free from it, the superficial clay has the least, and much less sulphur, showing that the calcium carbonate and pyrite have been leached out.

Tests of this cement have been satisfactory, and are elsewhere given.

"At various times while the dredges have been at work in the marl beds near the cement works, bones of prehistoric animals— or what are supposed to be the bones of extinct animals—have been exhumed. Chemist Brown, of the cement works, could not determine to what age they belonged and has sent a box of them to Chicago for classification. The bones of elk and deer are frequently found, and one workman on the dredge has a 'beautiful pair of antlers that are as perfect and sound as though just taken from the animal."—*Coldwater Courier.*

Michigan Alkali Co., Wyandotte (J. B. Ford).

This establishment originally came into Michigan in order to make soda for glass and other use, out of the vast beds of rocksalt which extend between Trenton, Michigan, all the way along the Detroit River and the Saint Clair River to Goderich in Canada, and Alpena, Mich.

The limestone is obtained from the company, extensive quarries at Bellevue but having yielded its carbonic oxide was of no farther use. To utilize this waste was a problem placed in the hands of their chemists. The plant was designed by the engineering firm of Lathbury and Spackman.*

After several trials a hard burned, dark green clinker was produced from the mixture of 100 parts of clay to 260 parts of waste, by weight, and tests showed the quality to be equal to the best of American or imported cement.

The clay is dredged a few hundred feet from the company's plant, and is conveyed to a stock shed; the clay is first run through a dryer, freeing it from water, then it is pulverized very fine and put into bins, then analyzed and properly proportioned by weight with the lime which has also undergone a purifying process. The raw materials are weighed exactly and the mixture is therefore absolutely correct. Afterward it passes through both pug mill and agitator and then ground. Proper proportioning of the raw materials is the most important factor in manufacturing a perfect cement and the product of the Wyandotte mill passes all chemical cement tests.

After leaving the rotaries, the clinkers pass through the finest of grinding machinery and all cement is passed through a mechanically agitated screen, before passing into the bins, thus insuring a uniformly ground product. Here the cement is thoroughly seasoned and none of it leaves the bins for the consumer until it is at least two months old.

During 1900 and 1901, the city of Detroit used Wyandotte Portland cement exclusively for all public work, which is in itself a fitting testimonial as to the efficacy of this superior product.

To show the standing of Wyandotte cement in the market it is but necessary to mention a few of the buildings in which it has been exclusively used. In the mosaic floors and artificial stone walks of the new Wayne county court house 3,500 barrels of the Wyandotte Portland cement were used; 1,200 barrels in Brown Bros. tobacco factory; 4,000 barrels in the engine foundations of the Detroit City Water Works building; 2,000 barrels in the Detroit Sugar Co.'s plant at Rochester, Michigan; hundreds of barrels in Wonderland Temple theater. Ten thousand barrels of Wyandotte Portland cement will be required in the construction of the great bridge across the Maumee at Maumee, Ohio, now being built by the Toledo Terminal railway company. The engineers, after careful tests of imported and American brands of cement, selected Wyandotte cement.

"The plant was erected on the low lands bordering the Detroit river. High grade materials were used throughout and the process made practically automatic. The buildings, constructed of steel with brick sides, have clear spans, the trusses being carried on brick pilasters. As water and quicksand were discovered at two feet, the walls were built on brick arches which transferred the entire weight to concrete piers extending to solid ground.

The mill building and stock house are parallel twin buildings, each with a 42-foot clear span; at the north end the roof is raised and 84-foot trusses span the width of both buildings, giving room for a second story. Adjoining the mill room but separated by brick partitions are the coal grinding, the engine and the boiler rooms. The clay building, with a 30-foot span, is of steel and corrugated iron, and runs toward the river at right angles to the mill building.

The waste material is transported to the mill by a travelling crane, which, securing a charge in the soda plant, transports it into the second story of the cement plant. The clay, after excavation, is stored in a clay building, from which it is conveyed to an elevator, discharging into a rotary dryer, where it is subjected to the direct heat of a coal fire and afterwards passed through a disintegrator from which it is elevated to the second floor, and discharged into steel bins, ready to be added to the lime waste.

The raw mix passes through a pug mill on. the second floor, which discharges into a storage tank directly underneath. This tank is provided with agitators which prevent any separation by settling. From this tank the slurry flows to wet-grinding tube mills for a final reduction. These discharge into concrete pits, so arranged that a high lime or clay slurry can be discharged into any of them to correct the chemical composition. After being analyzed and corrected if necessary, the material is pumped to steel storage tanks located in the second story. Agitators keep the slurry in motion in all pits until pumped into the rotary kilns. The material is fed to the kilns through water-jacketed chutes with pulverized coal; all three kilns discharge into a concrete pit, from which it is elevated to the cooling towers.

Air is forced in at the bottom of these steel cooling towers, 12 feet in diameter and 22 feet high, arranged with a succession of metal floors, having radial openings, through which the clinker is swept by a scraper fitted to a central shaft. The clinker is moved 350 degrees on each floor, before falling to the next. Arriving at. the bottom it is elevated into steel bins over the ball mills, from where it is raised and conveyed to bins over tube mills which finish the cement.

From here the cement is elevated and conveyed by an overhead conveyor, through the mill room wall, into the stock house, and discharged into two lines of conveyors resting on the top of the storage bins, thus delivering into any bin desired. These bins have hoppered bottoms and are arranged in two rows with a passageway between containing two lines of screw conveyors; these carry the cement drawn from the bins to an elevator at the packing room, which discharges it into the bins supplying the packing machinery.

The power plant consists of one 600 H. P. tandem compound condensing engine, and three water tube boilers. The river water passes from jet condensers to hot well from which feed water for the boilers is taken.

The engine is belted directly to the main line shaft which passes through the engine room walls in stuffing boxes, thus cutting out the dust from the mill; the engine room projecting beyond the walls of the mill so as to give clearance for main shaft. The shafting is so arranged that the power can be cut out from any department by the use of clutch couplings.

A notable feature of the plant is the relatively small area covered by the buildings when compared with the total capacity, making it one of the most complete plants in operation. Including the stock house with a capacity of 40,000 barrels, all the buildings cover an area of only 25,000 square feet, and the plant has a daily average of 450 barrels.

The above plants are those which were actually in operation in 1901. We take up-next proposed mills which will in all probability be running before this report is out. The most extensive in plans will be the Hecla, which will be a group of allied industries, more like the Michigan Alkali Company last mentioned. The remaining three are Portland cement propositions pure and simple.

Hecla Cement and Coal Co.

Organized April 6, 1901. Capital 15,000,000, in shares of $100. A West Virginia corporation, but with offices in Detroit and business centering around Bay City, consisting of marl lands in Ogemaw county, and coal and clay shale lands in Bay county.

The officers and directors of the company are: Julius Stroh, president; Cameron Currie, first vice president; Waldo Avery, second vice president; Edward H. Parker, treasurer; U. R. Loranger, secretary; Lem W. Bowen, Theodore D. Buhl, James N. Wright, M. M. Green.

Briefly the plans of the company can be outlined as follows: The manufacture of Portland cement from dry marl and clay shale; the mining of coal, of which the lump will be marketed and the slack used in the manufacture of cement and the creation of power to run the great mills; the evaporation of salt in large quantities with the exhaust steam and hot gases escaping from the rotaries; the by-products of salt and limestone to be used in the running of a large chemical plant; the erection of coke ovens, also used as an auxiliary to the plants; the operation of a standard gauge railroad to be utilized for hauling the coal to the dock of the company for lake shipment as well as the raw materials to the cement plant.

The novel features of their plans are,—the transportation of the marl to the clay and shipping point, instead of building the factory at the marl bed; the use of waste coal and slack, and especially of Michigan coal, as well as clay and marl; the utilization of by-products and waste heat, and the employment of a dry process. Ordinarily the marl being the most bulky raw material, does not pay to ship. In this case, however, we have to counterbalance it a saving on shipping coal, clay and cement, while the marl comes down grade.

In the planning of the plant, marl analyses have been made by R. E. Doolittle, State Analyst, Lathbury and Spackman, and others. To the courtesy of U. R. Loranger we owe details of the company's analyses which cover a range of materials and have a scientific value in showing how analyses of such material run in the State. We append extracts from the reports of some of their experts. Beside the draining of the lakes and handling of the marl or boglime dry,* another important feature of this plant is the proposed utilization of shales of the coal measures.

One mile of river front on the Saginaw river, near the month, and only a short distance below West Bay City, is owned by the Hecla company, where the cement plant has been erected. The erection of this plant will shortly be followed by the other mills included in the general plan of development.

The company owns about 6,000 acres of coal lands, about 800 acres of marl land, 2,000 acres of lime rock, and a mill site with nearly a mile of river front on the mouth of the Saginaw river, and is incorporated to manufacture and sell Portland cement, alkali, salt, paving and fire brick, coal, fire clay, etc. Experts who have looked over the property say that by reason of the fuel situation, with coal deposits under the company’s mill site, it will possess a great advantage over those who are obliged to buy their coal in the open market and pay freight on it. The company will sell the lump coal and use its slack coal.

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*American Engineering- Practice, p. 110 to 118, with view plan and profile from which we take the description below.

The four marl lakes, known as George, Edwards, Chapman and Plummer, are located on the headwaters of the Tittabawassee River, and all within the radius of five miles in the township of Edwards, Ogemaw county, Michigan, Plummer being on the Hampton branch of the M. C. R. R., and the others lying two, three and four miles respectively, from the same. There is a roadbed already constructed and in very fair condition, extending from Plummer Lake to Edwards Lake.

Your next deposit, known as Crapo Lake, lies a little less than two and one-half miles northeasterly from the village of West Branch, on the Michigan Central railroad, in Ogemaw county, Michigan, and about six miles north of George Lake.

Your Mills Lake deposit is located about four and one-half miles from the village of Prescott, on the Prescott branch of the Detroit & Mackinac railway, in Mills township, Ogemaw county.

George Lake.

The property at George Lake was found to consist of 380 acres, of which 200 acres are covered with marl. The marl is high quality, as shown by the following analysis, which is an average of samples taken from borings over the entire lake. Lab. No. 662 (see p. 260).

The chemical composition of the clay is shown by two average samples taken from the deposits as follows:*

Lab. No. 712 (see p. 266). Lab. No. 713 (see p. 266).

This lake presents probably the deepest deposit of marl of any owned by you, many borings showing a depth of from 27 to 34 feet, but the dry marl is thickly covered with a growth of small trees and brushwood, and a large portion of the deepest marl is under water of considerable depth. The water in this lake could, however, be reduced by deepening the channel at the outlet, but it is a question whether a sufficient change of water level could be made without an expenditure of a considerable sum of money.

Edwards Lake.

Edwards Lake lies in a southwesterly direction from George Lake and is about three miles distant. It contains the largest acreage of marl of any of your deposits. The land owned by you here aggregates about 400 acres, of which 240 acres are covered with marl, of an average depth of 20 feet. The lands of this property are situated in sections 21, 22 and 27, and a second body is located about one mile eastward on the stream formed by the outlet. The clay deposits immediately at the outlet of the lake extends under the surface, and has been found by careful examination to cover a tract one-half mile square, and is of good depth, though overlaid to some extent with sand and gravel. A second deposit further down the creek has been explored for about 40 acres, and shows a depth of 20 feet, at which point the bottom was not reached.

The analyses of these two clays are as follows:

Lab. No. 658 Edwards Lake, No. 1 (see p. 266).

Lab. No. 676. Edwards Lake, No. 2 (see p. 266).

The marls are also of most excellent quality, as shown by the following analysis, which represents an average of some thirty samples taken in various parts of the lake.

Lab. No. 659. Edwards Lake Marl (see p. 260).

Chapman Lake.

Chapman Lake is in the extreme southwest corner of Edwards township, sections 31 and 32. The property owned by you here consists of some 230 acres, of which 160 are marl. Chapman Lake is fully equal in the quality of the marl to the preceding lakes, and partakes equally with Edwards Lake in the advantages resulting from being readily drained.

An average analysis of Chapman Lake is as follows:

Lab. No. 663. Chapman Lake Marl (see p. 260).

The clay deposits examined in connection with this lake are located in section 7, Clement township, Gladwin county, about three miles distant from the lake. The bed is over 40 feet thick, and has been explored for a distance of over one-half a mile.

An average analysis of this clay is as follows:

Lab. No. 660. (Sec. 7, see p. 266).

Another clay deposit in section 3, same township and county was examined, an average analysis of which is as follows:

Lab. No. 661. (Sec. 3, see p. 266).

Plummer Lake.

Plummer Lake is the smallest of the group, but is advantageously located with regard to railroad transportation. The Hauptman branch of the Michigan Central railroad passes through your property at this point. The lake is situated about seven miles west from the main line of the Michigan Central railroad. At this point the property owned by you comprises some 120 acres of land, of which about 40 acres are marl, which is of exceptional purity, and only a small portion of it covered with water. The clay on this deposit lies in direct conjunction with the marl at the east end of the lake, and runs down under the marl at the southern side. The clay deposit is covered with about three feet of surface earth and is 40 acres in extent. The clay average is eight feet in depth.

An average sample of the marl shows the following analysis:

Lab. No. 623. Plummer Lake marl (see p. 260).

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*Edwards Lake has been lowered.

*It will be noticed that these and all the other clays which are surface clays in connection with the marl deposits are about one-fourth to one-fifth carbonates, with generally 5% MgO. The company is depending not on these, but on shale clays of the coal measures.

The analysis of the clay shows the best chemical composition for the manufacture of cement of any deposits examined in connection with the marl deposits, and is as follows:

Lab. No. 675. Plummer Lake clay (see p. 266).*

Crapo Lake.

Crapo Lake is located on the east side of the main line of the Michigan Central railroad, about two miles northeast of the village of West Branch in West Branch township, sections 7, 8 and 16. The property comprises 340 acres, of which about 240 acres are marl. This deposit has an average depth of about 12 feet, and is covered with a light growth of grass and brushwood, with a top coat of muck six inches deep. The brushwood can very readily be burned off, while the level of the lake can no doubt be lowered considerably by deepening the channel at the creek outlet, and thereby exposing nearly all the deposit. About two-thirds of this body of marl occurs in the low swampy basin which was formerly covered with water. At the present time several narrow channels pass through the deposit with here and there a small lake, all of which drains into the west branch of the Rifle River.

The marl in the small lakes shows a depth of at least 15 feet, while the water ranges in depth from two to fifteen feet. This deposit is entirely free from grit; analysis of samples shows it to be of uniform quality and containing a high percentage of carbonate of lime. Average analyses of samples taken from this lake give the following results:

Lab. No. 891. Crapo Lake marl, No. 1 (see p. 260).

Lab. No. 896. Crapo Lake marl, No. 2 (see p. 260).

The clay lands of the deposit are located along the bank of the lake, in sections 9 and 16, and cover about 40 acres, while the depth is about 30 feet.

Analyses of samples of these clays give the following results:

Lab. No. 822. Section 9 (see p. 265).

Lab. No. 823. Average of section 10.

Mills Lake.

Mills Lake deposit, located in Mills township, in sections 24 and 25, on the east side of the main line of the Michigan Central railroad, and about four miles from Prescott on the D. & M. railroad. This property covering 360 acres of land contains about 160 acres of marl. The main body of marl occurs in the lake under water, whose depth ranges from three to fifteen feet. The marl itself, has an average depth in the lakes of about 20 feet. At the north end of the lake a considerable part of the deposit of the marl is covered by water whose depth does not exceed three feet, and the entire lake level can be readily lowered by deepening the creek, and removing the log obstructions at the outlet. This will expose about three-fourths of the deposit. The marl in the lake is very uniform in quality, but in several spots is covered with a slight growth of vegetable matter; below this, however, the marl is of very great purity, having no topping or muck.

An average analyis of samples taken from this gives the following results:

Lab. No. 895. Mills Lake marl, No. 4 (see p. 260).

The clay deposits in connection with this lake are located about one-half mile below the lake outlet, bordering both sides of the creek draining same and covering about 80 acres. It is over 30 feet in thickness, and an average analysis gives the following results:

Lab. No. 904. Clay marked No. —04 (see p. 263).

Lab. No. 905. Clay marked No. 2 —05.

Samples of shale were taken from borings in four different locations on your coal field which show an extensive acreage, running from five to fifty feet. The analyses of four samples of these shales are as follows:

Lab. No. 727. Light shale (see p. 265).

Lab. No. 728. Dark shale (see p. 265).

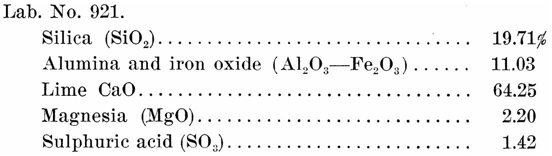
Lab. No. 863. Goetz shale, No. 1 (see p. 265).

Lab. No. 906. Clay marked 06 (see p. 263).

These shales are all suitable for combining directly with your marl in the manufacture of the Portland cement; Lab. No. 727 and Lab. No. 906, being especially good.

The coal properties are taken up and discussed in detail by the report of Mr. Brown, superintendent of the N. A. Chemical Company's coal mines, and the report of Lippencott & McNeil, mining engineers.

The raw material after being mixed, ground and burned in a set kiln, was ground, and the cement showed the following results:

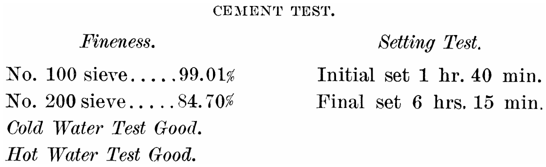


Lab. No. 921.

Silica (SiO_2)	19.71%
Alumina and iron oxide (Al_2O_3—Fe_2O_3)	11.03
Lime CaO	64.25
Magnesia (MgO)	2.20
Sulphuric acid (SO_3)	1.42

The marl was taken from your property at West Branch, and the shale from your property at Bay City.

In addition to the above analysis the finished cement was subjected to physical tests with the following results:



CEMENT TEST.

Fineness.	*Setting Test.*
No. 100 sieve.....99.01%	Initial set 1 hr. 40 min.
No. 200 sieve.....84.70%	Final set 6 hrs. 15 min.
Cold Water Test Good.	
Hot Water Test Good.	

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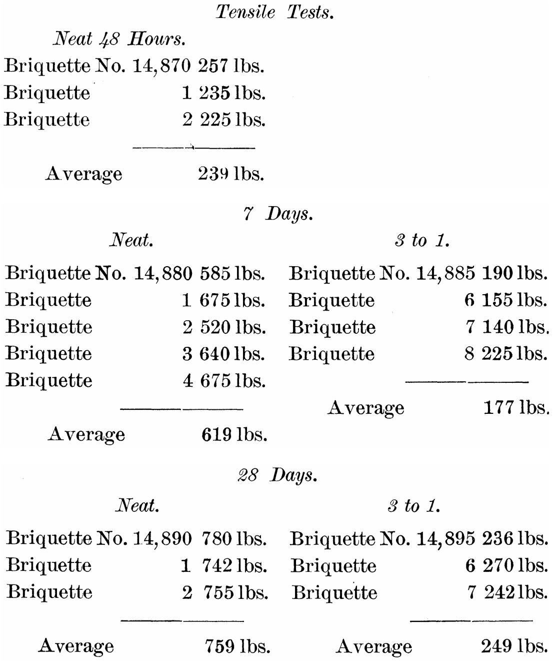
*See, as regards the availability of surface clays, pp. 267 and 268.



Tensile Tests.

Neat 48 Hours.

Briquette No. 14,870	257 lbs.
Briquette 1	235 lbs.
Briquette 2	225 lbs.
Average	239 lbs.

7 Days.

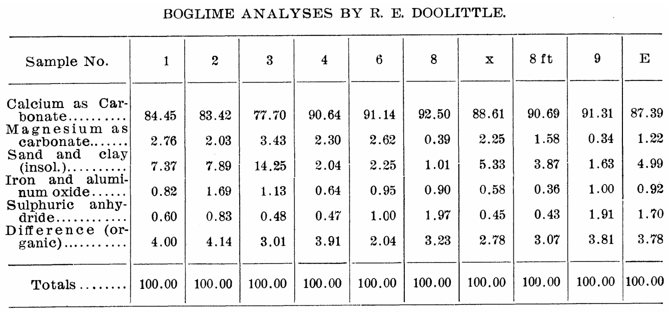
Neat.		*3 to 1.*	
Briquette No. 14,880	585 lbs.	Briquette No. 14,885	190 lbs.
Briquette 1	675 lbs.	Briquette 6	155 lbs.
Briquette 2	520 lbs.	Briquette 7	140 lbs.
Briquette 3	640 lbs.	Briquette 8	225 lbs.
Briquette 4	675 lbs.	Average	177 lbs.
Average	619 lbs.		

