmon
04	1,045	.410	1.5	2.90	Hard burned....	Salmon pink
02	1,090	.362	2.3	2.72	Hard burned.....	Salmon pink
1	1,130	.342	6.2	2.94	Hard burned....	Grayish cream
3	1,170	.015	7.4	2.13	Vitrified.....	Cream
5	1,210	....	....	....	Melted	

Blue clay intermixed with red. Free from lime and pebbles. Easily molded.
Burned by M. C. Huck.

There is a deposit of blue clay on the Binns farm across from N. A. Saunders' old brick yard at Addison Junction, about 150 feet west of the C. N. Railroad track, and about 30 rods north of the C. N. depot, Sec. 32, T. 5 S., R. 1 E. The deposit extends west about 20 rods and north to a marsh. The north part contains considerable sand and gravel. All told there is about 20 acres of grit-free blue clay with a depth of over 40 feet. This deposit was sampled and analyzed by Mr. Kane.

	Blue Clay Binns Farm	Yellow Clay 300 feet west of Brick Yard	Yellow Tile from Brick Yard
Silica SiO_2	49.08%	55.54%	56.50%
Alumina Al_2O_3	10.73	10.72	16.80
Iron Fe_2O_3	3.55	4.84	16.80
Lime CaO	14.04	9.85	9.10
Magnesia MgO	4.66	4.12	3.36

Another old brick yard is on the south side of town but no samples were taken or data collected. There is a large clay bank or hill of yellow clay on the south side of town.

LIVINGSTON COUNTY.

Some of the surface clays of Livingston County bear evidence of being derived from the Coal Measures shales. Sample 156 of the upper 7 feet of red boulder clay south and southwest of Howell in section 23, T. 2 N., R. 4 E., has a wide burning and vitrification range and is good material for face brick, tile, and vitrified ware. In many other places in the area through sections 2, 11, 14, and 23 this clay is free from stone and very usable.

Burning Test.

Sample No. 156. Field Sheet No. 156.
Section 23, T. 2 N., R. 4 E.
Plasticity .314 gm. water per gm. clay.
Average linear drying shrinkage 12.2 per cent.
Average tensile strength about 148 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.299	0.6 %	1.79	Soft burned.....	Salmon
08	990	.301	1.5	1.83	Soft burned.....	Light red
06	1,030	.266	2.5	1.89	Hard burned....	Red
04	1,070	.195	4.9	2.04	Hard burned....	Red
02	1,110	.070	8.8	2.30	Vitrified.....	Chocolate
1	1,150	.053	9.4	2.32	Vitrified.....	Chocolate
3	1,190	.026	8.3	2.28	Vitrified.....	Chocolate
5	1,230	.024	6.5	2.16	Vitrified.....	Chocolate
7	1,270	.023	+4.6	1.99	Vitrified.....	Chocolate
9	1,310	.222	−2.8	1.64	Vitrified.....	Chocolate brown

Yellow brown clay. Easy to mold. Suitable for brick, tile, face brick, and vitrified ware.
Burned by H. W. Jackman.

The Standard Portland Cement Company organized November 15, 1900, with a capital of $1,000,000,

proposed to use the clay and marl near Lakeland, T. 1 N., R. 5 E. The following analyses* of a clay were made for this company:

	Brick yard Pinckney	Local clay Lakeland
Loss on Ignition	12.44%	5.55%
Silica (SiO_2)	54.94	62.55
Alumina (Al_2O_3)	12.14	17.40
Ferric Oxide (Fe_2O_3)	4.88	5.08
Lime (CaO)	9.13	2.30
Magnesia (MgO)	3.65	1.69
Sulphur Trioxide SO_3	None	Trace
Sand		3.76

*By Prof. E. C. Campbell, Russell 22nd Ann. Rept. U. S. Geol. Survey, Part III, p. 671 (1902)
Mich. Geol. Survey VIII, Pt. III, p. 291.

In the northeastern part of the county one-quarter mile west of Runyan Lake in the western part of section 9, T. 4 N., R. 6 E., there is a large deposit of yellow brown glacial clay containing pebbles. Sample 152 is representative of this clay and also that farther to the east. The clay is from 10 to 35 or 40 feet thick and covers a large area.

Burning Test.

Sample No. 152. Field Sheet No. 169.
Section W. 9, T. 4 N., R. 6 E.
Plasticity .220 gm. water per gm. clay.
Average linear drying shrinkage 6.3 per cent.
Average tensile strength about 116 lbs. per sq. in.
Apparent Sp. Gr. dry 2.68.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	950	.385	0.0 %	2.75	Soft burned	Salmon
08	990	.378	−0.6	2.63	Soft burned	Light salmon
06	1,030	.380	0.0	2.68	Soft burned	Light samlon
04	1,070	.382	+0.4	2.73	Soft burned	Cream
02	1,110	.331	2.0	2.63	Hard burned	Cream olive
1	1,150	.223	5.3	2.54	Hard burned	Olive
3	1,190	.167	6.9	2.47	Vitrified	Olive
5	1,230	....	...	....	Viscous	

Brown clay. Easily molded.
Burned by H. W. Jackman.

MACOMB COUNTY.

Most of the clays of Macomb County are lake deposits. Only the lake clays have been worked. They are probably derived in considerable part from underlying shale formations. They burn to a very good color and are suitable for face brick. In some places they may be found suitable for vitrified ware.

About 4 miles east of Washington and ¾ mile south of Davis in section 31, T. 4 N., R. 12 E., East Gass operated a drain tile plant from 1894 to 1918. He has about 6 acres of blue clay, 3 acres of which is first class material for brick or tile . The clay is about 4 feet deep and then lime pebbles and marl appear in the clay. For this reason, and because drainage is difficult at greater depths, Mr. Gass never worked the deposits below 4 feet. There is a considerable amount of similar clay in the district, particularly to the east of his deposit.

Sample 15 was taken from some old unburned tile in the drying shed and is representative of the better clay of the district. The burning test shows it to be good material for brick or tile, and suitable for making front or face brick.

Burning Test.

Sample No. 15. Field Sheet No. 10.
Section 31, T. 4 N., R. 12 E.
Plasticity .362 gm. water per gm. clay.
Average tensile strength about 146 lbs. per sq. in.
Average linear drying shrinkage 16.3 per cent.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.324	0.7 %	1.71	Soft burned	Salmon
08	990	.289	2.0	1.78	Soft burned	Salmon
06	1,030	.222	4.6	1.94	Hard burned	Light red
04	1,070	.149	7.1	2.07	Hard burned	Red
02	1,110	.057	9.9	2.24	Vitrified	Dark red
1	1,150	.055	9.1	2.18	Vitrified	Chocolate red
3	1,190	.140	−4.4	1.48	Softening	Chocolate red

Brown clay. Easy to mold. Suitable for brick, tile, and may be used for face brick.
Burned by H. W. Jackman.

The plant, which is in good repair, comprises:

Wood burning five tube boiler.
Engine.
Pugmill.
Tile extrusion auger machine.
Air drying shed 216 feet long with drop doors.
Rectangular Eudaly wood fired kiln.

Mr. Gass was never able to get adequate help. His wife often fired the boiler and kept all the machinery running and oiled, while he fed the pugmill and carried tile to the drier. From Tuesday to Thursday night he fired the kiln himself, getting a few minutes sleep between firings. His product was first class and always in demand. Farmers loaded their wagons themselves directly out of the kilns. Mr. Gass worked hard and was successful.

The Fries Tile Works in the SW¼ Sec. 8, T. 2 N., R. 12 E., 4½ miles southwest of Utica and 1½ miles west of the Michigan Central Railroad, formerly worked a lake clay deposit that is very similar to that of East Gass. The usable deposit covers 10 to 20 acres and is very similar to other deposits in the vicinity. At a depth of 3 feet the clay contains lime pebbles and has never been used below this depth.

For a number of years the Fries family, with what help they could get, worked the clay into drain tile. The plant was shut down in 1908, after the father died, primarily due to inability to get steady help. Local market conditions were always good. Farmers loaded their own wagons. The product was a good tile, light red in color.

The equipment, including wood burning fire tube boiler, auger machine, drying shed, and wood-fired down draft kiln, are in poor repair and gradually becoming a complete wreck.

Sample 14 was taken from the old clay pit and is representative of the lake clay in this vicinity.

Burning Test.

Sample No. 14. Field Sheet No. 9. SW¼ Section 8, T. 2 N., R. 12 E.
Plasticity .335 gm. water per gm. clay.
Average linear drying shrinkage 14.0 per cent.
Average tensile strength about 150 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.315	0.2 %	1.71	Soft burned.....	Salmon
08	990	.296	1.6	1.80	Soft burned.....	Salmon
06	1,030	.250	3.8	1.91	Hard burned....	Salmon
04	1,070	.151	6.6	2.08	Hard burned....	Dark red
02	1,110	.104	7.5	2.14	Hard burned....	Chocolate red
1	1,150	.085	8.2	2.09	Vitrified.....	Chocolate red
3	1,190	.079	4.3	1.95	Vitrified.....	Chocolate red
5	1,230	.163	0.0	1.71	Overburned.....	Chocolate
7	1,270	....	...	....	Viscous	

Brown clay. Samples at Cones 06, 04, and 02 have white edges when burned. Suitable for face brick, tile, and possibly, sewer pipe, etc.
Burned by H. W. Jackman.

The Warren Brick Company is located just northeast of Warren on the west side of the Michigan Central Railroad, Sec. 4, T. 1 N., R. 12 E. This deposit has been worked 30 years, in which time about 20 acres have been dug over to a depth of 10 to 12 feet. The deposit is similar to the Detroit Clay beds and the section is:

1 to 3 ft. clean sand, used in molding.
7 to 8 ft. red clay.
4 ft. plastic heavy bluish clay.
Gravel and lime pebbles.

Sample 7 represents an average vertical section through the blue and red clay. The analysis suggests that this clay was derived in considerable part from the underlying shale formations. This conclusion is also borne out in the burning properties, which suggest that the sample is suitable for face brick or vitrified ware.

Chemical Analysis.

Sample No. 7. Field Report Sheet No. 15.
Of entire vertical section of deposit in section 4, T. 1 N., R. 12 E.

Loss on Ignition	9.03%
Silica SiO_2	51.88
Alumina Al_2O_3	19.94
Iron Fe_2O_3	6.24
Lime CaO	6.98
Magnesia MgO	3.37
Alkalies Na_2O K_2O	2.56

Analysis by H. W. Jackman,

Burning Test.

Sample No. 7. Field Sheet No. 15.
Section 4, T. 1 N., R. 12 E.
Plasticity .384 gm. water per gm. clay.
Average linear drying shrinkage 13.0 per cent.

Cone No.	Cone Temp. °C.	Porosity.	Linear Drying Shrinkage.	Hardness.	Color.
010	950	.400	0.0 %	Soft burned.....	Salmon
08	990	.405	0.4	Soft burned.....	Salmon
06	1,030	.392	2.8	Soft burned.....	Light tan
04	1,070	.297	5.3	Hard burned.....	Tan
02	1,110	.021	11.8	Hard burned.....	Dark brown
1	1,150	.039	10.1	Vitrified.....	Dark brown
3	1,190	.249	11.3	Vitrified.....	Chocolate brown
5	1,230	.180	12.7	Vitrified.....	Chocolate brown
7	1,270	....	....	Melted	

Molded easily. White spots on surfaces of all samples. Suitable for dark face brick or possibly vitrified ware.
Burned by H. W. Jackman.

The clay is dug by a steam shovel taking a vertical section through the clay bank with each bucket, loaded into narrow gage dump cars which are drawn to the plant or loading platform by a gasoline dinkey. The Alliance Brick Co., 2½ miles south, also obtains its clay from this pit. In wet weather the pit is drained by a gasoline engine driven pump.

The entire plant except the drain tile equipment has been recently rebuilt. The clay is tempered in a pug-mill and molded in a six brick soft mud molding machine with a capacity of about 24,000 brick a day. The green brick are dried on pallets in open air drying racks which make it possible to run the plant only 4 or 5 months a year. The brick are thoroughly dried in a week and are burned in scove kilns. The operators intend (1922) to install a steam heated drier so that the plant may be run 12 months of the year instead of 4. The plant produces a hard red brick of first quality.

The drain tile equipment is in good condition except the updraft kiln.

Two miles south of Warren on the east side of the Michigan Central Railroad Jacob Hartsig formerly made brick in section 9, T. 1 N., R. 12 E.

Across the road in NE¼ section 16, just east of the railroad is the new plant of the Alliance Brick Company. This company has a well built soft mud brick plant of the type used in the Detroit district, but no workable clay. Clay is obtained from the pit of the Warren Brick Company 2½ miles north and brought to the plant in motor trucks.

The equipment is well laid out in a light spacious plant, and includes:

Pug-mill.
Full automatic seven brick soft mud molding machine, capacity 50,000 bricks a day.
Steam heated drier with conveyor for pallets.
Scove kiln shed.

The clay this company expected to use lies to the south and west of the plant. It is about 2 to 3 feet deep and contains lime pebbles. The clay makes a poor product, full of lime pops unless special care is taken to handle the clay to the best advantage as is done in the State plant at Onondaga. Rolls were installed with the idea of crushing the pebbles, but apparently without marked improvement. Clay from the Warren Brick Co. pit was

then substituted. The product was much more satisfactory but could have been improved by making the machinery more adapted to the clay.

MANISTEE COUNTY.

Morainic clay is worked on a small scale by J. Kujawsky, 2½ miles south of Filer City on the highway. He has a few acres of red and blue stony clay about 350 yards east of the road, in Sec. 36, T. 21 N., R. 17 W. The clay is poor material, contains lime pebbles, and has little value. Kujawsky used this clay to make soft mud brick to build his home. The red clay in the upper part of the bed burns to a light red brick, and the blue clay making up most of the deposit burns cream. He now has a plunger stiff mud machine and expects to make some wire cut brick.

Farther north, near Onekama, about one-quarter mile east of Portage Lake, in section 36, T. 23 N., R. 16 W., Ernest Klein works a deposit of blue lake clay, single handed. On his property the clay is 200 feet deep under about two acres. The same kind of clay is found throughout the Onekama vicinity. Klein uses a plunger machine very similar to that used by Kujawsky, with which he can produce 2,000 brick or 1,500 drain tile a day. The green ware is dried in a closed shed and burned in scove kilns. A steam tractor supplies what power is used. Klein's equipment does not work the clay properly to obtain the best product. The analysis and burning properties of this clay are very similar to that of sample 33 from Harrietta. The clay from Onekama however has not been tested as a Fuller's earth.

Chemical Analysis.

Sample No. 40. Field Report Sheet No. 40.
Sample green bricks from clay. Sec. 36. T. 23 N., R. 16 W.

Loss on Ignition	14.26%
SiO_2	47.15
Al_2O_3	17.68
Fe_2O_3	4.32
CaO	11.95
MgO	1.80
Na_2O K_2O	2.84

Analysis by H. W. Jackman.

Burning Test.

Sample No. 40. Field Report Sheet No. 40.
Section 36, (North) T. 23 N., R. 16 W.
Plasticity .316 gm. water per gm. clay.
Average linear drying shrinkage 13.6 per cent.
Average tensile strength about 200 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Hardness.	Color.
08	990	.385	1.4 %	Soft burned	Light pink
06	1,030	.394	1.1	Soft burned	Cream
04	1,070	.396	2.2	Soft burned	Cream
02	1,110	.373	3.2	Soft burned	Cream
1	1,150	.202	7.6	Hard burned	Tan
3	1,190	.032	13.0	Vitrified	Olive
5	1,230	.020	12.1	Vitrified	Olive
7	1,270	.021	12.4	Vitrified	Olive
9	1,310	....	....	Melted	

Molded easily. Very plastic. Suitable for brick and tile or pottery.
Burned by H. W. Jackman.

East of Arcadia running back about one mile from the shore of Lake Michigan is an old lake bed. The blue clay is at least 20 feet deep, and is covered by red clay and some gravel apparently washed down from the moraine hills farther east. Sample No. 38 is taken from the blue lake clay found in Sections 10, 11, 14, and 15, and sample 39 is of the red glacial clay running 60 to 80 feet deep in the hills of sections 11, 12, and 14, and covered in places with sand and gravel. The red clay has a better burning range than the lake clay but contains stone and lime lumps. Both are suitable for making brick and tile.

Chemical Analysis.

Sample No. 38. Field Report Sheet No. 39.
Upper 8 feet, by auger, of clay in section 10, T. 24 N., R. 16 W.

Loss on Ignition	8.46%
Silica (SiO_2)	65.64
Alumina (Al_2O_3)	9.16
Iron (Fe_2O_3)	2.47
Lime (CaO)	7.59
Magnesia (MgO)	3.58
Alkalies (Na_2O, K_2O)	3.10

Analysis by H. W. Jackman

Burning Test.

Sample No. 38. Field Sheet No. 39.
Section 10, T. 24 N., R. 16 W.
Plasticity .168 gm. water per gm. clay.
Average linear drying shrinkage 4.2 per cent.
Average tensile strength about 100 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Hardness.	Color.
08	990	.322	−1.1 %	Soft burned	Salmon
06	1,030	.322	−0.8	Soft burned	Pink
04	1,070	.334	−1.1	Soft burned	Pink
02	1,110	.322	−1.0	Soft burned	Pink tan
1	1,150	.295	0.6	Soft burned	Olive tan
3	1,190	.259	2.1	Hard burned	Light olive
5	1,230	.225	3.1	Hard burned	Olive
7	1,270	.196	3.7	Hard burned	Olive
9	1,310	....	---	Viscous	

Molded easily. Suitable for common brick or tile.
Burned by H. W. Jackman.

Burning Test.

Sample No. 39. Field Sheet No. 39.
Section 11, T. 24 N., R. 16 W.
Plasticity .306 gm. water per gm. clay.
Average linear drying shrinkage 10.8 per cent.
Average tensile strength about 150 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Hardness.	Color.
08	990	.375	−0.5 %	Soft burned	Cream
06	1,030	.396	0.2	Soft burned	Cream
04	1,070	.386	1.1	Soft burned	Cream
02	1,110	.297	5.8	Hard burned	Tan
1	1,150	.214	6.0	Hard burned	Tan
3	1,190	.030	12.6	Hard burned	Olive brown
5	1,230	.038	10.4	Vitrified	Olive
7	1,270	.064	11.5	Vitrified	Olive

Molded easily. Contains lime lumps. These clays are probably suitable for brick and tile.
Burned by H. W. Jackman.

Chemical Analysis.

Sample No. 39. Field Report Sheet No. 39.
Upper 15 feet of clay in Section 11, T. 24 N., R. 16 W.

Loss on Ignition	9.57%
Silica (SiO_2)	52.80
Alumina (Al_2O_3)	17.76
Iron (Fe_2O_3)	3.27
Lime (CaO)	9.82
Magnesia (MgO)	4.44
Alkalies (Na_2O, K_2O)	2.34

Analysis by H. W. Jackman.

The Watervale Portland Cement Company organized by the same people who owned the Elk Rapids Co. and the Omega Co. proposed to erect a plant in this district and evidently planned to use some of this clay. None of the plans materialized.

MASON COUNTY.

Sample 1017 was taken from a deposit of glacial clay in the glacial outwash about ¾ mile west of Branch on the Pere Marquette Railroad. The clay is light colored, over 25 feet thick on more than 40 acres, and is covered with 3 to 4 feet of sand. The following burning test indicates that the clay may be used for making a soft burned porous brick or tile.

Burning Test.

Sample No. 1017. Field Sheet No. 1022.
Section 24, T. 18 N., R. 15 W.
Plasticity .264 gm. water per gm. clay.
Average linear drying shrinkage 9.0 per cent.
Average tensile strength about 175 lbs. per sq. in.
Apparent Sp. Gr. dry 2.53.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	950	.385	+0.6%	2.64	Soft burned.....	Salmon
08	990	.371	0.0	2.52	Soft burned.....	Cream salmon
06	1,030	.381	−1.5	2.46	Soft burned.....	Cream
04	1,070	.380	+1.8	2.66	Soft burned.....	Cream
02	1,110	.374	2.6	2.73	Soft burned.....	Very light olive
1	1,150	.308	6.2	2.72	Hard burned.....	Light olive
3	1,190	.017	10.4	2.20	Vitrified.....	Olive
5	1,230	....	....	....	Viscous	

Light brown clay. Molded easily.
Burned by H. W. Jackman.

A. A. Keiser of Ludington was formerly interested in a brick yard near the town. He reports the clay ran out some years ago and that he knows of only one bank of any commercial possibilities in the county. In the south central part of section 31, T. 19 N., R. 17 W., just northwest of the bend in the road there is a bank of red clay about 25 feet thick that was sampled, and tested at Bucyrus, Ohio, where brick and tile were made from this clay. The brick and tile specimens are perfectly satisfactory. The clay through this district to the east of Hamlin Lake is probably the best in the county and is suitable for use in making brick and tile. Up the Big Sable River and southeast of Ludington the clay becomes very stony.

MECOSTA COUNTY

Mecosta County is covered with morainic boulder clay, and sand or gravel outwash. The boulder clay and the clay found with the out-wash may be usable locally, but even this material is generally too stony to be of value.

In Big Rapids, on Milton Avenue, in the northeast part of the town, Section 2, T. 15 N., R. 10 W., W. F. Nehmer operates a brick yard making soft mud brick and tile, which is sold locally. The plant is driven by steam power and is equipped with rolls, pug mill, soft mud molding machine for brick, and two auger machines for extruding drain and building tile. The green ware is dried in the open air and burned in wood fired scove kilns. The clay deposit covers about 40 acres. There is three to four feet of red clay over about five to six feet of blue clay. This clay produces a good hard burned product at a low temperature, and has a wide burning range (over eight cones) that allows practically the entire kiln to be hard burned, without excessive failures or high fuel consumption. Because the clay is hard burned at a low temperature, it must be thoroughly oxidized before the temperature of burning is raised much above that necessary for water smoking.

Burning Test

Sample No. 31. Field Sheet No. 31.
Section 2, T. 15 N., R. 10 W. W. F. Nehmer, Milton Ave.
Plasticity .378 gm. water per gm. clay.
Average linear drying shrinkage 19.0 per cent.
Average tensile stress about 205 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Hardness.	Color.
010	950	.246	1.0%	Hard burned.....	Salmon
08	990	.187	2.9	Hard burned.....	Deep salmon
06	1,030	.181	...	Hard burned.....	Light red
04	1,070	.322	...	Hard burned.....	Red

Molded easily. Good material for common brick or tile but must be oxidized carefully. Burned by H. W. Jackman.

MIDLAND COUNTY

Midland County is covered by clay and sand deposited on the beds of the old glacial lakes which formerly covered this territory.

The northwest part of the county lying between the Pere Marquette railroad and the Tittabawassee River is largely clay. This clay is suitable for brick or tile if free from lime pebbles and in some places where the lime content is relatively low it shows possibilities of making a good hard burned red brick such as might be used for front or face brick. In general the lake clay throughout Arenac, Bay, Gladwin, Midland, Saginaw, and Tuscola counties is very similar.

Sample 85 was taken from the bank of the stream in the southeast corner of Section 25, T. 16 N., R. 1 W., just north of the bridge on the road two miles due north of

North Bradley. This sample is generally typical of the clay in this district. It is a smooth red clay containing some lime pebbles and runs to a bluish clay at about 6 to 15 feet below the surface. Apparently the red clay was formed by leaching lime out of the blue clay and by the oxidation processes of weathering.

Burning Test

Sample No. 85. Field Sheet No. 90.
Section No. 25, T. 16 N., R. 1 W.
Plasticity .357 gm. water per gm. clay.
Average linear drying shrinkage 14.0 per cent.
Average tensile strength about 157 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.375	3.3	1.66	Soft burned.....	Pink
08	990	.412	2.3	1.61	Soft burned.....	Cream pink
06	1,030	.420	2.7	1.63	Soft burned.....	Cream
04	1,070	.396	4.0	1.69	Soft burned.....	Cream
02	1,110	.228	9.8	2.03	Hard burned....	Very light olive
1	1,150	.022	14.1	2.38	Hard burned....	Light olive
3	1,190	.023	16.1	2.48	Vitrified.....	Olive
5	1,230	.033	14.7	2.39	Vitrified.....	Olive
7	1,270	.020	12.7	2.24	Partly viscous...	Olive

Clay molded easily and is suitable for common brick and tile. It contains some lime pebbles. Burned by H. W. Jackman.

About one mile northwest of North Bradley on the Pere Marquette railroad and State Highway M-20 is the tile plant of R. W. D. Fish. On his property there is about 100 acres of good blue clay running about two and one-half to four feet deep. Below this depth, lime pebbles, three and one-half feet of red clay, and then quicksand are found. Sample 86 was taken from the upper blue clay which is used in the plant.

The plant consists of a Fate Tile Auger machine, a closed drying shed, one Stewart type 24-foot round down draft kiln, and the wreck of another kiln of the same kind. The plant produces drain tile and building tile and has a capacity of about 4,000 four inch tile a day.

The following test of this sample indicates that the clay may be considered good material for brick and tile. It might be used for the manufacture of hard burned red brick suitable for fronts or face brick if properly handled.

Burning Test

Sample No. 86. Field Sheet No. 91.
Section 1, T. 15 N., R. 2 W. Upper clay on property of E. W. D. Fish.
Plasticity .331 gm. water per gm. clay.
Average linear drying shrinkage, 16.9 per cent.
Average tensile strength about 223 lbs. per sq. in.
Heated for four hours to burn out carbon.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	450	.232	0.9	1.88	Soft burned.....	Salmon
08	990	.235	1.7	1.90	Hard burned.....	Salmon red
06	1,030	.206	2.4	1.93	Hard burned.....	Light red
04	1,070	.120	3.2	2.02	Hard burned.....	Red
02	1,110	.092	2.7	1.97	Vitrified.....	Red brown
1	1,150	.109	−1.7	1.72	Vitrified.....	Red brown
3	1,190	.105	−6.5	1.79	Vitrified.....	Red brown
5	1,230	....	...	....	Viscous	

Light brown clay. Molds easily. Suitable for hard burned brick or tile and possibly face brick. Must be oxidized carefully.
Burned by H. W. Jackman.

About one mile north and one-half mile east of North Bradley the clay is covered by about three or four feet of sand and a layer of gravel. About seven feet below the top of the red clay is a few inches of quicksand and then more clay of the same kind, with a more bluish color. The following report of sample 87 represents the qualities of this clay:

Burning Test

Sample No. 87. Field Sheet No. 92.
Section 31 R. 1 W., between T. 15 N., and T. 16 N.
Plasticity .335 gm. water per gm. clay.
Average linear drying shrinkage 11.3 per cent.
Average tensile strength about 12 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.415	2.9 %	1.57	Soft burned.....	Salmon
08	990	.415	3.1	1.58	Soft burned.....	Cream
06	1,030	.425	3.3	1.60	Soft burned.....	Cream
04	1,070	.442	3.6	1.72	Soft burned.....	Cream
02	1,110	.394	6.0	2.25	Semi-hard burned.	Dark cream
1	1,150	.133	14.4	2.57	Hard burned.....	Light olive
3	1,190	.035	18.7	2.57	Vitrified.....	Olive
5	1,230	.024	17.9	2.07	Vitrified.....	Olive
7	1,270	.084	11.7	....	Overburned	

Red clay. Molded easily, but cracked easily on burning. Suitable for brick and tile. Burned by H. W. Jackman.

Along the east bank of the Tittabawassee River in Sections 1 and 2, T. 15 N., R. 1 W., is an outcrop of blue clay that seems very similar to the heavy blue clay found throughout this district (such as sample 170). Here the clay is exposed as a bank about 35 to 40 feet high.

In the southwest corner of Section 1, T. 16 N., R. 1 W., just south and east of the river fork, there is a flowing well which suggests clay beds in this area. The southeastern part of Midland County south of a line extending from Larkin south to Midland and thence southwest along the Chippewa river represents another large area that is chiefly clay.

The Midland Brick and Tile Company was formerly located just outside Midland about a mile and an eighth northwest of the center of the town and one-quarter mile northeast of P. M. R. R. in SW¼ Section 8, T. 14 N., R. 2 E. The plant shut down in 1910 after operating about three years. The clay runs about 15 feet deep, is yellow, red, and blue in color, and is covered by a little sand in some places. The following test of sample 141 taken from the old pit indicates that the clay is suitable for brick or tile:

Burning Test

Sample No. 141. Field Sheet No. 153.
SW¼ Section 8, T. 14 N., R. 2 E. Midland Brick and Tile Co.
Plasticity .252 gm. water per gm. clay.
Average linear drying shrinkage 7.7 per cent.
Average tensile strength about 137 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.394	0.6 %	1.56	Soft burned.....	Pink
08	990	.407	0.4	1.55	Soft burned.....	Pink
06	1,030	.405	0.8	1.58	Soft burned.....	Cream
04	1,070	.391	1.2	1.59	Soft burned.....	Cream
02	1,110	.389	1.9	1.62	Soft burned.....	Cream
1	1,150	.336	4.5	1.79	Hard burned.....	Very light olive
3	1,190	.131	11.5	2.22	Hard burned.....	Olive
5	1,230	.019	13.7	2.38	Vitrified.....	Olive
7	1,270	.009	13.7	2.40	Vitrified.....	Olive
9	1,310	....	....	....	Viscous	

Brown clay. Molded easily. Suitable for brick or tile.
Burned by H. W. Jackman.

There was formerly a brick yard on the present site of the Dow Chemical Company just north of the Pere Marquette Railroad in the NE¼ section 21, T. 14 N., R. 2 E. Mr. Woodworth, who drilled a well on this property for the Chemical Company, reports the clay to be 287 feet deep at this place, and not underlain by "hardpan" as is the clay two and one-half miles east in section 25.*

Three and one-third miles southeast of Midland on State Highway M-24 to Saginaw, one-half to three-quarters of a mile south of P. M. R. R. and on the east bank of the Tittabawassee river in sections 25, 26, 27, T. 14 N., R. 2 E., there is an outcrop of yellow and red clay that is also characteristic of the upper surface clay throughout Ingersoll Township (T. 13 N., R. 2 E). The upper five to six feet is red clay with a rectangular jointing and is represented by sample 172. Beneath there are eight inches of yellow clay (sample 173), and six to eight feet or more of mixed yellow and red clay (sample 174).

*The map of surface formations published as Plate VII of the Mich. Geol. Survey, Pub. 25, Surface Geology of Michigan, by Frank Leverett, shows a waterlaid moraine just east of Midland and corresponding with the data reported above.

