Burning Test

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

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

Light blue shale and clay—chiefly shale. Easy to mold. Contains lime pebbles.

Burned by H. W. Jackman.

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

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

ANTRIM COUNTY

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

The principal exposures are on the lake shore about a half mile south of Norwood, in the vicinity of Ellsworth, and Chestonia, East Port, and Central Lake. The exposures south of Norwood form bold cliffs along the lake. The shale is very black and pyritic. At some horizons the shale

is so full of pyrite in crystals, masses, and stringers as to make it of doubtful value for any use. In the Ellsworth vicinity the shale deposits are very large and numerous. Shale forms the core of most of the hills and is exposed in many of the bluffs and hills around the north end of Intermediate Lake.

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

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

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

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

A shaft had been sunk to a depth of 105 feet in the shale on the property of J. H. Kocher about six miles south of East Jordan on the W½ of the NE¼ of Section 3, T. 31 N., R. 6 W. The shale is gray-black in color and near the bottom of the shaft contained small selenite crystals but no pyrite was noticed. In testing the sample (R185) from shale it was found to have about 0.8% of soluble salts that formed a white coating on the surface during drying, which had to be carried on carefully as the sample had a tendency to crack. Burning had to be done carefully to oxidize the bituminous material. Tensile strength about 70-80 lbs. a sq. inch.

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

This same locality was visited in 1921. Most of the hills near Chestonia are shale rather densely covered by vegetation. Sample 188 was obtained by stripping the shale in the hills in eastern part of section 17, T. 31 N., R. 6. W. about 1½ miles west of Chestonia. Care was taken to remove all the weathered shale. This sample of the dark shale without

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

the characteristic rusty color which develops when the shale is exposed to the weather was tested as follows:

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

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

Chemical analysis:

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

Analysis by H. W. Jackman.

Burning Test

Water Plasticity. 0.25 gm. water per gm. clay.

Linear shrinkage. 4.7 per cent on drying.

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

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

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

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

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

Burned by H. W. Jackman.

The chemical analysis shows the shale to be suitable for Portland cement, and the burning test shows it to be good material for all kinds

of building brick, tile, and face brick. Some samples of the shale have been tested by the Bureau of Standards with very similar results.[1]

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

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

Ries[2] also reported shale outcropping along the road in section 13 between the old camp of the East Jordan Lumber Company and the town. Here the shale had weathered to a depth of 10 to 15 feet in many places. A sample (R177) of the weathered material, a tough reddish clay reported to be similar to the material used in the East Jordan brick yard, was very fine grained, slaked freely in water, and gave no effervescence with acid. It contained 0.8% of soluble salts which appeared on the surface in drying and burning. Air shrinkage 7%, hard burned at cone 05, vitrified at cone 01, with 13% shrinkage, and viscous at cone 2. It made a very smooth, deep red brick. Analysis (No. 14) of this sample:

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

Analysis by A. N. Clark.

[1]Sample No. 1 Chestonia Shale.

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

"Sample No. 2, East Jordan shale.

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

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

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

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

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

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

Required careful drying and burning.

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

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

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

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

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

*loc cit.

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

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

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

Burning Test

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

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

Light brown clay, easily molded. Contains small shaly lime lumps. Suitable for brick and tile.

Burned by H. W. Jackman.

Burning Test.

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

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.362	0.2	1.72	Soft burned...	Light salmon
08	990	.355	0.4	1.73	Soft burned...	Light salmon
06	1,030	.368	0.4	1.72	Soft burned....	Tan
04	1,070	.379	0.8	1.72	Soft burned...	Tan
02	1,110	.327	2.5	1.81	Hard burned...	Light brown (speckled)
1	1,150	.134	6.5	2.06	Hard burned..	Dark brown (white spots)
3	1,190	.036	1.4	1.74	Vitrified.....	Very dark brown (white spots)
5	1,230	....	...	....	Viscous	

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

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

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

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

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

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

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

Burning Test.

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

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

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

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

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

ARENAC COUNTY.

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

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

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

The Michigan Paving Brick Company's plant was located on the north side of the river across from the quarry where the sample was obtained. For about five years this company tried to make paving brick from this calcareous clay. Common brick and repressed brick were also produced. The plant was equipped with eight down draft kilns. The venture consumed $160,000 and was abandoned in 1912.

The product was inconsistent as to size. Apparently no effort was made to keep the different strata of shales separate. As the different shales had different burning properties this practice added to the troubles caused by lime pebbles in a calcareous shale of narrow burning range. The following burning test of this clay explains a large part of the trouble experienced by the paving brick company. If the shale had a vitrification range of four to six cones beginning at about cone 5 or 7, it would probably make good paving brick, but a vitrification range of two cones or less does not allow enough range in which to produce vitrified ware, particularly when accompanied by sudden failure as in

the case of the test sample. If a layer of this shale, practically free from lime, and having the required burning range, existed and had been used without mixing of the other clays, this plant might have had a different history.