28 Days.

Neat.		*3 to 1.*	
Briquette No. 14,890	780 lbs.	Briquette No. 14,895	236 lbs.
Briquette 1	742 lbs.	Briquette 6	270 lbs.
Briquette 2	755 lbs.	Briquette 7	242 lbs.
Average	759 lbs.	Average	249 lbs.

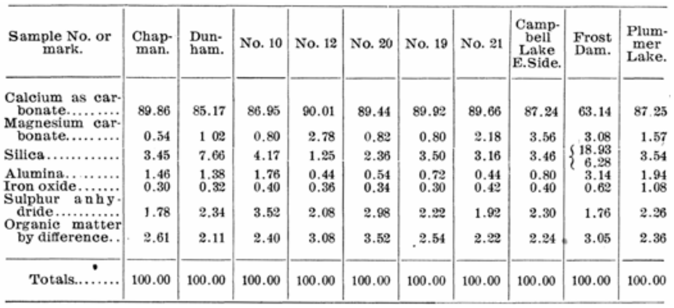
Respectfully submitted,
(Signed) LATHBURY & SPACKMAN.

The following extensive suites of boglime analyses, Which we owe to Mr. U. R. Loranger, are of especial value, as not select, but showing much better how an average deposit runs, than select analyses which are published in prospectuses. In regard to these analyses, however, as to many others, it must be remarked that probably what was directly determined was: calcium; magnesium; residue insoluble in HCl, which is called sand and clay, or silica; iron oxide and aluminum oxide precipitated together; and sulphuric anhydride. The calcium and magnesium are estimated as carbonates, and the difference between the total then and 100 per cent is called organic matter. But direct determination of the carbon dioxide shows as we have elsewhere mentioned, that it falls short of the amount calculated as sufficient to turn the calcium and magnesium into oxides by some two per cent. This is due to the fact that part of the calcium is combined with the sulphuric anhydride, and somewhat more with an organic acid (succinic acid). In practice, however, the calcium succinate would probably be soon broken up on heating into calcium carbonate and organic matter, so that it does not make much practical difference.



BOGLIME ANALYSES BY R. E. DOOLITTLE.

Sample No.	1	2	3	4	6	8	x	8 ft	9	E
Calcium as Carbonate..........	84.45	83.42	77.70	90.64	91.14	92.50	88.61	90.69	91.31	87.39
Magnesium as carbonate.......	2.76	2.03	3.43	2.30	2.62	0.39	2.25	1.58	0.34	1.22
Sand and clay (insol.)..........	7.37	7.89	14.25	2.04	2.25	1.01	5.33	3.87	1.63	4.99
Iron and aluminum oxide......	0.82	1.69	1.13	0.64	0.95	0.90	0.58	0.36	1.00	0.92
Sulphuric anhydride............	0.60	0.83	0.48	0.47	1.00	1.97	0.45	0.43	1.91	1.70
Difference (organic)..........	4.00	4.14	3.01	3.91	2.04	3.23	2.78	3.07	3.81	3.78
Totals	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00



Sample No. or mark.	Chapman.	Dunham.	No. 10	No. 12	No. 20	No. 19	No. 21	Campbell Lake E.Side.	Frost Dam.	Plummer Lake.
Calcium as carbonate.........	89.86	85.17	86.95	90.01	89.44	89.92	89.66	87.24	63.14	87.25
Magnesium carbonate.........	0.54	1 02	0.80	2.78	0.82	0.80	2.18	3.56	3.08	1.57
Silica............	3.45	7.66	4.17	1.25	2.36	3.50	3.16	3.46	{ 18.93 6.28	3.54
Alumina..........	1.46	1.38	1.76	0.44	0.54	0.72	0.44	0.80	3.14	1.94
Iron oxide.......	0.30	0.32	0.40	0.36	0.34	0.30	0.42	0.40	0.62	1.08
Sulphur anhydride...........	1.78	2.34	3.52	2.08	2.98	2.22	1.92	2.30	1.76	2.26
Organic matter by difference..	2.61	2.11	2.40	3.08	3.52	2.54	2.22	2.24	3.05	2.36
Totals........	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Sample No.

1 is from Edwards Lake, T. 21 N., R. 1 E., 11 feet thick.

2 is from Edwards Lake, "a little high in clay."

3 is from Edwards Lake, "very high in clay with some sand, not a good sample."

4 is from Plummer Lake, “a very good sample.”

5 is from Plummer Lake, "fair; rather high in sulphuric acid”

8 is from Plummer Lake, "fair; rather high in sulphuric acid."

X is from Plummer Lake, "a good, fair sample."

8 feet, Chapman Lake, "a very good sample."

9 Chapman Lake, "fairly good marl though a little high in sulphuric acid.”

E. Chapman Lake, "good, fair sample, a little high in sulphuric acid."

On the whole, the above set of analyses run high in silica for bog-limes, and especially in sulphur anhydride,—gypsum.

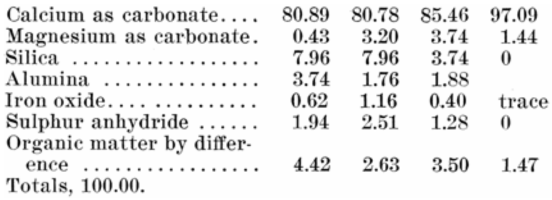
The first analysis of the second set comes from Chapman Lake, like No, 9, of the previous set.

The next comes from Dunham Lake, Sec. 19, T. 21 N., R. 1 E.

No. 10 comes from Campbell Lake in the same township.

Nos. 12, 20, 19, 21, and the rest of this set are all from this township.

All the above samples were analyzed by R. E. Doolittle, State Analyst, and as regards the amount of sulphuric anhydride, which is high, it will be noticed that the lakes are in a region just south of that where the Michigan series is bedrock, in which gypsum occurs frequently in the drift. Some of the limes highest in sulphates are not high in iron, and the sulphates are probably not largely derived from pyrite. Silica is also often high. Of the sample at the First Dam, 18.93% is soluble silica and fine sand, 6.28% coarser sand.

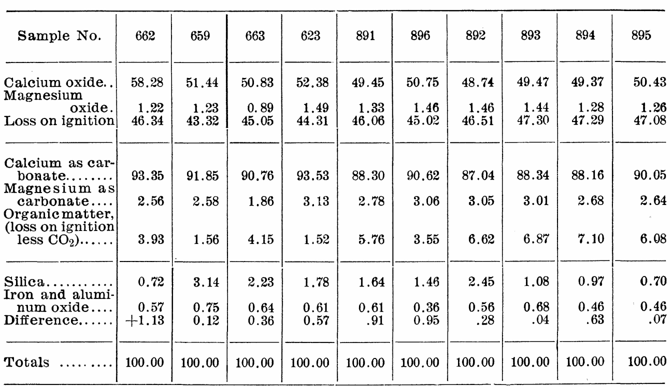


Calcium as carbonate....	80.89	80.78	85.46	97.09
Magnesium as carbonate.	0.43	3.20	3.74	1.44
Silica	7.96	7.96	3.74	0
Alumina	3.74	1.76	1.88	
Iron oxide...............	0.62	1.16	0.40	trace
Sulphur anhydride	1.94	2.51	1.28	0
Organic matter by difference	4.42	2.63	3.50	1.47

Totals, 100.00.

Of the set above, the first is from Plummer Lake, the second is also ("A"). The third is from Campbell's Lake, west side; the fourth from Plummer Lake, and all are by R. E. Doolittle. The first three have too much sand for cement,—better analyses are to be found in the other sets. There is more iron in the marls with sand and clay. In the pure boglimes it is only a fraction of a per cent.

BOGLIME ANALYSES BY LATHBURY AND SPACKMAN.



Sample No.	662	659	663	623	891	896	892	893	894	895
Calcium oxide..	58.28	51.44	50.83	52.38	49.45	50.75	48.74	49.47	49.37	50.43
Magnesium oxide.	1.22	1.23	0.89	1.49	1.33	1.46	1.46	1.44	1.28	1.26
Loss on ignition	46.34	43.32	45.05	44.31	46.06	45.02	46.51	47.30	47.29	47.08
Calcium as carbonate........	93.35	91.85	90.76	93.53	88.30	90.62	87.04	88.34	88.16	90.05
Magnesium as carbonate....	2.56	2.58	1.86	3.13	2.78	3.06	3.05	3.01	2.68	2.64
Organic matter, (loss on ignition less CO_2)......	3.93	1.56	4.15	1.52	5.76	3.55	6.62	6.87	7.10	6.08
Silica...........	0.72	3.14	2.23	1.78	1.64	1.46	2.45	1.08	0.97	0.70
Iron and aluminum oxide....	0.57	0.75	0.64	0.61	0.61	0.36	0.56	0.68	0.46	0.46
Difference......	+1.13	0.12	0.36	0.57	.91	0.95	.28	.04	.63	.07
Totals	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Lab. No. 662 is an analysis of an average of samples taken all over George Lake, Sec. 13, T. 21 N., R. 1 E.; of a property of 380 acres, 200 are covered with boglime.

Lab. No. 659 is an analysis of the average of 30 samples from Edwards Lake, Sections 21, 22, 27, 28, of the same township. There is said to be 240 acres of marl that averages 20 feet thick. The outlet from the lake to the Tittabawassee has been cleaned out, draining the boglime.

Lab. No. 663 is an average analysis from Chapman Lake in Sections 31 and 32 on the same township. There is said to be some 160 acres of boglime here, also readily drained.

Lab. No. 623 is an analysis of an average sample from Plummer Lake, near Sec. 8 of the same township, close to the Hauptman branch of the Michigan Central. There is only about 40 acres, but of very nice lime, and in conjunction with a clay deposit elsewhere analyzed.

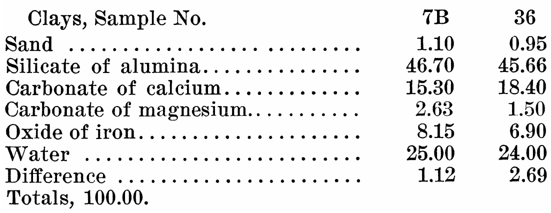
Lab. No. 891 is from Crapo Lake, Sections 7, 8, and 16, T. 22 N., R. 2 E. Here there are said to be about 240 acres of lime with an average depth of about 12 feet, covered with a top coat of peatmuck about six inches thick, and a growth of grass and brushwood. It is said that about two-thirds of the body of marl occurs in a low swampy basin, an old filled lake, now traversed by several narrow channels, with a small remnant lake here and there, the whole draining into Rifle River in such a way that much of it can be easily drained.

Lab. No. 896 is from the same lake.

Nos. 892 to 895 are Mills Lake marls, Nos. 1 to 4, Sections 24 and 25, T. 21 N., R. 3 E. Here there is about 160 acres of marl, mainly in the lake under from three to fifteen feet of water, but the outlet, it is said, can be readily deepened. There is a slight growth of vegetable matter over in some spots, but there is said to be no muck topping.

The somewhat larger amount of organic matter in the Mills Lake and Crapo Lake analyses is attributed by Lathbury & Spackman, who collected and analyzed them, to the relatively superficial character of the samples, and consequent larger amount of vegetable matter.

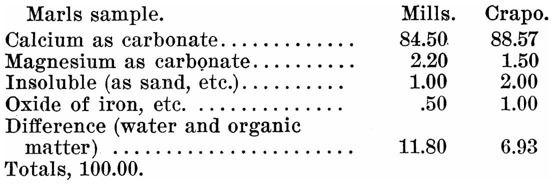
ANALYSES BY R. C. KEDZIE.



Clays, Sample No.	7B	36
Sand	1.10	0.95
Silicate of alumina...............	46.70	45.66
Carbonate of calcium.............	15.30	18.40
Carbonate of magnesium...........	2.63	1.50
Oxide of iron.....................	8.15	6.90
Water	25.00	24.00
Difference	1.12	2.69

Totals, 100.00.

These analyses were of clay near Plummer Lake; see Lathbury & Spackman's analysis.

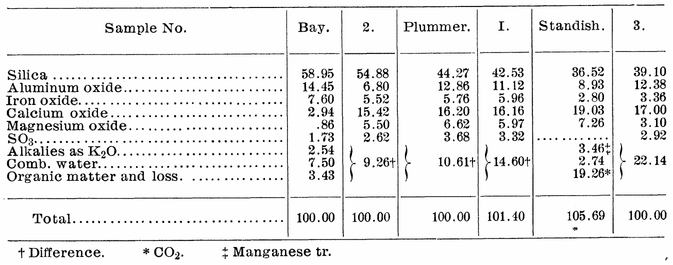


Marls sample.	Mills.	Crapo.
Calcium as carbonate.............	84.50	88.57
Magnesium as carbonate..........	2.20	1.50
Insoluble (as sand, etc.)..........	1.00	2.00
Oxide of iron, etc.	.50	1.00
Difference (water and organic matter)	11.80	6.93

Totals, 100.00.

These two samples from Mills Lake and Crapo Lake respectively, should be compared with Lathbury's analyses from the same place (891 to 896). The Crapo Lake analyses agree quite closely. The Mills Lake lime either contains more organic matter or is less dry.

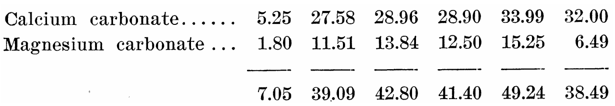
CLAY ANALYSES BY F. S. KEDZIE.



Sample No.	Bay.	2.	Plummer.	I.	Standish.	3.
Silica	58.95	54.88	44.27	42.53	36.52	39.10
Aluminum oxide.........................	14.45	6.80	12.86	11.12	8.93	12.38
Iron oxide..............................	7.60	5.52	5.76	5.96	2.80	3.36
Calcium oxide...........................	2.94	15.42	16.20	16.16	19.03	17.00
Magnesium oxide.........................	.86	5.50	6.62	5.97	7.26	3.10
SO_3......................................	1.73	2.62	3.68	3.32	....	2.92
Alkalies as K_2O.........................	2.54	9.26†	10.61†	14.60†	3.46‡	22.14
Comb. water.............................	7.50				2.74	
Organic matter and loss.	3.43				19.26*	
Total...................................	100.00	100.00	100.00	101.40	105.69 *	100.00

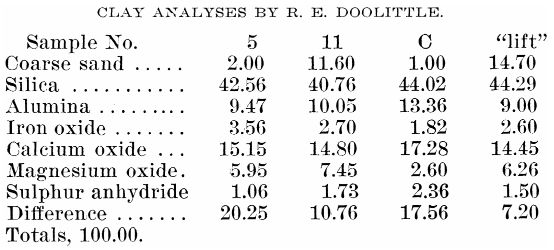
† Difference. * CO_2. ‡ Manganese tr.

With the exception of the first analysis, which is of a Bay County shale, and is a "good clay; it is entirely free from calcium carbonate, and is to be recommended for its content of silica and freedom from grit," the rest are surface clays with the usual large amounts of carbonates, and considerable percentages of magnesia. A number are, I believe, near Standish. No. 3 is from Plummer's Lake. Compare Lathbury & Spaekman^s analysis 675, which runs much higher in silica. The percentages of calcium and magnesium as carbonates are as follows:



Calcium carbonate......	5.25	27.58	28.96	28.90	33.99	32.00
Magnesium carbonate ...	1.80	11.51	13.84	12.50	15.25	6.49
	7.05	39.09	42.80	41.40	49.24	38.49

In the Standish analysis in which the CO_2 is determined, it will be noted that the sum of the calcium oxide, magnesium oxide and carbon dioxide is but 45.55 per cent, while the sum of the carbonates as above given, is 49.24, which shows that not all the calcium and magnesium oxide are combined as carbonates, but some, especially of the magnesia, probably are present as silicate.



CLAY ANALYSES BY R. E. DOOLITTLE.

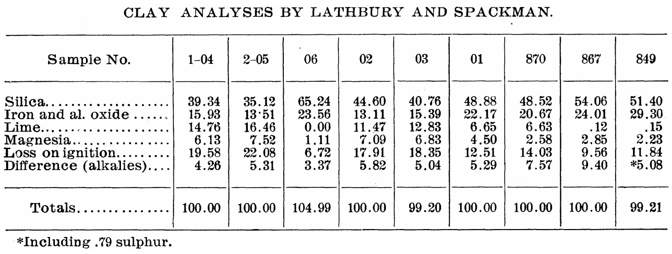
Sample No.	5	11	C	"lift"
Coarse sand	2.00	11.60	1.00	14.70
Silica	42.56	40.76	44.02	44.29
Alumina	9.47	10.05	13.36	9.00
Iron oxide	3.56	2.70	1.82	2.60
Calcium oxide ...	15.15	14.80	17.28	14.45
Magnesium oxide.	5.95	7.45	2.60	6.26
Sulphur anhydride	1.06	1.73	2.36	1.50
Difference	20.25	10.76	17.56	7.20

Totals, 100.00.

No. 5 is from Edwards township, No. 11 the same , but contains too much sand and gravel for cement making. C is the same in location. The other is from Chapman Lake.

These clays are all surface clays, with 35 to 40 per cent carbonates, and a high but variable percentage of magnesia. Owing to the large amount of carbonates it would be necessary to use a large amount of clay, and it would be hard to keep the magnesium as low as desirable, or, I fear, the composition uniform.

It is not intended to use any of these clays for cement manufacture, though similar clays have been sometimes endorsed.



CLAY ANALYSES BY LATHBURY AND SPACKMAN.

Sample No.	1–04	2–05	06	02	03	01	870	867	849
Silica....................	39.34	35.12	65.24	44.60	40.76	48.88	48.52	54.06	51.40
Iron and al. oxide	15.93	13·51	23.56	13.11	15.39	22.17	20.67	24.01	29.30
Lime.....................	14.76	16.46	0.00	11.47	12.83	6.65	6.63	.12	.15
Magnesia................	6.13	7.52	1.11	7.09	6.83	4.50	2.58	2.85	2.23
Loss on ignition.........	19.58	22.08	6.72	17.91	18.35	12.51	14.03	9.56	11.84
Difference (alkalies)....	4.26	5.31	3.37	5.82	5.04	5.29	7.57	9.40	*5.08
Totals...............	100.00	100.00	104.99	100.00	99.20	100.00	100.00	100.00	99.21

*Including .79 sulphur.

Lab. No. 904, field No. 1—04 is from Mills Lake, about half a mile below the outlet. The lime as carbonate would be 26.35 and the magnesia 12.86. The area is about 80 acres, the depth over 30 feet.

Lab. No. 905, field No. 2—05, from the same place, the lime carbonate 29.39, and the magnesia 14.78.

Lab. No. 906, field mark 06, from hole No. 11, on the Leinberger land, Frankenlust township, Bay County, Sec. 2, T. 13 N., R. 4 E.

The first two clays are like those analyzed by Doolittle, surface clays, about 40 per cent carbonates. Large quantities would have to be used of them, the amount of magnesia would be undesirably large, and it would probably be difficult to keep a uniform composition. The next is a regular coal measure shale clay, and would probably be a valuable paving brick clay, as well as suitable for cement.

Lab. No. 897, field No. 02, from Michigan Clay Co., Frankenlust township, Bay County, in the northeast part. This is a surface calcareous clay, properly called marl, the lime would be 20.48 as carbonate, and the magnesia 14.82, or over a third carbonates, and the remarks above upon surface clays apply.

Lab. No. 898, marked 03, is from the Williams Clay Co., just north, and is an entirely similar surface clay, with 22.91 per cent calcium carbonate and 14.30 per cent magnesia carbonate.

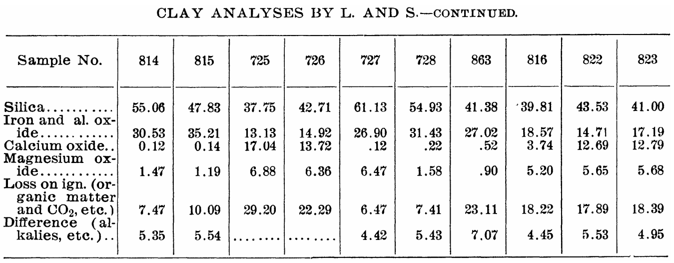
Lab. No. 887, marked 01, is from Everett's at Corunna, and is also a surface clay with a considerable amount of carbonates, although perhaps because it is farther from the outcrop of the Eocarboniferous Limestones, decidedly less, namely, 11.87 of calcium carbonate and 9.50 of magnesium carbonate. It is also said to have no sulphates, which is rather remarkable! It is probably derived largely and not very remotely from a coal measure shale clay, like the following analysis.

Lab. No. 870, also a Corunna clay, but with much less of carbonates, so much so, that it can hardly be a surface clay.