Burning Test

Sample No. 172. Upper six feet. Field Sheet No. 194.
Section No. 27, 26, 35, T. 14 N., R. 2 E.
Plasticity .296 gm. water per gm. clay.
Average linear drying shrinkage 9.9 per cent.
Average tensile strength about 160 lbs. per sq. in.
Apparent Sp. Gr. dry 2.65.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	950	.379	2.0 %	2.65	Soft burned.....	Pink
08	990	.386	1.4	2.65	Soft burned.....	Cream
06	1,030	.390	1.4	2.65	Soft burned.....	Cream
04	1,070	.375	1.7	2.66	Soft burned.....	Cream
02	1,110	.349	4.9	2.76	Hard burned.....	Cream
1	1,150	.167	8.7	2.50	Hard burned.....	Light olive
3	1,190	.184	9.1	2.54	Hard burned.....	Olive
5	1,230	.070	10.3	2.22	Softening.....	Olive
7	1,270	.068	8.3	2.12	Softening.....	Olive

Reddish brown clay containing lime pebbles. Molded easily.
Burned by H. W. Jackman.

Burning Test

Sample No. 174. Lower clay. Field Sheet No. 194.
Sections 27, 26, and 35, T. 14 N., R. 2 E.
Plasticity .210 gm. water per gm. clay.
Average linear drying shrinkage 6.2 per cent.
Average tensile strength about 106 lbs. per sq. in.
Apparent sp. gr. dry 2.64.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	950	.412	0.0 %	2.75	Soft burned.....	Pink
08	990	.417	−1.3	2.76	Soft burned.....	Cream pink
06	1,030	.410	−2.3	2.68	Soft burned.....	Cream pink
04	1,070	.405	0.9	2.72	Soft burned.....	Cream pink
02	1,110	.369	+1.2	2.68	Soft burned.....	Very light olive
1	1,150	.323	2.2	2.68	Hard burned.....	Light olive
3	1,190	.329	3.7	2.73	Hard burned.....	Light olive
5	1,230	.055	11.0	2.45	Vitrified.....	Olive
7	1,270	....	....	....	Vitrified.....	Olive
9	1,310	....	....	....	Viscous	

Brown clay containing lime lumps. Molded easily.
Burned by H. W. Jackman.

These samples might be used for brick or tile but the lime pebbles would probably cause serious trouble.

Southeast of Midland in section 25, T. 14 N., R. 2 E., The Consolidated Coal Co. was sinking a shaft in 1923. There were 80 feet of "hardpan" and some red clay, then 20 feet of blue clay (sample 170) and Avater bearing sand at 100 feet. This clay is high in lime with a narrow burning range, and is similar to most of the surface clay in this district. It is suitable for making cream colored soft burned brick or tile.

Burning Test

Sample No. 170. Eighty to 100 feet deep. Field Sheet No. 190.
Section 25, T. 14 N., R. 2 E.
Plasticity .266 gm. water per gm. clay.
Average linear drying shrinkage 8.1 per cent.
Average tensile strength about 142 lbs. per sq. in.
Apparent Sp. Gr. Dry 2.63.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	950	.381	2.0 %	2.67	Soft burned.....	Pink
08	990	.400	2.0	2.72	Soft burned.....	Cream
06	1,030	.412	1.0	2.71	Soft burned.....	Cream
04	1,070	.410	1.3	2.71	Soft burned.....	Cream
02	1,110	.404	2.3	2.78	Soft burned.....	Cream
1	1,150	.215	10.1	2.67	Hard burned.....	Light olive
3	1,190	.173	15.8	....	Hard burned.....	Olive
5	1,230	.025	10.3	2.16	Softening.....	Olive

Blue clay. Molded easily.
Burned by H. W. Jackman.

From 1891 to 1895, Woodworth used the clay in Section 25, T. 13 N., R. 2 E., northeast of Laporte, to make tile. The tile were burned in a round center stack kiln. The workings were abandoned because of poor market conditions. Woodworth reports he had some trouble with lime pebbles but that this was not serious. The same kind of clay is found in section 17 and also in T. 13 N., R. 1 E. Sample 171 was taken by trenching the side of a drainage ditch to a depth of eight feet in sections 16, 17, of T. 13 N., R. 2 E., and is typical of the district.

Burning Test

Sample No. 171. Field Sheet No. 193.
Section No. 16-17 (Center) T. 13 N., R. 2 E.
Plasticity .212 gm. water per gm. clay.
Average linear drying shrinkage 4.9 per cent.
Average tensile strength about 134 lbs. per sq. in.
Apparent Sp. Gr. dry 2.64.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	950	.398	−0.9	2.68	Soft burned.....	Pink
08	990	.404	−0.1	2.68	Soft burned.....	Pink
06	1,030	.409	−0.2	2.71	Soft burned.....	Pink
04	1,070	.395	+0.7	2.75	Soft burned.....	Buff
02	1,110	.366	0.9	2.63	Hard burned....	Buff
1	1,150	.289	6.3	2.78	Hard burned....	Olive
3	1,190	.265	5.2	2.59	Hard burned....	Olive
5	1,230	.062	5.9	2.06	Vitrified.....	Olive
7	1,270	....	....	....	Viscous	

Brown clay containing lime pebbles. Easily molded. Burned by H. W. Jackman.

MISSAUKEE COUNTY

About 1900 W. A. Minthorn made hand molded brick from clay on his property just south of Lake City on the railroad in Section 7, T. 22 N., R. 7 W. Sand was mixed with the clay in molding although good brick could be made from the clay alone. This brick, which is light in color, was used in constructing a church. Sample No. 1007 was taken from this deposit and seems to be suitable for cream colored common brick or tile.

Burning Test

Sample No. 1007. Field Sheet No. 1013.
Section 7, T. 22 N., R. 7 W., Reeder Township.
Plasticity 0.102 gm. water per gm. clay.
Average linear drying shrinkage 7.5 per cent.
Average tensile strength about 105 lbs. per sq. in.
Apparent sp. gr. of air dried sample 2.32.

Cone No.	Temp. of Pyrometer.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	910	.450	0.0	3.03	Soft.....	Pink
082	952	.398	1.7	2.54	Soft.....	Pink
063	1,015	.456	−0.5	2.94	Soft.....	Cream
040	1,070	.407	+0.5	2.78	Soft.....	Cream
02	1,110	.424	1.1	2.96	Soft.....	Cream
1	1,150	.350	2.0	2.89	Hard.....	Light gray
3	1,195	.376	2.9	2.86	Hard.....	Olive gray
5	1,225	.287	3.3	2.78	Hard.....	Olive gray
7	1,250	.242	5.4	2.73	Hard.....	Olive gray

Light gray sandy clay free from lime pebbles. Low plasticity. Burned by M. C. Huck.

On the south side of the village of McBain along the Ann Arbor Railroad, brick was made for some time previous to 1915. Nothing is left now but the pit covering about an acre on the property of Dennis Cotter. The old plant site is now occupied by a saw mill. The brick show white spots of limestone and are generally cream colored. When burned to a light red color the clay makes a brittle brick very similar to that made in Cadillac. This clay in section 30, T. 21 N., R. 7 W., is represented by sample 1006. Similar clay is found in a dredge cut two and one-half miles east and one-fourth mile south of the village where it is seen as a bank of red and blue clay about 15 to 20 feet deep covered by two to three feet of gravel.

Burning Test

Sample No. 1006. Field sheet No. 1012.
Section 30, T. 21 N., R. 7 W.
Plasticity 0.194 gm. water per gm. clay.
Average linear drying shrinkage 8.5 per cent.
Average tensile strength about 198 lbs. per sq. in.
Apparent Sp. Gr. of Air Dried Samples 2.22.

Cone No.	Temp. of Pyrometer.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	910	.455	4.5 %	3.34	Soft.....	Salmon
08	952	.422	4.6	3.09	Soft.....	Salmon
06	1,015	.387	1.7	2.72	Soft.....	Salmon
04	1,070	.350	1.8	2.69	Soft.....	Salmon
02	1,190	.331	3.1	2.69	Hard.....	Red
1	1,150	Cracked on	firing	....	Hard.....	Red brown
3	1,195	Lime pop	Bloated	....	Vitrified.....	Chocolate
5	1,225	....	...	....	Viscous	

Light gray clay containing lime pebbles. Easy to mold. Burned by M. C. Huck.

The presence of lime pebbles may make this clay useless; otherwise it is suitable for common brick or tile.

In the western part of the county in T. 23 N., R. 5 W., and T. 22 N., R. 5 W., there are some streaks of reddish boulder clay containing lime pebbles and running to sand in many places. The country is low and marshy and the clay of no value.

MONROE COUNTY

The surface clays of Monroe County are all lake or river clays and contain considerable lime. The burning properties of the red burning clay in Monroe County are very similar to the burning properties of the clays of Macomb County. These clays are good raw material for the manufacture of face brick or tile when free from lime pebbles, and in many places may be used for vitrified ware.

The Meyer Brothers operate a tile plant in Azalia, just west of the Ann Arbor railroad near the station, in the west central part of Section 25, T. 5 S., R. 6 E. The clay is about three to six or eight feet deep in pockets over about 160 acres along and north of Macon Creek. As the lower strata of clay contain limestone pebbles the upper three to five feet are stripped from the flats and hauled in wagons, to the plant. The clay is a yellow red clay, plastic and rather free from grit. It burns to a good hard product, deep red in color. Sample 59 was taken from the stock pile at the plant. The burning test indicates that the sample is excellent material for face brick and tile and that it could be used for vitrified ware.

Burning Test

Sample No. 59. Field Sheet No. 60.
Section 25, T. 5 S., R. 6 E.
Plasticity .260 gm. water per gm clay.
Average linear drying shrinkage 10.3 per cent.
Average tensile strength about 172 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.292	0.0 %	1.82	Soft burned.....	Light red
08	990	.285	0.2	1.85	Soft burned.....	Light red
06	1,030	.272	0.9	1.89	Soft burned.....	Red
04	1,070	.240	2.1	1.93	Hard burned.....	Red
02	1,110	.184	4.0	2.00	Hard burned.....	Dark red
1	1,150	.125	6.1	2.24	Vitrified.....	Chocolate red
3	1,190	.048	6.4	2.24	Vitrified.....	Chocolate red
5	1,230	.046	5.9	2.22	Vitrified.....	Chocolate
7	1,270	.043	4.1	2.10	Softening slightly...	Chocolate

Yellow red clay. Easy to mold. Good material for face brick, tile, or vitrified ware. Burned by H. W. Jackman.

The clay is prepared, molded, and burned in the following equipment driven by steam power:

Roll crusher.
Pug mill.
Brewer auger extrusion machine for tile 3, 5, or 15 inches in diameter.
Three rectangular Eudaly kilns, coal fired.

The plant has a daily capacity of about 10,000 three inch tile. Market conditions are generally good. The plant was not running up to capacity in 1922 because of coal shortage. In 1923 there was so much road building that no labor could be obtained and the plant did not run at all. Normally 12 to 15 men are employed. The plant has been in operation since 1895.

About one and one-fourth miles northwest of Azalia just west of the Ann Arbor railroad, in NE¼ Section 23, T. 5 S., R. 6 E., the yellow clay runs about 10 to 12 feet deep and is underlain by blue clay of unknown depth. The yellow clay contains some pebbles and is generally similar to the clay used at Azalia. It was sampled (1035) by trenching in the side of a drainage ditch. The blue clay was sampled (1036) by drilling with the auger. This blue clay is found under the yellow clay throughout Monroe County and contains more lime. The analyses of the two clays are very similar except for the lime content as carbonate and sulphate.

Burning Test

Sample No. 1036. Field Sheet No. 1042. Section 23, T. 5 S., R. 6 E.
Plasticity .200 gm. water per gm. clay.
Average linear drying shrinkage 4.8 per cent.
Average tensile strength about 108 lbs. per sq. in.
Apparent Sp. Gr. dry, 2.54.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. G.	Hardness.	Color.
010	950	.394	−0.6 %	2.74	Soft burned.....	Salmon
08	990	.415	0.0	2.91	Soft burned.....	Light salmon
06	1,030	.386	−0.4	2.70	Soft burned.....	Light salmon
04	1,070	.391	0.0	2.75	Soft burned.....	Buff
02	1,110	.358	+1.1	2.70	Hard burned....	Light brown
1	1,150	.211	6.7	2.59	Hard burned....	Olive brown
3	1,190	.102	7.0	2.26	Vitrified.....	Olive
5	1,230	....	...	....	Viscous	

Blue clay with lime pebbles. Molded easily.
Burned by H. W. Jackman.

Chemical Analysis

Sample No. 1036. Field Sheet No. 1042. Section 23, T. 5 S., R. 6 E.

Ignition Loss	13.65%
Silica (SiO_2)	48.00
Ferric Oxide (Fe_2O_3)	2.80
Alumina (Al_2O_3)	13.90
Lime (CaO)	13.60
Magnesia (MgO)	3.61
Sulphur trioxide (SO_3)	1.42
Alkalies	2.84
Total	99.82%

The Maybee Brick & Tile Co. is on the D. T. & I. Railroad within the village limits of Maybee, in section 29, T. 5 S., R. 8 E. The plant made tile chiefly, and shut down in 1921 because of a shortage of labor and coal. The railroad pays $5.00 to $6.00 a day for labor and the tile plant can get no one at $3.00 or $4.00, which is all that the company is willing to pay. The plant formerly employed six men to produce 8,000 to 10,000 brick or small tile a day. H. Leidel reports it is doubtful whether the plant will run again.

The clay is similar to that covering most of Monroe County. The company owns about 40 acres of clay which is covered by about two to three feet of sand. The clay has been used to a depth of five to six feet over about an acre. Sample 1038 was taken from the pit and seems to be suitable for all kinds of brick and tile.

Burning Test

Sample No. 1038. Field Sheet No. 1044.
Section 29, T. 5 S., R. 8 E., Twn. Exeter.
Plasticity 0.191 gm. water per gm. clay.
Average linear drying shrinkage 8 per cent.
Average tensile strength about 135 lbs. per sq. in.
Apparent Sp. Gr. of air dried sample 2.36.

Cone No.	Temp. °C. by Thermo-couple.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	910	.340	0.4 %	2.73	Soft burned.....	Light red
08	952	.293	−3.0	2.25	Soft burned.....	Light red
06	1,015	.317	−0.1	2.74	Soft burned.....	Light red
04	1,070	.294	1.75	2.75	Hard burned....	Red
02	1,110	.234	3.1	2.66	Hard burned....	Dark red
1	1,150	.176	4.1	2.71	Hard burned....	Chocolate
3	1,195	Lime pop	...	....	Vitrified.....	Chocolate
5	1,225	.016	5.0	2.2	Vitrified.....	Chocolate
7	1,250	.00	4.9	2.34	Vitrified.....	Chocolate

Yellow clay. Lime pebbles not numerous. Suitable for face brick and tile if lime pebbles can be controlled.
Burned by M. C. Huck.

The clay was spaded into a small horse car and drawn for 40 feet on a wooden track to the plant. The plant is equipped with:

Roll crusher.
Auger extrusion machine for tile or end cut brick.
Down draft kiln.

The Scofield Tile Company one-half mile west of Scofield on the D. T. & I. railroad in section 28, T. 5 S., R. 8 E., has not run since 1921. Demand was good but the company went bankrupt, reported due to poor management, and is now in the hands of Mr. McCormick, Carleton, Michigan, as receiver. The company owns 40 acres of clay similar to that at Maybee, and has dug over about two to three acres in four or five years operation. The clay was spaded into small horse cars and drawn to the plant where the cars were lifted on a steam hoist and dumped into a bin. The clay was passed through a, roll crusher and was extruded in a Brewer Tile Machine with automatic cut off. The tile were dried in a shed and burned in two down draft kilns, one of which is a complete wreck. The plant employed five to six men and produced 4,000 to 5,000 three inch tile a day. The high wages paid by the railroad and the large amount of road building made it difficult to obtain help. Mr. Fred Gorrick reports that there is not much hope of the plant operating again.

The clay is good material for brick or tile for the upper five or six feet. At greater depths lime pebbles are found and the lime content increases, giving a narrow burning

range. Sample 1039 is of the yellow clay in the upper six feet of the pit.

Burning Test

Sample No. 1039. Field Sheet No. 1045.
Section No. 28, T. 5 S., R. 8 E.
Plasticity 0.225 gm. water per gm. clay.
Average linear drying shrinkage 6 per cent.
Average tensile strength about 138 lbs. per sq. in.
Apparent Sp. Gr. of air dried sample 2.27.

Cone No.	Temp. °C. by Thermo-couple.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	910	.358	2.0 %	2.62	Soft burned.....	Salmon
08	962	.329	4.0	2.94	Soft burned.....	Salmon
06	1,015	.311	4.9	2.83	Soft burned.....	Salmon
04	1,070	.284	2.0	2.90	Soft burned.....	Red
02	1,110	.248	2.9	2.54	Hard burned.....	Red brown
1	1,150	Cracked	....	....	Hard burned.....	Chocolate
3	1,195	.030	3.1	2.20	Vitrified.....	Chocolate
5	1,225	.038	3.9	2.20	Vitrified.....	Chocolate
7	1,250	.026	2.0	1.98	Vitrified.....	Chocolate

Yellow clay—suitable for face brick and tile.
No lime pebbles. Burned by M. C. Huck.

John Klein formerly made tile at Carleton from the upper yellow clay similar to that at South Rockwood.

At South Rockwood there are two plants, both using the upper 2-2½ feet of yellow clay, as at greater depths the clay contains a layer of limestone pebbles in blue clay which is very similar to the blue clay underlying the yellow clay in the western part of the county. This blue clay probably underlies the entire county, since wherever the yellow clay was drilled with the sampling auger the blue clay was found underneath.

Mr. Roberts owns a tile plant in NW¼ Section 21, T. 5 S., R. 10 E. He is not familiar with the business and is not very successful, having done nothing since 1920. The plant is of the usual type including pug-mill, rolls, auger machine, closed drying sheds, and two 18 foot round, downdraft kilns.

A short distance east of the Roberts plant, Ritter operates a small flower pot pottery, using the upper part of the clay. The clay is prepared in a pug mill and roll crusher, and molded by two spindles for jolly pressing the flower pots. These presses can turn out as many as 10 pots a minute. The pots are dried in a closed shed and burned in a small rectangular down draft kiln. Ritter and his three sons operate the plant. Sample 71 was taken from the upper two feet of clay as used in the Ritter pottery. It is good clay with a wide burning range of over 10 cones.

Burning Test

Sample No. 71. Field Sheet No. 71.
NW¼ Section 21, T. 5 S., R. 10 E.
Plasticity .334 gm. water per gm. clay.
Average linear drying shrinkage 16.0 per cent.
Average tensile strength about 151 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.281	0.0 %	1.83	Soft burned.....	Salmon
08	990	.252	1.4	1.90	Hard burned.....	Salmon
06	1,030	.209	2.1	1.95	Hard burned.....	Red
04	1,070	.139	4.6	2.10	Hard burned.....	Red
02	1,110	.053	7.5	2.29	Hard burned.....	Dark red
1	1,150	.017	6.3	2.24	Vitrified.....	Dark red
3	1,190	.016	4.6	2.11	Vitrified.....	Chocolate
5	1,230	.043	0.5	1.84	Vitrified.....	Chocolate
7	1,270	.291	−3.8	1.66	Overburned.....	Chocolate

Molded easily. Face brick, tile, possibly vitrified ware or pottery.
Burned by H. W. Jackman.

Sample 1052 was taken from the upper stratum of red clay overlying the blue clay (sample 1051) being stripped off the silica rock in the quarry of the Rockwood Silica Co. The clay at this place is poor material.

Burning Test

Sample No. 1052. Field Sheet.
Section 15, T. 5 S., R. 10 E. Red clay from Rockwood.
Plasticity .294 gm. water per gm. clay.
Average linear drying shrinkage 9 per cent.
Average tensile strength about 84 lbs. per sq. in.
Average apparent Sp. Gr. (dry) 2.71.

Cone No.	Thermo-couple Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	905	.397	3.2 %	3.14	Soft burned.....	Salmon
08	945	.339	2.9	2.85	Soft burned.....	Salmon
06	995	.345	2.0	2.76	Hard burned.....	Salmon
04	1,045	.258	3.8	2.71	Hard burned.....	Salmon
02	1,090	.120	5.0	2.61	Hard burned.....	Dark salmon
1	1,130	.018	9.3	2.32	Vitrified.....	Brown
3	1,170	.057	3.5	2.08	Overburned.....	Brown
5	1,210	.150	−23.0	1.33	Overburned.....	Dark brown
7	1,255	....	....	....	Melted	

Red clay. Easy to mold. Containing some lime pebbles.
Burned by M. C. Huck.

Burning Test

Sample No; 1051. Field Sheet.
Section 15, T. 5 S., R. 10 E. Blue clay from Rockwood.
Plasticity .242 gm. water per gm. clay.
Average linear drying shrinkage 6.6 per cent.
Average tensile strength about 96 lbs. per sq. in.
Average apparent Sp. Gr. (dry) 2.85.

Cone No.	Thermo-couple Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	905	.365	1.9	2.87	Soft burned.....	Salmon
08	945	Lime pop	...	....	Soft burned.....	Salmon
06	995	.393	−0.4	2.96	Soft burned.....	Pinkish white
04	1,045	.391	−0.4	2.84	Soft burned.....	Pinkish white
02	1,090	.299	0.0	2.54	Soft burned.....	Pinkish white
1	1,130	Lime pop	...	....	Hard burned.....	Olive gray
3	1,170	.151	+4.0	2.48	Hard burned.....	Olive gray
5	1,210	Lime pop	...	....	Vitrified.....	Olive green
7	1,255	....	...	....	Melted	

Blue clay. Easily molded. Contains numerous lime pebbles.
Burned by M. C. Huck.

The yellow red clay was formerly worked at other places in the county. Gerard Rhu formerly made brick or tile near Strasburg. There is the wreck of an old brick and tile yard five miles south and one and one-fourth miles east of Petersburg in SW¼ section 35, T. 7 N., R. 6 E. Here the product shows evidence of lime pebbles in the form of lime pops. The remains of the following equipment are still evident:

Boiler.
Pug mill.
Auger machine.
Down draft kiln.

MONTMORENCY COUNTY

Although Montmorency County is underlain by the Coldwater shale, there is so much glacial drift covering this formation that the surface glacial clays only can be considered in discussing the clay resources. The clay generally is red but burns to a light color due to its high lime content.

Sample 165 taken just east of Hillman in Section 24, T. 31 N., R. 4 E., is generally typical of the smooth red clay in this district. The clay (sample 164) on the north side of Hunter's Creek is 15 feet or more in thickness and generally covered by sand or gravel. Through sections 34, 27, 35, 26 of T. 32 N., R. 4 E., it runs up to 30 feet deep, becoming stony in sections 25 and 36, and running to sand toward the east.

Burning Test

Sample No. 165. Field Sheet No. 185.
Section 26, T. 30 N., R. 3 E.
Plasticity .316 gm. water per gm. clay.
Average linear drying shrinkage 13.5 per cent.
Average tensile strength about 210 lbs. per sq. in.
Apparent Sp. Gr. 2.52.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp Gr.	Hardness.	Color.
010	950	.359	1.0 %	2.62	Soft burned.....	Light red
08	990	.349	1.0	2.57	Soft burned.....	Salmon
06	1,030	.342	2.0	2.75	Soft burned.....	Salmon
04	1,070	.345	2.1	2.65	Soft burned.....	Salmon
02	1,110	.161	6.6	2.41	Hard burned....	Salmon brown
1	1,150	.076	9.4	2.39	Hard burned....	Olive brown
3	1,190	.039	11.2	2.40	Vitrified.....	Olive
5	1,230	....	....	....	Viscous	

Light red clay. Molded easily. Fairly good material for common brick and tile and might be used for some pottery purposes.
Burned by H. W. Jackman.

In the southern part of the county there is some red burning clay. Samples 190 and 191 were taken by F. F. Stutesman from the southern edge of Montmorency County, section 34, T. 29 N., R. 3 E. According to Mr. Stutesman the samples were taken at different depths from a deposit of clay covered by a veneer of sand six inches to two feet thick.

Sample No. 190.
Section 34, T. 29 N., R. 3 E.

Cone No.	Cone Temp. °C.	Porosity.	Apparent Sp. Gr.	Linear Shrinkage.	Hardness.	Color.
010	950	25.28 %	2.43	...	Hard burned....	Light brown
08	990	26.55	2.51	...	Hard burned....	Red brown
06	1,030	28.57	2.68	0.5 %	.....	Red brown
04	1,070	18.95	2.48	3.5	.....	Red brown
02	1,110	12.42	2.42	...	Vitrified.....	Red brown
1	1,150	19.57	1.69	−6.3	Vitrified.....	Red brown
2	1,170	6.24	2.75	...	.....	Red brown
5	1,230	.....	....	...	Vitrified.....	Brown

Plasticity poor; material crumbled and could not be handled as clay.
Might be used for soft mud brick. Has peculiar colloidal properties not plastic.

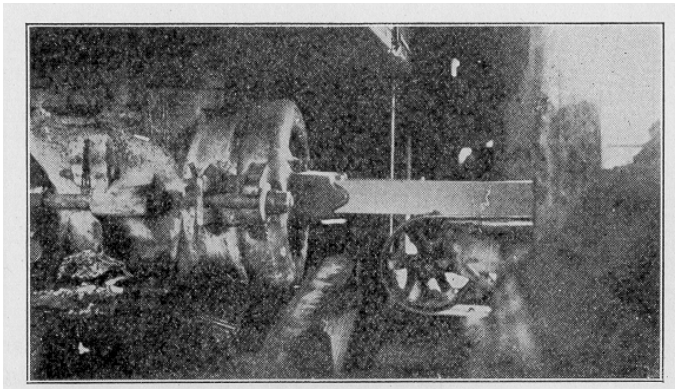

Plate XXXIX, Figure 1. Clay bars issuing from die of auger machine, Muskegon Brick Co.

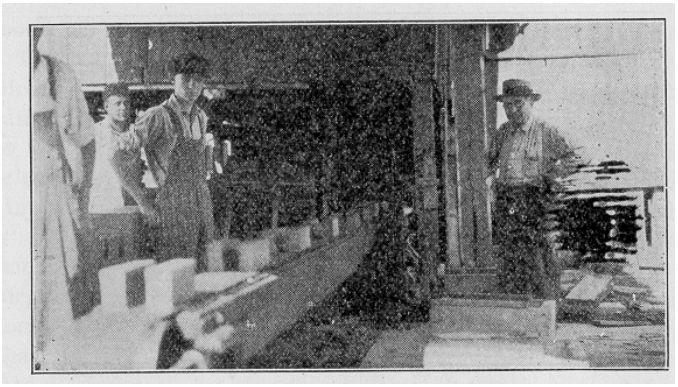

Plate XXXIX, Figure 2. Clay bar cut into bricks (end cut) on take-off belt, Muskegon Brick Co.

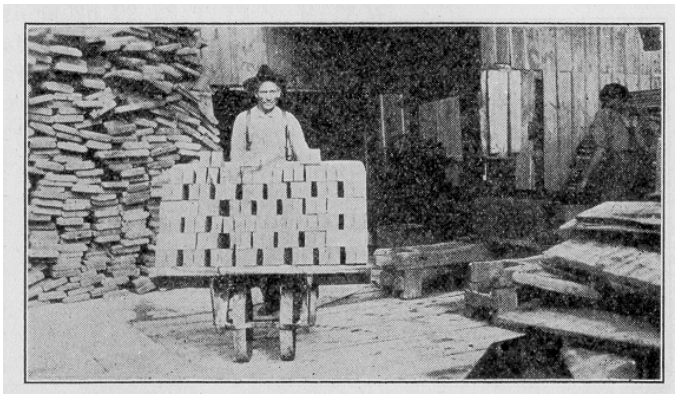

Plate XXXIX, Figure 3. Loaded pallet of green brick on two-wheeled truck, Muskegon Brick Co.

Sample No. 191.
Section 34, T. 29 N., R. 3 E.

Cone No.	Cone Temp. °C.	Porosity.	Apparent Sp. Gr.	Linear Shrinkage.	Hardness.	Color.
08	950	.....	....	.....	Soft burned.....	Cream
06	990	48.60 %	2.38	−5.85	Soft burned.....	Cream
04	1,030	55.08	2.96	−1.70	Soft burned.....	Cream
1	1,150	.....	2.86	+9.60	Soft burned.....	Cream
4	1,210	.....	....	.....	Soft burned.....	Cream
5	1,230	50.60	2.68	−2.0	Soft burned.....	Cream
8	1,290	50.98	2.80	−0.2	Soft burned.....	Cream
9	1,310	.....	....	−2.3	Soft burned.....	Cream

Plasticity poor,—like sand; material crumbled if handled.
Similar to 190 in properties except color.

MUSKEGON COUNTY

About 100 acres along the southeast side of White Lake near Whitehall, T. 12 1ST., R. 17 W., consist of one to four feet of red gravelly clay burning to a red brick, underlain by about 40 feet of smooth blue clay containing some lime pebbles and burning to a very light brick. This lower blue clay is typical of similar deposits in this district. The Ruggles clay pit is 200 yards north of the road just northeast of Whitehall in sections 22 and 28, T. 12 N., R. 17 W. This clay was used to make brick and drain tile for some years previous to 1907. Wood fuel has become scarce and the town has grown so that it now covers most of the deposit. Mr. Charles Ruggles reports that-they have no intention of working the deposit. Sample 42 was taken from the old Ruggles pit and has practically the same burning properties as sample 1021, Oceana County

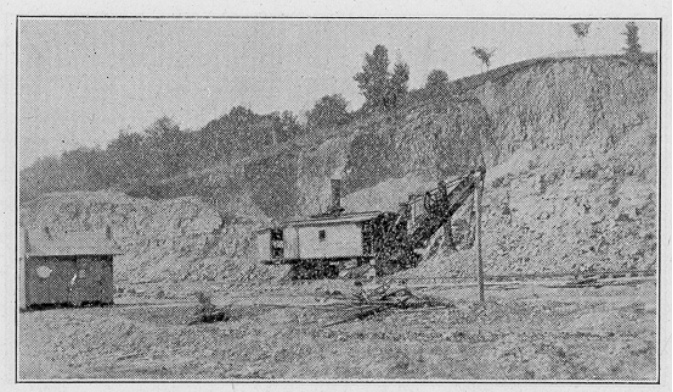

Plate XL, Figure 1. Ellsworth quarry (Upper "Antrim" or Bedford shale), showing yellow shale and main body of blue shale.