Burning Test.

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

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

Gray brown clay containing lime lumps. Suitable for brick and tile. Easily molded.

Burned by H. W. Jackman.

BARRY COUNTY.

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

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

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

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

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

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

Burning Test.

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

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

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

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

BAY COUNTY.

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

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

Ries* mentions the so-called "fire clay" underlying the coal seam of the old Monitor shaft in Section 33, T. 14 N., R. 4 E. This clay was reported similar to that quarried at Flushing and suitable for paving blocks. It was reported to be 8 to 10 feet thick at this place. This old shaft as well as the adjacent Old Bay No. 1 shaft had been abandoned and filled before the present survey was undertaken. The "Black Diamond" shaft of the Robert Gage Company had been opened in the north central part of Section 30, T. 14 N., R. 4 E. about one and one-half miles east of Auburn, and one mile south of the Michigan Central railroad or two miles west of the old Monitor shaft. Here the coal seam, 156 feet below the surface, is covered with 20 feet of bituminous shale (sample 139) and underlain by "fire clay," (sample 140). This sample shows a wide burning range and is good material for making all kinds of brick and tile and even some vitrified ware, but cannot be classed as a refractory clay.

Burning Test.

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

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

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

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

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

Measures shale as raw material and to use the heat in the kiln gases to evaporate salt solutions.

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

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

Analyzed by Lathbury & Spackman.

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

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

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

Burning Test.

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

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

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

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

[1]The Portland Cement Industry in Michigan, 22nd Ann. Rept. U. S. Geological Survey, Pt. III p. 670 (1902).
[2]Mich. Geol. Survey VIII, Pt. I, see also Pt. III, pp. 260-266.

Burning Test.

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

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

Chemical Analysis.

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

—A. N. Clark.

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

Water of Plasticity 17%.
Granular, lean and easily dried.
Air shrinkage 4%.
Tensile strength 55-60 lbs. per sq. in.
Soluble salts 0.7%.
Hard burned at cone 06.
Vitrified at cone 2.

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

Ries, Sample 180. Winona Coal Mine, Section 4, T. 14 N., R. 5 E.
Over shale.
Water of Plasticity 18% (Low plasticity).
Air shrinkage 3½%.
Tensile strength 55 lbs. per sq. in.
Soluble salts 0.6%.

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

Chemical Analysis.

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

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

BENZIE COUNTY.

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

Chemical Analysis.

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

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

Burning Test.

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

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

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

BERRIEN COUNTY.

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

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

Burning Test.

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

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	950	.381	1.1	2.60	Soft burned.....	Salmon
08	990	.389	1.3	2.68	Soft burned.....	Salmon
06	1,030	.384	1.3	2.60	Soft burned.....	Salmon
04	1,070	.368	0.9	2.56	Soft burned.....	Light brown
02	1,110	.219	5.6	2.39	Hard burned....	Light brown
1	1,150	.026	8.8	2.22	Vitrified.....	Olive brown
3	1,190	.019	12.6	2.38	Vitrified.....	Olive brown
5	1,230	....	....	....	Viscous	.....

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

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

The Mamer Brick Company formerly made brick from clay in Benton Harbor, near Paw Paw Avenue and the Pere Marquette Railroad. The deposit was exhausted in 1921 and the machinery sold. The former producers are now simply dealers in brick and building materials.

BRANCH COUNTY.

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

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

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

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

If heated too fast bricks warp.

Chemical Analysis (Ries 12).

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

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

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

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

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

	Upper Yellow Clay.	Lower Blue Shale.
	%	%
Loss on ignition	8.43	8.01
Silica ($SiO)_2$	65.62	57.68
Iron (Fe_2O_3)	6.72	7.52
Alumina	16.72	22.42
Lime (CaO)	Trace	0.60
Magnesia (MgO)	1.72	2.74
Sulphur trioxide (SO_3)	0.25	0.38
	99.46	99.35

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

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

Burning Test.

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

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

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

Burning Test.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Chemical Analysis[3]

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

[1]H. Lewis, Eng. Record XXXVII, 1898, pp. 470-472. Cement Industry, New York, 1900, pp. 33-14.
[2]Mich. Geol. Survey VIII, Pt. I, p. 43 (1900).
[3]Mineral Industry VI.