Both this and the previous analyses are remarkably high in iron and alumina, but Prof. Campbell of the University of Michigan got similar results for clays of this district, which are 15 to 20 feet thick, have little sand and occur on high ground directly over shale, to wit: about 48 per cent silica, 16 of alumina, and 5 of ferric oxide. In some cases of very fusible shale there was as much as 25 per cent alumina.

Lab. No. 867 is a clay from south of Tawas City, in Iosco County. The form of the analysis indicates that like the analyses of pp. 40 and 41, in Part 8, it is practically of a shale of the Michigan series. The high per cent of difference undetermined is probably sulphates (gypsum) as well as alkalies. There is, however, some uncertainty about this sample.

Lab. No. 849 is from a boring one mile north of Goetz farm, Sec. 36, Monitor township, Bay County, T. 14 N., R. 4 E. The lime is remarkably low in proportion to the magnesia. There is some pyrite (0.79 sulphur) and the large loss on ignition and large amount of alumina and iron are noteworthy. It should be readily fusible. This is not at all of the fire clay type.



CLAY ANALYSES BY L. AND S.—CONTINUED.

Sample No.	814	815	725	726	727	728	863	816	822	823
Silica...........	55.06	47.83	37.75	42.71	61.13	54.93	41.38	39.81	43.53	41.00
Iron and al. oxide............	30.53	35.21	13.13	14.92	26.90	31.43	27.02	18.57	14.71	17.19
Calcium oxide..	0.12	0.14	17.04	13.72	.12	.22	.52	3.74	12.69	12.79
Magnesium oxide............	1.47	1.19	6.88	6.36	6.47	1.58	.90	5.20	5.65	5.68
Loss on ign. (organic matter and CO_2, etc.)	7.47	10.09	29.20	22.29	6.47	7.41	23.11	18.22	17.89	18.39
Difference (alkalies, etc.)..	5.35	5.54	....	....	4.42	5.43	7.07	4.45	5.53	4.95

No. 814, St. Charles shale, No. 1, is a coal measure shale of the fusible variety.

No. 815, St. Charles shale, No. 2, is similar but even lower in silica. The lime, it will be noticed, is extremely low.

No. 725 is another surface clay with similarly high per cent of carbonates (30.46 calcium carbonate + 13.07 magnesium carbonate) and low silica.

No. 726 is a similar surface clay; it is from Sterling, not Standish, No. 2, S. W. Arenac County, not far off. Calcium as carbonate is 24.56 and magnesia 12.09.

No. 727 is a light shale from the Bay County coal field.

No. 728 is said to be a dark shale from the same field. The iron must contribute with the organic matter to the darker color.

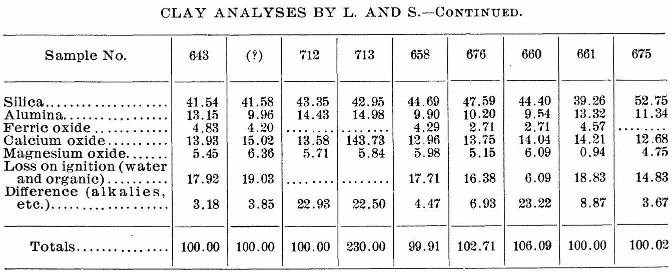
No. 863 is a shale from the Goetz land, Sec. 36, Monitor township, a coal measure shale. With the low amount of lime and magnesia characteristic of these shales, the large loss on ignition shows much organic matter (black shale), and it will be readily fusible.

No. 816 is from the Prairie farm, and I think the same deposit as No. 18 of Part I, though I cannot account for the discrepancy in silica. The lime as carbonate would be 24.38 and the magnesia 9.90,—about the usual 35 per cent carbonates of the surface clays.

No. 822 is a surface clay from Crapo Lake, T. 22 N., R. 2 E., an average of Section 9.

No. 823 is from the same locality, an average of Section 10.

The former has about 22.66 per cent calcium carbonate and 11.65 magnesium carbonate, and the latter has 22.83 per cent calcium carbonate and 11.70 magnesium carbonate, or as usual, about one-third carbonates.



CLAY ANALYSES BY L. AND S.—CONTINUED.

Sample No.	643	(?)	712	713	658	676	660	661	675
Silica	41.54	41.58	43.35	42.95	44.69	47.59	44.40	39.26	52.75
Alumina	13.15	9.96	14.43	14.98	9.90	10.20	9.54	13.32	11.34
Ferric oxide	4.83	4.20	....	....	4.29	2.71	2.71	4.57	....
Calcium oxide	13.93	15.02	13.58	143.73	12.96	13.75	14.04	14.21	12.68
Magnesium oxide	5.45	6.36	5.71	5.84	5.98	5.15	6.09	0.94	4.75
Loss on ignition (water and organic)	17.92	19.03	....	....	17.71	16.38	6.09	18.83	14.83
Difference (alkalies, etc.)	3.18	3.85	22.93	22.50	4.47	6.93	23.22	8.87	3.67
Totals	100.00	100.00	100.00	230.00	99.91	102.71	106.09	100.00	100.02

Lab. No. 643, clay 3—B, is a surface Bay County clay, with 24.87 calcium carbonate and 11.39 magnesia carbonate.

The next sample is similar, but has even more carbonates,—26.82 of calcium carbonate and 13.30 of magnesia, over 40% in all.

Lab. No. 712 is a clay from near George Lake, T 21 N., R. 1 E.,—also a surface clay with 24.25 calcium carbonate and 11.96 magnesium carbonate.

Lab. Nos. 658 and 676 are both near Edwards Lake in the same township, the former from a clay bed "directly at the outlet of the lake in Sections 25 and 27,—and has been found to cover a tract one half mile square, and is of good depth, though underlaid to some extent with sand and gravel." This has 23.14 calcium carbonate and 12.54 magnesium carbonate.

No. 676 comes from a deposit about one mile east and down the outlet stream, of over 40 acres area and over 20 feet depth. This has 24.57 calcium carbonate and 10.80 magnesium carbonate.

Lab. No. 660 comes from near Chapman Lake, Sec. 7, Clement township, Gladwin County, T. 20 N., R. 1 E.,—a bed "over 40 feet thick, explored for over half a mile." Here again we have 25.07 calcium carbonate and 12.78 magnesium carbonate.

Lab. No. 661 comes from Sec. e, near by and has 25.97 calcium carbonate and only 1.92 magnesium carbonate. This is the lowest in magnesia of any of the surface clays.

Lab. No. 675 is of a clay from Plummer Lake, "in direct conjunction with the marl at the east end of the lake, and runs down under the marl at the southern side. The clay deposit is covered with about three feet of surface earth and is 40 acres in extent," averaging eight feet in depth.

Taking the set all together, we see that these surface clays rarely run less than 35 per cent or over 45 per cent of carbonates, but that the amount of magnesia varies materially, though it is usually over a third of the carbonates.

The uncertainty as to whether the percentages will remain uniform through a deposit, and the difficulty in getting a satisfactory analysis from the resulting cement, are what make the surface clays not, except possibly in rare instances, to be recommended for the making of cement. All these clays will fuse readily.

12. The Great Northern Portland Cement Co.

Organized 1899, capital, $5,000,000, in 50,000 shares; there was $2,000,000 preferred stock bearing 7% interest, the balance common. In selling the preferred, a bonus of one-half share of common was given. Located at the company's village of Marlborough, two miles south of Baldwin, on the Pere Marquette R. R., Secs. 14 and 15, T. 17 N., R. 13 W., Lake County. They also own or control about 6,200 acres in the neighborhood, about 3,500 of them with bog lime, to wit: Sec. 13, T. 16 N., R. 13 W., lakes and lime; Sec. 15, and most of 21 and 10, T. 17 N., R. 12 W., also the N. ½ of the N. E. ¼, Sec. 18, surface clay, especially on 10, and marl; N. ½ of N. W. ¼ of Sec. 36; N. 14 of Sec. 34; Sec. 27; Sec. 14; E. ½ of Sec. 15 and part of Sec. 10 all in T. 17 N., R. 13 W. Also parts of sections 23, 26, 27, 34, 35, T. 18 N., R. 13 W.; Sec. 27 and parts of 26, 34, 35, T. 19 N., R. 13 W., all marl lands. There are in all some 17 lakes, generally with low shores, surrounded with a rim of marsh or tamarack growth underlain with marl. One of these lakes is said to have water from one to six feet deep with marl from 20 to 58 feet deep. In general the deposits are 18 to 20 feet deep.

The first unit, now nearly complete, to which one or two more may be added later, has a capacity of 4,000 barrels a day, with 24 rotaries.

The following is Booth, Garrett & Blair's report:

Great Northern Portland Cement Co.,

82 and 84 Griswold street, Detroit, Michigan.

Gentlemen:—

Following your visit to this city in September, we received in due course your letter of instructions to make a thorough investigation of your cement property in Lake County, Michigan, and agreeably therewith, our Mr. Whitfield made an extended examination of the property, taking a large number of samples, gauging and locating the deposits and establishing their quantity and accessibility. Since his return, we have made analyses of the samples selected, and have burned three lots of cement from suitable mixtures of these samples and subjected these cements to analyses and to numerous physical tests. All this data is now in your hands in a series of preliminary reports.

We are now prepared to render final report on the broad project which you have in view, to wit: the construction of a modern plant of large capacity for the manufacture of Portland cement, near Baldwin, and this report follows:

Raw materials.—Regardless of large tracts of land which you have since purchased, we find that the property examined by Mr. Whitfield contains deposits of raw materials suitable for high grade Portland cement, and in sufficient quantity to supply a large plant for many years. These raw materials are white shell marl and blue clay.

The clay "D," used by us so successfully in making cements, is found in immense quantities on Sec. 10, T. 17 N., R. 12 W. This locality is shown in relation to the marl tracts in the map attached to this report.

Cement.—An expression of opinion on the quality of raw materials for cement may in some cases be quite sufficient, but will never be so convincing to practical minds as an actual test. For this reason we have burned from your raw materials three successive lots of clinker with increasing percentages of lime, and have tested the cements with results as follows:

Samples.	No. 1.	No. 2.	No. 3.
Nominal lime content	64%	65%	66%
7 day tests of neat briquettes	660 lbs. 614 " 670 " 636 " 628 "	710 lbs. 790 " 672 " 820 " 890 "	930 lbs. 974 " 924 " 952 " 946 "
Average	641 lbs.	776 lbs.	945 lbs.
7 day tests, 1 cement to 3 sand	265 lbs. 282 " 270 " 262 " 250 "	396 lbs. 370 " 370 " 410 " 350 "	460 lbs. 424 " 432 " 448 " 420 "
Average	266 lbs.	379 lbs.	437 lbs.

Samples.	No. 1.	No. 2.	No. 3.
Nominal lime content	64%	65%	66%
Specific gravity	3 03	3.04	3.08
Initial set	1°50′	2°10′	1°25′
Final set	3°40′	4°40′	4°0′

ANALYSIS.

Silica	24.01%	24.84%	23.87%
Alumina	5.51%	4.51%	4.82%
Iron oxide	2.38%	1.74%	2.30%
Lime	63.91%	65.69%	66.01%
Magnesia	3.40%	3.10%	3.03%

28 day tests were made from lot No. 1 with results as follows:

	Neat.	1 cement to 3 sand.
28 day tests, sample No. 1	952 lbs. 918 " 980 "	470 lbs. 450 " 486 "
Average	950 lbs.	469 lbs.

Very truly yours,
BOOTH, GARRETT & BLAIR.

The clay bank in Sec. 10, T. 17 N., R. 12 W., covers some 400 acres. From the amount of magnesia in the finished cement, it would seem that there is as usual, some six or seven per cent of magnesia in the clay, though I have seen no series of analyses of it. This rises as a hill of clay, a bit of glacial deposit, some 90 to 150 feet high, in the midst of prevailing sand and gravel. It is said to be free from grit. Gravel for concrete was found in the excavations for the plant.

In the beginning, the lime of North Lake, right by the mill, will be used, and the clay shoveled by steam shovel and transported in special cars, and the marl in scows.

Prof. R. C. Carpenter reports in part, as follows:

"I find that the marl exists as is represented, and is found in a great number of lakes and surrounding marshes, occurring to a depth varying from 20 to 70 feet. The marl in every case is of excellent quality and free from any material which would interfere in the manufacture of cement. The clay deposit is located a short distance from the center of the marl deposits and the site of the works. The clay has been thoroughly tested by reputable chemists, and is found to possess all desirable qualities required, both as shown by analysis and by actual trial in the manufacture of cement. The clay deposit is of almost unlimited magnitude and would supply the plant for more than a century, even when working on a scale of 12,000 barrels per day. The examinations of the deposit have convinced me that the materials are all that has been claimed, both as to quality and quantity."

13. Detroit Portland Cement Co.

Organized March 7, 1900. Capital, $1,000,000. From the Fenton Independent of March 31, 1900, comes the following item (see Plate XXI and Fig. 28):

Deals for marl land on which the Becker Bros, hold options in Fenton township are being closed up. The lands embrace the marl on 110 acres of the McKugh farm at Mud and Silver Lakes, and the marl on 74 acres on the Beals farm at Silver Lake, and the marl on 89 acres on the Latourette farm on Mud Lake. Only the marl rights are purchased, the price paid Beals being $2,500, and the price paid Latourette being $800. The marl rights to 30 acres of the Tunison farm at Silver Lake were purchased for $900.

This factory is built on the line of the Grand Trunk. It is to be an eight rotary plant, with provision for enlargement (compare Plate V). The plant is designed by Lathbury & Spackman, and illustrated in their work, "Engineering Practice," already referred to so often. Their description is as follows:

The plant of this company, located at Fenton, Michigan, is now nearing completion. The mill is designed to manufacture Portland cement from a mixture of marl and clay by the wet process, and possesses some distinctive features not embodied in the marl plants heretofore erected.

The buildings substantially constructed of brick and steel, are fire-proof, and so designed that the material in process of manufacture will move in one direction from the time the raw materials are brought in at one end, until the cement is shipped out from the packing house at the farther end. All the buildings have clear spans. The mill is located on a slight elevation overlooking the large marl deposits of Mud and Silver Lakes, owned by the company. The clay is obtained from pits a few miles distant from the plant. The marl is dredged from the lakes and loaded into cars of two cubic yards capacity which run on a track along the edge of the lake. The cars are then drawn by cable hoist up an inclined trestle into the mill and dumped into the hopper over the stone separator. The clay is brought into the plant by rail. The two ingredients after passing through separate preliminary preparation are mixed together in the proper proportions and ground in tube mills. Large concrete storage pits contain the marl and clay before mixing, and similar pits are provided for the mix and ground slurry. It has heretofore been the practice to pass the clay through some suitable dryer, then after it has been ground to an impalpable powder, to mix this powdered clay with the marl. In this plant, however, the clay is unloaded directly from the cars into a disintegrator, from which it discharges into a pugging conveyor which carries it to a wash mill, where it is reduced to a thin sludge.

The marl passes, first, through a stone separator which reduces it to a smooth plastic state and removes any roots, grass or stones which may have been brought up by the dredge bucket. It is then stored in the marl pits. Each pit is provided with an agitator to prevent settling. The marl and clay are pumped to the mixing pits in proper proportions and thoroughly agitated. From these pits the raw mix is pumped to iron tanks above the tube mills, from which it is fed to the mills by gravity. After being ground in the tube mills, the slurry is discharged into concrete storage pits which supply the kilns, the slurry being pumped to a stand pipe from which it is fed at a constant pressure directly into the kilns. After passing through the kilns, of which there are eight, the clinker falls into air-tight, self-emptying concrete cooling vaults, located below the kiln room floor and directly under the discharge from the kilns, two vaults being provided for each kiln; the Lathbury & Spackman patent regenerative clinker cooling apparatus being used. Cold air is drawn in through openings in the bottom of these vaults, and passing upward through the clinker cools it. The hot air being exhausted from the top is forced into kilns mixed with pulverized coal, thus utilizing the heat contained in the clinker for burning. The clinker is drawn out at the bottom of the vaults into cars which run on tracks located in the tunnel below the clinker cooling vaults. These cars are run out of the tunnels and raised by an electric lift to the level of the top of the bins feeding the clinker ball mills, and the clinker is discharged from the cars into these bins. After passing through the ball mills, the partially ground clinker is elevated and conveyed to the bins supplying the tube mills. From these mills it is elevated and conveyed to the stock house and distributed in the bins. The stock house is equipped with Lathbury & Spackman self-discharging bins, described elsewhere in detail.

Conveyors in the tunnels of the stock house carry the cement to the packing room, located at the extreme end of the building, and deliver it to the bins over the packing machine. The packing department, fully equipped with both barrel and bag packing machinery, has a capacity of 1,500 barrels of cement per day.

The power house, located close to the main building, is equipped with four 200-horse power vertical water tube boilers. Two 500 horse power compound condensing engines, direct connected to two 300 K. W. direct current generators are located in the engine room. An auxiliary 150 K. W. direct connected dynamo and engine is provided to furnish current for lighting and power when the plant is operating under light loads. The power plant is completely equipped with the usual accessories, such as switchboards, pumps, condensers, etc., and special attention has been paid to securing economy in the generating of power. The entire plant is electrically driven, the motors being distributed throughout the plant, each machine being belted direct to its own motor.

ANALYSIS OF THE CLAY AND THE MARL.

	Marl.	Clay.
Silica, SiO_2	.96	54.70
Alumina, Al_2O_3	.44	18 80
Iron, Fe_2O_3		
Lime, CaO	52.43	7.17
Magnesia, MgO	1.66	3.87
Carbon Ioxide, CO_2	42.99	9.80
Difference	1.52	.96
Total	100.00	100.00

14. Egyptian Portland Cement Co.

Organized June 30, 1900. Capital, $1,050,000, in $10 shares. Also bonds, $350,000. The officers are, George A. Foster, president; J. Fletcher Williams, vice president and general manager; C. B. Shotwell, secretary, and E. D. Kennedy, treasurer.

The factories are at Fenton and Holly. Robert W. Hunt & Co., are engineers and W. H. Hess, chemist.

We reprint many of the careful surveys which were made of the company's lime lakes. One (Plate XXI) is of Silver Lake, the Fenton property, and another, (Fig. 21) is Raffelee Lake, the Holly property of the same company.

In Plate XXI the bluffs which mark the original margin of the lake are shown as in Fig. 13, and if we compare the outline of the lake with that shown in the county atlases from the original land office surveys, we find it entirely different. Apparently a good deal of this is due to the filling up of the lake by the deposits of boglime, isolating "daughter lakes," as Davis has described them, from Littlefield Lake. It is possible, however, that a change of lake level may also have been an important factor. Finally, but not least important, the surveyors in meandering these marsh bordered lakes, which are often full of rushes, find it very difficult to determine where marsh ends and lake begins. We also reproduce reductions of careful surveys of Runyan Lake, Sections 9 and 10, T. 4 N., R. 6 E. (Fig. 22), and of Mud Lake, just north of Silver (Fig. 23).

Also of lakes on sections 27, 28 and 30 and 29 of Holly township (Figs. 24 and 25).

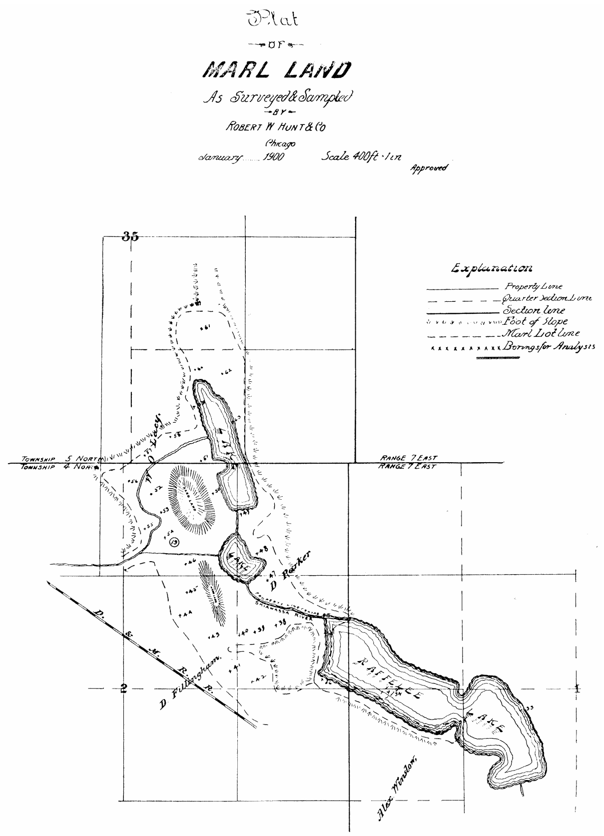


Figure 21. Plat of Raffelee Lake, Holly Township, Oakland Co.