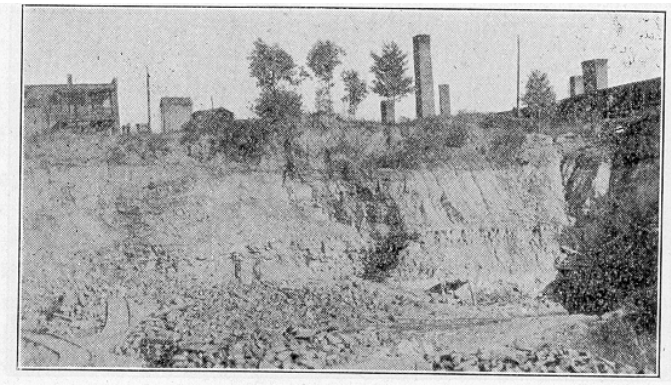

Plate XL, Figure 2. Coal measures shale at Corunna. Shale is loaded up on cars which coast down into the mine and are then drawn up into the plant by hoist.

Burning Test

Sample 42. Field Sheet No. 42.
Sections No. 22, 28, T. 12 N., R. 17 W.
Plasticity .261 gm. water per gm. clay.
Average linear drying shrinkage 8.3 per cent.
Average tensile strength about 130 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.369	2.1 %	1.64	Soft burned.....	Salmon
08	990	.384	2.4	1.63	Soft burned.....	Salmon
06	1,030	.431	1.8	1.60	Soft burned.....	Cream
04	1,070	.436	2.0	1.60	Soft burned.....	Cream
02	1,110	.435	2.0	1.61	Soft burned.....	Cream
1	1,150	.393	4.1	1.70	Soft burned.....	Cream
3	1,190	.120	13.4	2.32	Hard burned....	Olive
5	1,230	.033	17.2	2.68	Vitrified.....	Olive
7	1,270	.043	16.7	2.64	Vitrified.....	Olive
9	1,310	....	....	....	Melted	

Light gray-blue clay; molded easily. Can be used for cream brick and tile. Burned by H. W. Jackman,

West of the Pere Marquette Railroad in the western part of Section 16, T. 12 N., R. 17 W., the red clay is more pebbly.

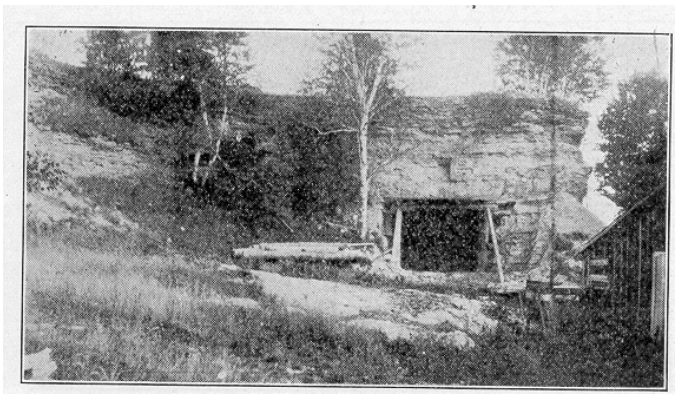

Plate XL, Figure 3. Quarry in upper blue shale, Stonington peninsula, Delta county.

The Muskegon Brick Company has its plant at Holton about one mile northeast of town on the P. M. R. R. in the SE¼ of Section 14, T. 12 N., R. 15 W. The clay deposit covers about 50 acres to a depth of 12 to 14 feet. The upper 12-18 inches of the deposit burn red (sample 44). Under this the main body of clay is composed of about six feet of varying red and blue clay, and about six feet of blue clay. Both of these lower layers, (sample 43) burn to a nearly white brick. Some sand pockets are found in the deposit. This sand is mixed with the clay at the pit, to temper the clay and reduce its shrinkage. A few lime pebbles are occasionally encountered, but not enough to cause trouble or loss. The following tests of the main clay bed indicate that the clay is good material for brick or tile.

Burning Test

Sample No. 43. Field Sheet No. 43.
Section 14, T. 12 N., R. 15 W., Muskegon Brick Co., Holton.
Plasticity .269 gm. water per gm. clay.
Average linear drying shrinkage 8.1 per cent.
Average tensile strength about 130 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Hardness.	Color.
06	1,030	.468	0.9 %	Soft burned.....	Cream
04	1,070	.462	0.9	Soft burned.....	Cream
02	1,110	.390	1.2	Soft burned.....	Cream
1	1,150	.390	3.7	Hard burned.....	Light olive
3	1,190	.390	3.8	Hard burned.....	Light olive
5	1,230	.315	8.6	Hard burned.....	Olive
7	1,270	.154	13.3	Hard burned.....	Olive
9	1,310	....	....	Melted	

Molded easily. Suitable for brick and tile.
Burned by H. W. Jackman.

Chemical Analysis

Sample No. 43. Field report Sheet 43.
Lower blue clay in deposit Section 14, T. 12 N., R. 15 W.

			Average
Loss on ignition..	19.32%	19.68%	19.50%
SiO_2	38.70	39.68	39.19
Fe_2O_3	3.54	3.40	3.47
Al_2O_3	20.90	20.92	20.91
CaO	14.49	14.77	14.63
MgO	1.31	.71	1.01
Na_2O K_2O	....	....	2.13
			100.84%

Analyzed by H. W. Jackman.

The plant is operated and one-third owned by Mr. Van der Heyden of Holton. Messrs. Buck and Mullen of Muskegon Building Materials Company each have one-third interest.

The clay is dug by means of a scoop drawn by a kerosene tractor. The tractor draws the two wheeled scoop up the inclined face of the bank, circles around, and draws the lowered scoop down the face of the pit. The loaded scoop is then drawn up on a loading platform. The clay is dumped directly into a wagon which carries the clay to the plant.

The equipment is driven by steam power and consists of a horizontal pug mill, a vertical pug mill mounted on an auger machine extruding through a twin die. The bricks are air dried under canvas for ten days, and burned in coal fired scove kilns using forced draft. The product is a first class cream brick, sometimes stained red by the action of the flames. The capacity of the plant is limited to about 20,000 brick a day by the drying yard. The annual production is about 2,000,000 bricks.

NEWAYGO COUNTY

Newaygo County is very similar to Lake, Osceola, and Mecosta counties. The surface is almost entirely moraine and outwash plains. In the northeast corner of the county in T. 16 N., R. 11 W., there is a sandy stony red clay, underlain by a clean sand. To the southwest, in T. 14 N., R. 13 W., east of Diamond Lake, (or Ramona) the same stony red clay of the moraine is underlain by a dense plastic blue clay. On the farm just southeast of the four corners, at the center of the line common to sections 11 and 12, in the NE¼ section 11, T. 14 N., R. 13 W., there is 12 feet of sandy red clay over 50 feet of dense plastic blue clay.

The sandy clay found in the glacial outwash in the southwest corner of Newaygo, Section 25, T. 12 N., R. 13 W., was formerly used by a brick yard making soft mud brick. This old yard was located on the P. M. R. R. at the southern limits of Newaygo.

About one mile west of the center of Grant just north of the road in section 14, T. 11 N., R. 13 W., are the remains of the Grant Tile Company. The steam power plant is a complete wreck. The auger machine has been run occasionally by a tractor, to extrude drain tile. The drying sheds are in ruins and in 1922 only one of the two down draft kilns appeared at all usable. The land near Grant is all low and marshy and appears to be largely clay, probably till clay deposited under the ice sheet. Around the plant of the Grant Tile Company the clay runs red to blue and about 15 feet deep. Sample 30 was taken from the stock pile of the plant. The following test indicates that the clay is good for brick or tile and could be used to make a hard red brick salable as face brick. The clay has a burning range of almost six cones and develops a good red color.

Burning Test

Sample No. 30. Field Sheet No. 29.
SE¼ Section 14, T. 11 N., R. 13 W.
Plasticity .313 gm. water per gm. clay.
Average linear drying shrinkage 13.9 per cent.
Average tensile strength about 200 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Hardness.	Color.
010	950	.319	0.2 %	Soft burned.....	Salmon
08	990	.293	0.2	Soft burned.....	Salmon
06	1,030	.293	0.5	Soft burned.....	Salmon
04	1,070	.226	2.7	Hard burned.....	Light red
02	1,110	.096	6.9	Hard burned.....	Red brown
1	1,150	.034	7.0	Hard burned.....	Red brown
3	1,190	.029	1.4	Vitrified.....	Chocolate
5	1,230	.032	−3.9	Overburned.....	Chocolate
7	1,270	....	...	Melted	

Molded easily. Begins to fail at cone 3. The vitrified bricks are brittle and easily broken. Suitable for brick and tile or possibly for a red brown face brick.
Burned by H. W. Jackman.

The Newaygo Portland Cement Company was organized on May 24, 1899, with a capital of $2,000,000. The factory was built in 1900 and 1901 on the present site to use the water power developed by the Muskegon River and local marl and clay. The local morainic clay was too sandy and stony, and the marl proved unsatisfactory. At present shale is obtained from Ellsworth, Charlevoix County, and limestone from Petoskey. The wet process is used. Recently waste heat boilers have been added to the kilns.

Originally clay was obtained along the Muskegon River opposite the plant. This clay is reported as follows:*

Silica (SiO_2)	55.84%
Iron Oxide (Fe_2O_3)	3.02
Alumina (Al_2O_3)	8.90
Lime (CaO)	9.98
Magnesia (MgO)	5.16
Ignition Loss	13.68

This clay is not satisfactory for cement and was superseded by clay found with the gypsum at Grand Rapids (in the Grand Rapids Series), and later by the shale from Ellsworth, Antrim County.

*Mich. Geol. Survey VIII, Pt. III, p. 241 (1900).

The plant is electrically operated by power obtained from two 500 H. P. generators driven by eight reaction water wheels under a 15 foot head. Recently waste heat boilers have been installed to supply additional power.

The slurry is agitated by air and lifted by compressed air in blow cases.

The limestone is obtained from Petoskey, crushed, mixed with shale from Ellsworth, and ground wet in Smidth Kominuters and Tube mills. The slurry then passes through the usual correction tanks, and is fed automatically to the kilns. The burned clinker is conveyed to the dry grinding building and finely ground in Griffin mills. The ground clinker is conveyed to the cement warehouse.

The coal is crushed, dried, ground in Griffin mills and screw-conveyed to bins over the kiln burners.

The following analysis of the shale obtained from Ellsworth was supplied by Mr. Miller, Chief Chemist:

Ignition loss	14.00%
Silica (SiO_2)	47.50
Alumina (Al_2O_3)	16.60
Iron (Fe_2O_3)	6.10
Lime (CaO)	6.70
Magnesia (MgO)	6.60

OAKLAND COUNTY

There is a deposit of smooth, blue, heavy plastic clay covering about 40 to 60 acres to a depth of 50 feet or more, about two miles east of Franklin in section 36, T. 2 N., R. 9 E. The clay outcrops on the north side of the river which has cut a 50 foot ravine through part of the deposit. In some places the blue clay is overlain by a few feet of red clay.

Many years ago this clay was worked up into hand molded soft mud bricks after being tempered by oxen in a tread mill. The Bigelow Clay Products Company is working the deposit and produces building tile sold chiefly in Detroit and suburban towns. Transportation is by truck 20 miles over concrete roads to Detroit, or the many improved gravel roads in the suburban district.

The clay is rather easy to mold but it has a rather narrow burning range so that it must be fired carefully. But in most places it is free from lime pebbles and generally is more satisfactory than the clay used by the State plant at Onondaga. Samples 1 and 2 were taken from the upper and lower parts of the deposit and were mixed for testing.

The short burning range and the occasional zones of lime pebbles have given much trouble. By careful preparation, drying, and burning of the clay good building tile is produced without excessive dryer and kiln losses.

Burning Test

Sample 1 and 2. Field Report Sheet No. 8.
30 ft. section through bank. Sec. 36, T. 2 N., R. 9 E.
Water of plasticity 0.278 gin. water per gm. clay.
Average linear drying shrinkage 7.37 per cent.
Samples held at 750°C. for 4 hours.
Tensile strength of air dried samples about 120 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Fired Linear Shrinkage.	Color.	Hardness.
010	950	.370	1.5 %	Salmon	Soft burned
08	990	.365	2.0	Salmon	Soft burned
06	1,030	.375	2.3	Buff	Soft burned
04	1,070	.293	4.4	Cream brown	Soft burned
02	1,110	.265	4.6	Light brown	Hard burned
1	1,150	.120	11.7	Brown	Vitrified
3	1,190	Cracked	....	Dark brown	Vitrified
5	1,230	Melted	....	Yellow	

Color air dried brick,—brownish gray.
Worked up fairly well.
Analysis by H. W. Jackman.

Chemical Analysis

Sample No. 1 & 2. Field Sheet No. 8.
30 ft. section through bank, Sec. 36, T. 2 N., R. 9 E.

Loss on ignition	13.69%
SiO_2	44.80
Al_2O_3	20.52
Fe_2O_3	3.89
CaO	13.10
MgO	1.85
Na_2O K_2O	2.15

In 1924 the Bigelow Clay Products Co. built a fine modern plant using all electric power and equipped to make building tile from this clay. The clay is dug by a large electric shovel, dumped into skip cars which are drawn up into the plant by a cable in the usual manner. The clay is then dumped into a large storage bin over the clay feeder and roll crushers. After passing through the double rolls the clay is conveyed to a pug mill on a raised platform from which it passes into the auger extrusion machine. The tile are cut by an automatic cut off and stacked on the drier cars. The drier is ten tunnel continuous drier, heated entirely by waste heat drawn from the cooling kilns. The tile are burned in seven oil fired, down draft kilns 32 feet in diameter. Burning takes about 70 hours and the kilns can handle only about one-half the daily capacity of the auger machine. Forced draft is now being used to aid in water smoking and another kiln is under construction. When completed this unit of the plant will have a daily capacity of about 30,000 twelve inch tile.

This is the only plant making building tile exclusively in the State. The product is a smooth uniform tile and is easily sold in the Detroit district. The narrow burning range of the clay was a serious difficulty which has now been completely overcome so that the kiln scrap is now well under three per cent. This is made possible by careful burning, controlled by two thermocouples in each kiln, one in the crown and the other in the side wall near the floor, and checked by six sets of cones, placed in strategic points in the kiln. This company has mastered a difficult proposition.

The Birmingham Brick and Tile Company formerly worked a deposit just south of Birmingham in Section 36, T. 2 N., R. 10 E. The property is now owned by Ed. Daniels who was one of the former operators. He reports that the clay is hopeless, full of lime pebbles, and found only in small pockets. There is no extensive bank or uniform deposit. Daniels operated the plant after the original company abandoned it. Then the local bank

aided by an experienced man from outside the state operated it for two years; but apparently without success.

OCEANA COUNTY

In the northwestern part of Oceana County, just east of Pentwater, T. 16 N., R. 18 W., there is a strip of blue clay in the lowland, about one-half mile wide and about four to five miles long, from north to south. About 1895 this clay was used to make a light colored brick used in local construction.

Some lake deposited clay is found in T. 15 N., R. 18 W., in the district just north of Silver Lake. This clay is light blue in color, dense and plastic, and seems very similar to the clay reported just east of Pentwater. The clay contains lime and is probably suitable for common brick only. Farther south in the Stony Lake district near Benona (T. 13 & 14 N., R. 18 W.) there is another area of plastic dense blue clay containing lime pebbles, gravel, and small boulders.

East of these deposits the surface clay is generally in moraines with a few small boulder clay plains. The clay is usually red, sandy, and stony, and underlain by blue clay or sand which is frequently wet.

There were formerly three different brick yards at various times near Hart, Section 17, T. 15 N., R, 17 W. In the northeast corner of Hart in Section 9, blue clay containing lime pebbles was used about 1880 to make light buff brick. The brick were of fair quality and were used locally. About one-half mile south of Hart, in section 21, H. Nort formerly made brick from similar boulder clay. There was also an old yard along the river in the northwest corner of the town in section 8.

South of Shelby in section 24, T. 14 N., R. 18 W., Clint Morningston about 1905 ran a brick yard on the Hill place. Throughout this district the clay is generally red on the surface and blue below. The clay is about 40 feet deep and underlain by water bearing sand or gravel. The clay contains lime, and frequently lime pebbles are found, which may have been one of the reasons for abandoning the brick yard. The following test shows the clay to be of little value:

Burning Test

Sample No. 1021. Field Sheet No. 1026.
Section No. 19, T. 14 N., R. 17 W. and section 24 T. 14 N., R. 18 W.
Plasticity .267 gm. water per gm. clay.
Average linear drying shrinkage 8.8 per cent.
Average tensile strength about 163 lbs. per sq. in.
Apparent sp. gr. dry 2.47.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	950	.430	1.1 %	2.72	Soft burned.....	Salmon
08	990	.430	+0.2	2.64	Soft burned.....	Cream
06	1,030	.446	−0.2	2.68	Soft burned.....	Cream
04	1,070	.458	+0.2	2.80	Soft burned.....	Cream
02	1,110	.448	1.7	2.81	Soft burned.....	Cream
1	1,150	.426	2.1	2.79	Soft burned.....	Cream
3	1,190	.360	7.0	2.86	Hard burned....	Cream olive
5	1,230	.130	13.2	2.67	Hard burned....	Light olive
7	1,270	.044	16.0	2.58	Vitrified.....	Olive
9	1,310	....	....	....	Viscous	

Rey clay; molded easily. Suitable for making cream colored common brick or tile.
Burned by H. W. Jackman.

OGEMAW COUNTY

A sample of boulder clay taken from the eastern part of the county, Section 13, T. 22 N., R. 3 E., seems to be suitable for common brick and tile where sufficiently free from stone and lime pebbles. The clay runs about 10 to 40 feet thick and in this place contains a layer of quicksand about six feet below the surface.

Burning Test

Sample No. 167. Field Sheet No. 187.
Section 13, T. 22 N., R. 3 E.
Plasticity .187 gm. water per gm. clay.
Average linear drying shrinkage 5.7 per cent.
Average tensile strength about 160 lbs. per sq. in.
Apparent Sp. Gr. dry 2.62.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	950	.372	1.2 %	2.77	Soft burned.....	Salmon
08	990	.387	0.1	2.77	Soft burned.....	Cream salmon
06	1,030	.410	+0.3	2.93	Soft burned.....	Cream salmon
04	1,070	.371	−0.2	2.68	Soft burned.....	Cream
02	1,110	.363	−1.3	2.60	Soft burned.....	Cream
1	1,150	.296	+3.5	2.69	Hard burned....	Light olive
3	1,190	.308	3.6	2.78	Hard burned....	Light olive
5	1,230	.139	8.0	2.54	Hard burned....	Olive
7	1,270	.113	9.8	2.60	Vitrified.....	Olive
9	1,310	....	...	....	Viscous	

Slightly grainy, reddish brown clay containing lime pebbles. Molded easily.
Burned by H. W. Jackman.

The Lupton Portland Cement Company, incorporated under the laws of New Jersey in January, 1901, for one and a quarter million dollars ($1,250,000) began construction in April, 1901, on a cement plant in Lupton. The company proposed to build a plant of 1,200 barrels daily capacity and to use the boulder clay and marl beds found near Lupton. The following analysis of the clay reported near Lupton was made for this company by Lathbury and Spackman of Philadelphia, Penn.*

Loss on ignition	7.58%
Silica (SiO_2)	56.09
Alumina+Iron Oxide (Al_2O_3+Fe_2O_3)	28.89
Lime (CaO)	0.00
Magnesia (MgO)	0.58
Sulphur Trioxide (SO_3)	0.41
Difference	6.45

The sample must have been taken from the surface and leached free of lime, but even this would seem unable to account for 0.00% of lime (CaO) in any boulder clay in this part of Michigan. If this analysis were representative of any clay near Lupton, which is probably not true, Lupton should be able to supply the district with excellent building brick and tile, if not even better grades of ceramic ware.

*Mich. Geo. Survey, Vol. VIII, Pt. III, p. 299.

OSCEOLA COUNTY

A brick yard two and one-half miles south of Marion ran for six months during 1908. The brick were of poor quality and crumbled. The clay is as much as 50 feet in

thickness but it is generally poor material and very variable in quality, as is most of the glacial clay.

Sample 32 was taken from this same morainic red clay in sections 25 and 26, T. 20 N., R. 8 W., about four miles west of Marion on the M. & G. Railroad and six miles north of Avondale. Here the clay is 30 to 40 feet deep and is covered by 20 inches of sand in places. The following burning test indicates that this clay would make good brick and tile and possibly brown face brick if not spoiled by lime pebbles.

Burning Test

Sample No. 32. Field Sheet No. 32.
Sections 25 and 26, T. 20 N., R. 8 W.
Plasticity .255 gm. water per gm. clay.
Average linear drying shrinkage 10.3 per cent.
Average tensile strength about 220 lbs. per so. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Hardness.	Color.
010	950	.302	−0.7 %	Soft burned.....	Light red
08	990	.316	−1.1	Soft burned.....	Light red
06	1,030	.322	0.4	Soft burned.....	Light red
04	1,070	.279	0.7	Hard burned.....	Red brown
02	1,110	.196	3.6	Hard burned.....	Dark brown
1	1,150	.168	4.4	Hard burned.....	Dark brown
3	1,190	.045	4.3	Vitrified.....	Chocolate
5	1,230	....	...	Melted	

Molded fairly easily; somewhat grainy. Lime pebbles.
Burned by H. W. Jackman.

About 1895 the clay in the moraine in the northwest corner of LeRoy on the G. E. & I. Railroad was used for making brick. The clay is red brown in color and covers about 40 acres. Brick made from this clay were used in building the school, church, and some homes in the town, and seem to be good brick. The following burning test indicates that this clay is fairly good material for brick or tile.

Burning Test

Sample No. 1020. Field Sheet No. 1024.
Section 13, T. 19 N., R. 10 W., LeRoy.
Plasticity .273 gm. water per gm. clay.
Average linear drying shrinkage 9.7 per cent.
Average tensile strength about 226 lbs. per sq. in.
Apparent sp. gr. dry 2.54.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	950	.360	+0.8 %	2.72	Soft burned.....	Salmon
08	990	.346	−0.4	2.56	Soft burned.....	Salmon
06	1,030	.354	+0.2	2.65	Soft burned.....	Faded salmon
04	1,070	.329	0.7	2.57	Soft burned.....	Faded salmon
02	1,110	.225	4.2	2.43	Hard burned.....	Salmon brown
1	1,150	.076	9.2	2.39	Hard burned.....	Purplish brown
3	1,190	.031	5.5	2.05	Vitrified.....	Olive
5	1,230	....	...	....	Viscous	

Brownish red clay containing some lime lumps. Molded easily.
Burned by H. W. Jackman.

OSCODA COUNTY.

Through the central part of the county there is a crescent shaped area running from south of Red Oak north to Fairview, that is largely red boulder clay from 8 to 40 feet thick containing some pebbles and stone. In the southern part of this area the clay is covered by sand and is blue in color. Sample No. 162 was taken from this district in section 27, T. 27 N., R. 1 E. Sample No. 163 was taken from section 25, T. 27 N., R. 2 E.

Burning Test.

Sample No. 162. Field Sheet No. 183.
Sections 27-26, T. 27 N., R. 1 E.
Plasticity .298 gm. water per gm. clay.
Average linear drying shrinkage 10.0 per cent
Average tensile drying strength about 165 lbs. per sq. in.
Apparent Sp. Gr. Dry 2.58.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	950	.354	−0.3 %	2.42	Soft burned.....	Salmon
08	990	.396	+2.6	2.69	Soft burned.....	Cream salmon
06	1,030	.390	2.1	2.73	Soft burned.....	Cream
04	1,070	.397	2.4	2.75	Soft burned.....	Cream
02	1,110	.388	2.6	2.78	Soft burned.....	Cream
1	1,150	.235	9.5	2.76	Hard burned.....	Light olive
3	1,190	.117	13.5	2.75	Vitrified.....	Olive
5	1,230	....	...	....	Viscous	

Blue clay. Molded easily.
Burned by H. W. Jackman.

Burning Test.

Sample No. 163. Field Sheet No. 184.
Section 25, T. 27 N., R. 2 E.
Plasticity 0.289 gm. water per gm. clay.
Average linear drying shrinkage 8.8 per cent.
Average tensile strength about 194 lbs. per sq. in.
Apparent Sp. Gr. of Air Dried Sample, 2.55.

Cone No.	Thermo-couple Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	910	.372	2.1 %	2.75	Soft burned.....	Salmon pink
08	952	.388	2.75	2.82	Soft burned.....	Salmon pink
06	1,015	.387	3.1	2.82	Soft burned.....	Salmon pink
04	1,070	.370	3.9	2.90	Soft burned.....	Salmon red
02	1,110	.260	5.2	2.94	Hard burned.....	Reddish brown
1	1,150	Cracked	in burning	....	Hard burned.....	Brown
3	1,195	.000	9.2	2.31	Vitrified.....	Dark beown
5	1,225	....	....	....	Viscous	

Yellow clay. Comparatively free from pebbles. Easy to mold.
Burned by M. C. Huck.

Morainic clay of the same general properties is found east of Luzerne in section 25, T. 26 N., R. 1 E., and sections 14 and 15, T. 26 N., R. 2 E. All of the clay is underlain by water bearing gravel at about 40 feet below the surface.

OTSEGO COUNTY.

Otsego County is completely covered with boulder clay of varying composition and content of pebbles. About 1899 a Mr. Comstock made brick from some boulder clay found in the moraine about one-half mile north of Gaylord on the Jessup property, section 28, T 31 N., R. 3 W. The clay is at least 25 feet thick at this place and seems to be quite free from stones. The same deposit extends for about 2 or 3 miles northward along both sides of the highway.

Sample No. 1009 taken from this deposit has burning properties very similar to the Antrim shale (sample 96) found on Pine Lake in Charlevoix County. The following

burning test indicates that this clay when free from stone is very suitable for brick and tile, and also for face brick:

Burning Test.

Sample No. 1009. Field Sheet No. 1016.
Section 28, T. 31 N., R. 3 W.
Plasticity .214 gm. water per gm. clay.
Average linear drying shrinkage 5.9 per cent.
Average tensile strength about 161 lbs. per sq. in.
Apparent Sp. Gr. dry 2.50.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	950	.316	−0.4 %	2.65	Soft burned.....	Salmon
08	990	.301	−0.8	2.63	Soft burned.....	Salmon
06	1,030	.288	+0.6	2.66	Soft burned.....	Light red
04	1,070	.247	2.5	2.62	Hard burned....	Dark red
02	1,110	.139	4.8	2.50	Vitrified.....	Chocolate red
1	1,150	.083	5.4	2.39	Vitrified.....	Chocolate
3	1,190	.050	+5.6	2.30	Vitrified.....	Chocolate
5	1,230	.046	−1.0	1.90	Vitrified.....	Chocolate brown
7	1,270	.056	−2.3	1.82	Overburned	
9	1,310	....	...	....	Viscous	

Brown clay; containing a few pebbles (not lime). Molded easily.
Burned by H. W. Jackman.

OTTAWA COUNTY.

The Zeeland Brick Company operated a plant until 1922, about one mile west of Zeeland, on the inturban line between Holland and Grand Rapids. The plant made wire-cut brick from clay in the NE¼ of Section 23, T. 5 N., R. 15 W. The clay ran about 15 feet deep with a stratum of lime pebbles near the top. All the usable clay was exhausted by the end of the season of 1922, when the plant was closed.

PRESQUE ISLE COUNTY.

In the western part of the county four miles south of Onaway, in T. 34 N., R. 2 E., the clay runs 90 feet deep in the northwest corner of section 32 where sample 160 was taken. Two miles north the clay is only 3 to 4 feet thick. In section 20 the red clay is 15 feet thick and is underlain by about 30 feet of blue clay.

In the central part of section 27, T. 35 N., R. 3 E., about 3½ miles north of Millersburg on highway M-10, the clay is found in hills and along the river bank with deposits of yellow sand. This clay seems to be free from pebbles and molds easily. The following burning test shows it to have an extremely narrow burning range, due to a high lime content, so that the clay can be used only for porous soft burned ware, such as common, brick and tile. The high lime content is due to the fact that most of this county is underlain at shallow depth by limestone.

Burning Test.

Sample No. 131. Field Sheet No. 141.
Section 27, T. 35 N., R. 3 E.
Plasticity .220 gm. water per gm. clay.
Average linear drying shrinkage 6.5 per cent.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.441	−1.2 %	1.44	Soft burned.....	Flesh
08	990	.472	−2.0	1.40	Soft burned.....	Flesh
06	1,030	.476	−2.2	1.38	Soft burned.....	Cream
04	1,070	.481	−2.2	1.37	Soft burned.....	Cream
02	1,110	.474	−2.6	1.38	Soft burned.....	Cream white
1	1,150	.473	−1.4	1.40	Soft burned.....	Cream white
3	1,190	.457	−0.2	1.46	Soft burned.....	Cream white
5	1,230	.460	+1.2	1.51	Soft burned.....	Cream
7	1,270	.455	+1.9	1.56	Soft burned.....	Cream
9	1,310	.037	14.8	2.31	Vitrified.....	Olive
11	1,350	....	....	....	Melted	

Light red clay. Molded easily.
Burned by H. W. Jackman.
This clay seems similar to samples 128 and 159 of Cheboygan County.

The Bell shale about 50 feet thick extends from Black or Cheboygan Lake east-southeastward through Presque Isle County, through Bell in T. 33 N., R. 8 E., to Rockport in the extreme northeast corner of Alpena County. Sample No. 132 was taken from a ledge of this shale about 3 miles west of Rogers City. At the surface the shale had weathered to a clay, but drill tests showed firm shale at shallow depth. Another exposure of Bell shale occurs in the northern part of section 13, T. 34 N., R. 6 E., but it was not sampled. These deposits of shale are extensive and deserve further investigation especially by the drill.

Burning Test.

Sample No. 132. Bell Shale. Field Sheet No. 142.
Section 30, T. 35 N., R. 5 E.
Plasticity .331 gm. water per gm. clay.
Linear drying shrinkage 9.7 per cent.
Average tensile strength about 70 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Absorption.	Linear Shrinkage.	Hardness.	Color.
010	950	.323	.200	−1.1 %	Soft burned.....	Tan
08	990	.316	.184	+1.1	Soft burned.....	Tan
06	1,030	.268	.144	3.7	Hard burned....	Light red
04	1,070	.183	.089	7.4	Hard burned....	Red
02	1,110	.009	.0035	10.0	Vitrified.....	Dark red
1	1,150	.008	.003	8.7	Vitrified.....	Brown
3	1,190	.014	.005	2.8	Vitrified.....	Dark brown
5	1,230	.088	.036	0.9	Vitrified.....	Dark brown
7	1,270	....	....	....	Melted	

Easily molded. Good material for all kinds of building brick, face brick, and tile, and might be used for some pottery purposes.
Burning test by H. W. Jackman.