The Peerless Portland Cement Company, Union City, was organized August 23, 1896, with a capital of $250,000, and completed their plant of 19 intermittent vertical kilns that year. The marl and clay were mixed and molded into bricks which were dried and stacked in the kilns with alternate layers of coke. In 1900 Dietch Continuous Vertical kilns were installed. These kilns were later replaced with 9 rotary kilns having a combined capacity of 1500 barrels a day. Marl is now obtained from Jackson County and shale from the local quarry about two miles south of the plant just west of Coldwater River, NW¼ section 15, T. 5 S., R. 7 W. The plant is just east of the main road going south and on the north side of the Michigan Central Railroad, on the west side of town, section 4, T. 5 S., R. 7 W. The wet process is used here as in all plants using marl.

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

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

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

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

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

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

Burning Test

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

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Bulk Sp. Gr.	Hardness.	Color.
010	950	.353	−1.2%	1.61	Soft burned...	Salomn
08	990	.337	0.0	1.65	Soft burned....	Salmon.
06	1,030	.333	+1.1	1.68	Soft burned....	Salmon
04	1,070	.308	3.2	1.76	Soft burned....	Light red
02	1,110	.270	5.0	1.89	Hard burned..	Red
1	1,150	.166	7.8	2.07	Hard burned..	Dark red
3	1,190	.118	8.7	2.16	Hard burned..	Chocolate
5	1,230	.067	9.5	2.21	Vitrified.....	Dark brown
7	1,270	.015	9.3	2.21	Vitrified.....	Dark gray brown
9	1,310	.182	2.6	1.79	Vitrified.....	Dark gray brown
11	1,350	.163	0.0	1.56	Over burned..	Dark gray brown

Molded fairly easily. Cracks readily unless carefully cooled from high temperatures.

Suitable for brick, tile, and vitrified ware.
Burned by H. W. Jackman.

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

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

Analysis by Peerless Portland Cement Co.

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

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

CALHOUN COUNTY

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

The Alpha Portland Cement Company of Bellevue, Eaton County (formerly the Burt Portland Cement Company) obtains its clay by truck from a pit in SE¼ section 7, T. 1 S., R 6 W., just west of trunk line road M-78 and 3½ miles south of the plant. The clay is blue, smooth, and comparatively free from lime pebbles. It is about 40 feet deep and covers about 47 acres. It runs to gravel on the east and quicksand on the west. So far the deposit has been worked to a depth of 20 feet over about 10 acres. The clay is excavated by a steam shovel and loaded on trucks which runs on a wooden track in the pit. The following analyses suggest that this clay is derived largely from the Grand Rapids or Michigan series shale as found under the limestone in the lime quarry at Bellevue:

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

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

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

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

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

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

Chemical Analysis

Sample No. 21. Field Sheet No. 18.

Depth 5-20 feet of deposit in Section 7, S. E. ¼, T. 1 S., R. 6 W.

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

Analysis by H. W. Jackman.

Burning Test

Sample No. 1026. Field Sheet No. 1032 and 18.

Section 7, T. 1 S., R. 6 W.

Plasticity .252 gm. water per gm. clay.

Average linear drying shrinkage 7.2%.

Average tensile strength about 107 lbs. per sq. in.

Apparent Sp. Gr. dry, 2.56.

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

Light brown clay containing lime pebbles. Molded easily.

Burned by H. W. Jackman.

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

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

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

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

CASS COUNTY

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

Burning Test

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

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

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

CHARLEVOIX COUNTY

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

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

purchased by the Newaygo Portland Cement Company in 1918. The quarry section is as follows:

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

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

Burning Test

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

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

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

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

The brick plants at East Jordan, Boyne City, and Boyne Falls have been closed for some time, and the demand for building brick is so great

that old brick buildings are being town down for the sake of the bricks contained in the walls.

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

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

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

Burning Test

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

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

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

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

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

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

Burning Test

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

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

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

Sample No. 97 taken from this pit shows a rather narrow burning range but suitable for all types of building brick and tile. The color is brown rather than red, which is generally preferred for face brick, so that the other parts of the Antrim shale are probably more suited for this purpose. This blue shale molds easily and does not crack on burning. This may be partly due to the fact that the shale is weathered to a greater extent than most of the rusty dark shale.