There is peat in connection with these deposits "partially overlying and directly contiguous, which it has been proposed to use as fuel, though it is not at present seriously planned. The coal and very probably the shale will come from the neighborhood of Corunna, The Grand Trunk and the Pere Marquette system cross at Holly.

A resurvey after some years, of such of these properties as may not have been seriously touched, will give important light on the growth of the deposits. Extracts from the prospectus, Robert W. Hunt & Co.'s report, are as follows:

Report dated Jan. 30, 1900.

We beg to submit the following report in full on the survey and investigation of the marl lands situated near the cities of Fenton and Holly, Michigan.

The marl land surveyed and sampled consisted of four separate deposits. The first and largest, is in the southeast corner of Genesee County, two miles west of the town of Fenton, and extends south into the northern part of Livingston county (Plate XXI).

The second is in Oakland County, two miles east of Fenton, and about midway between Fenton and Holly.

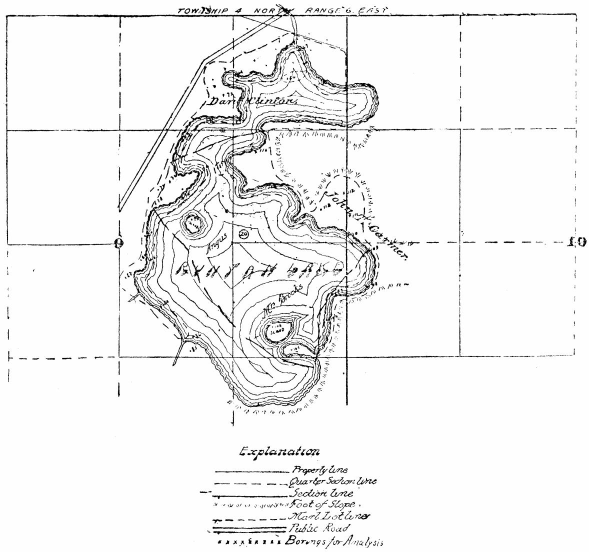


Figure 22. Runyan Lake. T. 4 N., R. 6 E., near Fenton.

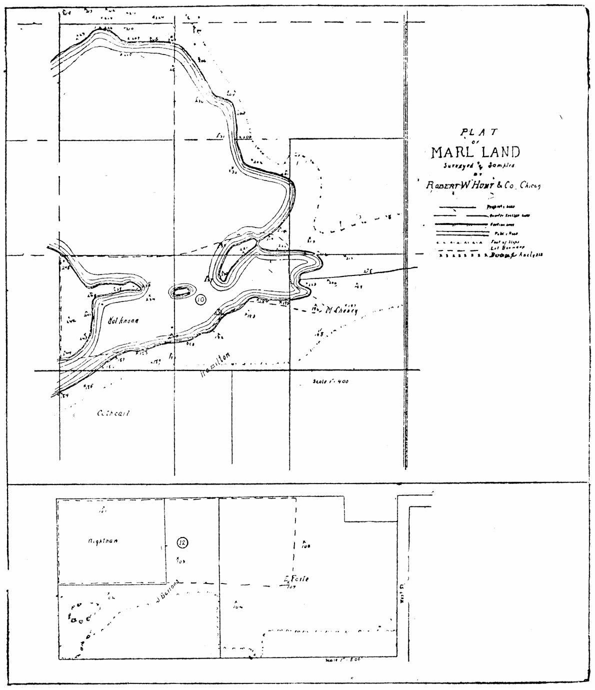


Figure 23. Mud Lake. Sec. 22, T. 5 N., R. 6 E.

The third deposit is in and north of the town of Holly.

The fourth deposit is about two miles southeast of Holly on Raffelee Lake (Fig. 21).

The first tract consists of Runyan Lake (Fig. 22), Marl Lake, Upper and Lower Silver Lake, a part of Mud Lake (Fig. 23), Squaw Lake, and the low swamp land contiguous to these lakes, together with a strip of land in the town of Fenton. As a rule the hills surrounding these lakes are high and steep, and the slope of the marl deposit is quite abrupt, which latter is also true of the lake bottoms. Many bars of marl, covered with only a few inches of water, extend into the lakes, but just off these bars the water is deep.

The second tract (Fig. 24) consists of marsh land around Warren Lake and several small ponds near by, Dickson Lake and the two Mineral Lakes. The hills around these are also high and steep and the shores are abrupt.

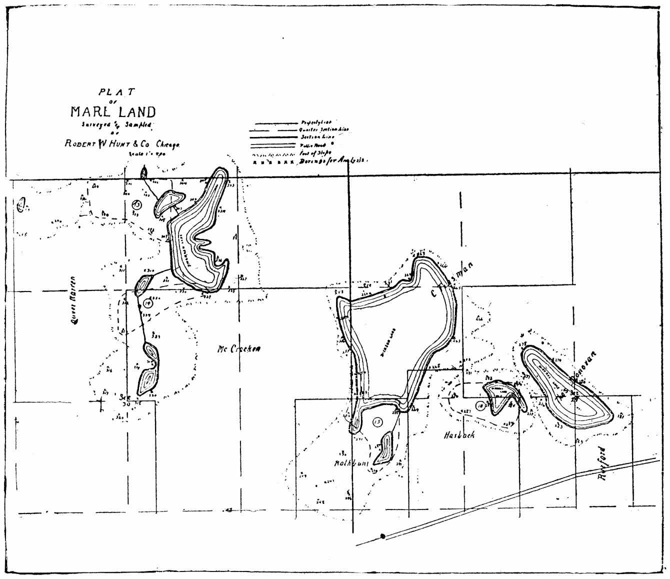


Figure 24. Warren, Dickson, Mineral and adjacent lakes and marl beds. Sections 29 and 30, T. 5 N., R. 7 E.

The third tract (Fig. 25) is in and around Bevin Lake and Bush Lake. There are no hills around these lakes, and the marl deposit is shelving, and the shores are not abrupt. A large part of Bush Lake is only a few feet deep. There is no tamarack or underbrush.

The fourth tract is along the south edge and west end of Raffelee Lake, including the swamp lands just west and northwest of Raffelee. Part of this swamp land is heavily timbered, and the average stripping is about two feet.

The first tract is cut by three highways and the Detroit, Grand Haven & Milwaukee railroad track, together with the public road which lies between Silver and Mud Lakes. Another road is just south of Silver Lake, and still another south of Marl Lake.

There are no public highways crossing the second tract, but the main highway between Fenton and Holly runs very close to it.

Between Bevin and Bush Lakes are the tracks of the Pere Marquette railroad, a public highway and some meadow land.

The Detroit, Grand Haven & Milwaukee railway runs alongside of Raffelee Lake. There are no highways crossing this tract, but it will probably be easy to secure one on the section line.

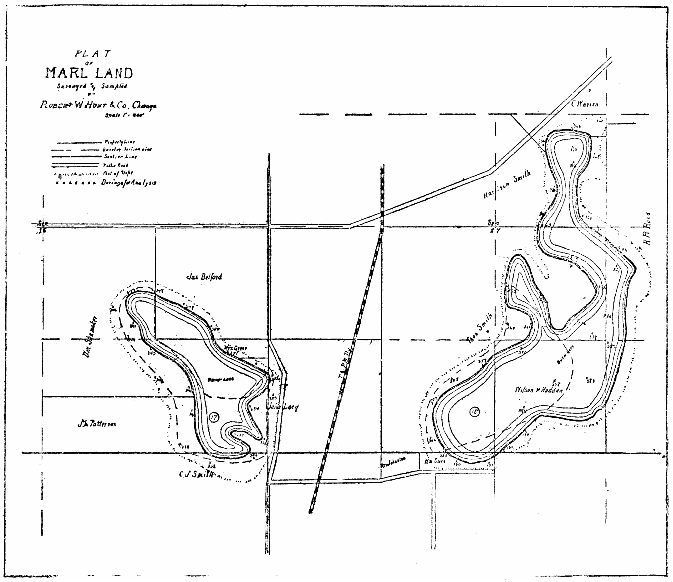


Figure 25. Bush Lake, Sec. 27, T. 5 N., R. 7 E, and adjacent marl beds nea Holly.

The maps which we send you will show the location of these different tracts. There are eight detail maps, which show all lands surveyed and sampled, except where the results were not good enough to justify mapping the properties out. These maps show location of property, name of original owner, and location of test holes from which marl samples were taken. The numbering of these test holes is the same as the sample numbers in the complete analysis.

In determining the extent of the deposits, about four hundred additional test holes were sunk, from which no samples were taken.

The following statement shows total acreage:

Examined.	Sampled and Mapped.
Tract No. 1	976.0 acres
Tract No. 2	190.6 acres
Tract No. 3	163.6 acres
Tract No. 4	239.5 acres
	1569.7 acres

Considering the results obtained from the chemical analysis of the marl, lots or deposits of marl have been located wherein the marl, as shown by the analysis, is of such composition as is required to make good cement.

The total amount of marl in the foregoing lots, upon which we report favorably, is 14,350,720 cubic yards, which is enough to manufacture about 28,700,000 barrels of cement.

The following tables show the maximum, minimum, and average determination of the samples from the accepted lots, together with the average depth of marl, quantity of stripping, and quantity of marl in each lot.

	Lot 1.	Lot 3.	Lot 5.	Lot 6.	Lot 7.	Lot 8.	Lot 9.	Lot 10.	Lot 11.
Calcium carbonate.									
Average	89.717	89.03	90.31	87.92	89.633	87.57	88.57	91.045	84.51
Range	92.19 85.19	95.00 85.71	94.64 85.89	92.86 83.75	92.1 86.61	90.71 80.89	92.86 83.57	93.39 87.14	92.86 78.21
Magnesium carbonate.									
Average	3.408	34.303	3.072	3.16	3.902	3.84	3.276	3.213	3.60
Range	4.76 1.97	3.74 2.82	3.65 2.62	3.48 2.66	4.35 2.70	4.27 3.57	3.69 2.82	4.16 2.57	4.54 3.18
Iron and Alumina.									
Average	.895	1.008	.765	.828	1 049	.92	1.22	....	1.035
Range	3.66 2.24	1.24 .82	1.46 .30	1.18 .58	2.72 .56	2.00 .54	1.44 1.04	3.34 .70	1.54 .70
Silica.									
Average	.708	.994	.959	1.415	.966	1.411	2.926	1.269	2.014
Range	1.20 .24	1.62 .40	2.82 .48	1.96 .72	1.92 .64	2.54 .84	5.44 1.28	1.76 .76	3.02 .70
Average depth feet	22 6 ft.	13.6 ft.	16.9 ft.	23.4	13.	11.8	16.4	21.3	20.
Stripping cu. yds.	153,920	70,340	77,280	4,000	7,600	61,380	None.	43,300	54,710
Lime cu. yds.	1,879,260	183,780	849,600	880,420	1,280,340	533,300	511,200	639,620	812,300

	Lot 12.	Lot 13.	Lot 14.	Lot 15.	Lot 16.	Lot 17.	Lot 18.	Lot 19.	Lot 20.
Calcium carbonate.									
Average	88.48	86.54	83.976	....	85.266	84.686	85.342	89.586	89.82
Range	90.71 86.79	88.13 85.20	88.14 79.48	89 75 86.73	87.00 82.43	85.47 83.24	88.09 82.34	92.99 84.40	92.18 86.63
Magnesium carbonate.									
Average	3.13	3.39	2.676	2.660	3.440	3.546	3.765	3.038	3.23
Range	3.63 2.24	3.82 3.02	3.56 1.66	4.088 .50	3.90 3.64	4.22 3.14	4.34 3.25	3.85 2.07	3.99 2.56
Iron and Alumina.									
Average	.57	1.38	1.446	1.046	2 57	1.992	.860	.93	1.57
Range	.78 .16	2.48 .90	2.30 1.00	1.42 .34	4.54 .84	3.84 .54	1.50 .40	1.86 .04	3.12 .58
Silica.									
Average	1 000	1.760	1.29	.97	1.695	2.44	1.924	0.88	1.60
Range	1.54 .68	2.94 .98	1.59 1.04	1.48 .54	2.38 1.01	3.22 1.18	2.44 1.08	2.06 .22	3.04 .28
Average depth	15.	11.8	17.	18.2	11.	11.8	12.5	27.	15.
Stripping cu. yds.	75,000	47,780	32,980	3,890	32,750	4,360	None	330,000	51,000
Lime cu. yds.	365,100	225,500	195,060	176,550	105,930	285,830	325,460	4,513,250	588,220

Total stripping cu. yards, 999,290. Total lime cu. yards, 14,350,720.

The best locations for cement plants are upon the Grand Trunk railway, between Silver and Mud Lakes at Fenton, and upon the same road at Raffelee Lake, just east of Holly. At the latter point the Pere Marquette system would doubtless be glad to build a switch into the plant, giving it the benefit of junction point rates, which could probably be extended to include the Fenton plant as well.

From the chemical analysis of marl, its desirability for the manufacture of cement is determined. The analysis also gives data for determining the amount of clay that should be mixed in order to give good results. A large percentage of silica is not desirable, but four to five per cent is not prohibitive, providing it does not vary to too great an extent. The amount of iron and alumina oxide that is detrimental depends upon the analysis of clay with which the marl is to be mixed. The magnesium carbonate should not be over four to five per cent, which, of course, will be reduced in the finished cement between two and three per cent.

If the amounts of silica, iron and alumina, and magnesia in a body of marl are small, a comparatively large variation in the calcium carbonate can be allowed, because its percentage will vary almost directly as the amount of organic matter.

We would respectfully recommend that all material possible be conveyed by mechanical means, and that the labor account be reduced as low as possible.

(Signed) ROBT. W. HUNT & CO.

Lansing, October 1, 1900.

Egyptian Portland Cement Company,
Detroit, Michigan.

Gentlemen—I beg leave to make the following report of tests of cement made from clay and marl received from you from Fenton, Michigan:

FINENESS.

Passing No. 50 mesh sieve	100%
Passing No. 100 mesh sieve	98

SETTING TIME OF NEAT CEMENT.

Initial set	2 hrs. 10 min.
Final set	4 hrs. 40 min.

CONSTANCY OF VOLUME TESTS.

Cold water pats	Sound and hard.
Boiling water pats	Sound and hard.

TENSILE TESTS OF STANDARD NEAT BRIQUETTES.

(1 square inch section.)

Serial No.	Hardening Period.			Neat Briquettes.	Sand Briquettes, 1:3.
	In Air.	In Water.	Total Days.	Strength in lbs.	Strength in lbs.
1165	1	0	1	270	50
1165	1	1	2	440	82
1165	1	2	3	545	135
1165	1	3	4	610	168
1165	1	4	5	680	190
1165	1	5	6	755	212
1165	1	6	7	815	246
Government Standard	....	....	....	400	160

Very respectfully,
(Signed) R. E. DOOLITTLE,
Chemist.

Lansing, Michigan, Oct. 1, 1900.

Egyptian Portland Cement Company,
Detroit, Michigan.

Gentlemen—I have been investigating the peat question, and submit for your information the following table:

	Carbon.	Hydrogen.	Oxygen.	Calorific or heat unit value.	Capacity of high heat, or calorific intensity Centigrade.
Wood	50.18	6.08	43.74	4212	2380°
Peat	61.53	5.64	32.82	5654	2547°
Lignite coal	67.86	5.75	23.39	6569	2628°
Bituminous coal	79.38	5.34	13.01	7544	2694°
Charcoal	90.44	2.91	6.63	8003	2760°
Anthracite	91.86	3.33	3.02	8337	2779°
Coke	97.34	0.49	....	8009	2761°

In examining this table, note the column designated "Calorific Intensity," and notice you can get as high heat with peat as you can with bituminous coal, lacking 150 degrees Centigrade, and the conclusion is therefore warranted that you can burn Portland cement with dried peat as rotary fuel. It would not cost over twenty cents per ton to prepare peat for rotary work, using waste heat as a drier. The grinding would be very easy.

Yours truly,
(Signed) W. H. HESS,
Chemist.

Twentieth Century Portland Cement Company.

Organized March 2, 1901. Capital, $750,000.00. Office at Fenton and plant about four miles from the village, and stock said to be mainly held there. It is said that marl options are held on Runyan Lake, mainly in Sec. 9 (see Fig. 23), and elsewhere, amounting to 526 acres, and 9,500,000 cubic yards. This is not a very large supply and so far as I know, this and the following companies and locations referred to are not very near production.

Zenith Portland Cement Company.

Organized July 17, 1900. Capital $700,000. Bonds $300,000. The board of directors were Marshall H. Godfrey, B. H. Rothwell, G. Johnston, E. T. Allen, Stowe, Fuller & Co., E. H. Evans, E. J. Foster.

The following are extracts from reports of engineers: Extract from prospectus of the Zenith Portland Cement Co.:

I have spent six months in Michigan in the examination of marl deposits, and have no hesitancy in stating that the Grass and Tims Lake deposits are far superior, both in quality and quantity, to any deposit I have examined. I estimate that there is enough marl in this deposit to make 30,000,000 barrels of high grade Portland cement, or enough to supply a factory of 1,000 barrels per day for over 100 years.

The banks of this phenomenal deposit are adjacent to the M. C. R. R., and well adapted by nature for a solid foundation and favorable location of the plant. Close at hand is found a very fine deposit of clay, which was originally used in the manufacture of brick, but will now be used in the manufacture of cement.

Having both of these raw materials so close at hand, a high grade cement can be made here cheaper than any other place I know of.

T. C. BEEBE, C. E.

Cleveland, Ohio, July 23, 1900.

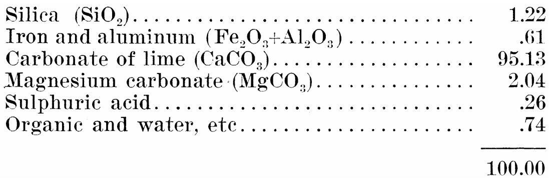
The Zenith Portland Cement Co.,
Detroit, Michigan.

Gentlemen—In answer to your letter of inquiry in regard to the marl bed at Grass Lake, Michigan, I would say that I have twice made an examination of this bed, and have had thorough analysis made from different sections. I have been over most of the marl beds in Michigan, and consider the Grass Lake bed equal in quantity of any in the State. As to chemical analysis, it runs about the same as the Brownson and Coldwater beds, but has the advantage of being much finer in texture. Ninety-eight per cent of this marl in its natural state will pass 20,000 mesh sieve, leaving only a very small residue, which is mostly organic matter, and will burn out in the rotaries. This fineness would save considerable wet grinding machinery. This marl is finer in its texture naturally, than any marl I know of now being used, even after grinding. This would insure a very fine mixture, and the very highest grade of Portland cement, as fineness of mix is one of the most important items in the manufacture. The marl bed itself is nearer the railroad than any I know of in the State. It needs no stripping, which will save much expense in handling. A factory can be located at this point to handle material both to and from the factory, of fine grade and cheaper than any place in this country.

Yours very truly,
C. B. STOWE.

The analysis of the Grass Lake clay is entirely satisfactory and the quantity is abundant.

Our marl has been repeatedly and carefully analyzed, and following results were universally obtained:



Silica (SiO_2)	1.22
Iron and aluminum (Fe_2O_3+Al_2O_3)	.61
Carbonate of lime ($CaCO_3$)	95.13
Magnesium carbonate ($MgCO_3$)	2.04
Sulphuric acid	.26
Organic and water, etc	.74
	100.00

It has a residue of less than two per cent on a sieve of 40,000 meshes to the square inch, thereby saving considerable expense in grinding the raw material; and as there is no muck or organic matter overlaying it, it can be excavated and conveyed to the works at a minimum cost.

The company's property virtually includes all of both Grass and Tims Lake, on which the original owners guarantee an average depth of 20 feet of marl on 400 acres. On this basis Grass Lake alone contains enough marl to supply a factory of 1,000 barrels per day capacity for 75 years, and Tims Lake enough more to supply the same demand 37 years. This marl requires no stripping. There is ample water to float our dredges, on each of which will be placed a pug mill.

The marl beds of this company lie in Sections 20, 29 and 30 of Grass Lake township, T. 2 S., R. 2 E. (Fig. 26), on the east side of Jackson County. Portage Lake and other lakes of this region are said to contain some marl, but this bed has the advantage of being close to the Michigan Central railroad, so that but a few hundred feet of siding will be necessary. At first, in the prospectus, the factory site was placed at the point marked A in the map, but now the foundations are at the point marked B.