The burning properties of this sample are very similar to those of sample 95, of the Antrim shale. The Bell "shale" has a narrower burning range than some parts of the Antrim shale, but molds more easily and is free from bituminous material. The Bell shale need not be ground to develop its plasticity and it can be oxidized much easier. Taking everything into consideration certain beds of the Bell shale probably are just as good material for making building brick, tile, and face brick, as the Antrim shale. But the Bell shale cannot be used for vitrified ware because the brick begin to fail almost as soon as they are vitrified and the vitrified product is rather brittle. The Bell shale, however, is known to contain thin partings of limestone and calcareous horizons, but the low lime beds appear to be of considerable thickness. While the presence of thin beds of limestone would be serious in the manufacture of

brick and tile, these would not be for use in making Portland cement. The shale is adjacent to very large deposits of exceptionally pure limestone; therefore conditions are favorable for making cement. Shale is also found in the limestone 3¼ miles south of Bell in section 34, T. 33 N., R. 8 E., on the road from Alpena to Bell. Sample No. 134 was taken from a 3-foot vein of soft shale found in the limestone at a depth of 12 to 13 feet when drilling a well in this section. Similar clay or clay shale is also found in creek beds and in the bottom of some sink holes in the limestone in this district at depths of 13 to 40 feet. This clay or shale near Bell postoffice gave the name "Bell" to the lowest member of the Traverse Formation.

ROSCOMMON COUNTY.

Roscommon County is largely sand and gravel with some small clay areas. Just northeast of Roscommon village the Au Sable River cuts through some red-blue clay about 10 to 20 feet thick which contains a few lime pebbles or lumps. This clay burns to light red color and might be used to make brick or tile if the lime pebbles can be handled. About 1903 brick was made from clay very similar to this about one mile north of the town, but the lime pebbles made serious trouble. Sample 1008 was taken from the river bank one-quarter mile from the Michigan Central railroad switch.

Burning Test.

Sample 1008. Field Sheet No. 1015.
Section 6, T. 24 N., R. 2 W.
Plasticity .301 gm. water per gm. clay.
Average linear drying shrinkage 12.3 per cent.
Average tensile strength about 200 lbs. per sq. in.
Apparent Sp. Gr. dry, 2.57.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	950	.284	0.4 %	2.44	Soft burned	Light red
08	990	.296	0.9	2.52	Soft burned	Salmon
06	1,030	.302	1.1	2.55	Soft burned	Salmon
04	1,070	.285	2.1	2.56	Soft burned	Light brown
02	1,110	.121	7.8	2.41	Hard burned	Brown
1	1,150	.035	9.8	2.36	Hard burned	Dark brown
3	1,190	....	....	....	Viscous	

Brown clay. Few lime pebbles. Molded easily.
Burned by H. W. Jackman.

Another sample of blue clay taken about a mile northwest of the town of Houghton Lake shows more promising burning qualities. The sample was taken from two places about one-quarter mile apart and is probably representative of the upper part of this deposit of clay. The clay runs from 12 to 30 feet deep and is covered by sandy loam which runs thicker to the southwest away from the lake. The upper clay is sandy and red in color, blending into the blue smoother clay below. There are pockets and veins of white sand through the clay which is probably a water deposit, and water bearing yellow sand underneath the blue clay. The deposit is not uniform, is sandy in places, and at a distance from any railroad, but its burning properties indicate that it is a good material for brick and tile.

Burning Test.

Sample No. 89. Field Sheet No. 94.
Section 11, T. 22 N, R. 4 W.
Plasticity .269 gm. water per gm. clay.
Average linear drying shrinkage 11.9 per cent.
Average tensile strength about 180 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.274	0.9 %	1.88	Soft burned	Light red
08	990	.270	0.9	1.90	Semi-hard burned	Light red
06	1,030	.283	1.5	1.92	Hard burned	Light red
04	1,070	.268	1.6	1.93	Hard burned	Light red
02	1,110	.155	5.0	2.15	Hard burned	Chocolate red
1	1,130	.125	4.8	2.14	Vitrified	Chocolate red
3	1,170	.043	2.3	2.00	Vitrified	Chocolate
5	1,230	....	...	....	Viscous	brown

Molds easily. Somewhat grainy. Suitable for brick and tile.
Burned by H. W. Jackman.

SAGINAW COUNTY

The Coal Measures shales of Saginaw County were investigated by Ries.

Sample 217 (Ries), was taken from the dense brownish shale containing plant stems that was found under the coal at the old shaft of the Standard Mining Company, in section 6, T. 11 N., R. 5 E., just southeast of Saginaw. This shale contained small mica scales but very little grit. When ground to 30 mesh it had the following properties:

Burning Test.

Sample R217. Sec. 6, T. 11 N., R. 5 E.
Water plasticity 20 per cent.
Air shrinkage 4 per cent.
Average tensile strength 60 lbs. per sq. in.
Soluble salts 0.2 per cent.

Cone.	Total Shrinkage.	Burning.	Color.
1	10 %	Hard	Red
4	....	Vitrified	
9	....	Viscous	

*Mich. Geol. Survey VIII, Pt. I, pp. 26, 28, 33.

Chemical Analysis

Silica (SiO_2)	55.3%
Alumina (Al_2O_3)	14.2
Ferris Oxide (Fe_2O_3)	3.62
Lime Carbonate ($CaCO_3$)	0.3
Magnesian Carbonate ($MgCO_3$)	2.61
Alkalies (Na_2O+K_2O)	2.15
Water & Organic (Difference)	21.82

In sinking a new shaft on the same property the following section was penetrated:

90 feet sandy clay.
10 feet fine grained blue clay (R212).
3 feet "Impure Fire Clay."
8 feet shale (Sample R220).
4 feet conglomerate.
20 feet black shale.
Coal.
6 feet "fire clay."

A burning test of the 8-foot shale bed at 103 feet below the surface gave the following results:

Sample (Ries) 220.
Water of plasticity 23 per cent.
Air shrinkage 3 per cent.
Tensile strength 35 lbs. per sq. in.
Soluble salts 0.3 per cent.

Cone.	Total Shrinkage.	Burning.	Color.
05	3 %		Buff
1	5		Red
3	7	Hard	Red
5	9		Deep red
7	...	Vitrified	
9	...	Viscous	

Moderate plasticity.

A sample taken from the shale underlying the coal at the old Pere Marquette shaft No. 1 had the following properties:

Sample (Ries) unnumbered.
Water of plasticity 16 per cent.
Air shrinkage 5 per cent.
Tensile strength 38 to 45 lbs. per sq. in.
Soluble salts 0.4 per cent.

Cone.	Total Shrinkage.	Burning.	Color.
01	6 %	Hard	Deep brownish red
4	11	Vitrified	
7	....	Viscous	

Another sample of the "fire clay" taken from under the coal seam 185 feet below the surface at the old shaft of the J. H. Somers Coal Co., near the M. C. Railroad station had the following properties:

Sample (Ries) unnumbered.
Grinds easily, but slakes slowly.
Water of plasticity 18 per cent.
Dried rapidly, air shrinkage 4 per cent.
Soluble salts 0.35 per cent.

Cone.	Total Shrinkage.	Burned.	Color.
1	7 %	Hard	Buff speckled
5	12	Vitrified	Gray buff
8	....	Viscous	

The "fire clay" underlying the coal 10 miles east of St. Charles; as in the NE¼ Section 23, T. 10 N., R. 4 E., Albee Township, was reported to be very plastic and more easily molded than the samples described above.

These tests of the coal measure shales found in Bay, Saginaw, and Genesee Counties as reported by Ries show conclusively that these shales cannot be called "fire clay". Many of the Michigan Carboniferous shales contain large amounts of bituminous material and are useless as ceramic material. Some of the miscalled "fire clays" have sufficiently wide vitrification ranges to be used for the manufacture of vitrified products and in some cases paving blocks.

The shales found in Bay and Saginaw counties 160 to 200 feet below the surface are relatively inaccessible and probably at best suited for pressed or face brick. It seems more probable that economic factors would favor the development of these shales in the counties south of Saginaw, where they are found near the surface. In fact the Old Saginaw Clay Manufacturing Company at Saginaw formerly made paving brick from the mixed shales obtained from the quarry at Flushing.

Ninety feet below the surface in section 6, T. 11 N., R. 5 E., a ten-foot bed of blue clay (sample R212) was reported by Ries.

Sample R212.
Fine grained clay 100% through 100 mesh.
Contains some lime pebbles.
Water of plasticity 33 per cent.
Air shrinkage 7 per cent.
Tensile strength 110 lbs. per sq. in.
Soluble salts 0.2 per cent.

Cone.	Total Shrinkage.	Burning.
05	....	Hard
01	18 %	Vitrified
3	....	Viscous

Very plastic.

Chemical Analysis

Silica (SiO_2)	47.75
Alumina (Al_2O_3)	17.60
Ferric Oxide (Fe_2O_3)	9.13
Lime Carbonate ($CaCO_3$)	2.6
Magnesium Carbonate ($MgCO_3$)	0.7
Alkalies (Na_2O+K_2O)	2.21
Water and Organic (difference)	22.01

Ries suggests that this clay may be weathered or slaked shale as it lies directly on bed rock.

The surface of Saginaw County is largely lake clay containing some sand and generally troublesome lime pebbles. In section 21, T. 13 N., R. 4 E. the surface clay is 65 feet deep and is underlain by 30 feet of hard pan and 10 feet of sand. Further west in section 24, T. 13 N., R. 3 E., the surface clay is 90 feet thick and underlain by 30 feet of sand and gravel and then 40 feet of sandy lake clay. In section 12, T. 13 N., R. 3 E., the surface clay is 65 feet thick and is underlain by 50 feet of hard pan.

Sample 175 was taken from the surface clay four miles east of Saginaw on State Highway M-31 in NW¼ section 23, T. 12 N., R. 5 E. The clay is mixed red and blue, with a cubic fracture, and is about 40 feet thick. In some places it is covered by as much as three feet of sand. The sample was taken by trenching and from a small pit in a drainage ditch. The burning test was made of the clay as sampled without screening out pebbles.

Burning Test.

Sample No. 175. Field Sheet No. 195.
Section No. 23, T. 12 N., R. 5 E.
Plasticity 0.204 gm. water per gm. clay.
Average linear drying shrinkage 3.0 per cent.
Average tensile stress about 165 lbs. per sq. in.
Apparent specific gravity air dried sample 2.24.

Cone No.	Temp °C. Thermo-couple.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	910	.404	0.5 %	2.61	Soft burned.....	Salmon
08	952	Lime pop	....	....	Soft burned.....	Cream white
06	1,015	Lime pop	....	....	Soft burned.....	Cream white
04	1,070	Lime pop	....	....	Soft burned.....	Cream white
02	1,110	Lime pop	....	....	Soft burned.....	Cream
1	1,150	.301	7.0 %	2.46	Hard burned.....	Light tan
3	1,195	Lime pop	....	....	Hard burned.....	Yellow
5	1,225	.03	16.0	2.6	Vitrified.....	Olive
7	1,250	Lime pop	....	....	Vitrified.....	Olive
9	.....	....	....	....	Viscous	

Yellow clay containing lime pebbles, which cause the burned clay to disintegrate when soaked in water. Burned by M. C. Huck.

Thomas Day operates a soft mud brick yard about ¾ mile southwest of Paines on the Michigan Central railroad in SW¼ section 31, T. 12 N., R. 4 E. The plant employs about 30 men and has a daily capacity of 22,000 brick. The clay is dug by a gasoline power shovel and drawn to the plant which is equipped with a Wellington pug-mill and a six brick soft mud molding machine. The green brick are dried in open air dry sheds and burned in scove kilns.

The clay has an appearance similar to that of the Detroit clays. The upper clay is reddish yellow in color, underlain by about one foot of yellow clay, then 8 to 10 inches of red clay, and by 20 feet or more of fat blue clay. It is generally covered by one to two feet of white sand, and contains some stone in places, but rarely any limestone. Sample 142 was taken from the upper red and yellow clay. Sample 143 is from the lower blue or gray clay which makes up the bulk of the deposit.

Burning Test.

Sample No. 143. Field Sheet No. 154.
Section 31, (SW), T. 12 N., R. 4 E.
Plasticity .276 gm. water per gm. clay.
Average linear drying shrinkage 8.3 per cent.
Average tensile stress about 115 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.416	1.3 %	1.57	Soft burned.....	Salmon
08	990	.439	1.3	1.56	Soft burned.....	Cream
06	1,030	.444	1.4	1.56	Soft burned.....	Cream
04	1,070	.439	1.6	1.56	Soft burned.....	Cream
02	1,110	.425	2.0	1.59	Soft burned.....	Cream
1	1,150	.318	7.4	1.88	Hard burned.....	Very light olive
3	1,190	.080	14.7	2.40	Hard burned.....	Light olive
5	1,230	.032	16.7	2.56	Vitrified.....	Olive
7	1,270	.022	16.9	2.60	Vitrified.....	Olive
9	1,310	....	....	....	Viscous	

Gray brown clay; molded easily. Suitable for brick or tile. Burned by H. W. Jackman.

The Miller City Co. operates a drain tile plant on the north side of the Michigan Central railroad about ⅞ mile southwest of Paines in SE¼ section 36, T. 12 N., R. 3 E. The clay (sample 144) is the same as that used by Day on the other side of the railroad. The whole plant is completely enclosed by a three-story barn-like structure. The steam plant, rolls, and tile machine are located on the ground floor adjoining the clay shed. The rest of the area is taken up by two 25-foot down draft intermittent kilns. The two upper floors are used as dry floors, being heated by convection from the kilns. The green tile is elevated to either of the two upper floors surrounding the kilns and dried. The dried tile is loaded into the kilns through holes in the tops of the kilns. The burned tile is unloaded in the usual manner through the door on the ground level.

The Saginaw Clay Products Company makes drain tile and building tile from the same lake clay (sample 143) at a plant ½ mile southwest of Paines on the Michigan Central just east of Day's plant in section 31, T. 12 N., R. 4 E. The plant is equipped with steam power, rolls, a Fate auger machine, 3 track tunnel drier heated by separate fires and three 30-foot down draft intermittent kilns. The plant was not operating in 1922 because of market conditions.

Southeast of Saginaw in section 18, T. 11 N., R. 6 E. the surface lake clay is 60 feet thick and is underlain by 30 feet of hardpan and 15 feet of sand.

A sample of clay (No. 1042) was taken near Burt, about 15 miles south of Saginaw, by J. C. Malone and submitted to the Department of Engineering Research of the University of Michigan. The test resulted as follows:

Burning Test.

Sample 1042. Submitted by J. C. Malone of Burt.
Plasticity .421 gm. water per gm. clay.
Average linear drying shrinkage 15 per cent.
Average tensile strength about 122 lbs. per sq. in.
Average apparent sp. gr. (dry) 2.93.
Held at 425°C, for 7 hours to completely oxidize organic matter.

Cone No.	Thermo-couple Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	905	.436	−1.5 %	2.89	Soft burned.....	Salmon
08	945	.421	−0.8	2.89	Soft burned.....	Salmon
06	995	.384	+1.4	2.79	Hard burned.....	Salmon
04	1,045	.376	1.6	2.78	Hard burned.....	Salmon red
02	1,090	....	...	...	Hard burned.....	Salmon red
1	1,130	.192	2.1	2.64	Hard burned.....	Salmon brown
3	1,170	.096	8.5	2.44	Vitrified.....	Chocolate
5	1,210	....	...	....	Starting to fail..	Chocolate
7	1,255	....	...	....	Melted	

Reddish brown clay. Free from lime pebbles and suitable for hard burned red brick or tile. Easily molded. Burned by M. C. Huck.

ST. CLAIR COUNTY.

St. Clair County is largely covered with Pleistocene lake clay.

The Central Peat Company is located on a peat bed 2½ miles west of Capac on the Grand Trunk Railroad in the SW¼ section 19, T. 7 N., R. 13 E. The peat runs about 6 to 14 feet thick over an area reported to be 1000 acres. Under the peat there is about 8 to 15 inches of a light gray clay (sample 150) which burns to a good color at cone 02.

Burning Test.

Sample No. 150. Field Sheet No. 167.
SW¼ section 19, T. 7 N., R. 13 E.
Plasticity .207 gm. water per gm. clay.
Average linear drying shrinkage 11.5 per cent.
Average tensile strength about 105 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.396	−0.4 %	1.73	Soft burned.....	Salmon
08	990	.326	−0.4	1.73	Soft burned.....	Salmon
06	1,030	.336	−0.2	1.75	Soft burned.....	Salmon
04	1,070	.321	0.5	1.78	Soft burned.....	Light red
02	1,110	.288	0.6	1.72	Soft burned.....	Red
1	1,150	.276	1.1	1.80	Soft burned.....	Red
3	1,190	.260	2.3	1.86	Hard burned.....	Dark red
5	1,230	.231	2.9	1.94	Hard burned.....	Dark red
7	1,270	.193	3.0	1.89	Hard burned.....	Red brown
9	1,310	.134	5.2	2.05	Hard burned.....	Gray red
11	1,350	.040	5.6	2.06	Vitrified.....	Gray
13	1,390	.139	−2.9	1.61	Overburned.....	Gray

Brown gray clay, grainy in texture.
Burned by H. W. Jackman.

Two miles west of Avoca and about one mile southwest of the Pere Marquette R. R., in sections 5 and 8, T. 7 N., R. 15 E., the surface clay is yellow to red and blue in color, generally typical of this district. Sample No. 178 was taken at this place by trenching to a depth of five feet.

Burning Test.

Sample No. 178. Field Sheet No. 199.
Sections 8, 5, T. 7 N., R. 15 E.
Plasticity .273 gm. water per gm. clay.
Average linear drying shrinkage 6.2 per cent.
Average tensile strength about 129 lbs. per sq. in.
Apparent Dry Sp. Gr., 2.40.

Cone No.	Cone Temp. °C.	Porosity.	Apparent Sp. Gr.	Linear Shrinkage.	Hardness.	Color.
010	950	.354	2.67	+0.8 %	Soft burned.....	Salmon
08	990	.335	2.50	−0.6	Soft burned.....	Salmon
06	1,030	.324	2.49	+0.2	Soft burned.....	Salmon
04	1,070	.296	2.51	1.5	Soft burned.....	Salmon red
02	1,110	.234	2.52	4.9	Hard burned.....	Red
1	1,150	.145	2.44	5.2	Hard burned.....	Red brown
3	1,190	.125	2.42	5.0	Hard burned.....	Dark brown
5	1,230	.081	2.36	7.6	Vitrified.....	Dark brown
7	1,270	.052	2.28	8.5	Vitrified.....	Dark brown
9	1,310	.159	2.12	1.9	Vitrified.....	Gray brown
11	1,350	....	....	....	Overburned	

Brown clay, molded easily.
Burned by H. W. Jackman.

This sample shows a wide burning range, uniform shrinkage, and burns to a good color at cone 02. It is free from stone and seems to be suitable material for the manufacture of face brick, and tile. Its vitrification range is not sufficient to recommend its use for vitrified ware, although such ware might be produced from this clay. This clay was probably derived from the Coldwater or Antrim shale which underlies the surface of St. Clair County and was redeposited by a plesitocene lake.

About 1½ miles west of Atkins, section 5, T. 7 N., R. 16 E., Fred Beard formerly made good common brick from the upper stratum of red burning clay.

In section 31, T. 7 N., R. 16 E., about one mile south of the Pere Marquette Railroad and 1½ miles north of the Grand Trunk Railroad, there is an outcrop of blue clay along the northeast bank of Pine River. The clay is covered with about three feet of sand and is at least 20 feet thick. Sample 179 was taken by trenching across the face of the outcrop.

Burning Test.

Sample 179. Field Sheet No. 200.
Section 31, T. 7 N., R. 16 E.
Plasticity 0.220 gm. water per gm. clay.
Average linear drying shrinkage 4.5 per cent.
Average tensile strength about 105 lbs. per sq. in.
Apparent Sp. Gr. air-dried brick 2.27.

Cone No.	Thermo-couple Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	910	.394	2.75 %	2.66	Soft.....	Salmon
06	1,015	.350	−1.75	2.39	Soft.....	Salmon
04	1,070	....	....	....	Soft.....	Light red
02	1,110	.304	6.0	2.58	Hard.....	Light red
1	1,150	....	....	....	Hard.....	Light brown
3	1,195	....	....	....	Vitrified.....	Brown
5	1,225	....	....	....	Viscous	

Blue clay containing some lime pebbles, easy to mold.
Burned by M. C. Huck.

Sample 180 was taken from the upper 8 feet of a clay bank exposed along the sides of a creek about two miles west of Port Huron in section 5, T. 6 N., R. 17 E. The clay contains lime pebbles which were not removed in making the following test:

Burning Test.

Sample No. 180. Field Sheet No. 201.
Section 5, T. 6 N., R. 17 E.
Plasticity 0.173 gm. water per gm. clay.
Average linear drying shrinkage 3.4 per cent.
Average tensile strength about 110 lbs. per sq. in.
Apparent Sp. Gr. air dried brick 2.38.

Cone No.	Thermo-couple Temp. °Co.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	910	.403	−1.6 %	2.77	Soft.....	Salmon
08	952	.364	−3.5	1.48	Soft.....	Salmon buff
06	1,015	Lime pop	....	....	Soft.....	Salmon buff
04	1,070	Lime pop	....	....	Soft.....	Salmon buff
02	1,110	Lime pop	....	....	Soft.....	Salmon buff
1	1,150	.294	0.5	2.86	Hard.....	Olive gray
3	1,195	Lime pop	....	....	Hard.....	Olive gray
5	1,225	Lime pop	....	....	Hard.....	Olive
7	1,250	Lime pop	....	....	Vitrified.....	Olive

Yellow clay. Numerous lime pebbles. Burned by M. C. Huck.

The New Egyptian Portland Cement Company has leased the old fort, at the river front in the northeastern part of Port Huron, formerly used as the railroad shops. The location was chosen because of its transportation facilities, being readily accessible to both railroad and water. The company is building a modern cement plant to have a capacity of about 6,000 barrels a day. When visited in August, 1923, the plant was just getting into operation with one kiln.

Limestone is shipped from Calcite (Rogers City), Presque Isle County, by water and unloaded and piled by a bridge type unloader. In 1923 clay was dredged from various places in the St. Clair delta south and west of Algonac and shipped to the unloading wharf at Port Huron. The river clay obtained in the St. Clair delta off Townsend's Coal Dock and under private royalty analyzed as follows:

Silica (SiO_2)	44.04%	44.36%
Alumina (Al_2O_3)	15.5	15.26
Iron (Fe_2O_3)	6.17	6.74
Lime (CaO)	12.61	14.60
Magnesia (MgO)	3.75	

The clay obtained under State royalty (sample 181) sections 14 and 23, T. 2 N., R. 15 E., from the St. Clair Delta, analyzed:

Silica (SiO_2)	49.56%
Alumina (Al_2O_3)	15.25
Iron (Fe_2O_3)	6.37
Lime (CaO)	8.03
Magnesia (MgO)	4.24

Analyses by Bateman, Chief Chemist New Egyptian Portland Cement Company.

Burning Test.

Sample No. 181. Field Sheet No. 202.
St. Clair River flats. Sec. 14 and 23, T. 2 N., R. 15 E.
Plasticity .322 gm. water per gm. clay.
Average linear drying shrinkage 10.1 per cent.
Average tensile strength about 121 lbs. per sq. in.
Apparent Sp. Gr. (dry) 2.57.

Cone No.	Cone. Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	950	.349	0.7%	2.55	Soft burned.....	Salmon
08	990	.361	+0.7	2.58	Soft burned.....	Salmon
06	1,030	.348	−0.2	2.52	Soft burned.....	Salmon
04	1,070	.331	+2.4	2.57	Hard burned.....	Salmon
02	1,110	.100	8.8	2.37	Hard burned.....	Brown gray
1	1,150	.025	8.6	2.14	Vitrified.....	Dark brown
3	1,190	.024	7.5	2.07	Vitrified.....	Dark brown
5	1,230	....	....	....	Viscous	

Blue clay. Molded easily. Suitable for brick and tile. Burned by H. W. Jackman.

A sample of lake clay obtained from Smith's Creek, Section 31, T. 6 N., R. 16 E., on the Grand Trunk Railroad and easily accessible to the plant has about the same analysis as the clay obtained from St. Clair River off Algonac.

Silica (SiO_2)	45.76%
Alumina (Al_2O_3)	15.32
Iron (Fe_2O_3)	5.84
Lime (CaO)	9.22
Magnesia (MgO)	4.92
Loss on Ignition	14.47
	95.53

Analysis by Bateman, Chief Chemist, New Egyptian Portland Cement Co.

The clay received at the plant is unloaded and put through a disintegrator and washer, in which the clay is worked up to a slip containing about 60% water. The washed clay is then pumped into a storage tank.

The ground limestone and washed clay are then mixed and finely ground in a 3 compartment ball mill containing alloy steel balls 4 inches in diameter in the first compartment, 2½ inches in diameter in the second compartment, and 1¼ inches in the third compartment. This tube mill has ample capacity for a daily production of 2,000 barrels of cement, and requires about 500 H.P. to drive it. The ground slurry from this mill containing about 35% water is then pumped to storage tanks and is generally analyzed before being burned in the kiln.

The plans call for 3 kilns 11 feet in diameter and 200 feet long. In 1923 one kiln was installed and operating. The kiln is fired with powdered coal and driven by a 90 H.P. motor. The slurry is fed to the mill by a feeder driven by the revolving kiln so that the feed is automatically stopped with the kiln. The gases leave the kiln at 600°-700°F. and are further cooled to 150°-200°F. in being drawn through a gas cooler and dust precipitator. The hot clinker discharged from the kiln is cooled by quenching in water and then conveyed to the clinker storage. The clinker is removed from storage as needed and ground in a three compartment ball mill similar in every way to the mill used in grinding the slurry. The ground clinker is transported to the packing room by a Fuller-Kinyon pneumatic conveyor. This system of conveying* consists in forcing a stream of powdered material (in this case ground clinker) into a small jet of compressed air by means of a worm pump similar to a screw conveyor. The quantity of air so mixed with the material is just sufficient to render the aerated mass fluid enough to be propelled through the distribution pipes by the pressure of the worm pump. Some troubles were experienced with the pumps when this system was first operated on the ground clinker.

Powdered slack coal is used as fuel for firing the kiln. The coal is first dried, then elevated to bins over the Fuller-Lehigh mills that are used to pulverize the coal. The plans call for 4 Fuller mills to handle the coal required by the three kilns. The powdered coal is conveyed to a bin at the kiln by the same Fuller-Kinyon system used on the ground clinker.

The St. Clair Brick Company's plant is just off River Road at the southwest corner of St. Clair north of the railroad in section 1, T. 4 N., R. 16 E. The plant is equipped to make soft mud brick with a hand dump molding machine, and drain tile with an auger machine. The green ware is dried in a steam heated drier. The brick are burned in oil fired scove kilns, and the tile in two coal-fired down draft kilns at the end of the kiln shed.

The clay bank is west of the plant across the river. The clay is a sandy red clay about 6 feet deep, underlain by sand and gravel. About 120 acres of land are owned by the company, 10 acres of which have been dug over. The clay is dug by a steam shovel and teamed to the plant. In June 1922 the plant was boarded up. Local information indicated that the plant was closed because of inability to keep labor at 50 cents an hour. The kiln yard still contained considerable brick although the plant operated only 3 months in 1921. The brick in the kiln were not of good quality but porous and cracked, as if the clay had been poorly prepared for molding. The clay is normally red burning but pockets of lime are encountered in the bank which cause many brick to burn buff. The following tests (sample 4) indicate that the clay is suitable for brick or tile and should give a good hard burned product at cone 04.

*Bur. Mines Bull. 217 (1923) Preparation, Transportation, and Combustion of Powdered Coal, John Blizard, p. 21.

Burning Test.

Sample No. 4. Field Report Sheet 11. Sample of 6 feet. Section 1, T. 4 N., R. 16 E., through bank.

Water of plasticity .268 gm. per gm. clay.
Average linear drying shrinkage 6.7 per cent.
Tensile strength of air dried samples about 206 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Fired Linear Shrinkage.	Hardness.	Color.
010	950	.340	0.5 %	Soft burned.....	Salmon
08	990	.340	2.1	Soft burned.....	Salmon
06	1,030	.348	2.4	Soft burned.....	Salmon
04	1,070	.207	3.7	Hard burned.....	Ligh brown
02	1,110	.188	5.8	Hard burned.....	Brown
1	1,150	.024	7.4	Vitrified.....	Dark gray brown
3	1,190	Cracked	....	Vitrified.....	Dark gray brown
5	1,230	.037	5.5	Vitrified.....	Dark gray brown

Easily worked and molded. Cracks easily on cooling.

Chemical Analysis.

Loss on Ignition	13.29%
Silica (SiO_2)	51.25
Alumina (Al_2O_3)	17.61
Iron Oxide (Fe_2O_3	4.94
Lime (CaO)	7.46
Magnesia (MgO)	1.57
Alkalies (Na_2O K_2O	3.88

Analysis by H. W. Jackman.

The Shriner Brick Company (Mr. Shriner, 379 Woodworth Avenue, Marine City), is located about one mile southwest of the St. Clair Brick Company in NW¼ section 7, T. 4 N., R. 17 E., on the outskirts of St. Clair. The clay is very similar to that used at the St. Clair Company's yard and the product is reported to be generally of about the same quality. The Shriner Brick Company was doing an active business in 1922 in an effort to supply the local market as the St. Clair Brick Company was not operating.

Sample 5 was taken from the upper five feet of a deposit of very plastic gray clay covering 30 to 40 acres or more in SW¼ section 18, T. 4 N., R. 17 E. The clay burns red and is hard burned at about cone 09. These properties make it a, good material for brick and tile. When burned to higher temperatures, unless carefully oxidized, the bricks puff up in a very interesting manner. The outside of the brick seems to vitrify at a low temperature so that the interior cannot be oxidized. When heated to higher temperatures the gases cannot escape and make blow holes in the weakest part of the outer layer.

Chemical Analysis.

Sample No. 5. Sheet 12.
Upper 4 feet of deposit, SW¼ Sec. 18, T. 4 N., R. 17 E.

Loss on Ignition	5.24 %
SiO_2	60.00
Al_2O_3	22.00
Fe_2O_3	6.95
CaO	1.96
MgO	.71
Na_2O, K_2O	3.14

Burning Test.

Sample No. 5. Field Sheet No. 12.
Upper 4 feet of deposit in SW¼ section 18, T. 4 N., R. 17 E.
Plasticity .291 gm. water per gm. clay.
Average linear drying shrinkage 13 per cent.
Average tensile strength about 110 lbs. per sq. in.
Apparent Sp. Gr. (dry) 2.47.
Samples held at 425°C. for 7 hours to prevent hard burning of surface before carbon and sulphur compounds were completely decomposed.

