

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 ₂ O ₃)	15.68
Iron (Fe ₂ O 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 Crosswell 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 Crosswell 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. 7 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.....	Buff
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.

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.

*Mich. Geol. Survey VIII, Pt. I, p. 27.

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.....	Dark brown
7	1,270	....	....	....	Viscous	Gray brown

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 (Galion, 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 ₂ O ₃	17.78
Iron Oxide Fe ₂ O 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, T. 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 NW¹/₄ 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 ₂ O ₃)	17.90
Iron (Fe ₂ O ₃)	4.36
Lime (CaO)	10.08
Magnesia (MgO)	3.31
Alkalies (Na ₂ O, K ₂ O)	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 SW $\frac{1}{4}$ 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.

SW $\frac{1}{4}$ 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	.351	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.	Thermocouple 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	995	.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 NW $\frac{1}{4}$ 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 $\frac{1}{4}$ " to $2\frac{1}{2}$ " very numerous. All samples disintegrated upon boiling in H₂O.

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 ($\frac{1}{4}$ " to 1"). Difficult to mold. All samples disintegrated upon boiling in H₂O. 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.	1/2 mile east on road, brick school house, Sec. 21, T. 3 S., R. 6 E.
Silica (SiO ₂)	62.26%	38.50%
Alumina (Al ₂ O ₃)	15.45	12.72
Ferric Oxide (Fe ₂ O 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 3 1/2 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 ₂ O ₃)	8.64	5.89
Alumina (Al ₂ O 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

Sample No. 1032. 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	2.88	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 ₂ O ₃)	4.97
Alumina (Al ₂ O 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 NW¹/₄ section 34, T. 2 S., R. 8 E., about 3/4 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:

*Mich. Geol. Survey VIII, Pt. I, p. 49 (1900).

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.....	19%	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 ₂ O ₃)	12.32
Iron (Fe ₂ O ₃)	4.82
Lime (CaO)	11.23
Magnesia (MgO)	5.42

Analysis by Wm. Kane, Cement City.

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 pro-

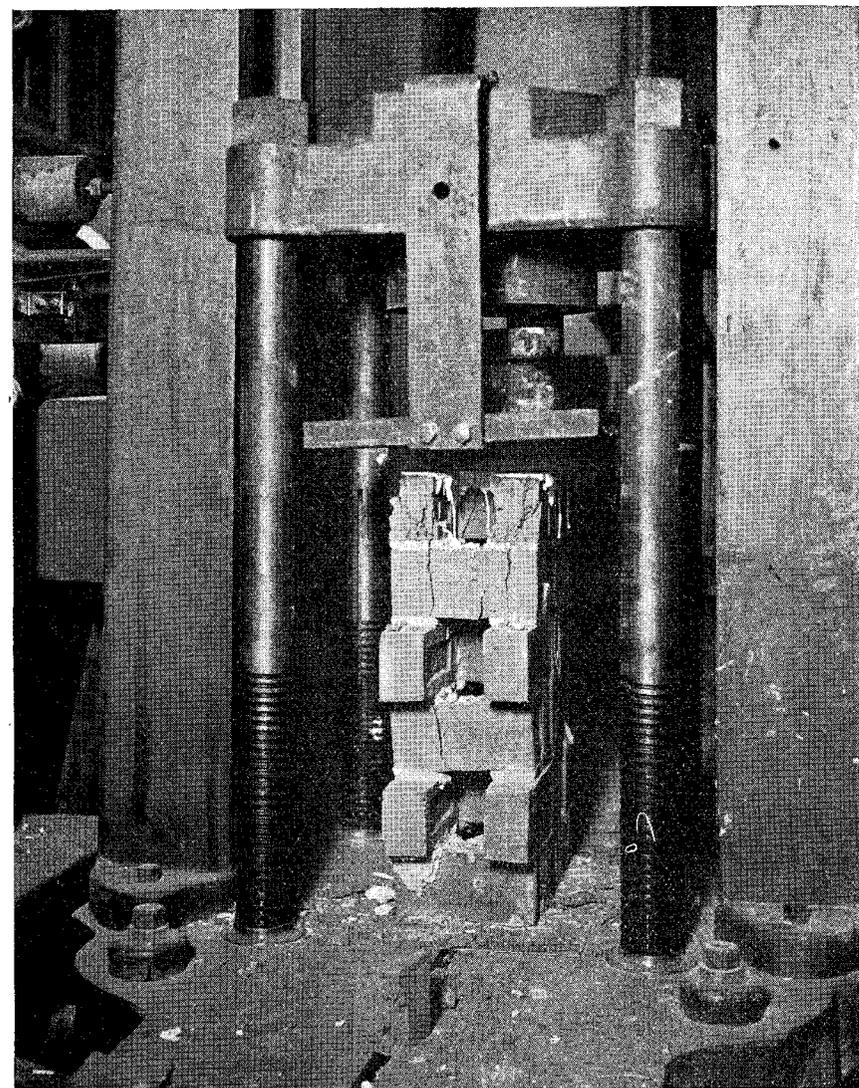


Plate XXXVII.—“Ideal Wall” of the Detroit Brick Manufacturing Association setting brick on edge in hollow wall (cross-section of wall section being tested).