Grass Lake is prevailingly shallow. The deeper holes do not appear to be over five to ten feet deep, and large areas are less than three feet deep. Over most of the lake bulrushes (*Scirpus lacustris*) are growing more or less scattered. In a general way they are most thinly scattered over the deeper holes, and these are points where the marl is covered by most water and appears to have most organic matter. On the figure their distribution, i. e., that of the marl which comes close to the surface and appears to be better is indicated. When the marl surface comes within a foot or so of the surface, Sagittaria and other plants join and soon the marl becomes covered with a peaty layer extending over the marl, ending abruptly in a vertical wall a foot or two high. Between localities 10 and 14 extends a tamarack swamp. At 14 good yellow marl is found beneath four feet of muck and sand, and at 10, which was at the inside edge of the belt of rushes and pond lilies, and at the beginning of that of tussocks, ferns, and ordinary swamp vegetation, there was marl close to the surface and over eight feet deep, so that the point 25 feet high with steep gravel banks, and shores terraced on the west side, which cuts off the northernmost bay of Grass Lake was once an island but is now joined to the shore on the east by this marl bottomed tamarack swamp.

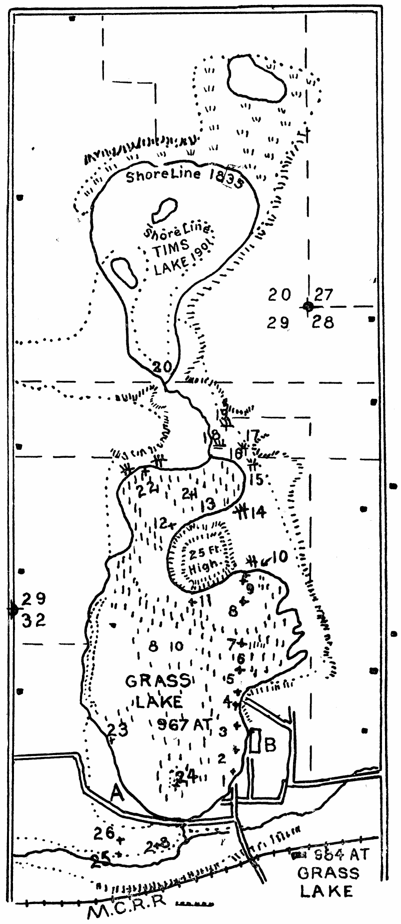


Figure 26. Sketch of Grass Lake, T. 2 S., R. 2 E. Property of Zenith Portland Cement Company. The numbers are references to tables of soundings, not of depths.

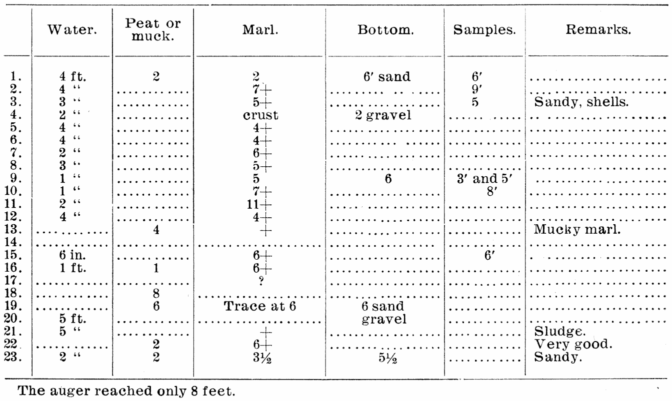
A similar marginal bog, a hundred feet wide, Soundings 15, 16, 17, and 18, lines the north shore, covering marl which is quite thick, but it does not extend up to Tims Lake, as might seem probable from the connecting marsh, and sluggish stream which joins the lakes, because at 18 there is eight feet of peat, and at 19 there is only a trace of marl under the peat at six feet,—below which is sand.

The marl is quite extensively covered with the creeping vine-like stems of Chara, which are brittle with coats of lime. The deeper holes are more likely to be covered with a darker green plant (Potamogeton).

The west shore is sandy or gravelly where dotted on the map. The land rises gently and the lake bottom is not marly. The water along the edge made a suds, showing an abundance of organic matter. In general the water of the lake seemed full of organic matter and was green rather than blue. Shells did not appear remarkably abundant on the marl beds. On the east side of the lake a point projects with steep bluffs, near which the marl appears to be thinner, poorer and mixed with sand (soundings 1 to 4), and it is said that a shoal streak extends across the lake. North of this point the lake deepens to four feet of water, then rises to a heavy bed of marl (sounding 7), then deepens very slightly.

It is not at all likely that this lake was originally abnormally shallow, and there is every indication that its present shoal character is due to its being filled up with lime, mainly deposited by the Chara growth from variable depths,—over a large part of the lake doubtless over 13 feet deep. There are about 560 acres of marl or more.

The following is a tabulation of the results of the soundings:



	Water.	Peat or muck.	Marl.	Bottom.	Samples.	Remarks.
1.	4 ft.	2	2	6′ sand	6′	....
2.	4 “	....	7+	....	9′	....
3.	3 “	....	5+	....	5	Sandy, shells.
4.	2 “	....	crust	2 gravel	....	....
5.	4 “	....	4+	....	....	....
6.	4 “	....	4+	....	....	....
7.	2 “	....	6+	....	....	....
8.	3 “	....	5+	....	....	....
9.	1 “	....	5	6	3′ and 5′	....
10.	1 “	....	7+	....	8′	....
11.	2 “	....	11+	....	....	....
12.	4 “	....	4+	....	....	....
13.	....	4	+	....	....	Mucky marl.
14.	....	....	....	....	....	....
15.	6 in.	....	6+	....	6′	....
16.	1 ft.	1	6+	....	....	....
17.	....	....	?	....	....	....
18.	....	8	....	....	....	....
19.	....	6	Trace at 6	6 sand gravel	....	....
20.	5 ft.	....	....		....	....
21.	5 “	....	+	....	....	Sludge.
22.	....	2	6+	....	....	Very good.
23.	2 “	2	3½	5½	....	Sandy.

The auger reached only 8 feet.

In Tims Lake (we had no boat there), the marshes surrounding the lake seemed very extensive and it appeared as though they connected the islands shown,—in fact the shores appeared somewhat like the dotted line of Fig. 26.

The general aspect of the lake, however, is like that of Grass Lake.

The temperature of the marl sample at eight feet at sounding 10 was 58°, while the water a foot or less deep was 71° F. and the air 83° F. At sounding 22 the temperature of the marl sample at eight feet was 66° F. During the day the water temperature warmed up from 79° to 83°. No material difference could be noted in the water at the surface and five or ten feet deep, for there was a fair southwest breeze.

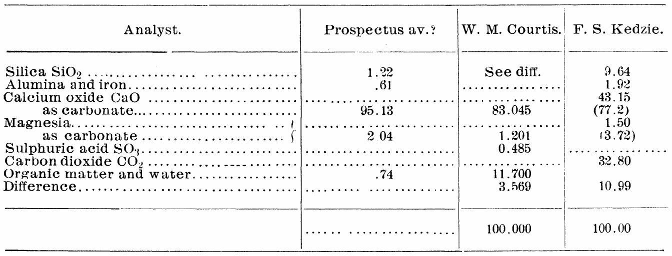
It is said that the company have clay lands in Ohio. There are brick clay pits to the south of this lake in the village of Grass Lake, and in the flat immediately adjoining the lake to the south, soundings 25 to 28, there are some smooth pebbleless clays, an analysis of a sample of which is given below, from the grass roots down, though in sounding 25 at six to seven feet down, a streak of very fine-grained quicksand was found.

The clay at the lake is the ordinary surface calcareous clay of Lower Michigan, the finer part of a rock flour derived from almost all kinds of rocks settled by itself, and its availability for Portland cement manufacture on a large scale is rather doubtful. For example, it is doubtful whether it will remain of the composition shown by analysis. The surface, where soundings 25 to 28 were, is less than eight feet above the lake.

The analysis of the marl cited in the prospectus is given in column (1). An analysis by W. M. Courtis of Detroit, is given in column (2), and one by Prof. F. B. Kedzie in column (3).

No. (1) is evidently of a sample of dried marl, and I think that more or less organic matter must have been removed with the water.

No. (2) is of a sample dried at 100° C. and only 42.11% of the original sample.



Analyst.	Prospectus av.?	W. M. Courtis.	F. S. Kedzie.
Silica SiO_2	1.22	See diff.	9.64
Alumina and iron	.61		1.92
Calcium oxide CaO			43.15
as carbonate	95.13	83.045	(77.2)
Magnesia			1.50
as carbonate	2.04	1.201	(3.72)
Sulphuric acid SO_3		0.485	
Carbon dioxide CO_2			32.80
Organic matter and water	.74	11.700	
Difference		3.569	10.99
		100.000	100.00

The character of the deposit is distinctly that of Chara lime and it will be noticed in analysis No. 2 that there is but 32.80% of CO_2 whereas to turn the calcium and magnesium oxides into carbonates 36.27% would be needed, so that probably quite a little of the lime is united either with sulphuric, or more likely an organic (succinic) acid.

The supply of marl is said to be equivalent to 400 acres 20 feet deep. As we could not sound over 13 feet, we have no means of checking the statement exactly. There is certainly a large supply of marl over most of which no stripping will be necessary.

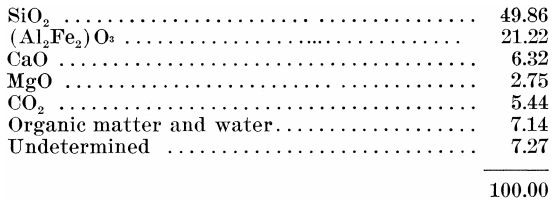
The plan is to dredge the marl, and transport by a lakeside entrance to the factory, and pump out. The plan is to have a rotary pump of the latest design and the cost is figured not to exceed 80 cents per barrel.

The prospectus figures selling price at $1.40 a barrel, which was probably right then, but later, September, 1901, cement was delivered in Lansing at from $1.40 to $1.50 per barrel, and even at times perhaps $1.25 for new brands, and I am told that it has been sold in Michigan f. o. b. at factory at 90 cents to $1.00. Cement advanced, however, during the printing of this report, to over $2.00.

The prospectus also says that "coal for power can be obtained in abundance within ten miles of the plant." There is very likely some coal at that distance, but hardly an abundant supply.

An analysis by Prof. F. S. Kedzie of an average marl from locations 5, 7, 9,15, 16, at 8, 6, 3 and 5, 6 and 8 feet, respectively, is given in column (3).

His analysis of the apparently best sample of clay at the south end of the lake, location 28 at eight feet depth, is as follows:



SiO_2	49.86
$(Al_2Fe_2)O_3$	21.22
CaO	6.32
MgO	2.75
CO_2	5.44
Organic matter and water	7.14
Undetermined	7.27
	100.00

Carbonates are unusually low for a surface clay, which is a good point, but the alumina is high.

Standard Portland Cement Co.

Organized November 15, 1900. Capital $1,000,000. Office at Detroit.

This company will develop the lime which exists in Zukey and adjacent lakes, at Lakelands, where the Ann Arbor R. R. and the Air Line of the Grand Trunk R. R. cross. Prof. I. C. Russell was employed to test the marl beds, but some time before I made a cursory examination. His report was published,—in part,—in the prospectus.

Referring to the map, Fig. 27, we see a group of lakes, which evidently were once much more continuous, and have been separated by marsh growth, while the 15 to 20-foot bluffs which mark the original borders of the lakes are plain. Zukey Lake was the one which I studied myself more carefully. The west side is lined with a thick and pure bed of bog lime which is capped by a growth of marsh plants and peat, a foot or two thick and coming up to the lake in a perpendicular wall. The marl bed projects out white beneath, and upon it there is Chara, and occasionally dead shells of Unio, etc., and twigs are heavily coated with lime. The north part of the lake has a sandy shore and the bluffs are of gravel, and the shells are not so coated. On the southeast side of the lake the marl seems to be covered with pebbles, brown above and green below, which prove, however, to be Schizothrix concretions.

The cuts through by the marl bottomed Bound Lake to Strawberry Lake are artificial, through a marsh covering a bed of boglime. In Strawberry Lake itself, which is merely an enlargement of Huron River, the lime does not seem to be so continuous, in this lake however, at the place which I have called Blind Island, is an atoll-like formation which is significant of the origin of the lime in general. There is a small, nearly circular area of uniformly shallow water, beneath which is boglime, around the margin of which there is a mat of vegetation of rushes and other aquatic forms, in a ring. Outside the ring the water drops off suddenly to a depth beyond my sounding pole. I should say that the whole region is one of irregular topography, of kames and gravel knolls, and the explanation of this island seems to be that in the original bottom of the lake there was a knoll which rose near enough to the surface of the water to make a good seat for the lime secreting plants, which built up the deposit to near the surface, thereafter building out slowly in all directions on the debris which forms and slides down the slopes, whereupon the other plants came in, but possibly the spring ice has checked the formation of a permanent bog mat of vegetation. If the explanation is correct, they are like the coral islands in origin as well as looks.

The cause of the distribution of the boglime is not altogether clear. It does not seem generally to prefer to run up against a gravel shore, but possibly that may be due to gravel washed down upon it. Silver Lake, for instance, which lies in quite a deep hollow, does not appear to have boglime, while the marshy hollows next east appear to be underlain with it.

This property is said to have been sold to Cincinnati capitalists recently.*

Prof. E. D. Campbell of Ann Arbor tested the materials. The analysis of the raw material "gathered by Prof. Russell during his examination and a composite sample" is No. 1. No. 2 is from Lime Lake, No. 3 from Zukey.

	No. 1.	No. 2.	No. 3.
Silica	.96	1.30	1.30
Ferric oxide	.62	.70	.58
Alumina	.00		
Calcium carbonate	93.92	94.98	94.52
Magnesium oxide	1.79	1.44	1.44
Sulphuric anhydride	.58	tr.	tr.
Difference, carbon dioxide and organic matter	2.13	1.58	2.16
	100.00	100.00	100.00

	Clay.
Sand	3.76
Silica	62.55
Alumina	17.40
Ferric oxide	5.08
Magnesium oxide	1.67
Sulphuric anhydride	tr.
Combined water and organic matter	5.55
Calcium oxide	2.30
Difference, alkalies, etc.	1.69
	100.00

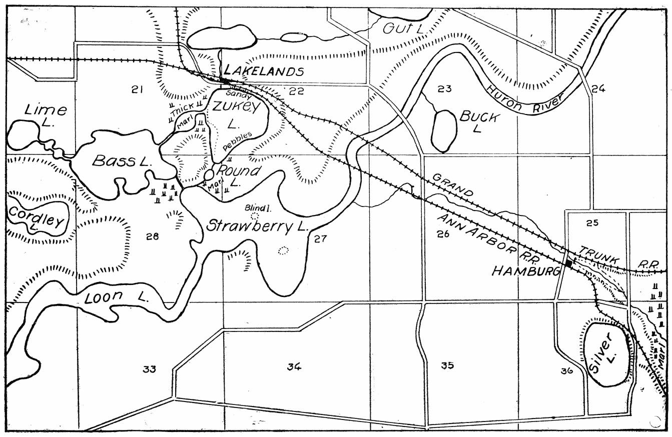


Figure 27. Lakes near Lakelands, T. 1 N., R. 5 E. Location of Standard Portland Cement Co.

Wayne Portland Cement Co.

Organized March 18, 1903. Capital $800,000, Office in Detroit.

Dr. G. Duffield Stewart says that they own 470 acres of marl land within six miles of Brighton on the T. & A. A. R. R.

Pyramid Portland Cement Co.

Organized January 17, 1901. Corporation office at Detroit. Capital $525,000,000.

This plant is to be located at Spring Arbor, where abundant material is said to be near. It is planned to be a 1,200 barrel a day plant.

The lime deposits here were noted by the Douglas Houghton Survey, and there are exposures of coal measure shales not far off.

An average analysis of the marl is given among Prof. Fall's analyses on p. 352,— and also an analysis of Jackson clay,—a little high in alumina.

German Portland Cement Co.

Organized March 29,1901. Capital $300,000.00. Office in Detroit.

This company was organized to develop the beds around White Pigeon, T. 8 S., R. 11 W. They are now building their plant near the village on the Lake Shore road, hoping to be ready by July, 1902.

They expect to use water power for grinding and electricity. The lime comes from Marl Lake, two miles southeast of the town, which has been described by Mr. Hale on p. 103.

Three Rivers Cement Co.

Organized August 10, 1900. Capital $20,000.00. Office at Three Rivers, and intended to develop the beds of boglime in that region, at Pleasant and Fisher's Lakes, where it is said to be all over the lakes and 14 feet, deep in some places. These plants are geologically in the same region as the already established Branch County plants, and in a general way similarly located, though there are no outcrops of shale clay at hand.

Farwell Portland Cement Co.

Organized June 29, 1901. Capital $350,000.00; $10 shares. Bonds $175,000.00, 6% twenty-year gold bonds. Officers: J. L. Littlefield. Geo. W. Graham, T. F. Bingham, W. C. Hull, W. C. Fuller.

This is the company organized to develop the Littlefield Lake marl deposits, elsewhere described by Prof. C. A. Davis,* and illustrated in Plate XIX. It will be noticed that the marsh covering is rarely as much as three feet, usually from two feet down.

The deposit, while not as accessible as some, is not far from the junction of the Ann Arbor and Pere Marquette systems, which will give good shipping facilities at Farwell, where the plant will be.

The analysis from samples collected by Prof. Davis personally, and analyzed by Prof. F. S. Kedzie, is as follows:

Calcium as oxide	51.00	51.67	51.04	51.23
Magnesium as oxide	1.75	1.22	1.61	1.20
Carbon dioxide	42.94	42.41	42.96	42.80
	95.69	95.30	95.68	95.23
Calcium as carbonate	91.1	92.2	91.2	91.6
Magnesium as carbonate	3.67	2.55	3.36	2.50
Shortage of CO_2	.92	.55	1.05	1.13
Insoluble (silica)	0.31	0.34	0.30	0.63
Iron and al. oxides	0.33	0.16	0.24	0.10
Difference (organic)	3.67	3.60	3.65	3.99
Total	100.00			

No. 1 is a mixed sample from the large islands.

No. 2 is from hole 24, unmixed.

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*Detroit Today, 12: 6: 1902.

No. 3 is a mixed sample from fifteen holes, the northwest half of the lake.

No. 4 is a mixed sample from five holes, the southwest half of the lake.

Farwell is only about 50 miles from the Saginaw coal fields by the Pere Marquette, and the Ann Arbor runs direct to Ohio, in case the clay should be drawn thence, and also passes close to the shale clays around Corunna, already mentioned,

In the Littlefield Lake marl the calcite is in lumps of all sizes, but even when no larger than 0.001 mm. often showing aggregate polarization. I was not able to discover any sharply crystalline grains like those in precipitates.

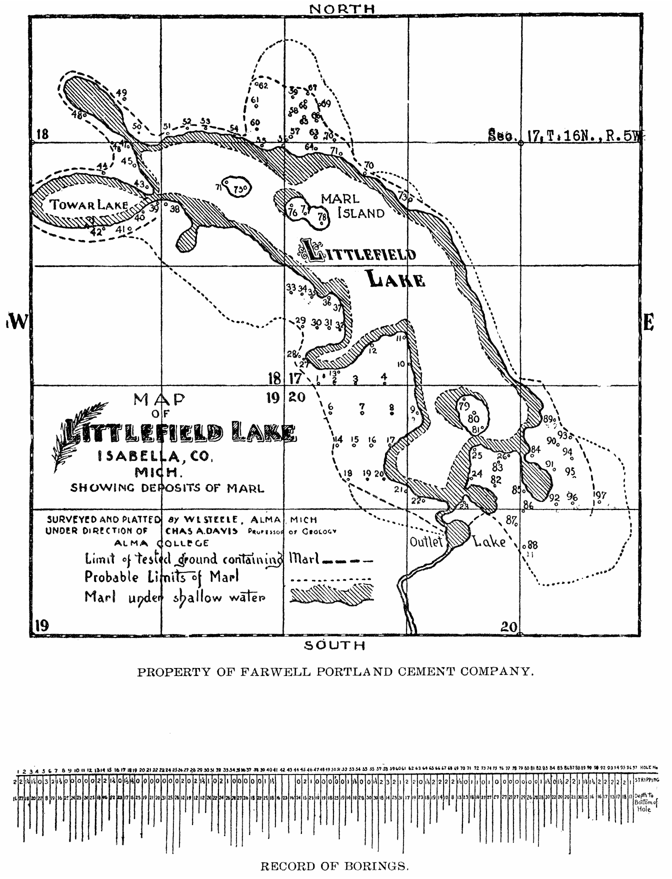

Plate XIX. Property and borings of Farwell P. C. Co. at Littlefield Lake.