Cone No.	Thermo-couple Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	905	.385	0.4 %	2.77	Soft burned.....	Salmon red
08	945	.314	2.8	2.77	Hard burned.....	Salmon red
06	995	....	....	....	Hard burned.....	Salmon red
04	1,045	.176	4.0	2.60	Hard burned.....	Red
02	1,090	.108	8.5	2.51	Hard burned.....	Red brown
1	1,130	.056	8.5	2.41	Vitrified.....	Red brown
3	1,170	....	...	Bloated	Overburned.....	Brown
5	1,210	....	...	....	Viscous	
7	.....	....	...	....	Melted	

Easily molded.
Burned by M. C. Huck.

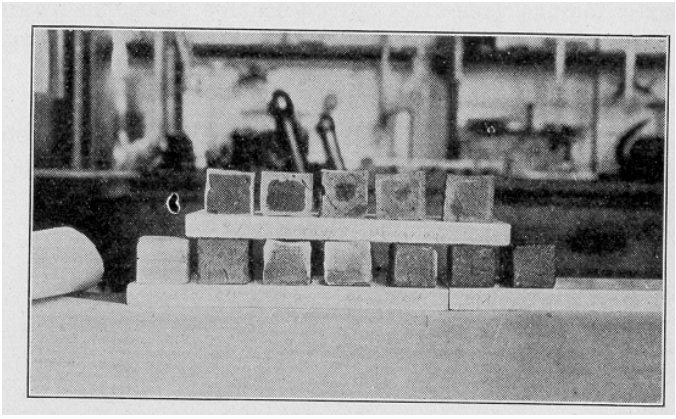

Plate XLI, Figure 1. Bituminous shale (Antrim) from East Jordan and Chestonia. Upper five samples show hourly progress of oxidation. Lower seven samples show results of burning to cones .014, .010, .08, .06, .04, .02, and 1 respectively. The third and fourth from the left show white discoloration.

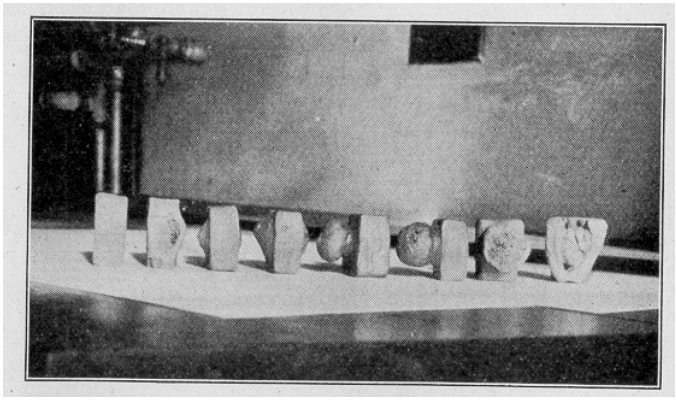

Plate XLI, Figure 2. An interesting exhibit of the results of incomplete oxidation. This clay becomes hard burned at a low temperature. The temperature exerted by the gases, liberated in the interior as the temperature was raised, blew bubbles in the weakest part of the softening exterior.

In 1921 Jos. Engleman of New Baltimore purchased the stiff mud brick machinery formerly used by Hucker at Mount Clemens and moved it to a clay bank on his property in east New Baltimore, north of the interurban right-of-way in section 7, T. 3 N., R. 15 E. His equipment consists of an oil burning engine, auger

machine for extruding brick or drain tile with automatic cut-off for brick, an air drying shed with drop doors, and a small down draft coal fired kiln. The plant is operated only two or three months each year.

The clay runs about 15 to 25 feet deep over about 50 acres. The upper 3 feet is red clay which is underlain by a few inches of lime pebbles and then a plastic blue clay over 15 feet thick. The land is low and will probably present a drainage problem. The clay is dug by means of a scoop drawn along the surface by the stationary engine. Sample 6 is of the upper red burning clay above the lime pebbles.

Chemical Analysis.

Sample No. 6. Sheet 13.
Main clay deposit in section 7, T. 3 N., R. 15 E.

Loss on Ignition	3.60%
Silica (SiO_2)	72.27
Alumina (Al_2O_3)	15.05
Iron Oxide (Fe_2O_3)	4.58
Lime (CaO)	.95
Magnesia (MgO)	.43
Alkalies (Na_2O, K_2O)	3.12

Analysis by H. W. Jackman.

Burning Test.

Sample 6. Sheet 13.
Section 7, T. 3 N., R. 15 E.
Upper red clay.
Plasticity .263 gm. water per gm. clay.
Linear drying shrinkage 7.5 per cent.
Average tensile strength about 120 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Absorption.	Fired Linear Shrinkage.	Hardness.	Color.
010	950	.311	.175	−0.7 %	Soft burned....	Light red
08	990	.310	.174	−1.0	Soft burned.....	Light red
06	1,030	.301	.168	−0.7	Soft burned.....	Light red
04	1,070	.283	.152	0.7	Hard burned....	Red
02	1,110	.200	.099	1.5	Hard burned....	Dark red
1	1,150	.147	.068	4.8	Hard burned....	Brown red
3	1,190	.095	.043	6.0	Vitrified	Brown red
5	1,230	.089	.040	5.9	Vitrified.....	Brown red
7	1,270	.063	.028	7.2	Vitrified.....	Brown red
9	1,310	.217	.129	−3.3	Partly melted...	Dark steel

Easily molded, making a smooth even colored brick. Good material for face brick or tile, and might be used for vitrified ware.
Burning test by H. W. Jackman.

The analysis suggests that the clay is in part, at least, probably derived from the shale that underlies this part of the State. The burning test indicates that the sample is good clay for all forms of brick or tile. It has a burning range of ten cones and is suitable for face brick and might be used for vitrified ware.

Paul Howcroft operated a drain tile plant until 1918 about 150 yards west of Engleman's property. The plant is equipped with a steam engine, auger machine, drying shed, and an open top up draft kiln. Sample 6 was taken from the clay deposit which is essentially a continuation of the one used by Engleman. The product from this plant was a high grade buff drain tile.

The clay sampled in this district was analyzed by the New Egyptian Portland Cement Company of Fenton as follows:

Silica (SiO_2)	65.72%
Alumina (Al_2O_3)	15.68
Iron (Fe_2O_3)	6.40
Lime (CaO)	3.62
Magnesia (MgO)	1.89

ST. JOSEPH COUNTY.

The clays of St. Joseph County are found in the glacial outwash and in the moraines. They are generally unsatisfactory and very similar to those of Cass County (see sample 184).

The German Portland Cement Company, a Detroit company, was organized March 29, 1901, with a capital of $320,000, to utilize marl deposits in the vicinity of White Pigeon for the manufacture of cement. The plant was to be located near White Pigeon on the Lake Shore Railroad. The enterprise never got beyond the newspaper stage.

SANILAC COUNTY

The clays of the western part of Sanilac County are largely boulder clays. Those of the eastern part are chiefly lake clays with some boulder clay.

About one-half mile west and a little south of Minden City in section 11, T. 14 N., R. 14 E., about one to one and one-half miles west of the P. M. R. R. there were formerly four brick yards. The clay appears to be a lake clay generally similar to the lake clay in the "Thumb." The upper three or four feet is a red burning clay which is underlain by 20 feet or more of blue clay, burning buff. The upper clay contains lime pebbles but the lower blue clay is reported to be free from them. The old yards produced good common brick and tile but all discontinued operations before 1910.

The Sandusky Tile & Brick Company is located on the eastern edge of Sandusky about one-fourth mile north of the center of the town and just south of the P. M. R. R. in section 33, T. 12 N., R. 14 E. The clay is boulder clay, typical of the "Thumb" district. There are three feet of red burning clay containing lime pebbles, a layer of gravel and lime, then blue clay burning buff and containing lime pebbles and boulders.

This deposit was originally worked successfully by Chambers in 1900 and later by Tom Moore. The present plant was originally built by a Mr. Wheeler but later rebuilt by the Marysville Land Company. The present layout is reported to have cost $75,000 and consists of:

Pug mill.
Rolls.
Auger machine for brick, drain tile, or building tile.
Tunnel drier.
Scove kiln shed.
3 downdraft kilns of construction similar to those at St. Louis and Cheboygan, also built by Mr. Wheeler.

The present plant seems to have been a failure from the start. It was shut down in 1920. When visited in September, 1922, the plant was boarded up and apparently in good condition.

The Port Huron Clay Products Company has a plant in the northern part of Croswell on the east side of the Pere Marquette railroad in Section 20, T. 10 N., R. 16 E. The clay deposit apparently free from lime pebbles covers 65 acres or more. The section is as follows:

Soil, 3 ft. 6 in.
Yellow clay (sample 148), 6-7 ft.
Blue smooth fine grained clay (sample 149), 2-4 ft.
Water bearing gravel, few inches.
Smooth fine grained blue clay.

The following burning tests indicate that these clays are suitable for common brick and tile but they have a burning range too narrow for making a good hard burned face brick. The lower blue clay (149) might make a slip clay as it is very fine grained and melts to a good glaze at about cone 5.

Burning Test.

Sample No. 148. Field Sheet No. 165.
Section 20 (center), T. 10 N., R. 16 E.
Plasticity .246 gm. water per gm. clay.
Average linear drying shrinkage 5.7 per cent.
Average tensile strength about 100 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.402	−0.4 %	1.55	Soft burned.....	Salmon
08	990	.319	−0.2	1.54	Soft burned.....	Salmon
06	1,030	.395	0.0	1.55	Soft burned.....	Cream salmon
04	1,070	.394	1.0	1.58	Soft burned.....	Cream salmon
02	1,110	.312	1.9	1.63	Soft burned.....	Cream
1	1,150	.308	4.6	1.78	Hard burned.....	Light brown
3	1,190	.101	9.3	2.12	Hard burned.....	Light olive
5	1,230	.022	7.6	2.04	Vitrified.....	Olive
7	1,270	....	...	....	Viscous	

Light olive brown clay. Molded easily. Suitable for common brick or tile.
Burned by H. W. Jackman.

Burning Test

Sample No. 149. Field Sheet No. 165.
Section 20, (center), T. 10 N., R. 16 E.
Plasticity .264 gm. water per gm. clay.
Average linear drying shrinkage 5.9 per cent.
Average tensile strength about 97 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.413	0.8 %	1.54	Soft burned.....	Salmon
08	990	.418	0.6	1.53	Soft burned.....	Salmon
06	1,030	.405	1.4	1.57	Soft burned.....	Cream salmon
04	1,070	.404	1.4	1.58	Soft burned.....	Cream salmon
02	1,110	.355	3.1	1.67	Soft burned.....	Cream
1	1,150	.221	7.4	1.90	Hard burned.....	Very light brown
3	1,190	.018	14.3	2.38	Vitrified.....	Brown
5	1,230	....	....	....	Viscous	

Light gray brown clay. Easily molded. Might be used as slip clay; suitable for brick or tile.
Burned by H. W. Jackman.

At the Croswell plant the clay is spaded and loaded into skip cars which are drawn up into the plant and dumped directly into the pug mill where the clay is tempered. The tempered clay is extruded in a Fate auger machine. The green tile are loaded on cars which are pushed into a four track tunnel intermittent drier. This drier is heated by "waste heat" from a cooling down draft kiln. A flue is provided that leads from under the floor of each of the three kilns to a fan at the end of the drier. This fan draws air through the kilns for cooling the burned tile, and forces the hot air heated by the cooling tile into the drier. The dry tile are removed from the drier, loaded into wheelbarrows, and stacked in the kiln. The plant includes three 30 foot down draft kilns, each of which will hold 27,500 four inch tile without crowding. Ten men are employed, and produced about 10,000 4-inch tile a day. The main products are drain tile and hollow building tile, although some brick are produced. In September, 1922, the 4-inch drain tile were selling for $20 a thousand at the plant.

There were formerly two other plants near Croswell but they ceased production some time ago.

At Brown City in the southeast corner of the town near the P. M. R. R. east center of section 18, T. 9 N., R. 13 E., the upper red burning clay appears rather free from lime pebbles and was formerly used to make brick by John Large. He has not operated since 1910 and the plant is torn down. Sample 1023A was taken from section 31, T. 9 N., R. 13 E., four miles south of Brown City from the bottom of a drainage ditch about 15 to 20 feet deep.

Burning Test

Sample No. 1023A. Field Sheet No. 1030.
Section 31, T. 9 N., R. 13 E.
Plasticity .244 gm. water per gm. clay.
Average linear drying shrinkage 6.7 per cent.
Average tensile strength about 87 lbs. per sq. in.
Apparent Sp. Gr. dry 2.52.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	950	.377	+0.2 %	2.68	Soft burned.....	Salmon
08	990	.366	−0.4	2.61	Soft burned.....	Salmon
06	1,030	.348	+1.9	2.74	Soft burned.....	Salmon
04	1,070	.325	1.5	2.57	Soft burned.....	Salmon
02	1,110	.223	5.6	2.63	Hard burned.....	Brown
1	1,150	.085	8.6	2.46	Hard burned.....	Gray chocolate
3	1,190	.052	6.2	2.15	Vitrified.....	Gray chocolate
5	1,230	....	....	....	Viscous.....	Gray chocolate

Blue clay containing lime pebbles. Molded easily. Could be used for brick or tile if lime pebbles are eliminated.
Burned by H. W. Jackman.

SHIAWASSEE COUNTY

In Shiawassee County about 80 per cent of the surface is clay land most of which is boulder clay. This clay is variable and generally similar to the clay in Gratiot and Clinton Counties. The glacial drift is much thinner in Shiawassee County than toward the northwest. This leaves the coal measure shales so near the surface that they may be profitably worked, as is done at the plant of the New Corunna Brick Company, east of Corunna.

The Coal Measure shales found with the coal at the old shafts of the Owosso and Corunna Coal Companies were reported by Ries.* These shales were brought to the surface with the coal. At the Owosso Coal Company

shaft, Sec. 23, T. 7 N., R. 3 E., the coal is underlain by a light gray, and in places sandy shale (R. 226), locally called "fire clay." This shale contains mica and some pyrite concretions and nodules of lime. When exposed to the weather for several months the shale slaked to a clay.

Sample R226.
Gritty clay sandy shale underlying coal.
Sec. 23, T. 1 N., R. 3 E.
Slakes slowly to angular fragments.
Water of plasticity 19 per cent.
Soluble salts 0.3 per cent.
Slight effervescence with dilute acid.
Tensile strength 37 lbs. per sq. in.

Cone.	Total shrinkage.	Burn.	Color.
05	6 %	Soft	Buff
02	7 %	Hard	
4	9 %	Vitrified	Buff
9	...	Viscous	

The shale is not consolidated so well as most of the Coal Measure shales, as this sample slaked more readily than shales from other places.

Overlying the coal was a black, brittle shale containing considerable bituminous matter and pyrite.

At the shaft of the Corunna Coal Company, the underlying shale was similar to that at the Owosso Coal Company's, but the overlying shale was more like the upper shale quarried at Flushing. The coal was reported to be 75 feet below the surface at each place.

*Mich. Geol. Survey VIII, Pt. I, p. 27.

The New Corunna Brick Company, (formerly the Wolverine Brick Company), is located in NW¼ Sec. 23, T. 7 N., R. 3 E., about two miles northeast of Corunna. This company makes face brick exclusively. Formerly paving brick were made from the same shale by the older company. The shale is covered by about six feet of soil and then runs about 35 feet deep to a three foot coal seam. Under the coal the shale is lighter and more plastic but has about the same burning properties.

Originally the property was a coal mine, presumably that of the Owosso Coal Company described by Ries. Shale and coal are mined from the old shaft. Additional shale is taken from an open pit, run down into the mine where it is taken up on the lift. Sample 154 was taken from the open pit and represents the shale found above the coal.

Burning Test

Sample No. 154. Field Sheet No. 175.
Section 23, T. 7 N., R. 3 E.
Plasticity .294 gm. water per gm. clay.
Average linear drying shrinkage 7.9 per cent.
Average tensile strength about 54 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.377	0.0 %	1.62	Soft burned.....	Pale salmon
08	990	.358	1.3	1.68	Soft burned.....	Pale salmon
06	1,030	.280	4.9	1.87	Soft burned.....	Salmon buff
04	1,070	.130	9.7	2.17	Hard burned.....	Dull red
02	1,110	.035	11.4	2.32	Hard burned.....	Dull red
1	1,150	.026	11.8	2.34	Vitrified.....	Dark brown
3	1,190	.027	12.0	2.37	Vitrified.....	Dark brown
5	1,230	.026	12.1	2.37	Vitrified.....	Gray brown
7	1,270	....	....	....	Viscous	

Dark blue shale. Molded easily. Good material for face brick and tile; might be used for vitrified ware.
Burned by H. W. Jackman.

The shale is ground in a dry pan and extruded in a Freese (Gallon, Ohio), pug mill, equipped with automatic cut-off. The green brick are dried in a waste heat drier taking hot air from the cooling kilns or from a separate fire when no kilns are cooling. Burning is done in twelve 30 foot 6 inch downdraft kilns, operated on a 27 day cycle. Each kiln has a capacity of 70,000 brick.

About a mile northeast of the New Corunna Brick Company there is a deposit of boulder clay used by the New Egyptian and Aetna Portland Cement Companies of Fenton. The Grand Trunk railroad runs a short line from Corunna to Kirby, which has switches at the brick plant and at the clay pit. The clay (Sample 155) is loaded directly into railroad cars on the siding by two steam shovels and shipped to Fenton. The clay is yellow brown for about four to ten feet below the surface. Under the yellow clay is about ten feet of blue clay making the total depth about 20 feet. About 18 acres have been dug over.

Burning Test

Sample No. 155. Field Sheet No. 174.
Section 13, T. 7 N., R. 3 E.
Plasticity .254 gm. water per gm, clay.
Average linear drying shrinkage 7.2 per cent.
Average tensile strength about 100 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.380	−0.2 %	1.62	Soft burned.....	Salmon
08	990	.384	0.2	1.61	Soft burned.....	Salmon
06	1,030	.363	0.4	1.63	Soft burned.....	Salmon
04	1,070	.342	1.2	1.68	Soft burned.....	Cream salmon
02	1,110	.278	3.6	1.79	Soft burned.....	Light brown
1	1,150	.140	8.7	2.08	Hard burned.....	Brown
3	1,190	.008	10.3	2.20	Vitrified.....	Dark brown
5	1,230	....	....	....	Viscous	

Light brown clay, easily molded, containing lime pebbles.
Burned by H. W. Jackman.

Analysis clay deposit in Sec. 13, T. 7 N., R. 3 E.

Loss on ignition	12.46%
Silica SiO_2	50.88
Alumina Al_2O_3	17.78
Iron Oxide Fe_2O_3	3.52
Lime CaO	8.79
Magnesia MgO	4.55

Analyzed by New Egyptian Portland Cement Co.

TUSCOLA COUNTY

The northwestern part of Tuscola County is largely covered with lake clay. A belt of morainic clays extends from the northeast corner to the southwest corner of the

county but the morainic clays are generally of minor importance for brick and tile or other clay products.

Sample No. 176 was taken by trenching the side of a drainage ditch about 10 feet deep in the eastern part of section 3, T. 12 N., R. 7 E., three and one-half miles east and one and one-half miles north of Reese and one mile south of the Pere Marquette Railroad. The clay is red and blue and contains some stone and lime pebbles, as does most of the clay in this district.

Burning Test

Sample No. 176. Field Sheet No. 197.
Section 3, (Center East), T. 12 N., R. 7 E.
Plasticity .184 gm. water per gm. clay.
Average linear drying shrinkage 4.4 per cent.
Average tensile strength about 115 lbs. per sq. in.
Apparent sp. gr. dry about 2.56.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	950	.392	−0.2 %	2.72	Soft burned.....	Salmon
08	990	.442	−3.0	2.76	Soft burned.....	Cream salmon
06	1,030	.447	−2.1	2.84	Soft burned.....	Cream salmon
04	1,070	.400	−1.2	2.66	Soft burned.....	Cream
02	1,110	.410	−0.2	2.78	Soft burned.....	Cream
1	1,150	.352	+2.7	2.71	Hard burned....	Light olive
3	1,190	.352	2.6	2.73	Hard burned....	Olive
5	1,230	.259	7.2	2.84	Hard burned....	Olive
7	1,270	.358	6.7	3.21	Hard burned....	Olive
9	1,310	....	....	....	Viscous	

Brown clay. Molded easily. Lime pebbles removed before burning. Good burning range for brick or tile if not ruined by lime pebbles.
Burned by H. W. Jackman.

At Fairgrove T. 13 N., R. 8 E., the surface clay is red and becomes yellow and stony north of Unionville.

At the Handy Brothers coal mine one and one-half miles south of Unionville on the Pere Marquette Railroad in the center of Section 12, T9 14 N., R. 8 E., the coal is overlain by a black bituminous shale (sample 145) and underlain by blue clay.

In the eastern part of the county, one and one-fourth miles south of Cass City, one-fourth mile east of the Grand Trunk railroad on the Cass river, in NW¼ section 4, T. 13 N., R. 11 E., the clay found in the old delta of the river has been used by Chas. Hall to make a buff or light red brick that has been used locally. The brick appear to be of good quality and are generally light red in color. The clay is yellow to blue in color and seems to be reasonably free from pebbles. Sample 146 was taken from the upper three to five foot stratum of clay which probably changes more to a blue color in the lower parts of the clay bed.

Burning Test

Sample No. 146. Field Sheet No. 159.
Section No. 4, (NW) T. 31 N., R. 11 E.
Plasticity .293 gm. water per gm. clay.
Average linear drying shrinkage 8.8 per cent.
Average tensile strength about 100 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.318	−0.2 %	1.72	Soft burned.....	Salmon
08	990	.312	0.6	1.76	Soft burned.....	Salmon
06	1,030	.270	2.1	1.84	Soft burned.....	Light red
04	1,070	.219	5.0	1.99	Hard burned....	Red
02	1,110	.138	7.6	2.16	Hard burned....	Dark red
1	1,150	.025	9.8	2.34	Vitrified.....	Dark red
3	1,190	.016	8.7	2.27	Vitrified.....	Dark red
5	1,230	.015	6.3	2.11	Vitrified.....	Chocolate
7	1,270	.022	5.3	2.03	Vitrified.....	Chocolate
9	1,310	.246	−3.1	1.57	Vitrified.....	Chocolate

Yellowish brown clay. Molded easily. Suitable for face brick, tile, and vitrified ware.

The burning test of the sample indicates that the upper clay is excellent material for tile or brick. It burns to a good red color and has a burning range of 10 cones and a vitrification range of over six cones. These properties, coupled with its high plasticity and uniform shrinkage suggest that it could be used for making face brick and vitrified ware such as sewer tile or vitrified stoneware. Its burning properties are very similar to those of the Coldwater shale which outcrops along Lake Huron in the southern part of Huron County (sample 147).

For about six or eight miles south of the Cass river, Tuscola County is covered with sand. South of this area are found morainic and till clay.

VAN BUREN COUNTY

In Bangor, just west of the Pere Marquette Railroad, on the northern edge of town, Section 6, T. 2 S., R. 15 W., there is the site of a brick yard formerly operated by F. E. Fish and J. S. Steward. Operations were abandoned in 1910 when the clay ran out.

Just south of Hartford out Bernard Street, southeast of the bend in the Pere Marquette railroad in Section 21, T. 3 S., R. 16 W., A. C. Acolliney makes drain tile and wire cut brick. The clay covers six to 10 acres to a depth of about eleven feet, and is covered by four to six feet of sand. It is blue in color and apparently free from lime pebbles. Sample 23 was taken by trenching the side of the clay pit to a depth of six feet.

The brick and tile are burned in a 30 foot down draft kiln, fired with coal. The product is a hard, dense, light buff brick of good quality. The capacity of the plant is about 25,000 brick a day. The market conditions were excellent in 1922.

Chemical Analysis.

Sample No. 23. Field Report Sheet No. 21.
Upper six feet of deposit in Section 21, T. 3 S., R. 16 W.

Loss of ignition	10.90%
Silica (SiO_2)	52.20
Alumina (Al_2O_3)	17.90
Iron (Fe_2O_3)	4.36
Lime (CaO)	10.08
Magnesia (MgO)	3.31
Alkalies (Na_2O, K_2O)	1.25

Analysis by H. W. Jackman.

Burning Test

Sample No. 23. Sheet 21.
Section 21, T. 3 S., R. 16 W.

Plasticity .253 gm. water per gm. clay.
Average linear drying shrinkage 6.0 per cent.
Average tensile strength about 130 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Hardness.	Color.
010	950	.399	0.5 %	Soft burned	Salmon
08	990	.385	0.9	Soft burned	Salmon cream
06	1,030	.370	0.9	Soft burned	Cream
04	1,070	.324	4.0	Soft burned	Cream
02	1,110	.206	6.5	Hard burned	Light cream
1	1,150	.027	10.7	Hard burned	Brown
3	1,190	.025	8.8	Vitrified	Light olive brown
5	1,230	....	....	Melted	Yellow

Easily molded, some lime pebbles present.
Burned by H. W. Jackman.

WASHTENAW COUNTY

Most of the clays of Washtenaw County are of direct glacial origin and very unsatisfactory, being full of lime and lime pebbles.

East of a line drawn through Ypsilanti and Saline the surface clays are chiefly lake clays. These deposits are a continuation of the deposits in northwestern Monroe County and northeastern Lenawee County, but are much higher in lime, therefore of less value. The area south of Ypsilanti covers 20 to 25 square miles. It is a varying deposit; in some places there are 20 to 30 feet of blue clay covered by a few feet of weathered yellow or brown clay; in others there are thin strata of clay in sand and quicksand. The clay contains some lime pebbles and is plastic. Sample No. 158 was taken from this deposit about three miles south of Ypsilanti in SW¼ section 21, T. 3 S., R. 7 E., and is probably representative of most of this area.

Burning Test

Sample No. 158. Field Sheet No. 179.
SW¼ section 21, T. 3 S., R. 7 E.
Plasticity .248 gm. water per gm. clay.
Average linear drying shrinkage 6.9 per cent.
Average tensile strength about 75 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.370	0.2	1.60	Soft burned	Light red
08	990	.387	0.2	1.58	Soft burned	Light red
06	1,030	.393	1.0	1.61	Soft burned	Salmon
04	1,070	.377	0.6	1.61	Soft burned	Salmon
02	1,110	.331	2.9	1.73	Soft burned	Cream brown
1	1,150	.319	6.8	1.95	Hard burned	Very light olive
3	1,190	.240	9.1	2.10	Vitrified	Olive
5	1,230	.071	3.7	1.84	Vitrified	Olive
7	1,270	....	....	....	Melted	

Brown clay with lime pebbles. Suitable for common brick and tile only. Molded easily. Burned by H. W. Jackman.

Burning Test

Sample No. 1034. Field Sheet No. 1041.
Section 1, mi. S. of Saline and D. U. R. on Toledo Rd.
Plasticity .184 gm. water per gm. clay.
Average linear drying shrinkage 3.5 per cent.
Average tensile strength about 80 lbs. per sq. in.
Average Ap. Sp. Gr. (dry) 2.84.

Cone No.	Thermo-couple Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	905	.358	0.0 %	2.83	Soft burned	Salmon pink
08	945	.406	0.9	3.02	Soft burned	Salmon pink
06	985	.384	1.0	3.02	Hard burned	Salmon pink
04	1,045	.383	1.2	3.01	Hard burned	Pinkish white
02	1,090	.381	1.9	2.98	Hard burned	Pinkish white
1	1,130	Lime pop	....	....	....	Gray
3	1,170	Lime pop	....	....	Vitrified	Olive gray
5	1,210	Lime pop	....	....	Vitrified	Olive green
7	1,255	....	....	....	Melted	

Yellow clay containing numerous and large lime pebbles. Clay lacks plasticity. Burned by M. C. Huck.

Morainic clay is found about four miles northeast of Manchester in hills of yellow clay streaked with blue clay and rather full of gravel. Sample 1028 was taken from NWi/4 Section 28, T. 3 S., R. 4 E., and represents this morainic clay. It is high in lime content and practically useless. Similar clay is found in the northeastern part of Ann Arbor near the new hospital. Two samples, one of the yellow upper clay and one of the lower blue clay, were taken from some of the excavations made by the Buildings and Ground Dept. of the University. The following tests show the practical worthlessness of these clays:

Burning Test

Sample No. 62.
Section 25, T. 2 S., R. 6 E,
Plasticity .112 gm. water per gm. clay.
Average linear drying shrinkage 5 per cent.
Average tensile strength about 83 lbs. per sq. in,
Apparent Sp. Gr. of air dried sample 2.91.

Cone No.	Temp. of Pyrometer.	Hardness.	Color.
010	910°C.	Soft burned	Pinkish white
08	953	Soft burned	Pinkish white
06	1,015	Soft burned	White
04	1,070	Soft burned	White
02	1,110	Hard burned	Grayish white
1	1,150	Hard burned	Olive gray
3	1,195	Hard burned	Olive green
5	1,220	Hard burned	Olive green
7	1,250	Vitrified	Olive green

Bluish gray clay. Pebbles ¼" to 2½" very numerous. All samples disintegrated upon boiling in H_2O.

Sample 63.
North end Section 25, T. 2 S., R. 6 E., Ann Arbor.
Plasticity .0736 gm. water per gm. clay.
Average linear drying shrinkage 7 per cent.
Average tensile strength about 148 lbs. per sq. in.
Apparent Sp. Gr. of Air Dried Sample 2.62.

Cone No.	Temp. by Thermocouple Pyrometer.	Hardness.	Color.
010	910	Soft burned	Salmon pink
08	952	Soft burned	Salmon pink
06	1,015	Soft burned	Salmon pink
04	1,070	Soft burned	Brownish pink
02	1,110	Soft burned	Brownish gray
1	1,150	Soft burned	Olive gray
3	1,195	Soft burned	Olive green
5	1,220	Soft burned	Olive green
7	1,250	Soft burned	Olive green

Yellow brown clay with pebbles (¼" to 1"). Difficult to mold. All samples disintegrated upon boiling in H_2O. Burned by M. C. Huck.

The following analysis of the glacial clay near Pittsfield Junction shows how variable these clays may be within even short distances.

	300 ft. east of Ann Arbor R. R. and south of L. S. R. R., Sec. 21, T. 3 S., R. 6 E.	½ mile east on road, brick school house, Sec. 21, T. 3 S., R. 6 E.
Silica (SiO_2)	62.26%	38.50%
Alumina (Al_2O_3)	15.45	12.72
Ferric Oxide (Fe_2O_3)	7.05	6.74
Lime (CaO)	1.90	19.93
Magnesia (MgO)	1.65	2.81
Ignition loss	7.35	15.70
	100.02%	100.20%

Analyses by Mr. DePont formerly of Michigan Portland Cement Co., Chelsea.