The dark rusty shale outcrops in many places throughout the county, some of which have been indicated on the map. An outcrop near Clarion

at the corner of sections 9, 10, 15, 16, in T. 33 N., R. 5 W. was analyzed by the Petoskey Portland Cement Company:

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

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

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

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

Burning Test

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

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

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

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

CHEBOYGAN COUNTY

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

Burning Test

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

Cone No.	Cone Temp. °C.	Porosity.	Absorption.	Fired Linear Shrinkage.	Hardness.	Color.
010	950	.439	.300	−0.7%	Soft burned.....	Salmon
08	990	.425	.298	−0.7	Soft burned.....	Salmon
06	1,030	.396	.258	+0.7	Soft burned.....	Salmon
04	1,070	.347	.210	3.2	Hard burned....	Red
02	1,110	.256	.139	6.9	Hard burned....	Dark red
1	1,150	.156	.076	....	Hard burned.....	Dark red
3	1,190	.082	.038	11.1	Vitrified.....	Chocolate
5	1,230	.058	.027	11.0	Vitrified.....	Chocolate
7	1,270	.056	.027	11.0	Vitrified.....	Chocolate
8	1,290	.014	.005	6.0	Vitrified.....	Chocolate.

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

Burned by H. W. Jackman.

The burning test shows the shale to have a wide burning range of 10 cones with practically no further shrinkage from cone 2 to 7. The color is a good dark red. The sample indicates that the shale will make excellent face brick and tile, and can be used for vitrified products such as

sewer tile, and possibly paving blocks for ordinary traffic. To obtain the best results the shale should be wet ground to develop plastic qualities, and carefully oxidized to burn out the bituminous material.

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

Shale Section

Diamond Drill Hole No. 2

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

	Surface.	Thickness feet.	Depth feet.
1.	Greenish gray very shaly limestone with occasional streaks of brown shale ($CaMgO$ 31.76 %)	14	17
2.	Greenish brown shale with spots and bands of greenish gray (SiO_2 50.80 %)	6	23
3.	Same but more calcareous ($CaMgO$ 9.73 %)	4	27
4.	Brown shaly limestone ($CaMgO$ 35.84 %)	2	29
5.	Very dark brown shale with pyrite (SiO_2 48 %)	10	39
6.	Light greenish calcareous shale with streaks and spots of dark brown shale (SiO_2 52 %)	5-6	44-6
7.	Gray calcareous shale (SiO_2 50.80)	5-4	50

Analyses of Afton Shale Samples

Diamond Drill Hole No. 2

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

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

Analysis by Aetna Portland Cement Co., 1924.

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

Burning Test

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

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

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

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

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

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

Burning Test

Sample No. 159. Field Sheet No. 180.
Section 36, T. 37 N., R. 1 W.
Plasticity 0.332 gm. water per gm. clay.
Average linear drying shrinkage 12.1 per cent.
Average tensile strength about 175 lbs. per sq. in.
Apparent Sp. Gr. dry, 2.64.

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

Red clay. Easily molded. This clay is suitable for making a light cream colored brick or tile and seems to be suitable for some pottery purposes.

Burned by H. W. Jackman.

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

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

The upper two feet of the clay used by the Cheboygan Tile Company is red. Below the red clay where the lime has not been leached out and the iron is not as well oxidized the clay is reddish blue in color. A sample from the deposit contains some pebbles which are not limestone,

and seems to be fairly good material for brick or tile. It is very similar to sample 159.

Burning Test

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

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

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

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

Burning Test

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

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

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

CLARE COUNTY

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

Chemical Analysis

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

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

Analysis by H. W. Jackman.

Burning Test

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

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

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

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

	Top.	20 ft. down.	30 ft. down.	Under marl.
	%	%	%	%
Volatile	1.64	2.91	3.13	2.98
Silica (SiO_2)	65.05	47.69	45.60	50.40
Alumina (Al_2O_3)	25.00	15.00	15.85	22.10
Iron (Fe_2O_3)	5.80			
Lime ($CaCO_3$)	2.05	28.29	28.82	24.00
Magnesium ($MgCO_3$)	0.40	6.00	8.60	00.52

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

CLINTON COUNTY

Clinton County is almost entirely boulder clay, generally stony and unsatisfactory. Sample 1002 was taken from the property owned by John Strause, seven miles north of St. Johns, section 9, T. 8 N., R. 2 W., by trenching the side of a large drainage ditch. The clay is red to blue in color and contains some pebbles. In some places the clay is covered with a few feet of sand; elsewhere the clay is at the surface. A well driven on H. S. Rue's property, across the road from the Strause farm, went through 48 feet of clay and then entered gravel.

Burning Test

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

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Apparent Sp. Gr.	Hardness.	Color.
010	950	.370	0.0%	2.62	Soft burned	Salmon
08	990	.367	0.2	2.61	Soft burned	Salmon
06	1,030	.379	0.2	2.70	Soft burned	Salmon
04	1,070	.360	0.2	2.60	Soft burned	Salmon
02	1,110	.299	3.5	2.64	Hard burned	Tan
1	1,150	.122	7.2	2.35	Hard burned	Olive brown
3	1,190	.225	7.3	2.68	Hard burned	Olive brown
5	1,230				Viscous	

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

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

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

EATON COUNTY

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

The Grand Ledge Sewer Pipe Company now the American Sewer Pipe Co. was the first to use these shales. A. C. Lane[2] described these shales "close to the Spiritualist Camp Meeting Grounds" (Sec. 3, T. 4 N., R. 4 W.) as follows:

"The section is

13 ft. stripping of till.