Clare Portland Cement Co.

Incorporated in New Jersey. Capital $1,000,000.00, with 100,000 shares.

The company owns 1,905.61 acres of land in Grant and Hatton townships, Clare County, T. 17 and 18 N., R. 4 W.

It is mainly located at Five Lakes, Sections 5, 8, 9 and 16.

The report of the consulting engineer, Prof. R. C. Carpenter, follows. It will be noticed that the clays are the ordinary surface clays with a large amount of carbonates, except one, which is probably only a relatively thin superficial layer in which the lime has been leached out.

A production of 1,000 barrels a day is planned.

The officers are, H. Robinson of Akron, president; C. W. Somers of Cleveland, and the J. H. Somers Coal Co., of St. Charles, vice president; C. W. Perry of Clare, secretary; F. G. Benham of Saginaw, treasurer.

Extract from Prof. Carpenter's report to the Clare Portland Cement Company.

In September last I made an examination of the Portland cement lands owned by W. H. Shepard and partners, of Saginaw, Michigan, and would respectfully report the following results of the examination:

Location.

These lands are located in township 17 north, range 4 west, known as the township of Grant. They comprise altogether 1,905.61 acres, and are principally located in Sections 5, 8, 9, and 16. They are situated at an average distance of about five miles from the city of Clare, and at a distance of about three and one-half miles from the village of Farwell. The lands are located about one mile from the Harrison branch of the Pere Marquette railroad, and about three miles from the Ann Arbor railroad. No less than five switches for logging railroads were at one time graded through the property, and these grades are now all in good condition for railroad service by simply laying of ties and track. The property is all owned by Mr. W. H. Shepard and partners, who claim to have a perfect title.

The country surrounding this property is a highly developed farming region with a clay loam or clay soil, and is quite rolling in character.

Amount of Cement Material.

The cement material which is found on this tract of land consists of marl and clay of very excellent quality.

The marl is found in the bed of five lakes, where it is covered with water, which varies in depth from a few inches to several feet; it is also found in several swamps which surround the lakes or lie adjacent to them, where it is covered with muck, having a depth which varies from a few inches to one or two feet. The total amount of the marl land as measured by a planimeter from an accurate map submitted, is 754 acres, of which 233 acres are lake and 521 marsh. The average depth of the marl over this entire tract would seem, from such information as I can obtain, which was checked from actual measurement, in a large number of places to exceed twenty feet in depth, but in order to make a safe estimate, I have assumed that it was but fifteen feet in depth. To determine* the amount of Portland cement which could be manufactured from this amount of

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*Page 92.

material, we will consider the following data referring to the composition of Portland cement.

One -barrel of Portland cement contains 380 pounds, of which, under usual conditions, 64 per cent would be lime (CaO) and the remainder part clay. Roughly speaking, two-thirds of the Portland cement is lime and one-third clay. The marl is carbonate of lime (CaCO). The weight of the carbonate of lime for a given bulk is in excess of that of the lime as 100 is to 56. Calculating from data thus submitted, it will be found that for one barrel of Portland cement would be required 570 pounds of carbonate of lime, which is about the equivalent of marl when perfectly dry. In order to account for impurities of various kinds, and to make the estimate doubly safe, it is assumed that 600 pounds of dry marl will be required for each barrel of cement.

The marl as found at the bottom of the lakes usually contains 70 per cent of water, and that from swamps usually contains 50 per cent of water. This would indicate that for each cubic foot taken from the bottom of the lake would contain 48 pounds and that from the marsh would contain 80 pounds of carbonate of lime. Consequently, it would require for each -barrel of cement made, 12.5 cubic feet of lake marl, or 7.5 cubic feet of marsh marl. It is seen from this that the marsh marl is preferable, for the reason that it contains less water, which must be evaporated during the process of manufacture.

One acre equals 43,560 square feet, and if worked fifteen deep would make 93,100 barrels of cement from the marsh marl and 52,150 barrels from the lake marl. The total capacity of the deposit by this calculation would be from the marsh marl 48,505,100, and from the lake marl 12,150,950 barrels, making a total of 60,650,050 barrels. If the deposit were worked at the rate of 1,000 barrels per day for 365 days each year, it would furnish a supply for 166 years.

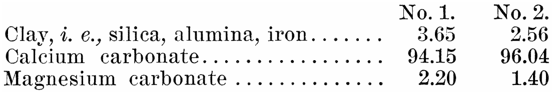
Clay of very excellent quality, as shown by the analysis accompanying the report, is found in large quantities immediately adjacent to the marl beds. The clay covers an area exceeding 160 acres and has a depth varying from 20 to 60 feet. About one and one-half cubic feet of clay are required per barrel of cement, although when carbonate of lime is mixed with the clay, as is found in this deposit, the amount required will be more, and may average two and one-half cubic feet per barrel. This condition, of course, implies the use of less marl, which is not taken into account in estimating our quantity. Taking the clay as averaging 30 feet in depth, one acre would supply enough for 493,000 barrels. This calculation indicates that the amount of clay available is much in excess of that required to manufacture the marl into Portland cement.

In addition to the clay in the upland adjacent to the marl, an investigation shows that it lies underneath the marl, and consequently the amount available is much in excess of what the calculation indicates.

Roughly speaking, there is enough material to operate a cement plant making a thousand barrels per day, for a period exceeding 166 years.

Character of Cement Material.

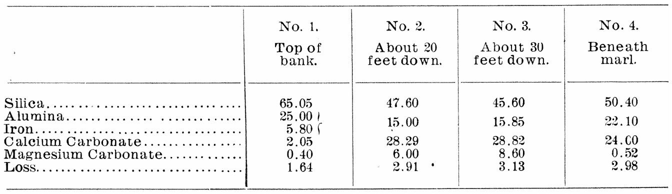
An analysis of the dry sample of marl shows as follows:



	No. 1.	No. 2.
Clay, *i. e.,* silica, alumina, iron	3.65	2.56
Calcium carbonate	94.15	96.04
Magnesium carbonate	2.20	1.40

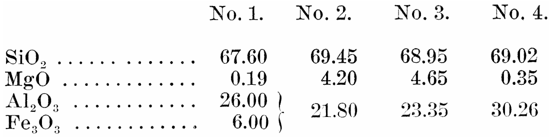
An examination of various samples has as yet shown no free sand. As the surrounding country is largely clay, it is very improbable that any is found in the marl.

An analysis of dried samples of clay shows the following results:



	No. 1. Top of bank.	No. 2. About 20 feet down.	No. 3. About 30 feet down.	No. 4. Beneath marl.
Silica	65.05	47.60	45.60	50.40
Alumina	25.00	15.00	15.85	22.10
Iron	5.80			
Calcium Carbonate	2.05	28.29	28.82	24.00
Magnesium Carbonate	0.40	6.00	8.60	0.52
Loss	1.64	2.91	3.13	2.98

These analyses differ from each other in the percentage of calcium carbonate present. This is a very desirable addition* to the, clay, but for the purpose of comparison, the following table is presented, which is calculated on the basis of no carbonate of lime being present, and magnesia is reduced from carbonate to oxide.



	No. 1.	No. 2.	No. 3.	No. 4.
SiO_2	67.60	69.45	68.95	69.02
MgO	0.19	4.20	4.65	0.35
Al_2O_3	26.00	21.80	23.35	30.26
Fe_3O_3	6.00			

These clays are all high in silica, which is the most desirable element in the manufacture of Portland cement, and they are low in any elements which are undesirable. In fact, these clays are hardly to be surpassed in chemical composition, and so far as the writer knows, are fully equal to those found in any locality.

In connection with the manufacture of Portland cement experience has shown much more difficulty in securing deposits of good clay than in obtaining carbonate of lime, and most of the difficulties which have been experienced in the manufacture of Portland cement have been due to the fact that the clays obtainable contain less than 50 per cent of silica. As showing the fact that a good cement is made with clay of a similar composition, I submit analysis of the Sandusky clay, used by the Sandusky Cement Company, and the Warner clay, used by the Empire Cement Company, two of the oldest companies using marl and clay, reduced to a similar basis as the table given above.

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*Compare calculations on page 39, and pages 167 to 168.

	Sandusky.	Empire.
SiO_2	72.2	65.50
Al_2O_3	18.30	33.50
Fe_2O_3	6.65	
MgO	2.08	0.82
	99.23	99.82

I have made in the laboratory of Sibley College, a small quantity of Portland Cement from this material. This was of excellent quality, giving a tensile strength as follows:

Age.	Strength (lbs.)	Remarks.	Age.	Strength (lbs.)	Remarks.
2 days.....	285	Neat.	1 month..	1022	Neat.
"	328	Neat.	1 " ..	1112	Neat.
2 "	375	Neat.	1 " ..	.962	Neat.
8 "	868	Neat.	7 days....	240	3 pts. sand.
8 "	860	Neat.	7 "	220	3 pts. sand.
1 month...	1056	Neat.	7 "	212	3 pts. sand.

All samples left one day in air and remainder of time in water.

Watervale Portland Cement Co.

Capital $1,000,000.00, of which 1600,000 common, $400,000 preferred, a share of the common being given with every share of the preferred.

The parties interested in this project were also interested in the Omega and Elk Rapids, and apparently are letting it lie dormant, until the latter are better established. The company was said to own 800 acres of marl bed, on the Willow Brook farm and about the Herring Lakes, in Sections 13, 14, 15, 22, 23, 24, T. 25 N., R. 16 W., and Sections 18 and 19, T. 25 N., R. 15 W. The average depth is said to be 20 feet. There is said to be also 60 acres of clay banks three feet deep and over, and 175 acres of other lands with houses, etc.

A feature of this proposition is the nearness to the Great Lakes, so that the lower lake can easily be made a harbor, being from 60 to 80 feet deep, while the upper lake, which is said to be shallow, is said to be underlain by over 25 feet of marl, which also extends beneath the swamps around its margin, where it is covered by not over three feet of vegetable matter.

One reason for the comparative scarcity of marl near the Great Lakes may be that owing to the relatively recent fluctuations of level, there has been not enough time for its accumulation, and it is worth noting that these lakes are close to an axial line of tilting, passing through Port Huron, along which the lake level must have been relatively permanent. The property was reported upon by Lathbury & Spackman, Prof. Delos Fall, and C. B. Stowe.

Lupton Portland Cement Co.

Organized under the laws of New Jersey, January, 1901. Office in Chicago. G. T. Stanley, president; E. A. Worthington, vice president and treasurer; W. Higgs, secretary; W. C. Edgar, assistant secretary; A. H. Cederberg, superintendent. Capital $1,250,000, of which $600,000 was to be placed on the market, two-thirds at two-thirds of par, the balance at par.

The size of the plant planned may be 1,200 barrels daily output.

The photographs in the prospectus show very well the swampy outbuilt margin to the lakes.

Mr. Stanley is we believe the prime mover in this company, having been engaged in lumbering around Lupton.

Extracts from the report of A. H. Cederberg:

Messrs. Lathbury & Spackman of Philadelphia, have analyzed our marl and clay, and the following is their analysis in full:

Lab. No. 942.—Marl from North Lake No. 1.

Silica (SiO_2)	.25%	
Alumina and Iron Oxide (Al_2O_3 Fe_2O_3)	.19%	
Lime (CaO)	52.38%	93.53%
Magnesia (MgO)	1.14%	$CaCO_3$
Sulphuric Acid (SO_3)	.18%	
Loss on Ignition	46.05%	
	100.19	

Lab. No. 943.—Marl from North Lake No. 2.

Silica (SiO_2)	.24%	
Alumina and Iron Oxide (Al_2O_3 Fe_2O_3)	.08%	
Lime (CaO)	52.97%	94.58%
Magnesia (MgO)	1.13%	$CaCO_3$
Sulphuric Acid (SO_3)	.08%	
Loss on Ignition	45.49%	
	99.99	

The analyses of marls show them to be very uniform and high in lime, while they are low in injurious ingredients, such as magnesia and sulphuric acid, hence are well adapted to the manufacture of Portland cement.

Lab. No. 957.—Blue Clay No. 2.*

Silica (SiO_2)	56.09%	
Alumina & Iron Oxide (Al_2O_3 & Fe_2O_3)	28.89%	Very
Lime (CaO)	00.00%	little
Magnesia (MgO)	0.58%	Iron
Sulphuric Acid (SO_3)	0.41%	Oxide
Loss on ignition	7.58%	
	93.55	
Difference (alkalies)	6.45	

This clay is well adapted for the manufacture of Portland cement. A mixture of equal parts of blue clay No. 2, and the Spring Lake clay† would give a clay with a better ratio between the alumina and silica than the blue clay alone; also the percentage of magnesia in this mixture would be low.

The village of Lupton is on the Rose City branch of the Detroit and Mackinac railway, about 27 miles from the Emery Junction. The conditions for a mill site are more than satisfactory. A mill could be erected, as suggested, right on the outskirts of the village of Lupton, or down by the lakes, which are situated about a mile from the village itself.

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*In this statement, Prof. Carpenter differs from the prevailing opinion, as may be noted by comparing statements elsewhere in the report. This is not because the calcium carbonate itself is deleterious, but because as the analyses show it is liable to be very variable, and to be associated with much magnesia, so that it is more difficult to make the cement of a constant composition. L.

The marl deposits are, I may say, inexhaustible; and from samples taken, not only by myself, but that have also been forwarded to me from Lupton, and to Messrs. Lathbury & Spackman of Philadelphia, I can state that the marl is superior in its quality to most of the marl beds that have come to my notice. The conditions for getting at this marl are very easy. One of the lakes could be drained at an expense of a few hundred dollars to such an extent that steam shovels would be entirely unnecessary, thus reducing the cost of putting the marl on cars to the mill, to a minimum.

The clay that has been found on the property is not very well adapted to the mixture for first-class Portland cement; but only a few miles away from there another clay deposit is of superior quality, and which clay, I am informed, can be deposited at the mill at a cost of thirty cents per ton. The ratio between marl and clay necessary for a mixture would lie between the figures of four and five to one.

After having made thorough chemical analyses of the raw material, and which analyses correspond entirely to those made by Messrs. Lathbury & Spackman, I went to work and ran through a rotary kiln enough raw material to produce a sufficient quantity of Portland cement, in order to make necessary physical tests. The chemical mixture in the raw was made so as to conform to the standard requirements of Portland cement by the American Society of Civil Engineers, which requirements, as you well know, are higher even than those of the United States government. The fineness of the cement produced was satisfactory, the color was pure Portland shade and tensile strength on the briquettes made was as follows:

After 24 hours: 444 and 486 lbs. Average 460 lbs. (Final set in air and balance in water.)

After 3 days: 618 and 643 lbs. Average 633 lbs. (1 day in air; 2 days in water.)

After 7 days: 702 and 829 lbs. Average 815½ lbs. (1 day in air and 6 days in water.)

After 30 days: 891 and 916 lbs. Average 903½ lbs. (1 day in air, 29 days in water.)

Only the regular methods adopted in cement making were used in the making of these briquettes. The initial setting was 172 minutes; the final setting 360 minutes in all instances. The amount of sulphuric acid in the finished product was 1.53 per cent, thus insuring a cement of superior quality and of which there can be no doubt as to its durability.

In using the above figures, I have taken into consideration the fact that you must produce 1,200 barrels of Portland cement every 24 hours. That means that a plant must be constructed that has a capacity of turning out 1,500 barrels in the same time—24 hours. It may astonish you to hear of this, but it remains as an absolute fact. We very often hear that parties go to work and construct a cement plant of 1,200 barrels capacity, and they will figure in this 1,200 barrels on no repair account whatever. As a result, there are in the United States to day only two mills to my knowledge that have a capacity of standing by the figures agreed upon for a 24 hour output. These two mills are the Lehigh Portland Cement Company's mill "B," at West Coplay, Pennsylvania, and the Whitehall Portland Cement Company's mill at Cement Town, Pennsylvania. It must be very evident to you that if an engineer guarantees to turn out cement at a certain figure, he must rely upon it that his output is never decreased, but if anything, increased during the 24 hour run. We very often hear some engineers that guarantee 200 barrels of clinkers per day in a 60-foot rotary kiln. That guarantee is all nonsense. It is an absolute impossibility. In the first instance, every rotary kiln must stand idle from three to four hours every day, owing to what is in burning practice called "patching." Hence, if a cement mill has got, say for instance, twelve rotary kilns, it means to say that two rotary kilns will practically lie idle during the 24 hours.

Furthermore, patching is not the only cause of shutting down a kiln. The brick lining in a rotary kiln is subjected to an intensely hard wear and tear, and it is nothing unusual to see rotary kilns relined partly every two months. That means another shut down of the rotary kilns for two whole days. In my experience, I have found that it is a safe guarantee to figure on a rotary kiln having an average monthly capacity of 130 barrels of clinkers in 24 hours. So much in the rotary kiln process.

If we go to the grinding process, the conditions there are just the same. A maker of machinery has been invited to figure on an outfit to produce so many barrels. He gives you a figure. You go to another manufacturer and he turns in another figure. The manufacturer that turned in the first figure has probably been a trifle too high. He wants to reduce his first figure in order to obtain the bid, and the first thing he overrates the grinding capacity of the machine he proposes to furnish. Knowing this full well, it is an absolute necessity to have a surplus of grinding capacity in both raw and clinker departments of not less than twenty-five per cent, thus doing away with any danger whatever tending to reduce your 24 hour output and increase the manufactured cost per barrel.

It is also a very noticeable fact that repairs cost as a rule a mere trifle as far as cost is concerned, and that the largest expense in connection with the cement mill is the shut downs, thus decreasing the output and increasing the cost to a considerable degree.

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*Apparently a Michigan series shale clay. L.

†A brown clay used to reduce the ratio of alumina which is rather too high.

Standiford Portland Cement Company.

In the northwest corner of Branch County, not far from Union City but nearer Athens, are some extensive beds of marl which have been investigated for the Standiford Portland Cement Company by Prof. Delos Fall and H. K. Whitney. The results of a thorough survey and a large series of analyses are shown in the map and tables herewith given. Mr. Whitney says that over one thousand soundings of same were taken, 508 on land, 96 on the shore line and 445 on the lakes when covered with ice.

"The bottom of lakes, except at mouths of cracks and in the deepest portions of the line of flow is clear clean marl. At the mouths of creeks and in the deepest portions of Kynion and Lehr Lakes in line of flow it is overlain with sediment as indicated on the large map. It is a soft dark sediment, apparently organic material, or the same mixed with marl and is almost entirely in deep water and outside the estimated 240 acres."

"A large part of the surface material (peat, muck, etc.) on the marl lands could readily be burned off in time of low water. Points when it is four feet deep are in general two feet above ordinary water level; some points four or five feet above. It is, however, quite possible that it might have value for fuel.

"The difference in water level between the lakes (between Lehr and Kynion Lakes, 5 meters between Kynion and Clayton Lakes 1 inch), could be readily eliminated by dredging for marl. On May 9, 1900, Clayton Lake was 2 feet 4½ inches above the river at mouth of outlet from lakes at time of medium high water. At ordinary or low water it would be as much as 3 feet. The distance is 1¼ miles direct (about 1¾ miles on the line of the creek). For about $1,000 the water in lakes could be lowered about 1½ to 2 feet, with a benefit of about $1,000 to the adjoining property, aside from marl beds. Then at low water nearly all of the surface material could be burned off from the marl lands, with little trouble and at nominal expense. Similar large marshes in the vicinity have been burned off below the ordinary water level, accidentally or intentionally."