The first sample is relatively low in lime and may be usable for brick or tile.

The West German Portland Cement Co. organized Aug. 13, 1902, or the Millen Portland Cement Company built its plant between Dexter and Chelsea at the southern end of Four Mile Lake on the Michigan Central Railroad. This plant was destroyed and later rebuilt by the Michigan Portland Cement Company. This plant began producing in 1911. In 1923 the plant was purchased by the State and is now operated as the State Portland Cement Plant.

Originally marl and clay were obtained from Four Mile Lake. At present limestone from the Michigan Limestone Company (Calcite, Presque Isle County) is shipped in, and clay is obtained from the old lake deposit. The clay bed is covered by 3½ to 4 feet of peat and runs 30 to 50 feet deep. It is a blue clay containing pockets of marl which give a high lime content. The clay is dug by a clam shell bucket, loaded on dump cars and brought in about one-half mile to the plant. Here it is dumped into the washer or disintegrator and water is added to make a thin slip. This passes through a grating to remove sticks and large stones into a sump where the coarse sand and gravel separate out. From the sump the clay slip is pumped to storage tanks and analyzed preparatory to making up the slurry or clay and limestone that is fed to the kiln. This slurry contains about 32 per cent water.

The plant is equipped with three kilns 125 feet long with a combined operating capacity of about 2,200 barrels per day. The composition of the clay is well represented by the following analyses:

	Analysis	
Loss on Ignition	18.6 %	18.2 %
Silica (SiO_2)	42.46	39.2
Ferric Oxide (Fe_2O_3)	8.64	5.89
Alumina (Al_2O_3)	11.48	15.57
Lime (CaO)	16.31	16.00
Magnesia (MgO)	2.32	3.54

The burning properties are very similar to those of the other high lime clays of the county.

Burning Test

Sample No. 72. Field Sheet No. 72.
Sestion 4, T. 2 S., R. 4 E.
Plasticity .359 gm. water per gm. clay.
Average linear drying shrinkage, 6.5 per cent.
Average tensile strength about 80 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
08	990	.371	.02 %	1.59	Soft burned	Cream
06	1,030	.383	.02	1.57	Soft burned	Cream
04	1,070	.396	.06	1.57	Soft burned	Cream
02	1,110	.346	3.1	1.70	Semi-hard burned	Light brown
1	1,150	.064	12.0	2.28	Hard burned	Olive brown
3	1,190	.043	11.7	2.25	Vitrified	Olive
5	1,230	....	....	....	Viscous	

Contains lime lumps. Molded easily.
Burned by H. W. Jackman.

WAYNE COUNTY.

The clays of Wayne County are somewhat similar to the clays of Macomb and Monroe Counties. The surface clays of the Detroit district north and west of the Detroit River are generally more sandy and calcareous than the clays found west of Lake St. Clair and Lake Erie. In many respects they resemble river clays. The main body of clay is always a lake clay. The lower blue clay of this district seems about intermediate between the vitrifying and red burning blue clay of Macomb County and the calcareous blue clay of Monroe County.

Since 1904 the Bunte Bros. Tile Company one mile north of Flat Rock in section 30, T. 4 S., R. 10 E., has used the upper 3 feet of a yellow red clay deposit that is very similar to the clay found in South Rockwood, Monroe County. Below a depth of 3 feet limestone pebbles cause trouble. The clay is recovered by horse drawn scrapers, dumped into a skip car and pulled up an incline into the plant by a cable wound on a power driven drum. The plant is supplied with power from a boiler and an 80 H.P. engine. The clay is worked in the following equipment:

Pug-mill.
Roll crusher.
Brewer tile machine with automatic cut-off for extruding 3, 4, 5, 6 and 8-inch tile.
Air drying sheds.
Four downdraft kilns, each with a capacity of 18,000 to 20,000 three-inch tile.

Twelve to fifteen men are employed. Sample 1032 taken from the clay pit has burning properties very similar to those of sample 59 taken from Azalia, Monroe County.

Burning Test

No. 1082. Field Sheet No. 1039.
Section 30, T. 4 S., R. 10 E.
Plasticity .214 gm. water per gm. clay.
Average linear drying shrinkage 5 per cent.
Average tensile strength about 181 lbs. per sq. in.
Apparent sp. gr. of air dried sample 2.35.

Cone No.	Temp. °C. by Thermo-couple.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	910	.355	−1.7 %	2.6	Soft burned	Light red
08	952	.293	−1.4	2.42	Soft burned	Light red
06	1,015	.276	1.0	2.49	Soft burned	Light red
04	1,070	.238	2.0	2.58	Hard burned	Red
02	1,110	.187	3.5	2.62	Hard burned	Dark red
1	1,150	.154	4.7	2.60	Hard burned	Dark red
3	1,195	.126	4.8	2.52	Vitrified	Chocolate
5	1,225	.051	4.8	2.43	Vitrified	Chocolate
7	1,250	.021	4.8	2.12	Vitrified	Chocolate

Yellow clay, easy to mold. Suitable for face brick, tile, and possibly for vitrified ware. Burned by M. C. Huck.

Chemical Analysis.

Sample No. 1032. Sheet No. 1039.
Section 30, T, 4 S., R. 10 E.

Ignition Loss	6.75%
Silica (SiO_2)	65.30
Ferric Oxide (Fe_2O_3)	4.97
Alumina (Al_2O_3)	16.03
Lime (CaO)	1.80
Magnesia (MgO)	1.84
Sulphur Trioxide (SO_3)	None
Alkalies	2.75
Total	99.44

Similar clay is found in many places in the southern and western parts of Wayne County. Sample No. 1033 was taken by trenching the side of a drainage ditch in section 27, T. 4 S., R. 11 E., about two miles northeast of Waltz.

Sample No. 1030 was taken by trenching the bank of the Rouge River near the road one-quarter mile north of Inkster in section 19, T. 2 S., R. 10 E. Here the yellow top clay contained some pebbles and seems to be about 20 to 25 feet thick.

Burning Test

Sample No. 1030. Field Sheet No. 1040.
Section 29, T. 4 S., R. 11 E.
Plasticity .215 gm. water per gm. clay.
Average linear drying shrinkage 4.5 per cent.
Average tensile strength about 95 lbs. per sq. in.
Apparent Sp. Gr. (dry) 2.75.

Cone No.	Thermo-couple Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	905	.440	2.8 %	3.52	Soft burned	Salmon pink
08	945	.455	1.9	3.47	Soft burned	Salmon pink
06	945	.428	2.3	3.31	Soft burned	Pinkish white
04	1,045	Lime pop	....	....	Hard burned	Pinkish white
02	1,090	Lime pop	....	....	Hard burned	Pinkish white
1	1,130	.412	2.5	3.16	Hard burned	Olive gray
3	1,170	Lime pop	....	....	Vitrified	Olive green
5	1,210	....	....	....	Melted	

Yellow clay containing numerous lime pebbles. Granular on tempering.
Burned by M. C. Huck.

Sample 1031 represents the stiff blue clay underneath the yellow clay, (sample 1030), Section 19, T. 2 S., R. 10 E. The blue clay also contains some pebbles and is at least 6 feet thick. It was sampled by drilling with the auger.

Sample 1029 was taken just west of Canton in the NW¼ section 34, T. 2 S., R. 8 E., about ¾ mile north of the Michigan Central railroad. The clay is yellow to blue and contains some pebbles.

The Detroit district has been building up very rapidly in the last 25 years and being well supplied with lake clay is the most important brick making center in the State. Ries* has described these lake clays as an upper bed averaging six feet thick of sandy calcareous clay underlain by a very plastic, less fusible clay, something over 4 feet thick. His tests of these clays resulted as follows:

Upper clay from Clippert Bros. yard.
Effervesces freely with acid.
Slakes rapidly into a powdery mass.
Highly plastic although containing considerable fine grained sand.
Fine grained:
2% on 60 mesh (fine sand).
0% on 100 mesh.
2% on 150 mesh.
Water of plasticity 24 per cent.
Drying shrinkage 4 per cent.
Soluble salts 0.6 per cent.
Tensile strength 150-190 lbs. per sq. in.

Cone.	Total Shrinkage.	Burned.	Color.
05	6 %	Soft burned	Red
01	14 %	Hard burned	Buff
2	....	Vitrified	Reddish buff
4	....	Viscous	

Lower clay in vicinity of Detroit
Extremely plastic blue clay containing very little grit.
Slakes more slowly than the upper clay.
Water of plasticity 26 per cent
Tensile strength air dried 175-200 lbs. per sq. in..
Soluble salts 0.4 per cent.

Cone.	Total Shrinkage.	Burned.	Color.
05	9 %	Burned hard	Gray red
1	15 %	Vitrified	
5	....	Viscous	

The following analysis is of the upper yellow clay of the Detroit district:

Yellow clay, traces of fine sand or grit.

Chemical Analysis.

Silica (SiO_2)	55.90%
Alumina (Al_2O_3)	12.32
Iron (Fe_2O_3)	4.82
Lime (CaO)	11.23
Magnesia (MgO)	5.42

Analysis by Wm. Kane, Cement City.

*Mich. Geol. Survey VIII, Pt. I, p. 49 (1900).

At the present time, so far as can be determined, the Detroit clays are used for soft mud common brick exclusively. Ries mentioned that some yards employed the stiff mud process in 1900. At that time the clay raw or mixed with some sand if necessary, was tempered in shallow rectangular soak pits over night and conveyed

into the molding machines the following day. Driers were the exception.

Most of the brick making is at present centered in Springwells. But the increased property values are beginning to force the brick yards still further from the city as is evidenced by the purchase of 200 acres of clay property in Dearborn by the Clippert Brick Company.

There are about a dozen brick yards in the Detroit district. The clay is all of the same general lake deposit.

> 6 to 8 feet of sandy yellow and red clay, then about 7 to 10 feet of plastic blue clay running to lime pebbles.

All the yards make soft mud brick dried on pallets in steam heated drying rooms and burned in scove kilns which may be fired by oil or coal. The differences in the yards are chiefly in condition of equipment.

The Mercier-Bryan-Larkins Brick Company, Michigan Avenue and Miller Road, has a modern soft mud brick plant with a daily production of about 100,000. This plant is typical of the plants making soft mud brick in the Detroit district and includes two seven-brick molding machines equipped with automatic dump, pallet conveyors, steam chamber driers, and oil fired scove kilns. The product is a good common brick of about a salmon color.

The clay pit is to the southwest of the yard. The deposit is worked to a depth of 17 feet and consists of three strata, the uppermost five feet of yellow clay, underlain by three feet of red clay and then 9 feet of very plastic blue clay. Attempts have been made to go deeper with disastrous results to the product as lime pebbles are encountered in the blue clay at this depth. The clay is removed by an Erie shovel operated to gather the clay from the bottom to the top of the deposit with each digging, thus giving a uniform mixture of clay at each load. The skip cars are hauled in by a friction drive gasoline dinkey and drawn up into the plant by a cable wound on a power driven drum.

The pit is well drained. In six years about 10 or 11 acres have been dug over.

Porath Brothers operate a yard south of Michigan Avenue about 500 yards east of the Pere Marquette railroad crossing, equipped with one hand-dump, 7-brick molding machine, with a daily capacity of about 32,000 brick. The deposit contains six feet of red clay over about 8 or 9 feet of bluish clay running to lime.

J. S. Haggerty operates two yards north of Michigan Avenue, east of Miller road and the Pere Marquette railroad crossing. Yard No. 1, adjacent to Michigan Avenue, is equipped with two hand-dump, 7-brick molding machines. The total daily capacity is 68,000 brick. Yard No. 2, 200 yards or so in the rear of No. 1, is equipped with one hand and one automatic molding machine. Capacity about 82,000 brick.

The Clippert Brick Company has three yards on the Michigan Central railroad. This company is one of the oldest operators in Detroit. Plant No. 1 has run out of clay. They have given up the idea of using more clay in Springwells as the property is too valuable for other uses and they figure the city of Detroit will soon crowd them all out before the clay becomes unavailable from other causes. They have purchased 200 acres of land in Dearborn which is a continuation of the same clay deposit as occurs in Springwells.

Yard No. 2.—3 hand dumps—capacity 100,000 bricks.

Yard No. 3.—2 auto dumps—capacity 100,000 brick.

They sell 6 cu. yds. (2 team loads) of clay daily to Semet-Solvay for claying up coke ovens.

The clay pit contains about 6 feet of red clay over 9 or 10 feet of bluish dense clay.

Walker & Frank brick yard is also on the Michigan Central railroad about one mile east of Miller road. It consists of the usual soft mud plant with 2 seven-brick automatic dumpers having a combined capacity of 95,000 to 100,000 brick daily.

The clay pit lies to the southeast of the yard. Its own deposit of about 8 acres being exhausted, it is now operating on leased adjacent land. The usable clay is about 16 feet deep. The clays are mixed in digging and produce a light red brick.

John A. Mercier completed a model soft mud brick plant at Roulo Avenue and the Michigan Central Railroad in 1924. This plant is equipped with two complete units of automatic soft mud machinery and has a daily capacity of about 100,000 brick. The power plant burns powdered coal and is far superior to power plants usually found in common brick plants.

The plant is of the standard Detroit type and includes the following:

> Steam shovel.
> Skip cars.
> Gasoline engine.
> Drum skip hoist.
> Pug-mill.
> Soft mud molding machine.
> Pallet conveyor.
> Chamber drier.
> Scove kilns.

The Detroit Brick Manufacturers' and Dealers' Association, Geo. Bowen, Secretary, has become interested in improving the quality of Detroit brick. As a preliminary to any effort to improve the present product the bricks as now produced were carefully tested by Lucius E. Allen* of Detroit.

Interesting tests were made of brickwork set with Detroit brick. Five brick piers and one hollow wall unit were built for this purpose, using commercial sand as supplied in Detroit, Petoskey Portland Cement, and Urschel Hydrated Lime in the proportions of three parts sand to one part of cement containing 25 per cent by volume hydrated lime. The bricks were set in the ordinary way

by a Detroit mason with mortar joints of ⅜ to ½-inch. The piers and samples of mortar were allowed to cure for 33 days before testing.

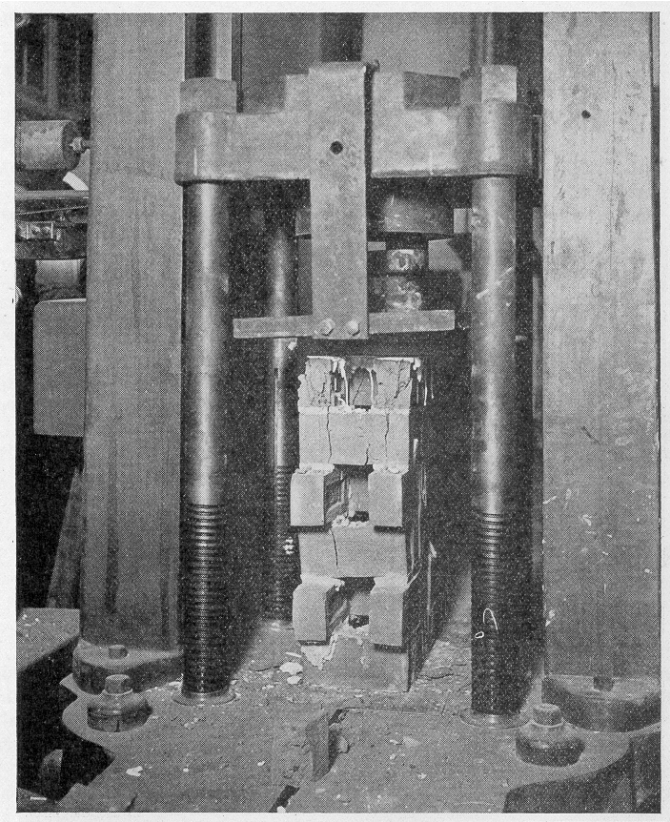

Plate XXXVII. "Ideal Wall" of the Detroit Brick Manufacturing Association setting brick on edge in hollow wall (cross-section of wall section being tested).

The mortar used had a compressive strength of about 1600 lbs. per sq. in.

The solid pier of brick laid flat withstood 1089 pounds per sq. in. without failure.

The hollow pier of brick laid flat failed at 1144 lbs. per sq. in. Two hollow piers of brick laid on edge failed at 1541.6 pounds per sq. in.

The hollow "Ideal Wall" of brick laid on edge failed at 976.4 pounds per square inch. This structure had been injured before testing and this result may be relatively too low.

> "In order to secure uniformity in the tests and that results might be comparable with results obtained in other sections of the United States the methods followed in all cases are those specified by the American Society for Testing Materials.
>
> All samples of brick were procured on the same day from all the plants. Samples were taken at random from the various kilns and were fairly representative of the product being marketed at the time. In order to secure uniformity all brick used for building the test piers were taken from the same plant."

Absorption of the Detroit brick varies from 5.55 per cent for hard burned brick to over 22 per cent for the soft burned brick. The average absorption was found to be about 13.75 per cent and the average of the individual maximum was 17.49 per cent. These results grade Detroit bricks as "Medium Brick" so far as absorption is concerned.

Compression strengths vary from about 1700 to 4600 pounds per square inch, with a general average of about 2912 pounds. Modulus of rupture as determined by tranverse tests varied from about 460 to 1028 with an average of 620 pounds per square inch.

The compressive tests classify the Detroit brick as a "Medium Brick" and the transverse as a "Hard Brick."

*Efficiency of Detroit Common Brick and Common Brickwork by Lucius Allen, published by Detroit Brick Manufacturers and Dealers Association, Penobscot Building, Detroit.

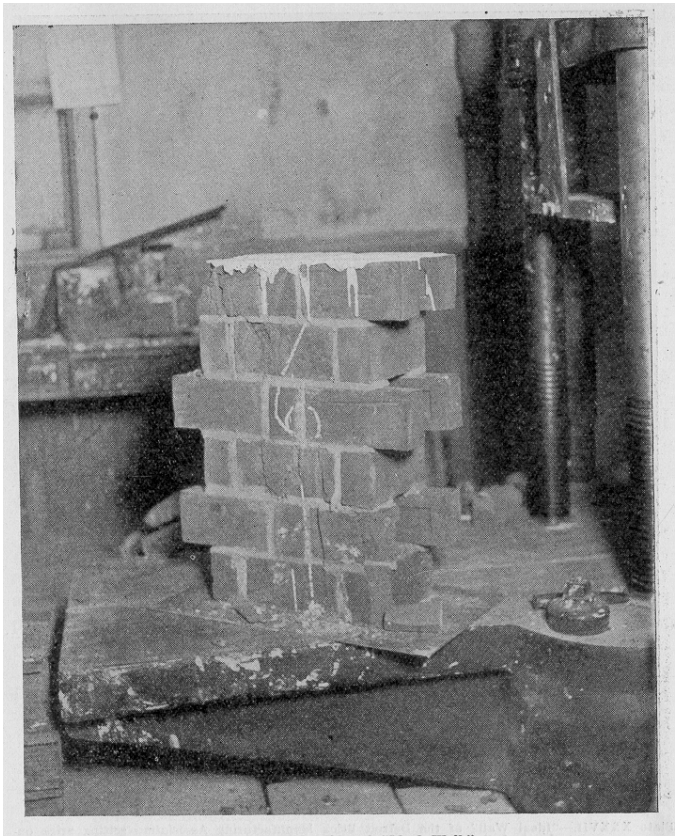

Plate XXXVIII. Side of "Ideal Wall." (From Detroit Brick Mfrs. Assoc.)

These tests lead to the conclusion that although Detroit brick rank higher than the official standards for "Medium Brick" so far as transverse strength is concerned, they should be classed as "Medium Brick"[1]. If all the brick were hard burned the absorption could be easily reduced and the compressive strength raised so that the brick might be classed as "Hard Brick." This can be done only by adopting better methods of burning than can exist in ordinary scove kilns.

Grade.	Absorption per cent.		Compressive Strength on Edge. Lbs. per Sq. In.		Modules of Rupture. Lbs. per Sq. In.	
	Mean 5 tests.	Indv. Max.	Mean 5 tests.	Indv. Min.	Mean 5 tests.	Indv. Min.
Vitrified brick	5 or less	6.0	5,000 or over	4000	1,200 or over	800
Hard brick	5 to 12	15.0	3,500 or over	2500	600 or over	400
Medium brick	12 to 20	24.0	2,000 or over	1500	450 or over	300
Soft brick	20 or over	no limit	1,000 or over	800	300 or over	200

These tests indicate the economy and increased strength obtained where brick are laid edgewise. The "Ideal Wall" a double wall of brick laid on edge, tied together, and with broken joints, seems to be a logical type of construction for small buildings.

Tests on Large Brick Piers U. S. Bureau of Standards. Age of brickwork one month in all cases.

Brick Used.	No. of Tests.	Ultimate Strength Lbs. per Square Inch		Per cent Efficiency.
		Brickwork.	Brick.	
Pittsburg District (no lime in cement)	3	1,647	6,070	27.2
Pittsburg District (15 % lime by weight)	3	1,463	6,070	24.1
New Orleans District (15 % lime by wt.)	2	1,710	6,880	24.9
New York District (15 % lime by wt.)	3	1,260	4,430	28.3
Chicago District (15 % lime by wt.)	3	720	3,150	22.9
Pittsburgh District (15 % lime by wt.)	2	1,785	2,450	70.3
Average	16	1,391	4,841	32.9
Detroit Tests added for Comparison				
Detroit District (25% lime by vol.	5	1,253	4061	30.9

In 1906 the Detroit Roofing Tile Company built a plant at Detroit,[2] It used the plastic blue clay in Springwells common to the Detroit district and with the following properties:

Water of plasticity 16.13 per cent.
Air Drying shrinkage:

Per cent loss of water	Per cent linear shrinkage
1.95	1.0
4.02	2.5
5.21	4.0
6.84	4.0
10.28	4.5
12.33	5.0
13.90	5.0
16.90	5.0

Cross breaking strength of dried clay bar 9.05 lbs. per sq. in.

Oxidization takes about 36 hours at 600°-700°C. for a 2x2x4 inch briquette.

[1]American Society for Testing Materials Brick Classification

[2]Worcester, Geol. Surv. Ohio, Series IV, Bulletin II (1910), pages 20, 169, 191, 196, 200, 212, 253, 296, 297, 311, 312, 383, 405.

Cone	Porosity.	Apparent Sp. Gr.	Total Linear Shrinkage per cent.	Fire Shrinkage per cent.	Hardness.	Color.
010	.3712	2.64	5.50	0.00	Softer than steel	Very light red
08	.3825	2.70	5.50	0.00	Softer than steel	Very light red
06	.3764	2.68	6.50	0.00	Softer than steel	Gray buff
04	.3720	2.67	6.00	0.50	Softer than steel	Gray buff
02	.3642	2.66	6.50	0.50	Softer than steel	Gray buff
1	.1825	2.43	9.00	2.50	Almost hard burned	Gray
2	.1786	2.44	9.50	3.75	Hard burned	Gray
3	.0368	2.36	11.00	5.50	Almost vitrified	Dark gray
4	.2104	2.46	11.00	6.00	Almost vitrified (softer)	Dark gray
5	.0101	2.02	....	....	Melted	Yellow brown

The clay began to fail at cone 02, has a poor color, and is suitable for a porous tile only when slipped for the proper color.

The clay was spaded into a small tram car and pushed a short distance to a central dumping point where the clay was shoveled on to a belt conveyor about 15 inches wide, which carried the clay some 50 yards into the grinding room of the plant. Originally the clay had been shoveled directly on to the belt but as digging progressed the primitive transportation system became necessary. The clay was fed directly from the belt through wet grinding rolls* driven at different speeds. The small roll, nine or ten inches in diameter and two feet wide, ran at about 500 r.p.m. The larger roll, about 18 inches in diameter, was driven at 150 r.p.m. This type crusher not only squeezes the pebbles but also shreds or tears the clay. The clay was dropped from the rolls directly into an open top pug-mill eight feet long. As the clay dropped out of the pug mill it was picked up and "slammed" into storage or aging bins.

*Smooth rolls made by Horton Man. Co. of Painesville, Ohio.

After aging for three days to equalize the moisture content the clay was extruded into flat blanks in an auger machine. These blanks were of different cross section depending on the style of roofing tile to be produced. For Spanish tile they were about 2½ x 4 inches. The streams issuing from the die were passed under a reel cutter which cut the clay into lengths about 12 inches long. Issuing from the cutter the blanks were carried by an endless belt to the pressman or feeder. These blanks were "hacked" on a bench beside the feeder to tide over interruptions in the operation of the auger extrusion press.

In pressing by the Pentagon press the plaster dies are first well saturated with water. The feeder takes up a blank with both hands and slams it with considerable force on to the face of the die. The pentagon making one-fifth of a revolution, brings this newly filled die under the top die which descends, forcing the blank to fill up all parts of the space between the top and bottom dies and squeezing out all excess clay. The pentagon moves again. The off-taker or tailsman places a pallet upon the tile, and waits for the die to reach the third position, when the tile releases easily.

The pallet with its tile is then put on a belt conveyor driven from the pentagon shaft in such a manner that it moves forward about two feet with the pentagon. Between these intervals the tile is trimmed by boys or girls on either side of the belt and punched with the nail holes or the lugs as the under side are perforated. The tile are taken from the end of the belt and put on the drier cars.

Hip and valley tile were cut by laying them in the proper position over a slot in a long table. The operator then steps up on a platform over the table and walking the necessary length of the table draws a piano wire held taut by a weight on the lower end lengthwise through the

slot. In this way the tiles were cut to the proper angle as readily as they could be laid.

The tiles were dried on pallets and set in the Mitchell kiln* without the use of kiln blocks, except at the bottom, by carefully wedging in each course to prevent rolling.

The old Beardsley Brothers deposit of clay is located in the northeastern part of the town of Redford, about the center of Section 10, T. 1 S., R. 10 E. This deposit has not been worked for a number of years, and is now laid out in lots as a real estate development.

The upper fourteen feet, more or less, runs a sandy yellowish red clay, containing considerable lime and slakes rapidly. It appears to be very similar to the upper part of the clay deposits in Dearborn, Springwells, and Detroit. The lower three feet consists of a heavy, plastic smooth bluish clay very similar to the lower part of the Springwells' deposits. Beneath this bluish clay is a water bearing gravel.

*See Burning Clay Ware, Kilns.

The Wyandotte Portland Cement Company originally used the calcium carbonate waste from the alkali plant, but this proved unsatisfactory. The limestone is obtained from Alpena. Clay is obtained from the stripping or overburden of the limestone at Sibley. The following analysis was supplied by Mr. Beal, chief chemist of the Wyandotte. Cement Company:

Ignition Loss	14.88%
Silica (SiO_2)	50.90
Alumina (Al_2O_3)	13.60
Iron (Fe_2O_3)	5.20
Lime (CaO)	12.00
Magnesia (MgO)	3.52

The plant uses the wet process. The clay is dried, ground in a dry pan, and mixed with the lime sludge in pug-mill. This slurry is then ground in a tube mill and clinkered in three kilns 100 feet long and seven feet in diameter.

This plant has a daily capacity of 1000 barrels. About 200 pounds of coal are used to clinker one barrel of cement.

The Peerless Portland Cement Company is building a new plant on River Rouge within the city limits of Detroit to have a daily capacity of about 5,000 barrels. The plant is equipped with waste heat boilers and all modern improvements. Clay is obtained 16 miles away. Limestone is shipped from Calcite and the plant may use some caustic waste from the adjacent plant of the Solvay Process Company.

This plant has been located adjacent to the market on expensive land instead of near the raw material on low priced land as is usual.

WEXFORD COUNTY.

The Wilcox Brothers owned a brick yard just south of Cadillac, which used the clay bank in the center of section 10, T. 21 N., R. 9 W. The clay is blue and contains lime pebbles. The product was a very brittle porous brick, light gray in color, and would not stand more than 4 or 5 years in a chimney. The clay is very similar to that found in the southwestern part of. Missaukee county and used at Lake City and McBain, and also to that near Long Lake in T. 22 N., R. 9 W. At the latter place the clay seems to be free from pebbles but has the same burning properties. When his brother died, John Wilcox closed the yard as he was not satisfied with the clay nor the brick being made. The clay is of poor quality.

Ries* reports two extensive outcrops of clay at Harrietta, one to the north of the village in section 7, T. 22 N., R. 11 W., at the brick yard operated by George Heath, now owned by Alfred Fellers, and the other in a ravine near the water tank just east of the railroad station.

*Part I, Vol. VIII, Mich. Geol. Survey, p. 53 (1900).

The clay used in the brick yard consists of an upper layer burning buff or salmon, and a lower member burning cream. Ries gives the following report of the burning properties of the lower clay:

Slakes readily.
Water of plasticity 0.29 grams.
Drying shrinkage 8% of plastic clay.
Average tensile strength 175-200 lbs. per sq. in.

Cone.	Total Shrinkage from plastic clay.	Hardness or Fusion.	Color.
05	10 %		Cream
1	17 %	Hard burned, Incipient Fusion	Cream
3	22 %	Vitrified	Greenish yellow
5	....	Viscous	.....

Very plastic; hard to mold and to dry.

The upper clay:

Slakes readily but contains more sand than the lower clay.
Water of plasticity .30 grams.
Soluble salts 0.2 per cent.
Drying shrinkage 7 per cent.

Cone.	Shrinkage (total).	Hardness.	Color.
04	11 %	Hard burned	Nearly white
1	17 %	Vitrified	Buff
4	....	Viscous	.....

Compare these tests with the following of a sample taken from this same pit in 1923:

Burning Test

Sample No. 1019. Field Sheet No. 1023.
Section 7, T. 22 N., R. 11 W.
Plasticity .328 gm. water per gm. clay.
Average linear drying shrinkage 12.2 per cent.
Average tensile strength about 200 lbs. per sq. in.
Apparent Sp. Gr. Dry 2.59.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	950	.390	2.1 %	2.61	Soft burned.....	Salmon pink
08	990	.413	1.8	2.72	Soft burned.....	Cream
06	1,030	.419	1.0	2.71	Soft burned.....	Cream
04	1,070	.410	1.3	2.73	Soft burned.....	Cream
02	1,110	.407	2.8	2.79	Soft burned.....	Cream
1	1,150	.261	8.2	2.65	Hard burned....	Cream
3	1,190	.011	16.1	2.54	Vitrified.....	Light olive
5	1,230	.043	....	2.18	Vitrified.....	Olive
7	1,270	....	....	....	Viscous.....	.....

Bluish gray clay, molded easily.
Burned by H. W. Jackman.