4 ft. gray shale.

1 ft. black shale passing into coal.

2 ft. white shale, so-called fire clay. The lower line of this white shale undulates so as to indicate that it is merely an alteration of the shale below.

4 ft. blue shale. This and the shale above the coal both contain nodules of kidney iron ore, sometimes showing some zinc blende. This also shows traces of ferns (Sphenophyllum cuneifolium).

1 ft. darker shale, the floor of the quarry.

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

[1]Rominger, Geol. Surv. Mich. III, Pt. I, p. 131.
[2]Mich. Geol. Surv. VIII, Pt. I, p. 37, 1900.

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

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

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

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

Burning Test

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

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

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

Chemical Analysis

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

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

Analysis by H. W. Jackman.

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

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

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

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

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

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

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

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

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

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

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

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

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

Sample Scum.

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

The Grand Ledge Clay Products Company uses the same shale for making sewer pipe, conduits, flues, coping, etc. Their plant is just north of the Pere Marquette Railroad about one and one-fourths miles west of Grand Ledge. The sand overburden is removed by a gasoline tractor. The shale is blasted and picked up by hand. It is prepared in one dry pan and two wet pans, and extruded in an auger machine or a steam sewer pipe press. The ware is dried in the factory on steam heated, wood slatted floors, and burned in downdraft kilns. The kiln yard includes 14 thirty foot kilns, and one forty foot kiln. The plant was down in 1922 during the coal shortage.

The American Sewer Pipe Company south of the Pere Marquette Railroad, about one mile west of Grand Ledge was burned in November, 1924.

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

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

Burning Test

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

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

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

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

Burning Test.

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

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Hardness.	Color.
010	950	.350	2.1 %	Soft burned.....	Salmon
08	990	.364	1.3	Soft burned.....	Dull salmon
06	1,030	.372	1.0	Soft burned.....	Cream
04	1,070	.333	1.9	Soft burned.....	Cream brown
02	1,110	.288	3.2	Hard burned....	Light brown
1	1,150	.086	13.0	Hard burned....	Gray brown
3	1,190	Very low	14.7	Vitrified.....	Olive brown
5	1,230	....	....	Melted.....	Olive brown

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

Chemical Analysis.

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

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

Analysis by H. W. Jackman.

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

Burning Test.

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

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

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

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

The plant uses the dry process in 8 kilns 6½ x 60 feet. The clay and limestone are mixed and crushed, dried, and ground by preparatory mills. This mixture is then stored, sampled, and analyzed, and properly proportioned or "corrected," mixed and reground and calcined. The daily capacity is 2,000 bbls., with an average coal consumption of 109 pounds per barrel of clinker.

EMMET COUNTY.

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

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

Chemical Analysis.

Sample No. 95. Field Report Sheet No. 102.

Reddish dark brown shale, Section 36 (southern edge), T. 34 N., R. 6 W.

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

Analysis by H. W. Jackman.

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

Burning Test.

Sample No. 95. Field Sheet No. 102.

Reddish dark brown shale, section 36 (southern edge), T. 34 N., R. 6 W.

Water of plasticity .275 gm. water per gm. clay.

Average linear drying shrinkage 5.4 per cent.

Samples held at 750°C. for 5 hours to burn out bituminous material.

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

Brown shale. Vitrifies between cones 02 and 1.

Burning test by H. W. Jackman.

The burning test shows the shale to have a wide burning range of over 6 cones, developing a uniform red brown color in a hard burned brick of uniform size from cone 06 to cone 1. The dry ground shale does not mold easily, so that for extruding brick or tile in an auger machine it would probably be necessary to grind the shale in a wet pan or allow the shale to weather thoroughly to develop the desired plasticity. If treated in some such manner to develop its plasticity, the Antrim shale at this place would make excellent face brick or tile. The Antrim

shale is always bituminous and must be carefully oxidized to avoid early failure in buring. The small testing briquettes were completely oxidized in about 5 hours when heated at 750°C. in a strong oxidizing atmosphere.

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

"Treatment.

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

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

Results of Firing.

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

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

The bricks made from the shale treated with concentrated hydrochloric acid, and with dilute acid, at 80 to 90 degrees centigrade, behaved practically the same. Samples taken between cones 8 and 15 had the following properties:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

The shale and limestone are drawn out of storage through gates in the roof of the tunnel into separate hoppers feeding a 24-inch belt conveyor. This conveyor discharges to a bucket elevator which carries the

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

shale and limestone to bins over the ball mills. As the raw material is fed to the mills the proper amount of water (32-33 per cent) is added.