The estimated acreage of marl with an average depth of 20 feet is computed as follows by Mr. Whitney:

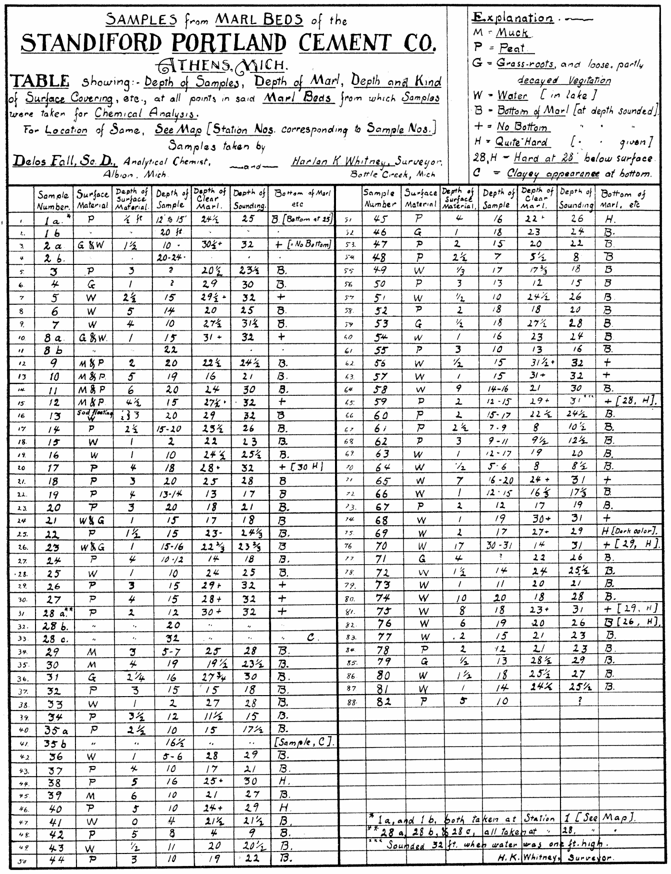
	Acres.	Acres.
Area of lakes more than 20 feet deep	136	
Area of lakes less than 20 feet deep	104	
Total area of lakes		240
Area of land 10 feet or more marl, 4 feet or less of surface	90	
Area of land 10 feet or more marl, 4 feet or more surface	52	
10 to 30 feet of marl (average 20 feet)	142	
5 to 10 feet of marl (average 7 feet)	33	175
Area of land and water		415
Less allowance (possible error)		15
		400

For commercially available marl we shall have, however, within 30 feet of surface:

	Acres.
Area of land, 10 to 30 feet thick, averaging 20 if we neglect thickness above 30 feet	142
Area in lakes to 20 feet of water	104
	246
Less allowance for error	6
Total acreage 20 feet thick	240
The 33 acres of marl between 5 and 10 feet thick would be equivalent to	10
Total	250

Which would be equivalent to over 8,000,000 cubic yards.

Prof. Fall went over the bed and took at proper intervals a series of 84 samples, and the analyses given in the table annexed are of the entire series not omitting any.



SAMPLES from MARL BEDS of the

STANDIFORD PORTLAND CEMENT CO.

ATHENS, MICH.

TABLE showing:- Depth of Samples, Depth of Marl, Depth and Kind of Surface Covering, etc., at all points in said Marl Beds from which Samples were taken for Chemical Analysis.

For Location of Same, See Map [Station Nos. corresponding to Sample Nos.]

Samples taken by

Delos Fall, Sc. D., Analytical Chemist, Albion, Mich —and— Harlan K Whitney, Surveyor, Bottle Creek, Mich

Explanation.
M = Muck
P = Peat
G = Grass-roots, and loose, partly decayed Vegitation
W = Water [in lake]
B = Bottom of Marl [at depth sounded]
+ = No Bottom " " "
H = Quite Hard [" " given]
28, H = Hard at 28' below surface
C = Clayey appearance at bottom.

	Sample Number.	Surface Material	Depth of Surface Material.	Depth of Sample	Depth of Clear Marl.	Depth of Sounding.	Bottom of Marl etc
1	1 a.*	P	½ ft	12' to 15'	24½	25	B. [Bottom at 25]
2.	1 b	"	"	20 ft	"	"	"
3.	2 a	G & W	1½	10 "	30½+	32	+ [= No Bottom]
4	2 b.		"	20-24 "	"	"	"
5.	3	P	3	?	20½	23½	B.
6.	4	G	1	?	29	30	B.
7	5	W	2½	15	29½+	32	+
8	6	W	5	14	20	25	B.
9.	7	W	4	10	27½	31½	B.
10.	8 a.	G & W.	1	15	31+	32	+
11	8 b	"	"	22	"	"	"
12	9	M & P	2	20	22½	24½	B.
13	10	M & P.	5	19	16	21	B.
14.	11	M & P	6	20	24	30	B.
15.	12	M & P.	4½	15	27½+	32	+
16	13	Sod floating W	½ 3	20	29	32	B
17.	14	P	2½	15-20	25½	26	B.
18.	15	W	1	2	22	23	B.
19.	16	W	1	10	24½	25½	B.
20	17	P	4	18	28+	32	+ [30 H]
21.	18	P	3	20	25	28	B
22.	19	P	4	13-14	13	17	B
23.	20	P	3	20	18	21	B.
24	21	W & G	1	15	17	18	B
25.	22	P	1½	15	23-	24⅓	B.
26.	23	W & G	1	15-16	22⅔	23⅔	B
27.	24	P	4	10-12	14	18	B.
28.	25	W	1	10	24	25	B.
29.	26	P	3	15	29+	32	+
30.	27	P	4	15	28+	32	+
31	28 a.**	P	2	12	30+	32	+
32.	28 b.	"	"	20	"	"	"
33.	28 c.	"	"	32	"	"	" C.
34.	29	M	3	5-7	25	28	B.
35.	30	M	4	19	19½	23½	B.
36.	31	G	2¼	16	27¾	30	B.
37.	32	P	3	15	15	18	B.
38.	33	W	1	2	27	28	B.
39.	34	P	3½	12	11½	15	B.
40.	35 a	P	2½	10	15	17½	B.
41.	35 b	"	"	16½	"	"	[Sample, C].
42.	36	W	1	5-6	28	29	B.
43.	37	P	4	10	17	21	B.
44.	38	P	5	16	25+	30	H.
45.	39	M	6	10	21	27	B.
46.	40	P	5	10	24+	29	H.
47.	41	W	0	4	21½	21½	B.
48.	42	P	5	8	4	9	B.
49.	43	W	½	11	20	20½	B.
50	44	P	3	10	19	22	B.
51	45	P	4	16	22+	26	H.
52	46	G	1	18	23	24	B.
53.	47	P	2	15	20	22	B.
54	48	P	2½	7	5½	8	B
55	49	W	⅓	17	17⅔	18	B
56	50	P	3	13	12	15	B
57	51	W	½	10	24½	26	B.
58.	52	P	2	18	18	20	B
59	53	G	½	18	27½	28	B.
60	54	W	1	16	23	24	B
61	55	P	3	10	13	16	B.
62	56	W	½	15	31½+	32	+
63.	57	W	1	15	31+	32	+
64	58	W	9	14-16	21	30	B.
65.	59	P	2	12-15	29+	31***	+ [28, H].
66	60	P	2	15-17	22½	24½	B.
67	61	P	2½	7-9	8	10½	B.
68	62	P	3	9-11	9½	12½	B.
69	63	W	1	12-17	19	20	B.
70	64	W	½	5-6	8	8½	B.
71	65	W	7	16-20	24+	31	+
72	66	W	1	12-15	16⅓	17⅓	B.
73.	67	P	2	12	17	19	B.
74	68	W	1	19	30+	31	+
75.	69	W	2	17	27+	29	H [Dark color].
76	70	W	17	30-31	14	31	+ [29, H].
77	71	G	4	?	22	26	B.
78.	72	W	1½	14	24	25½	B.
79.	73	W	1	11	20	21	B.
80.	74	W	10	20	18	28	B.
81.	75	W	8	18	23+	31	+ [29, H]
82.	76	W	6	19	20	26	B [26, H].
83.	77	W	2	15	21	23	B.
84.	78	P	2	12	21	23	B.
85.	79	G	½	13	28½	29	B.
86	80	W	1½	18	25½	27	B.
87	81	W	1	14	24½	25½	B.
88.	82	P	5	10		?	

* 1 a, and 1 b, both taken at Station 1 [See Map].
** 28 a, 28 b, & 28 c, all taken at " 28. "
*** Sounded 32 ft. when water was one ft. high.

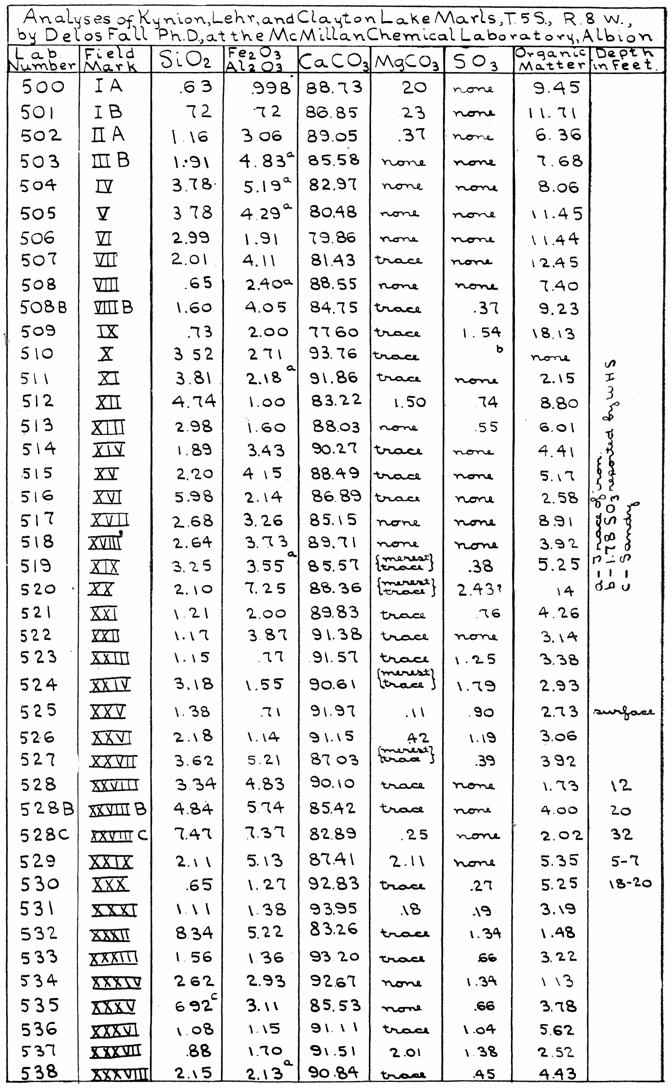
H. K. Whitney, Surveyor.

Figure 28. Table of data relative to the samples, the analyses of which are given on subsequent pages. The numbers in the second column correspond to the Roman numerals in the second columns of Figs. 29 and 30. Soundings of Standiford Portland Cement Company on Kynion, Lehr and Clayter lakes, Sections 4, 5, 8, 9, 16 and 17, T. 5 S., R. 8 W.

The material in every case was dried at 100 C. to expel moisture and sampled. The tables give the amount of each substance found in 100 parts of the dried samples. The samples were taken with apparatus especially prepared for the purpose by which it was possible to know accurately the depth from which the samples came. The average analysis is given among the other analyses by Prof. Fall, page 352, and “exclusive of organic matter the carbonate of lime in these eighty-four samples would average 93.10%, a showing which is remarkably high when it is taken into account the nearly five per cent of clay which the marl contains."

The marl is also very finely and evenly divided.

One peculiarity of this bed to which he calls attention is that a small percentage of clay, ranging from two to six per cent, is found as an admixture with the marl. This of course would be no detriment to the quality of the cement, for as he remarks, the percentage of magnesia and sulphuric acid are insignificant.



Analyses of Kynion, Lehr, and Clayton Lake Marls, T. 5 S., R. 8 W., by Delos Fall Ph.D., at the McMillan Chemical Laboratory, Albion

Lab Number	Field Mark	SiO_2	Fe_2O_3 Al_2O_3	$CaCO_3$	$MgCO_3$	SO_3	Organic Matter	Depth in Feet.
500	IA	.63	.998	88.73	20	none	9.45	
501	IB	72	72	86.85	23	none	11.71	
502	II A	1.16	3.06	89.05	.37	none	6.36	
503	III B	1.91	4.83[a]	85.58	none	none	7.68	
504	IV	3.78	5.19[a]	82.97	none	none	8.06	
505	V	3.78	4.29[a]	80.48	none	none	11.45	
506	VI	2.99	1.91	79.86	none	none	11.44	
507	VII	2.01	4.11	81.43	trace	none	12.45	
508	VIII	.65	2.40[a]	88.55	none	none	7.40	
508B	VIII B	1.60	4.05	84.75	trace	.37	9.23	
509	IX	.73	2.00	77.60	trace	1.54	18.13	
510	X	3.52	2.71	93.76	trace	[b]	none	
511	XI	3.81	2.18[a]	91.86	trace	none	2.15	
512	XII	4.74	1.00	83.22	1.50	74	8.80	
513	XIII	2.98	1.60	88.03	none	.55	6.01	
514	XIV	1.89	3.43	90.27	trace	none	4.41	
515	XV	2.20	4.15	88.49	trace	none	5.17	
516	XVI	5.98	2.14	86.89	trace	none	2.58	
517	XVII	2.68	3.26	85.15	none	none	8.91	
518	XVIII[c]	2.64	3.73	89.71	none	none	3.92	
519	XIX	3.25	3.55[a]	85.57	{merest trace}	.38	5.25	
520	XX	2.10	7.25	88.36	{merest trace}	2.43?	14	
521	XXI	1.21	2.00	89.83	trace	.76	4.26	
522	XXII	1.17	3.87	91.38	trace	none	3.14	
523	XXIII	1.15	.77	91.57	trace	1.25	3.38	
524	XXIV	3.18	1.55	90.61	{merest trace}	1.79	2.93	
525	XXV	1.38	.71	91.97	.11	.90	2.73	surface
526	XXVI	2.18	1.14	91.15	42	1.19	3.06	
527	XXVII	3.62	5.21	87.03	{merest trace}	.39	3.92	
528	XXVIII	3.34	4.83	90.10	trace	none	1.73	12
528B	XXVIII B	4.84	5.74	85.42	trace	none	4.00	20
528C	XXVIII C	7.47	7.37	82.89	.25	none	2.02	32
529	XXIX	2.11	5.13	87.41	2.11	none	5.35	5-7
530	XXX	.65	1.27	92.83	trace	.27	5.25	18-20
531	XXXI	1.11	1.38	93.95	.18	.19	3.19	
532	XXXII	8.34	5.22	83.26	trace	1.34	1.48	
533	XXXIII	1.56	1.36	93.20	trace	.66	3.22	
534	XXXIV	2.62	2.93	92.67	none	1.34	1.13	
535	XXXV	6.92[c]	3.11	85.53	none	.66	3.78	
536	XXXVI	1.08	1.15	91.11	trace	1.04	5.62	
537	XXXVII	.88	1.70	91.51	2.01	1.38	2.52	
538	XXXVIII	2.15	2.13[a]	90.84	trace	.45	4.43	

a – Trace of iron.
b – 1.78 SO_3 reported by WHS
c – Sandy

Figure 29. Analyses of the Standiford P. C. Co. marl by Delos Fall. See Fig. 28.

Bellaire Portland Cement Co.

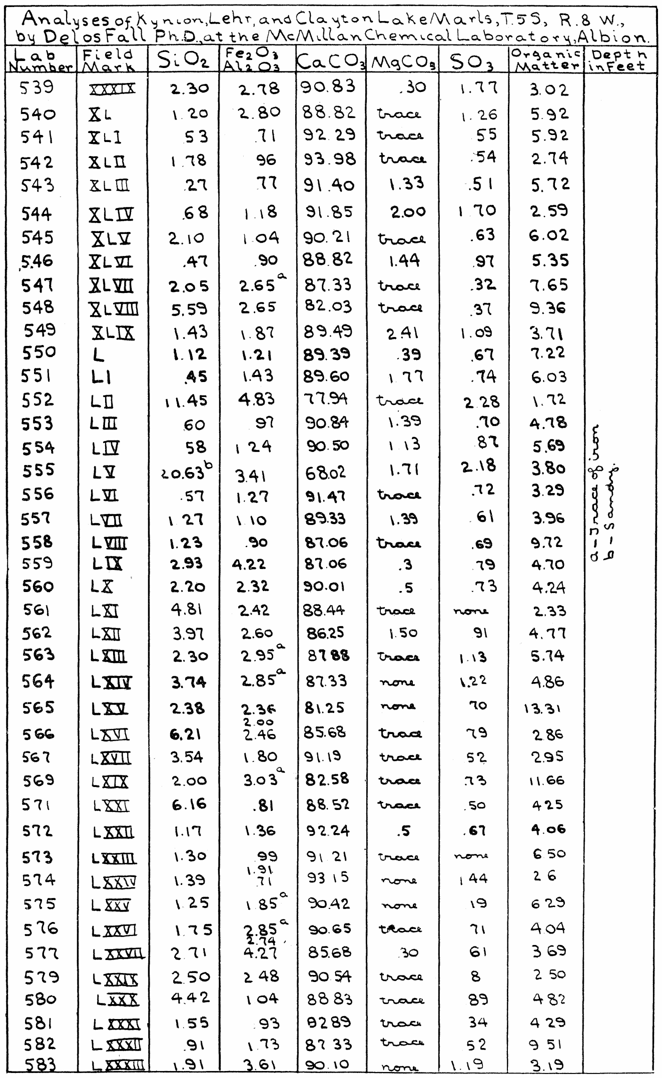
This company has been but recently organized to operate near Bellaire, Antrim County. The conditions will be not unlike those at Elk Rapids. It is, I presume, a successor of the Lake Shore company.

West German Portland Cement Co.

Articles filed at Ann Arbor Aug. 13, 1902. Capital $1,000,000, half preferred. Object to manufacture cement, coke and peat in Lima Township. Linus E. Leach of Detroit appears to be chief stockholder. The marl beds are around Four Mile Lake.

Locations reported by Douglas Houghton Survey.

The first geological survey of the State back in the forties, paid considerable attention to the location of marl, not, however, for its value for cement, but as a fertilizer, though at that time it was also extensively used for making quick-lime. A brief summary of the locations which they noticed, should be given here, since the reports in question are not only out of print, but not easy to obtain second-hand. I have added foot-notes calling attention to the fact, when the locations have since been utilized.



Analyses of Kynion, Lehr, and Clayton Lake Marls, T. 5 S., R. 8 W., by Delos Fall Ph.D., at the McMillan Chemical Laboratory, Albion.

Lab Number	Field Mark	SiO_2	Fe_2O_3 Al_2O_3	$CaCO_3$	$MgCO_3$	SO_3	Organic Matter	Depth in Feet
539	XXXIX	2.30	2.78	90.83	.30	1.77	3.02	
540	XL	1.20	2.80	88.82	trace	1.26	5.92	
541	XLI	53	.71	92.29	trace	55	5.92	
542	XLII	1.78	96	93.98	trace	.54	2.74	
543	XLIII	.27	77	91.40	1.33	.51	5.72	
544	XLIV	.68	1.18	91.85	2.00	1.70	2.59	
545	XLV	2.10	1.04	90.21	trace	.63	6.02	
546	XLVI	.47	.90	88.82	1.44	.97	5.35	
547	XLVII	2.05	2.65[a]	87.33	trace	.32	7.65	
548	XLVIII	5.59	2.65	82.03	trace	.37	9.36	
549	XLIX	1.43	1.87	89.49	2.41	1.09	3.71	
550	L	1.12	1.21	89.39	.39	.67	7.22	
551	LI	.45	1.43	89.60	1.77	.74	6.03	
552	LII	11.45	4.83	77.94	trace	2.28	1.72	
553	LIII	60	97	90.84	1.39	.70	4.78	
554	LIV	58	1.24	90.50	1.13	87	5.69	
555	LV	20.63[b]	3.41	68.02	1.71	2.18	3.80	
556	LVI	.57	1.27	91.47	trace	.72	3.29	
557	LVII	1.27	1.10	89.33	1.39	.61	3.96	
558	LVIII	1.23	.90	87.06	trace	.69	9.72	
559	LIX	2.93	4.22	87.06	.3	.79	4.70	
560	LX	2.20	2.32	90.01	.5	.73	4.24	
561	LXI	4.81	2.42	88.44	trace	none	2.33	
562	LXII	3.97	2.60	86.25	1.50	91	4.77	
563	LXIII	2.30	2.95[a]	87.88	trace	1.13	5.74	
564	LXIV	3.74	2.85[a]	87.33	none	1.22	4.86	
565	LXV	2.38	2.36 2.00	81.25	none	70	13.31	
566	LXVI	6.21	2.46	85.68	trace	79	2.86	
567	LXVII	3.54	1.80	91.19	trace	52	2.95	
569	LXIX	2.00	3.03[a]	82.58	trace	.73	11.66	
571	LXXI	6.16	.81	88.52	trace	.50	4.25	
572	LXXII	1.17	1.36	92.24	.5	.67	4.06	
573	LXXIII	1.30	99	91.21	trace	none	6.50	
574	LXXIV	1.39	1.91 .71	93.15	none	1.44	2.6	
575	LXXV	1.25	1.85[a]	90.42	none	19	6.29	
576	LXXVI	1.75	2.85[a] 2.74	90.65	trace	71	4.04	
577	LXXVII	2.71	4.27	85.68	.30	61	3.69	
579	LXXIX	2.50	2.48	90.54	trace	8	2.50	
580	LXXX	4.42	1.04	88.83	trace	89	4.82	
581	LXXXI	1.55	93	92.89	trace	34	4.29	
582	LXXXII	.91	1.73	87.33	trace	52	9.51	
583	LXXXIII	1.91	3.61	90.10	none	1.19	3.19	

a – Trace of iron
b – Sandy.