At the old plant owned by Steve Millard and Robt. Wilson of Cadillac stiff mud brick were made by feeding the clay through rolls into a Kells stiff mud machine, drying the green brick in an open yard and burning in a scove kiln. The yard was closed about 1915, reported to be due to excessive overhead. It is now a wreck.

In the southwest part of the village of Harrietta on the property of Alfred Fellers, in section 13, T. 22 N., R. 12 W., there is a deposit of a somewhat sandy red clay running 25 to 50 feet deep and covering 50 acres or more. The clay seems free from stone and somewhat resembles a lake deposited clay. Sample 1018 taken from this deposit indicates that this clay is superior to that used in the old brick yard. It is good material for brick and tile and might be used for brown face brick.

Burning Test

Sample No. 1018. Field sheet No. 1023.
Section 13, T. 22 N., R. 12 W.
Plasticity .305 gm. water per gm. clay.
Average linear drying shrinkage 10.1 per cent.
Average tensile strength about 198 lbs. per sq. in.
Apparent sp. gr. dry 2.45.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	950	.298	0.0	2.53	Soft burned.....	Salmon
08	990	.307	1.1	2.61	Soft burned.....	Salmon
06	1,030	.279	2.0	2.60	Hard burned....	Salmon
04	1,070	.178	6.1	2.58	Hard burned....	Red brown
02	1,110	.067	8.9	2.46	Hard burned....	Dark brown
1	1,150	.042	7.9	2.36	Vitrified.....	Chocolate red
3	1,190	.031	+4.9	2.14	Vitrified.....	Chocolate
5	1,230	.114	−2.3	1.90	Vitrified.....	Chocolate
7	1,270	.178	−9.6	1.72	Softening.....	Chocolate

Reddish brown clay, molded easily.
Burned by H. W. Jackman.

Another deposit just east of Harrietta was reported by Ries, but it was evidently not visited by him. It was reported as readily fusible and suitable for a slip clay. It does not soften below cone 8, and its color is poor. This deposit in sections 6 and 7, T. 22 N., R. 11 W., is an extremely fine grained, grit less clay, resembling Fuller's earth. The deposit covers 60 acres on the farms of J. Z. Stanley and Rogers and is about 30 to 50 feet thick. The Rogers farm was purchased on February 23, 1921, by the Michigan Fuller's Earth Company of Cleveland. James Evans of Cleveland, who first recognized the value of this clay in clarifying oils, had some of it tested by the Pan American Refining Company. This company found it very satisfactory and just as effective as Florida earth in clarifying their oils. Comparative tests of drillings from this deposit with a commercial Fuller's earth in the author's laboratory showed that the Harrietta earth absorbs less oil and filters faster, but gives a slightly darker initial product when used in a column filter. When clarified by batch filtration this difference in the product is not noticed. If this deposit were developed in a conservative manner this earth probably could be sold in competition with the Florida earth and have the advantage of lower freight rates to the northern refineries.

The following tests were also made on samples from this deposit. The mode of formation or deposition of this earth in a glacial moraine is not obvious, but it seems to be a lake deposit as does other clay near Harrietta.

Chemical Analysis.

Sample No. 33. Sheet No. 34.
Taken about 20 feet below top of deposit in a small pit, Section 7, T. 22 N., R. 11 W.

Loss on Ignition	15.87%
Silica (SiO_2)	42.15
Alumina (Al_2O_3)	17.91
Iron (Fe_2O_3)	4.27
Lime (CaO)	13.10
Magnesia (MgO)	4.17
Alkalies (Na_2O, K_2O)	2.53

Analysis by H. W. Jackman.

Burning Test.

Sample No. 33. Field Sheet No. 34.
Sections 6 & 7, T. 22 N., R. 11 W.
Plasticity .306 gm. water per gm. clay.
Average linear drying shrinkage 11.4 per cent.
Average tensile strength about 120 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage	Bulk Sp. Gr.	Hardness.	Color.
010	950	.397	1.9 %	1.62	Soft burned.....	Salmon
08	990	.444	1.5	1.59	Soft burned.....	Cream
06	1,030	.449	2.2	1.59	Soft burned.....	Cream
04	1,070	.426	2.8	1.61	Soft burned.....	Cream
02	1,110	.403	3.6	1.69	Soft burned.....	Cream
1	1,150	.239	10.8	2.12	Soft burned.....	Very light olive
3	1,190	.023	17.6	2.65	Hard burned.....	Olive
5	1,230	.018	16.0	2.53	Vitrified.....	Olive
7	1,270	.012	14.1	2.36	Vitrified.....	Olive
9	1,310	....	....	....	Melted.....	.....

Light grayish pink clay. Easy to mold. Suitable for brick, tile or pottery.
Burned by H. W. Jackman.

CHAPTER IX. NORTHERN PENINSULA

GENERAL DESCRIPTION.

West of a line from Marquette to Menominee the Northern Peninsula is underlain by rock formations (Fig. 68) of Pre-Cambrian age. The Paleozoic rocks of the eastern part of the Peninsula extends for some distance west of the Marquette-Menominee line, lapping upon the older crystalline rock. In places the Paleozoic sandstones and limestones occur as patches on the Pre-Cambrian rocks.

None of the Pre-Cambrian formations or the Paleozoic rocks of the Northern Peninsula appear to have any value as sources of material for ceramic products.

The surface deposits are of glacial origin and overlie the hard rocks in extremely variable thickness, and are also in most areas very variable in character. Rock is at or near the surface in numerous areas. Rocky or thinly drift covered areas form an almost continuous belt from the end of Keweenaw Peninsula southwest to the Wisconsin line. The northern half of Marquette and the east central portions of Baraga Counties are largely rocky or thinly drift covered. A large rocky rugged area occurs in the southern part of Dickinson County and numerous but smaller areas occur in other parts of the county and in the southeastern part of Iron County.

The hilly tracts or moraines deposited along the ice front contain much boulder clay but in most places the excessive content of sand, pebbles, and boulders makes the clay unsuitable for the manufacture of clay products. Excessive boulders and pebbles are characteristic of the morainic clays in the vicinity of the rocky or thinly drift covered areas. The morainic deposits are extensive in western Menominee County and over the interior portions of the western half of the Northern Peninsula.

The gently undulating or rolling till plains deposited under the ice sheet are extensive only in central Menominee County, southeastern Marquette County, and in the southern part of Iron County. The till clays are generally less stony than the morainic clays, but in many places, especially where the drift is thin, boulders and pebbles are apt to be excessive. The boulder clay of Menominee County bears evidence of being derived in part directly from the Cincinnatian shales as found in the vicinity of Bay de Noc.

A large part of northern Ontonagon County and portions of Houghton and Baraga Counties are covered by relatively level deposits of fine grained clay, locally containing few or no pebbles or boulders. These clays, called glacial lake clays, were mud deposited in the beds of former glacial lakes, caused by ponding of waters in basins in front of the ice sheet. The largest of these lakes were Lake Ontonagon and Lake Duluth. The latter covered most of the northern part of Ontonagon County and portions of adjoining counties. Its border is marked by the southern limit of the lake clay deposits in Ontonagon, Gogebic, and Houghton Counties.

A large part of the eastern half of the Northern Peninsula is covered by swamps, sandy plains, and thinly drift covered areas. The largest area of clay deposits are the lake clay deposits in eastern Chippewa and central Mackinac Counties. These deposits are very thick, in some places 300 feet or more, and generally contain clay suitable for brick or tile. The till plains of Menominee County, southeastern Marquette County, and adjoining portions of Delta and Alger Counties, are extensive but generally unsatisfactory for clay products. There are two important but relatively small areas of lake clays in Delta County. The morainic deposits in the vicinity of Manistique are clayey but in northwestern Chippewa, central Luce, and northeastern Alger Counties they are in general sandy at the surface. A belt in which the drift is generally thin or absent extends from Green Bay along the northern shores of Lake Michigan and Lake Huron eastward into Drummond Island. The deposits of boulder clays in this belt are limited and apt to be pebbly and very high in lime. The lake deposited clays are generally similar to the other lake clays of this district and suitable for brick or tile.

Much of the clay of the Northern Peninsula is red or pinkish at the surface, but below the clay is blue or even light colored. The red color apparently is due indirectly to the abundance of iron oxide, especially hematite, in some of the underlying rock formations from which a considerable or large part of the clayey material was derived. The morainic clays and the till plain clays are generally too stony to be suitable material for making brick and tile products. The lake clay deposits of Ontonagon County are usually very thin and underlain by boulder clays too stony for use except for making common brick. Where the lake clay deposits are relatively thick they are free from pebbles and much more likely to be suitable for making clay products. Figure 69 roughly indicates the general character and distribution of the principal clay areas.

In general the shales of the Northern Peninsula are unsuited for ceramic purposes or cement manufacture. In contrast to conditions in the Southern Peninsula the lake clay deposits are fairly uniform and much more suitable for ceramic uses.

Description and Tests by Counties

ALGER COUNTY

Alger County is about two-thirds covered by sand with one-sixth of its area surface clay. There is some glacial lake clay in the old basin of Lake Algonquin near Munising covering about six square miles in T. 46 N., R. 19 W., and also just south and west of Grand Marias covering about 10 to 15 square miles in T. 49 N., R. 13 W., and R. 14 W.

Sample 104 is of the upper red clay in section 16, T. 46 N., R. 19 W., about three and one-half miles southwest of Munising and three-fourths of a mile east of Munising Junction, about one-fourth mile north of the Duluth, South Shore & Atlantic Railroad, and one-fourth mile south of Marquette and Southeastern Railroad. The clay runs about 30 feet deep at this place. It was formerly used to make brick by A. W. Shaw and Nathaniel Lobb, now postmaster at Munising. Operations were suspended about 1912. At that time brick was selling for $6.50 a thousand. The upper layers of red clay from which the sample was taken burn to a red brick, the lower layers of blue clay burn cream white. The clay has a narrow burning range but gives a good red, hard burned brick at cone 02, vitrified at cone 1, and viscous at cone 3. The following burning test indicates that it is usable only for common brick or tile:

Burning Test.

Sample No. 104. Field Sheet No. 114.
Section 16 (center), T. 46 N., R. 19 W.
Plasticity .310 gm. water per gm. clay.
Average linear drying shrinkage 9.7 per cent.
Average tensile strength about 145 lbs. per sq. in.

morainic deposits in the vicinity of Manistique lakes are clayey but in

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.333	1.2 %	1.70	Soft burned.....	Salmon pink
08	990	.346	0.4	1.68	Soft burned.....	Salmon pink
06	1,030	.340	0.4	1.67	Soft burned.....	Salmon pink
04	1,070	.329	0.9	1.69	Soft burned.....	Salmon pink
02	1,110	.183	6.0	1.97	Hard burned....	Light brown
1	1,150	.009	10.6	2.42	Vitrified.....	Dark brown
3	1,190	....	....	....	Viscous.....	.....

Red clay. Easy to mold.
Burned by H. W. Jackman.

Shale outcrops along the Minneapolis, St. Paul, and Sault Ste. Marie Railroad, near Trenary, in sections 19 and 30 of T. 44 N., R. 21 W.

This shale is similar to the outcrops on the Stonington Peninsula of Delta County, but is somewhat darker and probably is the Utica member of the Upper Ordovician or Cincinnatian series.

BARAGA COUNTY

Baraga County contains about 15 square miles of lake clay in T. 51 N., R. 34 W., and about 100 square miles of sandy clay till largely in the northeast part of the county (T. 51 N., R. 32, 33, 34 W., T. 52 N., R. 30, 31, 32, 33, W.). There is some stony boulder clay of no economic value in the glacial moraines throughout the county.

A sample (No. 106) of the lake clay was taken in SW¼ Sec. 31, T. 51 N., R. 34 W., within the basin of glacial Lake Algonquin. The deposit covers 15 square miles to a depth of 30 feet or more and runs into what appears to be boulder clay. The sample shows some pebbles, not lime, good but moderate plasticity, and a wide burning range, indicating that it may be suitable for the manufacture of tile, common brick, or face brick, as it burns to a good red brown color.

Burning Test

Sample No. 106. Field Sheet No. 116.
Section No. 31 S. W., T. 51 N., R. 34 W.
Plasticity .306 gm. water per gm. clay.
Average linear drying shrinkage 6.6%.
Average tensile stress about 93 lbs. per sq. in.

Cone No	Temp	Porosity	Linear Shrinkage	Bulk Sp Gr	Hardness	Color
010	950	.360	0.2	1.60	Soft burned ..	Light red
08	990	.357	0.2	1.60	Soft burned ..	Light red
06	1,030	.32.	1.3	1.67	Soft burned ..	Light red
04	1,070	.199	5.5	1.99	Hard burned .	Red
02	1,110	.043	11.2	2.31	Vitrified.....	Red
1	1,150	.017	11.7	2.31	Vitrified.....	Chocolate red
3	1,190	.023	8.0	2.10	Vitrified.....	Chocolate red
5	1,230	.022	5.4	1.97	Vitrified.....	Chocolate red
7	1,270	....	....	....	Viscous	.....

Contains pebbles—Not lime.
Red clay. Easy to mold.

The clay may be suited for the manufacture of vitrified ware such as sewer pipe, but not paving brick, because the clay sample showed positive signs of swelling when burned to cone 3 and first developed the vitrified structure at cone 02. The vitrified bricks were rather easily broken and seemed lacking in toughness unless carefully cooled. The clay deposit is well worth further investigation to prove up large areas as a raw material for the manufacture of all forms of building brick and tile. Most of the clay in the northwestern part of the Upper Peninsula has a very narrow burning range, becoming viscous at cone 3.

This deposit is cut by the Mineral Range Railroad two and one-half miles north of the place where sample (106) was taken, making the markets of Houghton, Calumet, and other mining towns easily accessible.

About 1895 soft mud brick were made one-quarter of a mile or so north of the center of the village of L'Anse, along the lake shore (SW¼ sec. 35, T. 51 N., R. 33 W.). The raw material was obtained from a deposit of sandy clay moraine washed by Lake Nippissing. A sample (105) taken from the workings shows a narrow burning range, becoming viscous at cone 3, very similar to the slip clay from Rockland (sample 107) and most of the clay in Ontonagon County. The clay as sampled is not good material for the manufacture of hard-burned brick, but satisfactory common brick seems to have been made except when too much sand was included with the clay. The plant is a total wreck, nothing being left except a few brick in low piles.

The clay to the northeast of L'Anse and near Skanee was not investigated but is probably somewhat similar to this sample from L'Anse (105) in that it is easily molded and red burning, although its burning range may be wider and therefore more suitable for building brick or tile.

Burning Test.

Sample No. 105. Field Sheet No. 115.
SW¼ Section 35, T. 51 N., R. 33 W.

Plasticity .314 gm. water per gm. clay.
Average linear drying shrinkage 8.4 per cent.
Average tensile strength about 125 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.367	0.2 %	1.61	Soft burned.....	Salmon pink
08	990	.378	0.2	1.60	Soft burned.....	Salmon pink
06	1,030	.376	0.4	1.61	Soft burned.....	Salmon pink
04	1,070	.357	0.9	1.64	Soft burned.....	Salmon pink
02	1,110	.085	10.2	2.20	Hard burned....	Brown
1	1,150	.018	12.0	2.33	Vitrified.....	Chocolate
3	1,190	....	....	....	Melted.....	.....

Red clay. Molded easily. The vitrified brick is brittle and easily broken.
Burned by H. W. Jackman.

CHIPPEWA COUNTY

Most of the eastern part of Chippewa County is covered with thick clay, in places probably about 300 feet thick. The clay is mostly lake clay deposited in the bed of glacial Lake Algonquin.

At Rudyard there are two brick yards in operation, both built by Thornton. The older yard in the western part of the town on the Minneapolis, St. Paul, & Sault Ste. Marie Railroad just behind the station was sold in 1920 to a Mr. Collins of Grand Rapids, and is operated as the Zeeland Brick Company. This plant makes soft mud brick burned in wood-fired open top, up-draft kilns. Power is supplied by two steam boilers. The clay is dug by a small steam shovel, mixed with a little sand, and passed successively through a pug mill, rolls, another pug mill, and molded in a S S S six brick soft mud molding machine. The bricks are dried on pallets supported by open racks in the drying yard, and in a one aisle steam heated drier. The product is a good grade of common brick that is easily sold. The capacity of this yard is probably about 20,000 brick a day.

The clay pit is just northwest of the yard and contains about 12 feet of clay burning to a light red color, underlain by a pink clay which burns to a lighter color. Sample 102 taken from this pit is also representative of the clay used in the new Thornton Brick Yard about two-fifths mile west of Rudyard station on the M. St. P. and S. S. M. railroad.

Burning Test

Sample No. 102. Field Sheet No. 111.
Western part of Rudyard, Sec. 6, T. 44 N., R. 2 W.
Water of plasticity .347 gm. per gm. clay.
Average linear drying shrinkage 10.6 per cent.
Samples held at 750°C. for 4 hours.
Tensile strength of air dried samples, about 150 lbs. per sq. in.

Cone.	Temp. °C.	Porosity.	Fired Linear Shrinkage.	Color.	Hardness.
010	950	.397	−0.2 %	Pink.....	Soft burned
08	990	.401	−0.9	Light pink.....	Soft burned
06	1,030	.405	−1.4	Light pink.....	Soft burned
04	1,070	.149	9.2	Grayish brown....	Hard burned
02	1,110	.248	6.3	Brown.....	Hard burned
1	1,150	.200	8.8	Brown.....	Hard burned
3	1,190	Cracked	...	.....	Vitrified
5	1,230	Melted	...	Bright yellow	.....

Easily worked and molded.
Air dried brick is light reddish brown.
Burning test by H. W. Jackman.

The Thornton Brick Yard is located in the southeast corner of Sec. 1, T. 44 N., R. 3 W. This yard was still under construction when visited in 1922, although in continuous production. The clay is similar to sample 102 just described. Thornton has drilled 105 feet into the clay without reaching the bottom of the deposit. About two and one-half feet down from the top, a layer of hard granules is encountered which seem to be of about the same composition as the clay.

In this yard the clay is dug by spading, then pugged, passed through rolls and extruded in a Brewer Auger machine, making side cut brick. Three rods are used behind the die to prevent tendency toward lamination. The brick is free from lamination, due probably to adjustment of the die and auger as much as to the rods. Electric power is used to drive the machinery. In 1922 the brick were being dried in open racks until the four track continuous tunnel drier was completed. These racks were protected from the wind the first day to prevent too rapid drying of the green brick. Scove kilns, wood fired, were used temporarily for burning as it was planned to build two thirty foot down draft periodic kilns. When completed this plant will have cost about $25,000 and have a capacity of about 25,000 brick a day.

There is a steady demand for brick in this district. Mr. Thornton is selling most of his brick in Sault Ste. Marie and reports excellent market conditions in Canada.

The clay is good material for common brick, building tile, and drain tile, and might possibly be used for face brick, although its color is lighter than that usually preferred for front brick.

This same deposit of clay continues north through Brimley to Sault Ste. Marie, covered in places by sand. Sample 1011 from section 4, T. 46 N., R. 2 W., about one-fourth mile north of Brimley and the D. S. S. & A. R. R. is from a heavy red clay at least 40 feet thick, overlain by four to 15 feet of sand.

Burning Test

Sample No. 1011. Field sheet No. 1023.
Section 4, T. 46 N., R. 2 W.
Plasticity .356 gm. water per gm. clay.
Average linear drying shrinkage 15.5 per cent.
Average tensile strength about 188 lbs. per sq. in.
Apparent sp. gr. dry 2.50.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage	Apparent Sp. Gr.	Hardness.	Color
010	950	.303	0.7 %	2.56	Soft burned.....	Salmon
08	990	.301	0.2	2.54	Soft burned.....	Salmon
06	1,030	.280	0.7	2.49	Soft burned.....	Salmon
04	1,070	.122	6.8	2.47	Hard burned....	Brown
02	1,110	.009	8.7	2.32	Vitrified.....	Chocolate
1	1,150	.018	7.5	2.25	Vitrified.....	Chocolate
3	1,190	....	....	....	Viscous.....	.....

Red clay. Molded easily.
Burned by H. W. Jackman.

The above burning test indicates that this clay is good material for brick, and tile, as it developes a fair color and is easily molded, it is possible that face brick can be made from this clay near Brimley.

About two and one-half miles south of Sault Ste Marie on the west side of the State highway (M-12) in the southwest quarter of Sec. 25, T. 47 N., R. 1 W., the clay is reddish blue to light brown in color and was used to make soft mud brick about 1905. The old yard operated by Mr. Beadle burned down about 1907. There is now no sign of a brick yard. Sample 101 was taken from the upper part of the clay on or near the site of the old brick yard.

Burning Test

Sample No. 101. Field sheet No. 110.
Section 25, (SW), T. 47 N., B. 1 W.
Plasticity .381 gm. water per gm. clay.
Average linear drying shrinkage 17.1 per cent.
Average tensile strength about 200 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.364	0.5%	1.67	Soft burned.....	Salmon
08	990	.365	0.5	1.67	Soft burned.....	Light salmon
06	1,030	.375	1.0	1.67	Soft burned.....	Light salmon
04	1,070	.386	3.4	1.81	Soft burned.....	Light salmon
02	1,110	.040	11.5	2.33	Vitrified.....	Red brown
1	1,150	.041	5.0	1.89	Vitrified.....	Dark red
3	1,190	....	....	....	Viscous	.....

Light brown clay. Easily molded.
Bricks must be cooled carefully to avoid cracking.
Burned by H. W. Jackman.

This clay has a high drying shrinkage and very narrow burning range. It may be used for common brick and tile but it cracks easily when vitrified.

The following analysis of a clay from Sault Ste. Marie is reported by Israel C. Russell.*

Loss on ignition	5.34
Silica (SiO_2)	61.62
Alumina (Al_2O_3)	17.20
Iron oxide (Fe_2O_3)	5.99
Lime (CaO)	5.62
Magnesia (MgO)	2.82
Sulphur trioxide (SO_3)	.46
	99.00

Analysis by E. D. Campbell.

*The Portland Cement Industry in Mich. 22nd Ann. Rept. U. S. Geol. Survey. Part III, 67 1902).

To the south a sample was taken (No. 100) from Sec. 7, T. 44 N., R. 1. W., about five miles north of Pickford. In this district the clay is smooth, red in color, with quicksand pockets and runs 15 to 20 feet or more in depth. It was being used in large quantities to build the bed for this part of State Highway M-12. The clay has little plasticity, is difficult to mold, and must be burned and cooled carefully. It has a fairly good burning range and can be used for common brick and tile. It burns to a commercial color in a hard burned brick and might be used for face brick.

Burning Test

Sample No. 100. Field Sheet No. 109.
Section 7, T. 44 N., R. 1 W.
Plasticity .235 gm. water per gm. clay.
Average linear drying shrinkage 3.2 per cent.
Average tensile strength about 70 lbs. per sq. in.
Heated for five hours to burn out carbon.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.358	−0.2%	1.64	Soft burned	Salmon
08	990	.361	−0.8	1.63	Soft burned	Salmon
06	1,030	.354	−0.8	1.63	Soft burned	Salmon
04	1,070	.337	+0.2	1.67	Soft burned	Salmon
02	1,110	.233	4.7	1.92	Hard burned	Brown
1	1,150	.085	8.8	2.18	Hard burned	Dark brown
3	1,190	.014	8.8	2.20	Vitrified	Chocolate brown
5	1,230	.014	8.5	2.15	Vitrified	Chocolate brown
7	1,270	.013	6.7	2.02	Viscous	Chocolate brown

Light brown clay—very fine flour-like particles.
Hard to mold—non-plastic.
On exceeding given water of plasticity all becomes pasty.
Must be carefully cooled to prevent cracking of vitrified brick.
Burned by H. W. Jackman.

DELTA COUNTY

In Delta County, shales of the lower Silurian and upper Ordovician age outcrop on the east shore of Little Bay de Noc along the west side of Stonington Peninsula. Here there are two to three feet of limestone on the top, then 60 feet of shale underlain by limestone. This outcrop extends for about three miles north of Stonington in cliffs along the bay. Some shale is being removed from about the center of the bed, and used locally as fertilizer as it is claimed to contain phosphates. A sample of the shale (No. 116) shows very much the same burning properties as the glacial clay throughout Menominee County and at Vulcan in Iron County. It has a very narrow burning range, and is of little value as a ceramic material.

Burning Test

Sample 116. Sheet 126. Section 25, T. 39 N., R. 22 W.
Plasticity .203 gm. water per gm. clay.
Linear drying shrinkage 5.1 per cent.
Average tensile strength about 75 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Adsorption.	Fired Linear Shrinkage.	Hardness.	Color.
010	950	.467	.315	−0.5%	Soft burned	Cream
08	990	.482	.331	−0.5	Soft burned	Cream
06	1,030	.503	.364	−2.4	Soft burned	Cream
04	1,070	.481	.3 1	−3.7	Soft burned	Cream
02	1,110	.527	.403	−3.7	Soft burned	Cream
1	1,150	.531	.407	−3.0	Soft burned	Cream
3	1,190	.536	.405	−2.7	Soft burned	Cream
5	1,230	.535	.397	−2.3	Soft burned	Cream
7	1,270	.506	.366	−1.2	Soft burned	Cream
9	1,310	.059	.026	14.1	Vitrified partly melted	Dark brown

Easily moulded.
Burned by H. W. Jackman.

Sample No. 116 taken from the center ten feet of this bed of shale has the following compositions:

Analysis	
Moisture	0.18%
Loss on ignition	29.57
Silica (SiO_2)	22.36
Iron (Fe_2O_3)	1.70
Alumina (Al_2O_3)	12.65
Lime (CaO)	25.50
Magnesia (MgO)	7.87
Phosphorus (P_2O_5)	1.03
Total	100.68%

The fact that the shale has much the same properties and composition as the glacial clay in Dickinson and Menominee Counties indicates that the glacial clay throughout this district was probably formed in considerable part by the abrasive action of the ice sheet on the underlying shales. Jaeger's farm about two miles southwest of Escanaba and about one mile in from the lake in section 15, T. 38 N., R. 23 W., is almost entirely underlain with weathered shale, gravel, and quicksand, with some areas of red clay.

About four or five miles north of Stonington in section 11, T. 39 N., R. 22 W., there is an outcrop of greenish shale at about the lake level. It underlies the blue shale to the south. A number of years ago this shale was quarried and skidded across on the ice to Escanaba where it was used to make brick by the soft mud method. A sample of this shale (No. 114) was vitrified at about cone 5 and fused to viscosity at cone 9. The burning properties are otherwise similar to those of the blue shale.

It is possible to make good quality brick from this material although it cannot be considered good raw material for even common brick, because of its poor color and narrow burning range at a fairly high temperature.

Burning Test

Sample 114. Shale Sheet 124.
Section 11 (center), T. 39 N., R. 22 W.
Plasticity .215 gm. water per gm. clay.
Linear drying shrinkage 4.37 per cent.
Average tensile strength about 75 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Fired Linear Shrinkage.	Hardness.	Color.
08	990	.488	−0.3	Soft burned	Pink
06	1,030	.503	−1.0	Soft burned	Cream pink
04	1,070	.494	−1.4	Soft burned	Cream
02	1,110	.526	−3.0	Soft burned	Cream
1	1,150	.510	−1.0	Soft burned	Light tan
3	1,190	.450	2.1	Soft burned	Olive brown (speckled)
5	1,230	.160	16.3	Vitrified	Olive brown (speckled)
7	1,270	.141	17.1	Vitrified	Olive brown (speckled)
9	1,310	....	....	Melted	....

Fairly easily molded.
Burned by H. W. Jackman.

Shale occurs about one and one-fourth mile east of Ensign, Delta County, and is well exposed in a railroad cut. The following analysis shows that it is highly calcareous, similar to the shale near Stonington. Its lower magnesian content, however, suggests that it might be used in the manufacture of cement:

Analysis	
Silica (SiO_2)	20.20%
Alumina (Al_2O_3)*	9.41
Iron (Fe_2O_3)*	1.33
Lime (CaO)	36.20
Magnesia (MgO)	1.77

*Proportions estimated, total correct. Anslysis from H. Vanderwerp.

There are two areas of lake clay in the county, one of about 10 square miles in T. 40, 41, 42 N., R. 18 W., in the basin of glacial Lake Algonquin, and another small deposit of about 60 acres, stratified with sand, about three to five miles north of Escanaba along the west shore of Little Bay de Noc, at the outer limits of the Algonquin Delta. This latter deposit was sampled by drilling with an auger in the NW¼ of Section 6, T. 39 N., R. 22 W. The deposit runs three feet six inches of sandy soil, two feet six inches of red clay, two feet six inches of sandy clay, three feet six inches of red clay running to blue, and then at least four feet of sand. The sample (No. 113) of the two clay strata mixed, burned to a steel hard gray brick at cone 04, vitrified at cone 1, and melted to a yellow glaze at cone 5. It is good material for common brick and might be used as a slip clay for glazing, but the deposit is not large and would demand careful mining to keep out an excessive amount of sand. For these reasons it has probably no economic value except to a small plant making common brick.

Burning Test

Sample 113. Field sheet 123.
Section 6, T, 39 N., R. 23 W.
Plasticity .237 gm. water per gm. clay.
Average linear drying shrinkage 4.7 per cent.
Average tensile strength air dried bricks about 75 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Hardness.	Color.
010	950	.370	−0.2%	Soft burned	Light pink
08	990	.367	−0.2	Soft burned	Light pink
06	1,030	.358	+0.6	Soft burned	Light gray
04	1,070	.279	4.0	Hard burned	Gray
02	1,110	.248	4.9	Hard burned	Gray
1	1,150	.036	10.2	Vitrified	Greenish gray
3	1,190	.008	10.0	Vitrified	Gray green
5	1,230	....	....	Melted	Yellow

Molded easily.
Burned by H. W. Jackman.

DICKINSON COUNTY

Dickinson County has about 75 square miles of clay till in T. 41 N., R. 27 W., T. 42 N., R. 27 W.; T. 43 N., R. 27, 30 W., most of which is probably of little value.

The Vulcan Brick Company (W. S. Turner) has a plant about three-fourths mile south of Vulcan in the center of section 15, T. 39 N., R. 29 W., near the Wisconsin and Michigan Railroad. The plant has not been operated for some time but the equipment was in fairly good shape in 1922, with the exception of the kiln shed. The brick was extruded in a triple die auger machine, dried in open air racks, and burned in scove kilns. An old horse drive, soft mud molding machine was also in evidence. The clay pit is flooded.

The deposit is covered by sand. There is about six or seven feet of red clay (sample 110) over about 20 or 30 feet of pink blue clay (sample 111). The clay is high in lime, as evidenced by its rapid failure on burning and its olive color.