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

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

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

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

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

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

From the four Lehigh mills the coal is elevated to a storage bin and screw conveyed to the hoppers feeding the kiln burners. These burners

consist simply of a pipe through which the primary air is blown and into which coal is fed at a regulated speed. Secondary air is drawn through the clinker cooler and is considerably preheated.

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

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

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

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

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

GENESEE COUNTY.

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

The quarry of the old Saginaw Clay Products Company is located about a mile and a half north of Flushing on the Flint river in Section 22, T. 8 N., R. 5 E. This quarry was described by Ries*. The shale is very similar to that worked by the New Corunna Brick Company east of Corunna. The upper shale (R222) is dark gray, fine grained, and somewhat brittle. This is covered by about five feet of soil and underlain by a thin seam of coal. It contains some sand often in the form of thin seams.

Burning Test.

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

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

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

Burning Test.

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

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

Clay contains some iron carbonate concretions and considerable fine mica.

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

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

Burning Test.

Sample (Ries) 183. Ground to pass 60 mesh.
Section 22, T. 8 N., R. 5 E.
Water of plasticity 22 per cent.
Air shrinkage 5½ per cent
Average tensile strength 55-60 lbs. sq. in.

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

Chemical Analysis

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

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

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

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

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

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

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

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

Burning Test.

Sample No. 153. Field Sheet No. 171.
Section 31, SE¼, T. 6 N., R. 6 E.
Plasticity .294 gm. water per gm. clay.
Average linear drying shrinkage 11 per cent.
Average tensile strength about 125 lbs. per sq. in.

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

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

This clay was tempered with water in the pit and allowed to stand overnight in a bin before working. The clay was fed into a 9A Brewer auger tile machine, equipped with automatic cut-off for making drain tile up to 18 inches in diameter. The tile were dried in a closed drying shed and turned end for end to promote even drying. One down-draft

kiln was used for burning. This plant made an excellent tile from the clay described above, until it was shut down in 1917, because no help could be obtained at that time. The equipment was in good condition in 1922.

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

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

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

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

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

The New Egyptian Cement Company is south of the railroad about opposite the other plant. This plant is equipped with nine 60-foot kilns about 6 feet in diameter having a combined capacity about equal to that of the two larger kilns of the Aetna Cement Company (1600 bbls. per day). The New Egyptian plant feeds a slurry of about 47-48 per

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

cent water content which requires about 230-250 pounds of coal per barrel of cement. No wash mills are used on the clay.

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

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

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

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

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

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

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

GLADWIN COUNTY

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

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

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

Burning Test

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

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

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

About three and one-half miles north and six miles east of Gladwin, in Section 13, T. 19 N., R. 1 W., on the banks of the river there is an outcrop of red clay apparently a lake deposit. The clay is 30 to 40 feet deep and extends under the sand in all directions. About three miles south of this place where sample 168 was taken, the clay is covered by

about two feet of sand. About six miles further south in section 1, T. 17 N., R. 1 W., sample 169 was taken. Here the clay is covered by 10 to 14 inches of sand and carries water at a depth of five feet.

Burning Test

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

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

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

Burning Test

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

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

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

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

GRAND TRAVERSE COUNTY

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

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

Burning Test

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

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

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

GRATIOT COUNTY

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

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

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

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

Two of the four 30 foot kilns had been rebuilt and were turning out a fairly satisfactory product on about 12 tons of coal instead of 50 but the drainage problem was still very serious. The drying tunnels had been rebuilt and each equipped with 900 feet of steam pipe to supersede the fire drying. Steam was supplied by two 75 H. P. Atlas boilers which were also required to run a 125 H. P. engine to drive the machinery. Labor conditions were favorable and the local market would absorb all the tile that could be produced, at $30 to $90 a thousand.

The clay pit lies to the south of the plant and seems to be a deposit of boulder clay. The clay covers about 15 acres and is locally considered usable to a depth of two to three feet. It is full of lime pebbles in places and contains sand pockets. Because of these variations in the deposit it must be carefully dug to prevent spoiling the product by the inclusion

of lime pebbles or excessive sand. Sample 81 represents the good clay from this pit.

Burning Test

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

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

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

Burned by H. W. Jackman.

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

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

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

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

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

The section through the deposit is as follows:

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

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

Burning Test

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

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

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

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

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

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

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

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

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

Burning Test

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

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

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

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

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

Burning Test

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

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

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

Burned by H. W. Jackman.