duct 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 $\frac{3}{8}$ to $\frac{1}{2}$ -inch. The piers and samples of mortar were allowed to cure for 33 days before testing.

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 transverse 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."

These tests lead to the conclusion that although Detroit brick rank higher than the official standards for "Medium Brick" so far as trans-

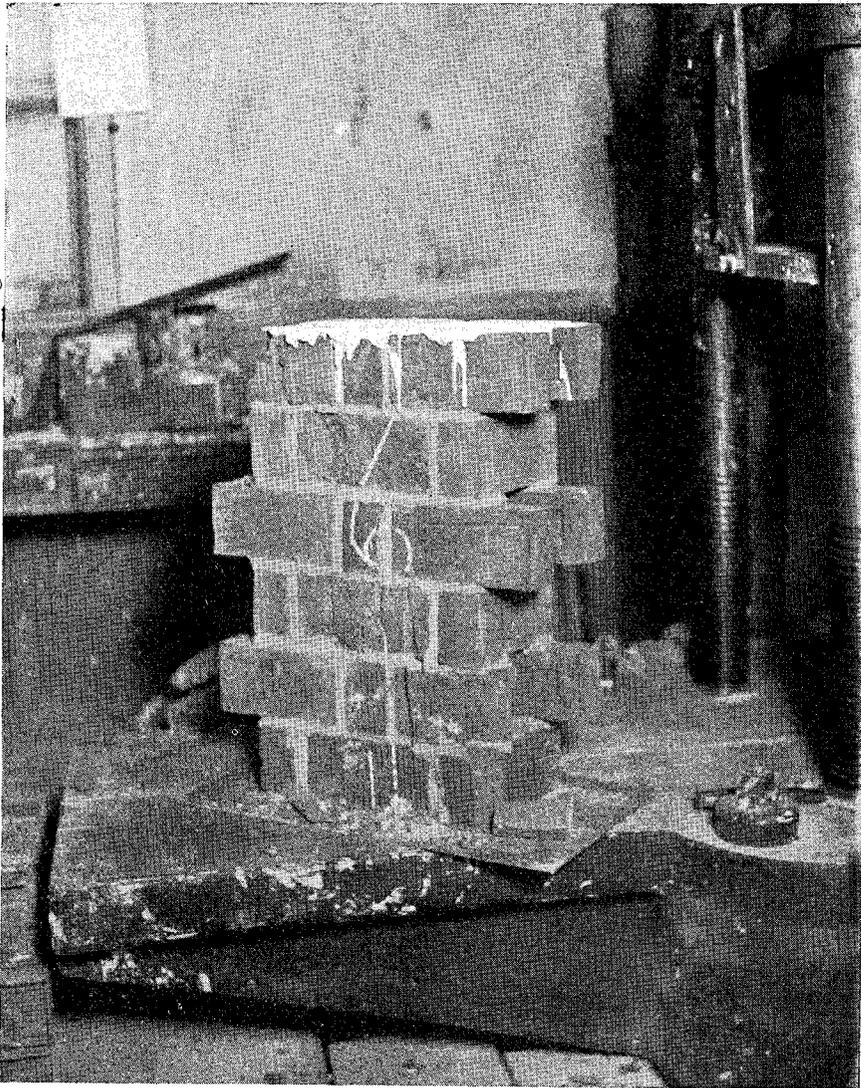


Plate XXXVIII.—Side of "Ideal Wall."
(From Detroit Brick Mfrs. Assoc.)

*Efficiency of Detroit Common Brick and Common Brickwork by Lucius Allen, published by Detroit Brick Manufacturers and Dealers Association, Penobscot Building, Detroit.

verse strength is concerned, they should be classed as "Medium Brick", If all the brick were hard burned the absorption could be easily reduced and the compressive strength raised so that the brick might be

Grade.	Absorption per cent.		Compressive Strength on Edge. Lbs. per Sq. In.		Nodules 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

classed as "Hard Brick." This can be done only by adopting better methods of burning than can exist in ordinary scove kilns.