Burning Test

Sample No. 110. Field sheet No. 120.
Section 15 (center) T. 39 N., R. 29 W.
Plasticity .238 gm. water per gm. clay.
Average linear drying shrinkage 5.6 per cent.
Average tensile strength about 95 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.430	−0.2 %	1.49	Soft burned.....	Light salmon
08	990	.444	−0.4	1.46	Soft burned.....	Light salmon
06	1,030	.445	−0.2	1.46	Soft burned.....	Cream
04	1,070	.445	0.4	1.49	Soft burned.....	Cream
02	1,110	.437	0.7	1.51	Soft burned.....	Cream
1	1,150	.430	2.3	1.58	Soft burned.....	Cream
3	1,190	.408	5.0	1.70	Soft burned.....	Cream
5	1,230	.282	12.0	2.13	Hard burned.....	Light olive
7	1,270	.072	14.1	2.32	Hard burned.....	Olive
9	1,310	....	....	....	Melted	.....

Red clay. Easy to mold.
Burned by H. W. Jackman.

Burning Test

Sample No. 111. Field sheet No. 120.
Section 15 (center) T. 39 N., R. 29 W.
Plasticity .203 gm. water per gm. clay.
Average linear drying shrinkage 3.7 per cent.
Average tensile strength about 95 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.468	−1.0	1.45	Soft burned.....	Light salmon
08	990	.472	−1.1	1.43	Soft burned.....	Cream salmon
06	1,030	.485	−2.4	1.38	Soft burned.....	Cream
04	1,070	.510	−2.2	1.39	Soft burned.....	Cream
02	1,110	.513	−2.0	1.40	So ft burned.....	Cream
1	1,150	.510	−1.3	1.42	Soft burned.....	Cream
3	1,190	.500	−0.7	1.46	Soft burned.....	Cream
5	1,230	.495	+0.4	1.51	Soft burned.....	Cream
7	1,270	.475	+2.3	1.58	Soft burned.....	Cream brown
9	1,310	.018	14.1	2.35	Vitrified.....	Olive
11	1,350	....	....	....	Melted	.....

Red day. Easy to mold.
Burned by H. W. Jackman.

The upper clay has been weathered and leached so that it does not expand as much as that from the lower stratum on burning. Both clays burn to a rather soft porous cream colored brick.

GOGEBIC COUNTY

A continuation of Lake Algonquin and Lake Duluth glacial lake clays along the Lake Superior shore and about 20 square miles of glacial Lake Ontonagon deposits in T. 47 N., R. 41 W., probably include most of the promising clay areas in Gogebic County. This clay is much the same as that of the adjoining areas in Ontonagon County.

HOUGHTON COUNTY

Houghton County is largely sandy till but contains about 200 square miles of glacial lake clay and water laid moraine. The areas north of Twin Lakes in T. 53 and 54 N., R. 36 W., and around Hazel and Alston, T. 50 and 51 N., R. 35 W., are covered by lake clays of Lake Algonquin, and the area around Kenton, T. 47 and 48 N., R. 36 and 37 W., covered by lake clays of the earlier Lake Ontonagon. There is no available record of any of these deposits ever having been worked within the county. The general character of these clays is similar to that of the clays of the adjoining counties, Baraga on the east and Ontonagon on the west. The following analyses of clay samples are from the report of the State Geologist for 1892:

	R. 41, Sec. 8, T. 47 N., R. 37 W. Red clay	R. 42, Sec. 6, T. 47 N., R. 36 W. Brown clay
Silica SiO_2	51.05	51.6
Alumina Al_2O_3	21.42	16.43
Iron Oxide Fe_2O_3	7.81	7.27
Lime CaO	1.93	5.40
Magnesia	3.73	2.88
Difference	14.06	16.62

Analyst—Arthur Uddenburg.

These analyses show the high iron content common to all of the clays in the iron and copper bearing regions of the Northern Peninsula.

There is an area of stony and sandy glacial driftclay covering about 25 square miles and running 250-300 feet (in some places 400 feet) thick as shown by mine drillings in T. 55 N., R. 34 W. In the southeast corner of section 33 on the west bank of the Sturgeon River, and on the east bank about the center of section 3, the clay was used to make hand molded brick about 1900 to 1902. The yards were located directly on the river which was used as a means of transportation. The remains of the shipping dock may still be seen. Both plants are reported to have closed down because of serious trouble with the stone in the clay.

LUCE COUNTY

There is an area of two square miles of lake clay in sections 7, 8, and 9 of T. 45 N., R. 10 W., and another larger area of similar clay in T. 45 N., R. 8 W., as chartered on the map. The larger deposit contains some gravel and stone, in places. A sample (No. 103) from the southern part of Section 12, T. 45 N., R. 9 W., burns steel hard at cone 04 and viscous at cone 3.

It molds easily and is probably fairly good material for common brick and tile. It is very plastic and may be suitable for some pottery purposes.

Burning Test

Sample No. 103. Field Sheet No. 113.
Section 12 (south central) T. 45 N., R. 9 W.
Plasticity .350 gm. water per gm. clay.
Average linear drying shrinkage 13.5. per cent.
Average tensile strength about 175 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bukl. Sp. Gr.	Hardness.	Color.
010	950	.331	0.2 %	1.67	Soft burned.....	Salmon
08	990	.340	1.4	1.72	Soft burned.....	Salmon
06	1,030	.317	0.7	1.72	Soft burned.....	Salmon
04	1,070	.263	3.0	1.84	Hard burned.....	Salmon
02	1,110	.018	10.0	2.30	Vitrified.....	Red brown
1	1,150	.022	3.2	1.82	Softening.....	Chocolate red
3	1,190	....	....	....	Viscous	.....

Red clay. Easy to mold, Brick or tile.
Burned by H. W. Jackman.

MACKINAC COUNTY

Except for an island around Garnet and Caffey, and another small area in T. 43 N., R. 2 W., all of Mackinac County was submerged by glacial Lake Algonquin. For this reason the clays in Mackinac, Luce, and Chippewa Counties are generally true lake clays, and are relatively free from stone. It is to be expected from their mode of deposition that the clays of the Northern Peninsula east of Manistique and Munising would be generally more satisfactory than the drift and boulder clays found in the western part. The burning properties and composition of the eastern clays do not differ in general from those west of Manistique, but their physical condition as true lake clays is generally more favorable to their economic use.

Sample No. 125 was taken from a deposit of clay covering about one-half a section in the southwestern part of section 28, T. 42 N., R. 11 W., six and one-half miles directly south of Gould City and about two and one-half miles north of Lake Michigan. The deposit is covered by about three feet of sand and runs about 20 to 25 feet of clay which is light pink in color except for the upper three or four inches, which is red. The clay is smooth, free from pebbles, and bears all the marks of a lake clay. There is probably more clay of the same general type through the western part of Mackinac County and Schoolcraft County, although none was noticed due to the sand which covers most of this area.

Burning Test

Sample No. 125. Field Sheet No. 135.
Section 28, T. 42 N., R. 11 W.
Plasticity .351 gm. water per gm. clay.
Average linear drying shrinkage 1.55 per cent.
Average tensile strength 275 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Absorption.	Linear Shrinkage.	Hardness.	Color.
010	950	.283	.154	1.0 %	Soft burned.....	Salmon
08	990	.250	.132	1.4	Hard burned.....	Light red
06	1,030	.100	.046	6.1	Hard burned.....	Red
04	1,070	.038	.017	7.8	Vitrified.....	Dark red
02	1,110	.038	.017	8.0	Vitrified.....	Dark red
1	1,150	.018	.008	5.0	Vitrified.....	Chocolate
3	1,190	....	....	...	Melted.....	.....

Suitable for face brick, common brick, tile.
Molded easily.
Burned by H. W. Jackman.

This sample of clay has a wide burning range of over six cones, and burns to a good color in a hard burned product at the low temperature of cone 06, indicating that the clay can be burned easily with relatively little fuel. The shrinkage remains fairly constant from cone 06 to cone 1, making it easy to produce a product of uniform size. For these reasons it seems probable that this deposit six and one-half miles south of Gould City on the M. St. P. and S. Ste. M. R. R. is a very satisfactory raw material for making all kinds of building brick and tile.

The large area of very thick clay found in the southern part of Chippewa County and used in the Rudyard Brick yards extends south into Mackinac County to within about eleven miles of St. Ignace. A sample (No. 99) taken from the southern limit of this area in the eastern part of section 31, T. 42 N., R. 3 W., burns as follows:

Burning Test

Sample No. 99. Field sheet No. 108.
Section 31 (east) T. 42 N., R. 3 W.
Plasticity .216 gm. water per gm. clay.
Average linear drying shrinkage 4.7 per cent.
Average tensile strength about 70 lbs. per sq. in.
Apparent Sp. Gr. dry, 2.69.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	950	.503	−0.5 %	2.80	Soft burned.....	Salmon
08	990	.555	−1.1	3.00	Soft burned.....	Cream salmon
06	1,030	.513	−1.6	2.75	Soft burned.....	Cream
04	1,070	.522	−2.7	2.72	Soft burned.....	Cream
02	1,110	.530	−1.9	2.83	Soft burned.....	Cream
1	1,150	.512	−1.2	2.76	Soft burned.....	Cream
3	1,190	.517	−0.3	2.88	Soft burned.....	Cream
5	1,230	.392	+6.9	2.85	Hard burned.....	Brown
7	1,270	.312	+10.8	2.85	Hard burned.....	Brown
9	1,310	....	....	....	Viscous.....	.....

Red clay. Fairly easily molded.
Burned by H W. Jackman.

The clay at this place is stony, has a narrow burning range similar to that in Menominee County, and is not nearly so satisfactory as the sample (125) just described. As this deposit is traced north into Chippewa County it improves, becoming free from pebbles toward the north.

About four miles northwest of St. Ignace on the D. S. S. & A. R. R. in the western part of Section 35, T. 41 N., R. 4 W., is the old brick yard owned by E. C. Pryor of Houghton and E. A. Reavie of St. Ignace. The plant is equipped with a siding and the following machinery, which has stood idle since 1910:

Buckeye clay digger.
Boiler and steam engine.
Rolls and pug mill.
Auger stiff and brick machine equipped with a, single die for end cut brick. Made by Chambers Bros., Philadelphia.
A six track tunnel Raymond Steam Drier.

The brick-was burned in scove kilns. The last run of 32 days was made with 20 men in 1910, turning out an average of 25,500 brick a day. Most of the brick was sold in Marquette to N. G. de Hass. Special freight rates were granted by the P. S. S. & A. R. R. and orders were plentiful. Apparently lack of funds and inefficient operation were the causes for the shut down.

The clay contains some lime pebbles and covers upwards of 50 acres. A sample (126) taken from the old pit, burns as follows:

Burning Test

Sample No. 126. Sheet 136.
Section 35 (W) T. 41 N., R. 4 W.
Reddish blue clay.

Plasticity .254 gm. water per gm. clay.
Linear drying shrinkage 14.1 per cent.

Cone No.	Cone Temp. °C.	Porosity.	Fired Linear Shrinkage.	Hardness.	Color.
08	990	.412	+1.2 %	Soft burned	Light pink
06	1,030	.422	−0.3	Soft burned	Cream
04	1,070	.429	−0.3	Soft burned	Cream
02	1,110	.456	−0.3	Soft burned	Cream
1	1,150	.398	+2.0	Hard burned	Tan
3	1,190	.158	11.0	Hard burned	Light olive
5	1,230	.050	14.6	Vitrified	Light olive
7	1,270	.058	13.8	Vitrified	Light olive
9	1,310	....	....	Melted	.....

Molded easily. Rather difficult to dry.
Burning test by H. W. Jackman.

The clay molds easily and burns pink, then cream, and to a tan color running into an olive as the ware is vitrified. It would be difficult to make a good hard burned brick from this clay, but it can be used satisfactorily to make a rather porous cream brick or tile. The few piles of brick left in the yard showed decided laminations which would be overcome by proper adjustment of the auger and die.

MARQUETTE COUNTY

Marquette County apparently contains little usable clay. About three miles west of Marquette, section 30, T. 48 N., R. 25 W., G. W. Shaw, now manager of the Northwestern Hotel of Marquette, formerly tried to make brick from a small pocket of boulder clay. The clay is reported to have been exhausted about 1910 or 1912, and the results were generally unsuccessful. The same operator made an unsuccessful attempt to make brick at Munising Junction, Alger County.

Ries reports a partial analysis of a clay sample from section 23, T. 46N., R. 24 W., west of Skandia.*

$SiO_2 + Al_2O_3$	67.85%	
CaO	14.24	
Fe_2O_3 about	2.35	?
MgO about	1.39	?

*Analysis 43, Part I, Vol. VIII, Mich. Geol. Survey.

MENOMINEE COUNTY

The clays of Menominee County are largely boulder or till clays that have been deposited directly by the ice sheet. The clays are generally high in lime and possess a very narrow burning range.

Formerly there was a brick yard on the Woznink place, seven miles north of Menominee, in section 12, T. 32 N., R. 27 W. The brick yard suspended operations about 1890 for an unknown cause. T. R. Hasley, City Engineer of Menominee, had analysis made of a sample of this clay by the Detroit Testing Laboratory:

Loss on ignition	16.86%
Silica (SiO_2)	43.56
Iron (Fe_2O_3)	0.94
Alumina (Al_2O_3)	19.45
Lime (CaO)	12.90
Magnesia (MgO)	0.78
Sulphate (SO_3)	0.31
Phosphate (P_2O_5)	3.58
Alkalies ($Na_2O + K_2O$)	1.62

The clay is gray in color and along Green Bay is covered by sand. Sample No. 1016 taken from the same general location was burned with the following results:

Burning Test

Sample No. 1016. Field sheet No. 1029.
Section 6 T. 32 N., R. 26 W.
Plasticity .237 gm. water per gm. clay.
Average linear drying shrinkage 7.6 per cent.
Average tensile strength about 100 lbs. per sq. in.
Apparent Sp. Gr. dry, 2.54.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	950	.450	−5.4 %	2.53	Soft burned	Salmon
08	990	.475	−3.9	2.61	Soft burned	Cream salmon
06	1,030	.495	−3.4	2.73	Soft burned	Cream
04	1,070	.500	−4.6	2.67	Soft burned	Cream
02	1,110	.492	−2.1	2.75	Soft burned	Cream
1	1,150	.492	−1.6	2.81	Soft burned	Cream
3	1,190	.392	+9.4	3.24	Hard burned	Light olive
5	1,230	.061	15.0	2.67	Vitrified	Olive
7	1,270	....	....	....	Viscous	.....

Grayish blue clay. Molded easily. Hard burned bricks cracked when not cooled carefully.
Burned by H. W. Jackman.

A sample of clay (112) from the bed of Cedar River, about one mile northwest of Spaulding, where the State highway M-12 crosses the river, NW¼ of. section 8, T. 38 N., R. 26 W., shows much the same burning properties as the clay near Menominee and also at Vulcan, Dickinson County.

Burning Test

Sample No. 112. Field sheet No. 121.
NW¼ Section 8, T. 38 N., R. 26 W.
Plasticity .153 gm. water per gm. clay.
Average linear drying shrinkage, 3.1 per cent.
Average tensile strength, about 100 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.468	−3.1	1.44	Soft burned	Cream salmon
08	990	.466	−3.7	1.43	Soft burned	Cream
06	1,030	.480	−4.0	1.43	Soft burned	Cream
04	1,070	.478	−4.8	1.40	Soft burned	Cream
02	1,110	.484	−4.4	1.39	Soft burned	Cream
1	1,150	.484	−4.3	1.40	Soft burned	Cream
3	1,190	.466	−3.7	1.43	Soft burned	Cream
5	1,230	.412	0.5	1.60	Soft burned	Dark cream
7	1,270	.245	7.5	1.99	Hard burned	Ligh olive
9	1,310	.008	11.4	2.26	Viscous	Olive

Very light brown clay, containing a few lime pebbles. Easy to mold.
Burned by H. W. Jackman.

Practically all of Menominee County and a large part of southern Dickinson County is covered with boulder clay. This clay contains a large amount of lime and possesses a very narrow burning range as evidenced in samples 110, 111, 112, and 1016. Most of the clay is stony and generally unsuited for use in making brick. However, in some places the clay may be sufficiently free from lime pebbles to permit burning without cracking. It can then be used to make a soft burned cream brick not of the best quality. There is a demand for brick and tile in this district which is now being met by material shipped in from the south even as far as St. Louis, Missouri.

ONTONAGON COUNTY

Sample No. 1014 of red clay from the bed of Lake Ontonagon in section 15, T. 48 N., R. 41 W., about one mile northwest of Matchwood just north of the D. S. S. & A. R. R, on. state trunk highway M-28, is generally similar to most of the clay in the Ontonagon River basin. At this particular place the upper part of the clay deposit is stony but the lower parts seem to be relatively free from stone. The clay is very fusible, but burns to a light red color in a hard burned brick at cone 010 as shown by the following burning test:

Burning Test

Sample No. 1014. Field Sheet No. 1026.
Section 15, T. 48 N., R. 41 W.
Plasticity 0.413 gm. water per gm. clay.
Average linear drying shrinkage 19.7 per cent.
Average tensile strength about 280 lbs. per sq. in.
Apparent sp. gr. dry 2.45.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage	Aparent Sp. Gr.	Hardness.	Color.
010	950	.271	2.1 %	2.51	Hard burned....	Light red
08	990	.248	3.1	2.53	Hard burned....	Light red
06	1,030	.107	−4.9	2.26	Hard burned....	Red
04	1,070	.239	−5.7	1.96	Overburned.....	Grey red

Dark red clay. Swelled at cone 04. Other samples cracked on firing. Contains pebbles (not lime).
Burned by H. W. Jackman.

From this test of the clay sample it could be recommended for common brick as it burns to a good color giving a hard brick at a low temperature. The clay contains pebbles which will cause some trouble, but not serious as the pebbles are not lime. The clay is very plastic and is apt to crack in drying, and in cooling after burning.

Sample No. 1015 from section 4, T. 48 N., R. 42 W., about one and one-half miles southeast of Bergland between the west branch of the river and the D. S. S. & A. R. R. along the highway (M-28) is also from the bed of Lake Ontonagon and seems to be the same kind of clay as sample No. 1014.

In an earlier report[1] the chemical analyses of clays from the eastern part of the bed of Lake Ontonagon in southwestern Houghton County were given and are repeated in this report under Houghton County.[2]

In about the center of section 17, T. 50 N., R. 33 W. on the east bank of the Ontonagon River about 2 miles southwest of Rockland is a deposit of nearly white clay about 12 feet thick, covered and underlain by red clay. This bank runs along the river for about one-quarter of a mile and extends back about an equal distance. The river is rapidly undercutting the bank which is falling into the river.

This clay is an excellent slip clay, maturing at cone 3. It has been used by the Robinson Clay Products Company of Ohio in small amounts. This company owns part of the deposit. Their local agent, Vogtlin, hauls the clay up to a closed shed on the C. M. & St. P. R. R. siding where it is stored and shipped as called for. Vogtlin also has his own deposit, as have Jeffs and Emmond. Very little clay has been shipped.

[1]Mich. Geological Survey, Report of State Geologist, 1892, p. 173.

[2]See Samples R 41, R 42, Houghton County.

The bank of clay dips away from the river and what was formerly considered a thirty-foot bank was undercut by the river and fell away exposing the present 12-foot bank at the bend of the river. The deposit probably runs thinner back from the river. The clay is very smooth, seems to be absolutely free from grit, with practically no plasticity. The deposit of slip clay (sample No. 107) is within the shore line of glacial Lake Algonquin. It underlies the surface clay and is similar in composition and burning range to most of the clay deposited within the basin of glacial Lake Duluth. Probably this slip clay was deposited in a very quiet arm or bay of Lake Duluth:

Burning Test.

Sample No. 107. Field Sheet No. 117.
Section 17 (center) T. 50 N., R. 33 W.
Plasticity .288 gm. water per gm. clay.
Average linear drying shrinkage 1.6 per cent.
Average tensile strength about 20 lbs. per sq. in.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness	Color.
010	950	.447	0.4 %	1.44	Soft burned.....	Flesh pink
08	990	.459	0.2	1.45	Soft burned.....	Flesh pink
06	1,030	.458	0.2	1.44	Soft burned.....	Flesh
04	1,070	.442	0.5	1.45	Soft burned.....	Flesh
02	1,110	.267	7.8	1.82	Hard burned.....	Light brown
1	1,150	.015	16.0	2.30	Vitrified.....	Brown
3	1,190	....	....	....	Viscous.....	Brown

Pink slip clay. Very soft and like flour.
Almost no plasticity. Hard to mold.
Would not come through extrusion press.
Burned by H. W. Jackman.

This clay was analyzed by A. N. Clark.* The sample was obtained from the deposit owned by Wm. Jeffs and was reported as "calcareous lake clay near Rockland, of fine grain, easily fusible, and forms a natural glaze. It has little plasticity and acts like fine grained silica when mixed with water."

Silica SiO_2	52.92
Alumina Al_2O_3	12.25
Iron Fe_2O_3	6.45
Lime $CaCO_3$	13.84
Magnesium $MgCO_3$	3.55
Alkalies $(NaK)_2O$	3.35
Difference H_2O and Organic	7.14

*Ries—-Mich. Geol. Survey VIII Pt. I p. 60.

Another sample of clay (108) taken from the center of section 34; four miles south of Rockland, ½ miles south of the Ontonagon River, T. 50 N., R. 33 W., has burning properties very similar to the above slip clay, but is more plastic with about four times the air shrinkage. This deposit is about 30 feet deep and seems similar to clay throughout the district. It contains thin strata of blue clay running through the red clay which up the bulk of the deposit. The relative amount of blue clay increases

toward the deeper parts of the bed. The clay is covered in many places by red sand.

Burning Test.

Sample No. 108. Field Sheet 118.
Section 34 (Center) T. 50 N., R. 33 W.
Plasticity .315 gm. water per gm. clay.
Average tensile strength about 59 lbs. per sq. in.
Average linear drying shrinkage 6.5 per cent.

Cone No.	Cone Temp. °C.	Porosity	Linear Shrinkage	Bulk Sp. Gr.	Hardness	Color.
010	950	.401	0.6 %	1.55	Soft burned.....	Light salmon
08	990	.401	0.8	1.56	Soft burned.....	Light salmon
06	1,030	.389	0.6	1.56	Soft burned.....	Pink
04	1,070	.378	1.9	1.61	Soft burned.....	Pink
02	1,110	.235	7.0	1.90	Hard burned....	Light brown
1	1,150	.009	13.7	2.36	Vitrified.....	Chocolate brown
3	1,190	....	....	....	Melted.....	.....

Red clay. Easy to mold. Narrow burning range.
Burned by H. W. Jackman.

Somewhat similar clay extends all through the clay area of Ontonagon County and into Gobebic County, T. 47 N., R. 41 W. South of Brace's crossing in the area above the level of Lake Ontonagon the clay is stony and in many places covered with sand.

About 1895 Roderick Tullock made hand molded slop (soft mud) brick from the clay in section 9, T. 50 N., R. 38 W., about 2 miles southeast of Mars City, just south of C. M. St. P. R. R., on Matt Heckler's property. The clay is about 80 feet deep here and is reported to be underlain by sandstone.* A railroad spur runs into the old brick yard but nothing is left except the clay pits. The brick was used in chimneys of houses in Mars City and is reported to have been good quality common brick as is evidenced by its successful use in chimneys. The people in Mars City anxious to see the yard operated again as brick is very scarce in this part of the State. This yard was abandoned more than 15 years ago. Sample 1013 was taken from the old pits.

*Mr. Chas. Naid furnished the Information reported concerning the old brick yard.

Burning Test.

Sample No. 1013. Field Sheet No. 1025.
Section 9, T. 50 N., R. 38 W.
Plasticity 0.386 gm. water per gm. clay.
Average linear drying shrinkage 17.4 per cent.
Average tensile strength about 302 lbs. per sq. in.
Apparent Sp. Gr. dry, 2.33.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	950	.310	2.1 %	2.55	Soft burned..	Salmon (white scum)
08	990	.303	0.5	2.46	Soft burned..	Salmon (white scum)
06	1,030	.320	1.7	2.57	Soft burned..	Salmon (white scum)
04	1,070	.227	3.6	2.49	Hard burned	Brown (white scum)
02	1,110	.067	9.0	2.36	Vitrified.....	Brown (white scum)
1	1,150	.148	0.2	1.99	Swelled.....	Dark brown (white scum)
3	1,190	....	....	....	Viscous.....	

Dark red clay.
Large amount of soluble salts which came to surface as a white deposit during drying, forming "kiln-white" and "dryer-white."
Sample contains some lime pebbles.
Burned by H. W. Jackman.

Sample 1012 was taken in the northeast quarter of section 21, T. 51 N., R. 37 W., from a cut along State Highway M-26 about one-quarter mile west of the Copper Range R. R. The clay seems reasonably free from stone and at least 50 feet deep. The clay extends throughout the district covered by a few inches to 3 feet of sand and gravel.

Burning Test.

Sample No. 1012. Field Sheet No. 1024A.
NE¼ Section 21, T. 51 N., R. 38 W.
Plasticity .238 gm. water per gm. clay.
Average linear drying shrinkage 5.6 per cent.
Average tensile strength about 233 lbs. per sq. in.
Apparent Sp. Gr. dry, 2.39.

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	950	.300	−0.6 %	2.56	Soft burned...	Salmon
08	990	.311	−0.2	2.58	Soft burned...	Salmon
06	1,030	.300	+0.4	2.59	Soft burned...	Salmon
04	1,070	.274	2.6	2.68	Soft burned...	Red brown
02	1,110	.064	6.1	2.32	Hard burned	Dark brown
1	1,150	.023	8.0	2.36	Vitrified.....	Chocolate
3	1,190	.022	4.6	2.16	Vitrified.....	Dark chocolate
5	1,230	....	....	....	Viscous.....	.....

Red gray clay. White streaks developed on surfaces during firing. Molded easily. Burned by H. W. Jackman.

The surface clays of Ontonagon County are largely boulder clays covered by a thin layer of lake deposits, and therefore generally stony and suitable only for common brick to be sold in the district. In some places the old lake deposits are reasonably thick and the clay free from stone and therefore better suited for brick manufacture. All of the clay is very fusible, melting at cone 3 to cone 5 or below, but some of the clay burns to a hard product of light red or brown color before failing.

The exceptionally smooth, non-plastic slip clay near Rockland differs only in physical structure from the rest of the clay in that district, and seems to have been deposited by the waters of Lake Duluth in a particularly quiet spot such as a protected bay, as is indicated by the shore line of Lake Algonquin.

The shaded area indicates the only area where workable clay deposits are likely to be found, and only in limited parts of that area.

The bed rock through the northwest center of the county, T. 50 N., R. 40, 41, 42, and 43 W., is made up partially of the Nonesuch shale of the Upper Keweenawan Series. This is the only possible shale resource in the county and it is not generally accessible and has no proved value.

GENERAL SUMMARY.

Most of the surface clays of Michigan are of low grade and of three general classes: (1) morainic or drift clays; (2) lake clays; and (3) river silts.

The morainic and drift clays are generally stony and contain high percentages of lime or lime pebbles. In this condition these clays are suitable only for common brick and then only when more suitable material is not available. In some parts of the State the glacial drift appears to have been derived from an older drift and is relatively free from stone. If reasonably low in lime or sufficiently leached to reduce the lime content, these clays may be suitable for brick, tile or low grade pottery products.

The lake clays generally have about the same composition and burning properties as the morainic clays, but contain less stone and are more workable. On the eastern part of the Northern Peninsula there are large areas of thick lake clay which is very suitable for brick, tile, and similar products. On the western part of this peninsula the lake clay areas are relatively thin and may be considered largely as lake washed areas rather than lake deposited. Some deposits of slip clay are found in this area in Ontonagon County. Deposits of Fuller's Earth have been noted on the Southern Peninsula near Petoskey and near Harrietta, Wexford County. These special clays, as well as deposits of red burning pottery clay are lake deposits. In many of the lake clays leaching has proceeded to a depth of a few feet where a layer of lime concretions is found. The leached clay may be red burning and the lower clay high in lime, buff burning.

River silts are generally sandy but reasonably free from pebbles and are frequently suitable for brick or tile but not for pottery.

The Antrim, Coldwater, and Coal Measures shales are generally suitable for, face brick, tile, and frequently suitable for vitrified ware. These shales are extensive and should be considered seriously as good raw materials for these products. Their value as a raw material for cement has been recognized by the various cement companies, but so far they have not been developed extensively for brick, tile and similar products. Some of the Coal Measures shales, particularly the light colored shale known as "fire-clays", are semi-refractory clays. The Bell Shale is plastic clay, very suitable for high grade brick, tile, or for some forms of pottery.

There is no known deposit of white burning clay in Michigan, and very little chance of any being found. Many of the calcareous clays burn to a light cream, almost white, color at certain temperatures, but these must not be confused with the kaolin and ball clays used in making pottery, sanitary ware, and electrical porcelain.

Brick and Tile Industry: A generation ago about 200 brick and tile yards were struggling for existence in the State of Michigan. These 200 plants had a combined output* of about 200,000,000 brick valued at about $1,000,000. By 1921 the number of plants operating had decreased to about 60, but the total annual production was maintained at about 200,000,000 brick valued at about $2,500,000. In 1922 58 plants produced 250,000,000 brick valued at about $3,600,000.

In the early days the State was oversupplied and brick sold for four to five dollars a thousand. Since 1900 the tendency has been toward larger plants producing from 30,000 to 100,000 brick a day. The old brick yard with open air or shed drying is obsolete. Although many of these yards are still operating using surface clays, the modern brick plant with continuous kilns and a daily production of 50,000 to 200,000 brick, using the more reliable shale beds of the Southern Peninsula, offers the better opportunity for profit.

The technical development of the brick and tile industry has been very slow compared with other industries using similar processes. The properties of clay have not been generally understood by the small producers. For this reason when a producer finally discovers a reasonably satisfactory method for working his clay by which he can make a modest profit, he is very slow to change to other methods, for fear of losing all the investment. The larger companies can afford to employ competent engineers to design and operate their plants, and therefore are in better position to operate profitably than the small "yard."

Michigan clays are generally very calcareous and methods that produce excellent ware in Ohio and other states frequently fail absolutely when applied to Michigan clays. For this reason it is imperative that a clay deposit be carefully sampled and tested by a competent engineer, preferably familiar with Michigan conditions, before any money is spent on development.

Other Uses for Michigan Clay: Although brick, tile, and cement will always consume the major part of Michigan clays, careful testing has and will indicate other uses for many clays.

*For statistics of production and value of clay products see various volumes of Mineral Resources of Michigan, Mich. Geol. Surv. Dept. Conservation.