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

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

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

HILLSDALE COUNTY.

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

The Omega Portland Cement Company, organized Feb. 18, 1899, with a capital of $300,000 completed their factory of five 6 x 60-foot kilns at Mosherville, section 15, T. 5 S., R. 3 W., in 1900. This company found the local clays so unsatisfactory that they imported clay from the lake deposits of Ohio near Milbury and Bryan.* This plant failed a number of years ago.

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

Burning Test.

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

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

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

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

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

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

Analyses of blue clay.

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

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

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

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

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

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

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

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

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

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

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

HURON COUNTY.

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

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

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

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

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

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

At Bad Axe both the upper and lower strata were worked. The lower blue clay, particularly when fired in the center part of the kiln where the temperature may have been higher and the gases less oxidizing burned buff and upper red clay burned red. Some trouble was experienced by soluble salts, but lime pebbles seemed to have caused little trouble.

Two and a half miles southwest of Ubly on the county line south center of section 33, T. 15 N., R. 13 E., the river or lake clay has about two or three feet of red burning clay on top, underlain by blue, buff-burning clay. This clay was formerly used by Wyers and later by John Ruddy to make common brick. In 1910 the plant stopped production because of the scarcity of wood fuel.

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

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

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

"Excellent exposures of Coldwater shale occur along the shore of Lake Huron between White Rock and Forestville, but they have not thus far been utilized.

The shale forms a line of cliffs and when fresh appears brittle and gritty; in places, however, it has been mellowed down to a tough clay.

The rock is thinly laminated shale (R179) which contains much sand of a very fine nature and slakes slowly along the layers."

Sample R179.

Water of Plasticity 19 per cent.

Total air shrinkage 4 per cent.

Tensile strength 36 to 42 lbs. per sq. in.

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

Chemical Analysis.

	%
Silica (SiO_2)	58.7
Alumina (Al_2O_3	18.31
Ferric Oxide (Fe_2O_3)	7.19
Lime Carbonate ($Ca\ CO_3$)	1.80
Magnesium Carbonate ($MgCO_3$)	0.98
Alkalies (Na_2O+ K_2O)	3.67
Water and Organic (Difference)	9.35
	100.00
Ferrous Oxide	2.73

In September 1922 this outcrop, still unused, was visited and sampled (sample No. 147) about ¾ mile south of White Rock, two miles north of Forestville, east of the highway, where the shale outcrops in the bed of a stream in the eastern part of section 32, T. 15 N., R. 16 E. The

shale is over 50 feet thick and is covered by gravel, sand, red and blue clay, 30 feet thick in places. The upper two or three feet of the shale runs dark gray or black. The main body of shale is blue black with a few ledges about an inch thick of reddish brown shale. When weathered the shale becomes blue or covered by rust.

Burning Test.

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

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage	Bulk Sp. Gr.	Hardness.	Color.
010	950	.322	−0.2 %	1.77	Soft burned	Salmon
08	990	.299	0.8	1.82	Soft burned	Salmon
06	1,030	.228	3.9	1.97	Semi-hard burned	Light red
04	1,070	.147	7.2	2.18	Hard burned	Light red
02	1,110	.046	8.9	2.30	Hard burned	Red brown
1	1,150	.024	10.0	2.37	Vitrified	Red brown
3	1,190	.031	9.6	2.32	Vitrified	Chocolate
5	1,230	.040	8.6	2.27	Vitrified	Chocolate
7	1,270	.086	6.2	2.12	Vitrified	Chocolate
9	1,310	.174	1.8	1.85	Vitrified	Chocolate brown

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

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

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

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

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

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

"The sample collected (182) gave no effeverscence with acid and slaked very slowly in water. It contained 0.25 per cent of soluble salts.

Water of plasticity 17 per cent.

Air drying shrinkage 5 per cent.

Average tensile strength 100 lbs. per sq. in.

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

INGHAM COUNTY.

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

The shale beds in the vicinity of Williamston are known to have a thickness of over 100 feet and in an area between trunkline highway M-16 and the railroad have been penetrated in numerous test holes to depths varying from 18 to over 60 feet. The upper shales are a series of dark gray and black, locally containing a thin coal seam, which was formerly mined on a small scale. The lower shales of the drilled section are light gray and very uniform in color, and apparently in general chemical and physical properties.

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

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

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

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

Burning Test.

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

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

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

Burned by H. W. Jackman.

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

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

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

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

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

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

Sample No. 198.
NE¼ Sec. 1, T. 3 N., R. 1 E.
Plasticity .176 gm. water per gm. clay.
Average linear drying shrinkage 2.71 per cent.