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
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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:

¹American Society for Testing Materials Brick Classification

²Worcester, Geol. Surv. Ohio, Series IV, Bulletin II (1910), pages 20, 169, 191, 196, 200, 212, 253, 296, 297, 311, 312, 383, 405.

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 2 x 2 x 4 inch briquette.

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	.0568	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.

After aging for three days to equalize the moisture content the clay was extruded into flat blanks in an auger machine. These blanks were

*Smooth rolls made by Horton Man. Co. of Painesville, Ohio.

of different cross section depending on the style of roofing tile to be produced. For Spanish tile they were about $2\frac{1}{2} \times 4$ 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.

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 ₂ O ₃)	13.60
Iron (Fe ₂ O 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.

*See Burning Clay Ware, Kilns.

*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 %	Hard burned, Incipient Fusion... Vitrified..... Viscous.....	Cream
1.....	17 %		Cream
3.....	22 %		Greenish yellow
.....
5.....	.....		.....

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, gritless 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 drill-

ings 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 ₂ O ₃)	17.91
Iron (Fe ₂ O ₃)	4.27
Lime (CaO)	13.10
Magnesia (MgO)	4.17
Alkalies (Na ₂ O, K ₂ O)	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.

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Burned by H. W. Jackman.

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 south-eastern 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 Cincinnati 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.

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 Cincinnati 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 SW $\frac{1}{4}$ 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 (SW $\frac{1}{4}$ 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.

SW $\frac{1}{4}$ 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 develops 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., R. 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 ₂ O ₃)	17.20
Iron oxide (Fe ₂ O ₃)	5.99
Lime (CaO)	5.62
Magnesia (MgO)	2.82
Sulphur trioxide (SO ₃) .....	.46

Analysis by E. D. Campbell.

99.00

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,

*The Portland Cement Industry in Mich. 22nd Ann. Rept. U. S. Geol. Survey. Part III, 67 (1902).

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	.31	-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 ₂ O ₃)	1.70
Alumina (Al ₂ O ₃)	12.65
Lime (CaO)	25.50
Magnesia (MgO)	7.87
Phosphorus (P ₂ O 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	.525	-3.9	Soft burned.....	Cream
1	1,150	.510	-1.0	Soft burned.....	Cream
3	1,190	.450	2.1	Soft burned.....	Light tan
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 ₂ O ₃)*	9.41
Iron (Fe ₂ O ₃)*	1.33
Lime (CaO)	36.20
Magnesia (MgO)	1.77

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 NW¹/₄ of Section 6, T. 39 N., R. 22 W. The deposit runs three feet six inches of sandy soil, two

*Proportions estimated, total correct. Analysis from H. Vanderwerp.

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	.243	4.9	Hard burned.....	Gray
1	1,150	.026	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	.232	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	Soft 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 clay. 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. 42, Sec. 6, T. 47 N.,
R. 37 W. R. 36 W.
Red clay Brown clay

Silica SiO ₂	51.05	51.6
Alumina Al ₂ O ₃	21.42	16.43
Iron Oxide Fe ₂ O 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 R. 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 D. 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. 46 N., R. 24 W., west of Skandia.*

SiO ₂ + Al ₂ O ₃	67.85%
CaO	14.24
Fe ₂ O 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 ₂ O ₃)	0.94
Alumina (Al ₂ O ₃)	19.45
Lime (CaO)	12.90
Magnesia (MgO)	0.78
Sulphate (SO ₃)	0.31
Phosphate (P ₂ O ₅)	3.58
Alkalies (Na ₂ O + K ₂ O)	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, NW $\frac{1}{4}$ 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.

NW $\frac{1}{4}$ 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	Light 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	Apparent 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 report¹ 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.

¹Mich. Geological Survey, Report of State Geologist, 1892, p. 173.

²See 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 ₂ O ₃	12.25
Iron Fe ₂ O ₃	6.45
Lime CaCO ₃	13.84
Magnesium MgCO ₃	3.55
Alkalies (NaK) ₂ O	3.35
Difference H ₂ O 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 makes 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	.373	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 Gobebe County, T. 47 N., R. 41 W. South of Bruce'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 seem 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.

NE $\frac{1}{4}$ 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 Keweenaw 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

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brick and tile
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1922 58 plants

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Mineral Resources

Most of the general class river silts.

The morai percentages suitable only material is appears to be from stone.

the lime content pottery production

The lake clay is having properties workable. In large areas of similar production areas are related areas rather in this area been noted on Wexford Clay ing pottery has proceeded is found. There is lime, buff

River silts are frequently

The Antrim shales are excellent materials for has been recorded have not been Some of the known as "plastic clay, of pottery.

There is not a little chance a light cream

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.

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