Cone No.	Cone Temp. °C.	Perosity Per cent.	Apparent Sp. Gr.	Linear Shrinkage.	Hardness.	Color.
010	950	36.10	2.82	.....	Soft burned.....	Flesh pink
08	990	35.78	2.82	.....	Soft burned.....	Flesh pink
06	1,030	.....	....	.....	Soft burned.....	Light red
04	1,070	19.55	2.01	−2.70	Hard burned.....	Red
02	1,110	.....	2.75	−2.24	Hard burned.....	Red
1	1,150	15.76	2.15	0.05	Hard burned.....	Red
2	1,170	15.47	2.33	.....	Hard burned.....	Red
3	1,190	16.04	2.46	.....	Hard burned.....	Red brown
5	1,230	11.95	2.64	11.45	Vitrified.....	Red brown
9	1,310	10.62	2.69	13.70	Vitrified.....	Red brown

Suitable for face brick.
Burned by Beatty.

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

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

Burning Test.

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

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

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

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

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

At the Clippert & Spaulding, now the Briggs Company, brick yard in Lansing a short distance north of East Michigan Avenue and about

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

one-quarter mile east of the city limits, in NW¼ section 14, T. 4 N., R. 2 W., a morainic clay* is used for making common brick. The deposit is practically solid clay from the surface down. At the bottom of the bed some lines of stratification are noticable but they seem entirely lacking in the main mass of the bed.

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

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

Sample (Ries analysis No. 30).

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

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

Burning Test.

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

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

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

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

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

The plant equipment comprises the following:

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

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

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

Burning Test.

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

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Hardness.	Color.
010	950	.470	1.2 %	Soft burned.....	Salmon
08	990	.450	0.7	Soft burned.....	Cream salmon
06	1,030	.470	0.5	Soft burned.....	Cream
04	1,070	.484	1.0	Soft burned.....	Cream white
02	1,110	.461	1.6	Soft burned.....	Cream
1	1,150	.337	15.7	Hard burned.....	Light olive
3	1,190	.144	14.0	Vitrified.....	Light olive
5	1,230	....	....	Melted.....	Light olive

Easily molded.
Burned by H. W. Jackman.

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

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

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

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

Burning Test.

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

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

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

Burning Test

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

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

Burned by Beatty.

*Had small lime lumps.

Burning Test

Sample No. 219. From Hole 2, northeast part of pit.
NE¼ section 33, T. 1 N., R. 2 W. State Prison Brick Plant. Onondaga.
Plasticity .246 gm. water per gm. clay.
Average linear drying shrinkage 4.83 per cent.

Cone No.	Thermo-couple Temp. °C.	Porosity Per cent.	Apparent Sp. Gr.	Linear Shrinkage Per cent.	Hardness.	Color.
010	860	....	....	....	Soft burned.....	Flesh pink
08	895	38.8	2.63	2.0	Soft burned.....	Flesh pink
06	920	37.2	2.60	1.4	Soft burned.....	Flesh pink
04	1,054	37.7	2.61	1.4	Soft burned.....	Cream
02	1,075	41.4	3.11	3.5	Hard burned....	Cream
01	1,090	....	....	....	Hard burned....	Olive
1	1,110	19.3	2.47	11.8	Vitrified.....	Olive
3	1,125	0.8	2.93	18.1	Vitrified.....	Olive
4	1,135	Cracked	....	....	Vitrified.....	Olive
5	1,145	Cracked	....	....	Viscous.....	Olive

Burned by Beatty.

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

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

Burned by Beatty.

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

*Had lime spots.

Burning Test.

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

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

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

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

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

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

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

[1] F. Isbell, Bert Morgan, or Walter Michols, Stockbridge.
[2] 22d Ann. Rept. U. S. Geo. Surv. Pt. III. 671 (1902).

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

Burning Test.

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

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

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

IONIA COUNTY.

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

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

Burning Test.

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

Cone No.	Cone Temp. °C.	Porosity.	Linear Shrinkage.	Hardness.	Color.
08	990	.407	2.6 %	Soft burned.....	Pink
06	1,030	.436	2.0	Soft burned.....	Cream
04	1,070	.420	1.8	Soft burned.....	Cream
02	1,110	.424	2.7	Soft burned.....	Cream
1	1,150	.248	9.4	Hard burned.....	Light olive brown
3	1,190	.035	16.6	Vitrified.....	Olive
5	1,230	.033	14.8	Vitrified.....	Olive
7	1,270	.033	14.9	Vitrified.....	Olive
9	1,310	....	....	Melted	

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

Burned by H. W. Jackman.

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

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

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

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

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

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

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

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

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

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

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

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

This plant is of particular interest for two reasons. For 40 years it has successfully made earthenware from Michigan boulder clay. Re-