Figure 29. Analyses of Fig. 28 continued; where ever in column 4, there are are two sets of figures, the upper is for the total iron and alumina, the lower the alumina alone.

That marls were generally attributed to shells may be indicated by the fact that the symbols used on the maps to denote the location of marls was a small figure of a shell.

First Annual Report, 1838, H. D. No. 4, pp. 276-317, No. 14, pp. 1-39, p. 13 or 287, description of Chara deposits near Grand Rapids, in Saline Springs; p. 34 or 306, northern part of St. Joseph,* Monroe near Monroe,† and Jackson County.‡

Second Annual Report, 1839, H. D. No. 23,
p. 393, White River.
p. 451,
p. 464, Sec. 15, T. 1 N., R. 1 W.
33 Leslie township.§
35, T, 2 N., R.1 W.
p. 479, Sections 2, 4, 5, 8, 22. 27, Plymouth Township, Oakland County.
Sec. 9, Canton.
495, Monroe, Sections 7 and 9, T. 6 S., R 9 E.

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*See p. 312. †See p. 312 ‡See pp. 291. 309, 315.

§See p. 316.

From Third Annual Report of State Geologist, p. 94 of the separate edition.

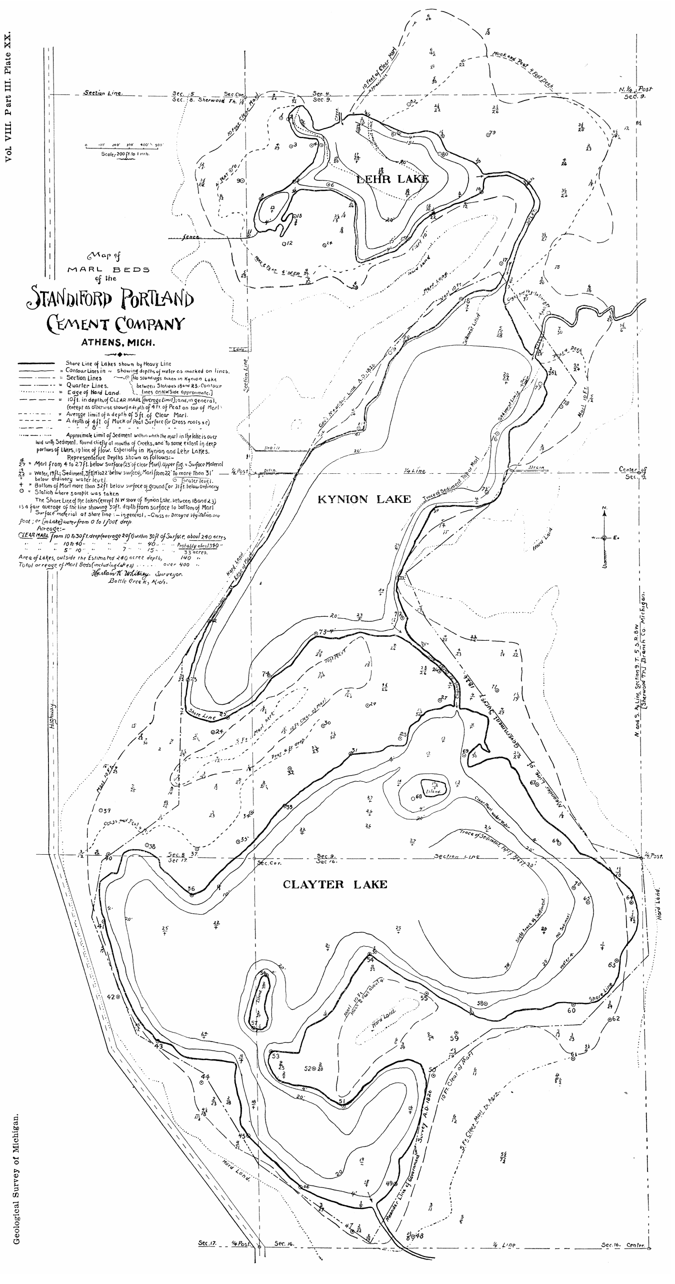

Plate XX. Map of Marl beds of the S. P. Cement Co., Athens, Mich.

MARL OR BOG LIME AND TUFA.

"That variety of the mineral which is here designated by the name of marl, is chiefly a carbonate of lime, or lime combined with carbonic acid. It is frequently argillaceous, and mixed with earthy and carbonaceous matters. Throughout the counties enumerated, this mineral is found only in the gravels, sands and clays which overlie the rocks, and may be defined as an alluvial deposit from the waters which have percolated soils charged with lime. On reaching the surface, the water parts with a portion of its carbonic acid, and becomes no longer capable of holding lime in solution, which is then deposited in the form of a pulverulent, chalky substance, in the beds of lakes or beneath the peat marshes.

"As carbonate of lime is a constituent of the covering of molluscous animals, these circumstances are favorable to the collection of great numbers of shells, so that these not unfrequently constitute even the main portion of the bed itself, which may then receive the name of 'shell marl.'

"That form of lime which is called tufa, has a similar origin. It differs in external character, being hard, light and porous, and is that which is familiarly known as 'honey-comb lime.' This characteristic difference is the result of circumstances, not of composition. Tufa is formed in situations which allow access of air, when a strong union of the particles takes place. Marl being always deposited under water, or beneath the peat of bogs, the surrounding fluid prevents cohesion. This condition is that which is very commonly designated as bog lime."

p. 95. "Thus, according to circumstances, we find a variety of forms assumed by these deposits, from a 'tufaceous marl,' in which the particles have but partially cohered, to a hard 'tufa' or travertin rock, appearing as ledges in exposed hillsides.

"All these recent fresh water limes exist in great abundance in most of the counties enumerated, as well as throughout the interior of the State. In the northern part of Hillsdale,* and the counties of Washtenaw and Oakland, in particular, so extensive and universally distributed are the beds of this useful mineral, that an attempt to ascertain and enumerate all the places in which it exists, is unnecessary, if not impossible.

"But notwithstanding its wide distribution, the uses, and even the existence of this mineral are so little known or heeded, even by those who have most reason to appreciate its value, that I shall adventure some remarks upon its application to practical purposes, and the method of ascertaining its presence.

"For making quicklime, the value of marl and tufa is already appreciated in those parts of our State which, like the counties under review, are nearly destitute of lime rock. Consequently these have supplied the deficiency, and been applied to all the purposes of the best rock lime. Though somewhat inferior in strength, the lime thus obtained is even preferred for particular purposes. It is said, for instance, to be preferable as a wash, owing to its superior whiteness. Its real value is frequently underrated from its not being sufficiently burned; marl being erroneously supposed to require a less degree of heat than limestone.

"Some of the largest deposits of tufa I have met with are formed along the banks of the Huron Valley, between Ypsilanti and Dexter, at several of which, large quantities of lime are manufactured.

"The circumstances which may give rise to the formation of either tufa or shell-marl, where the same source of supply exists, are hereby exemplified. Ledges of tufa occupy the elevated sides of the valley, while copious springs discharging from its foot, occasion a peat morass between it and the river, beneath which is a body of soft marl several feet in thickness.

"Impressions of leaves and branches of trees, and even bones of animals, are numerous in some portions of the tufa, these substances have evidently served as nuclei around which the particles of lime were deposited from the water of the springs, thus both giving an interesting character to the bed and illustrating its formation."

p. 98. "After this recommendation of marl, it may be expected that I advise under what circumstances to look for it. Marl is frequently to be recognized by its light ash color, about the margin and occupying the shallows of lakes. In general, the marl which is most obtainable, will be found to be overlaid by peat or muck of the marshes, often at a depth of several feet. Sometimes its presence, under these circumstances, is indicated by a slight coating of lime visible upon the vegetation on the surface. The growth of the marl bed often causes the overlying bog to swell up into a protuberant form. But such indications are not always visible, and then trial may be made by thrusting down a pole or rod through the peat, when sufficient of the marl, if there be any, will adhere, usually, to make known its presence.

"Every farmer ought to examine well his marshes with this view, and if there is any reason to believe that marl exists there, to test the question fully by digging.

"It may be advisable to raise the marl in the fall and subject it to the action of the winter's frost, in order to bring it to a pulverized state previous to use upon land."

p. 55. "Marl, which is more universally distributed than any other of the calcareous manures of this district, and which will, in consequence of this fact, admit of a universal application, is in itself more valuable for this purpose than limestone, since it generally contains vegetable and animal matter in combination, and its effects are more immediate. It exists in a state of minute subdivision, and is in a condition prepared to become directly a constituent of the soil, while it is necessary that limestone, as well as gypsum, should first be reduced to powder.”

Marl.

"Deposits of marl were found in nearly every town in the counties under consideration, occurring in beds and banks of lakes and streams, in marshes, as well as occasionally, on the more elevated and dry lands, at a considerable distance from water.

"This latter position is riot unfrequent, but marls found in this situation, invariably show that they occupy what has heretofore been the bed of of some lake or pool. Thus the marl does not seem to be confined to any particular soil or geological position.

"For further particulars, respecting the origin and formation of marl, I refer you to Mr. Hubbard's report."

Local Details of Marl. Jackson County.

"Shell-marl occurs more or less abundantly in the town of Napoleon, on Sections 12, 14, 15, and 19, and other deposits of minor importance were also noticed in this town.

"In the town of *Columbus*, marl occurs, forming very extensive deposits in the vicinity of dark's Lake. It also occurs abundantly on Sections 8, 9, 13, 19, 28, and 29, in the same town. Several of these deposits have an area of more than one hundred acres.*

"Several very extensive beds of marl were noticed in the (P. 56) town of *Liberty*, on Sections 11, 13, 23, 24, and 27, as well as in the bed of Powell’s Lake and its vicinity.

"The town of *Spring Arbor* abounds in extensive beds of marl, which were more particularly noticed on Sections 21, 28, and 29.*

"*Hanover*.—A bed of marl having an area of more than one hundred acres, was noticed, forming a portion of the bed and banks of Farwell’s Lake. Inexhaustible deposits of shell and tufaceous marl occur near a lake which forms the head of Kalamazoo River.†

"Town of *Sandstone*.—Marl is not unfrequently met with in making excavations in the marshes in this town. It was noticed near the village of Barry, and also on the farm of Hon. Mr. Gridley.

"*Pulaski*.—Marl occurs in abundance in many of the lakes and marshes of this town. A very extensive bed of shell and tufaceous marl was noticed on the farm of Isaac N. Swain, Sec. 2, occupying an area of more than 60 acres, and having a thickness exceeding six feet. An extensive bed was also notice 1 on Section 25.

"*Rives*.—A somewhat extensive deposit of marl occurs on Section 9.

"*Leoni*.—Marl, in inexhaustible quantities, occurs near the outlet of Wolf Lake, and also upon Sections 4, 11, 12, 22, and 23.

"Town of *Jackson*.—Marl occurs in this town, in abundance, on Sections 20, 21, 26, 27, and 31 (town 3

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*Location of Omega plant.

*These deposits are not far from the Peninsular plant.

south, range 7 west), and also on Section 31 (town 2 south, range 1 west).

"*Concord*.—Several extensive beds of marl occur in this town which were more particularly examined on Sections 8 and 9. Also in the bed and banks of the Kalamazoo River.

Grass Lake.—On Sections 13 and 29,‡ in this town, extensive beds of shell-marl were examined.

"*Springport*.—An extensive bed of marl occurs on Section 15,

"*Tompkins*.—An extensive bed of shell-marl was examined on Section 17, in this town."

Eaton County.

p. 57. "*Kalamo*.—Several very extensive beds of marl were observed on Sections 22 and 25 (town 2 north, range 6 west), and on Sections 19 (range 5 west)."

Kalamazoo County.

"*Texas*.—Shell and tufaceous marl occur in beds of several lakes in this town. Also on Sections 31 and 32 of the same town, is an extensive deposit of this mineral.

"*Alamo*.—On Sections 1, 9, 12, and 24, extensive beds of marl were examined.

"*Cooper*.—Marl is not unfrequently met with in the alluvial lands in the vicinity of the Kalamazoo River.

"*Ross*.—Marl was noticed in several of the lakes and marshes of this town.

"*Kalamazoo*.—Tufaceous and shell-marls occur in a large marsh and in the valley of a small stream northwest from the village of Kalamazoo.*

"*Chester*.—Extensive deposits of marl abound in this town, on Sections 4, 9, 10, 11, 12, and 24"

Calhoun County.

"Marl occurs at intervals† through this county in the alluvial lands of the Kalamazoo River, and pebbles and boulders are not unfrequently seen in the bed of the stream, incrusted with a thick coat of tufaceous marl.

"*Milton*.—Marl was observed in this town on the farm of Hon. S. McCamly. It also occurs in several of the small lakes and streams.

"*Marengo*.—Marl is not of very frequent occurrence in this town. An extensive bed was observed on Sections 1 and 2.

"Marl was observed in the town of *Marshall*, near the Hon. Mr. Pierce's mills. Also, in comparatively small quantity, in the lowlands between the village of Marshall and the Kalamazoo River."

Kent County,

p. 58. "Town 6 North, Range 2 West. Tufa occurs in this township in the bed of the Flat River, on Section 26, in a very extensive deposit.‡

"Marl was observed on Sections 3 and 8, Township 6 north, Range 12 west.

"Extensive deposits of shell-marl occur on Sections 22 and 23, township 7 north, range 10 west.

"Marl was examined in township 8 north, range 11 west, on Sections 13 and 14, in a dry burr oak plain."

Ionia County.

"Tufaceous‡ marl occurs in inexhaustible quantities in the vicinity of Lyon, town, Maple P. O. Incrusted in some portions of the tufa, are quantities of leaves, recent shells, and in one instance have been found the vertebra and other remains of a large snake.

"Marl occurs on Section 1, township 6 north, range 5 west; its extent unknown.

"Extensive beds of shell and tufaceous marl exist near Mr. Dexter's mill in the village of Ionia. Also, in the bed and banks of several of the small streams west of Ionia village.

"Extensive beds of marl occur on Sections 10, 11 and 22, township 8 north, range 8 west.

"This abstract of the locations of this valuable mineral only includes some of the most extensive deposits. It is sufficient, however, to render it apparent that marl is distributed in sufficient abundance to afford a ready supply for use as a manure, as also for the manufacture of quick lime. It is within the reach of every man to obtain this restorative for his soils or a lime for economical purposes; an article of which otherwise much of the country would be nearly destitute.”

p. 73 (Report of C. C. Douglass).

The great profusion in which the deposit is distributed through the counties of VanBuren, Allegan, and Ottawa, is deemed a sufficient reason for noticing a few of the most extensive deposits.

On Sections 20 and 21, half a mile northeast from Mr. Newell's steam mill, on Maskego Lake, is a very extensive deposit of shell-marl that may be profitably used as a manure on the sandy lands of that vicinity.

Extensive deposits of shell and tufaceous marl occur in the valley of the Kalamazoo River, on Sections 9, 10, 16 and 17, township 3 north, range 15 west, of more than one hundred acres. Also on Sections 16 and 17, township 4 north, range 16 west, there is a deposit of shell and tufaceous marl occupying the area of more than seventy-five acres,

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*This is the location of the Pyramid Portland Cement Co.; the Peerless have recently bought beds here.

†These deposits are not far from the Omega plant.

‡Location of the Zenith plant.

*Probably the site of the original Portland cement plant.

†Six places are noted on the map issued by the Douglass Houghton Survey.

A very extensive deposit of marl was examined on Sections 16 and 17, township 3 north, range 13 west. Some of the portions of this marl are found to contain too much iron ore to make good quicklime. Care should therefore be had in selecting that portion of the marl which is free from this mineral.

On Sections 13 and 14, township 2 south, range 13 west, marl of a good quality occurs.

Fourth Annual Report, 1841? p. 104, marl and peat, p. 122, marl and peat.

The remaining references to minor, or at least not extensively exploited deposits, will be arranged according to counties, proceeding east and north from Monroe County.

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‡This is tufa and not the bog lime desired by cement plants.

Locations arranged by counties.

1. (68) *Monroe County*.—The marl deposits referred to by the Douglass Houghton Survey above have been also described by Sherzer in his recent report on the county.* He lists: Claim 422, the largest; claim 161;"claim 520 (?); S. E. quarter of Sec. 24,* Summerfield; Sec. 7 of Exeter; Sec. 9 of Ash; Sec. 9 of London.

A good sample of marl taken from along the line of the Detroit and Lima Northern was sent in by G. A. Chambers, in September, 1898.

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*Vol. VII, Part I, p. 200. "No large beds of this substance are known to occur."

2. (67) *Lenawee County*.—Marl has been reported two miles from Britton, Deerfield township, which is probably calcareous clay and not bog lime.

In the extreme northwest corner we have the Peninsular plant, and there is a good deal of bog lime in this region, e. g., Lowe's Lake, T. 5 S., R. 3 E.

3. (66) *Hillsdale County*.—Besides the deposits of the Omega plant there is said to be a bed of bog lime 11 to 28 feet thick at Nettle Lake, just south of Camden. It is said to have been examined by Mr. Hunter of Philadelphia.

Another bed is near Reading. It belongs to the Monolith Portland Cement Co., whose officers are L. McCoy of Battle Creek, president; M. H. Lane of Kalamazoo and I. P. Baldwin, vice-presidents; H. T. Harvey of Battle Creek, secretary; G. B. Tompkins of Sturgis is treasurer.

Another deposit is at Sand Lake, three and one-half miles west of Hillsdale, Sec. 1, T. 6 S., R. 3 W.

4. (65) *Branch County*.—The plants of this county have already been described by Mr. Hale, and in connection with factories. The county is very rich in bog lime. See the descriptions of the plants at, and visits to, Quincy, Coldwater, Bronson, Union City.

Still other factories are planned at Helmer on the Fort Wayne branch of the L. S. & M. S. R. R. and just west of Coldwater on the river.

5. (64) *St. Joseph County*.—Marl beds near Sturgis have been tested by the same people interested in Bristol and Turkey Lakes, Indiana.

6. (63) *Cass County*.—Near Vandalia at Donald's Lake, Sections 31 and 32, T. 6 S., R. 1 W, is said to be a large deposit, in some places over 25 feet deep.

Near Dowagiac, just north of town, in the lowlands of this old glacial drainage valley, is bog lime. It is said that there are 600 acres, running from 18 to 28 feet in depth, with a percentage of from 75 to 84% calcium carbonate.

Near Niles, beside the bed described by Mr. Hale,* on the farm of R. A. Walton, within half a mile of the C. C. C. and St. L. R. R. is said to be a large bed of marl of excellent quality, along a small stream. Marl was also found with mastodon bones near here.

Harwood Lake on the St. Joseph county line, about 10 miles from Constantine, is said to be surrounded by bog lime. The circumference is about 2 miles and the depth in one place over 50 feet. The owner is W. W. Harvey of Constantine. He also owns a 200 acre bed near Bair Lake, Sec. 5, T. 6 S., R. 13 W.

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*Page 107.

7. (62) *Berrien County*.—As mentioned on p. 154 by Mr. Hale, bog lime occurs in the marshes near Benton Harbor.

8. (61) *Van Buren County*.—There is marl in Secs. 13 and 14, T. 2 S., R. 13 W.

9. (60) *Kalamazoo County*.—This is the county where cement was first manufactured, as already described by Mr. Hale,* and Kalamazoo has been quite a headquarters for such enterprises. (Indiana Portland Cement Company, Kalamazoo Portland Cement Company.) Beside the old site and the Hope township regions described by Mr. Hale there are:

Sugar Loaf Lake, southeast of Schoolcraft, T. 4 S., R. 12 W.

Mud Lake north of Schoolcraft.

Vicksburg, T. 4 S., R. 11 W. Around Vicksburg in Kalamazoo County there are lakes with abundant marl, and directly west is a shaking bog (bog lime) where the Grand Trunk has had much difficulty in maintaining grade. The neighborhood is heavily covered with drift with a good deal of sand.

Near Climax, "100 acres with 20 feet of marl."

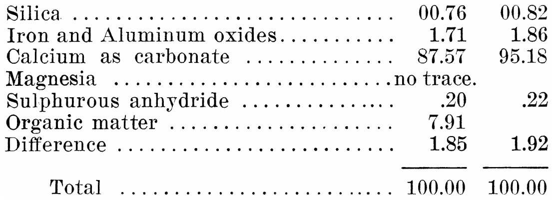
10. (59) *Calhoun County*.—Homer Lake on the farm of H. O. Cook, and under the lake and under 120 acres of the marsh is bog lime varying from 10 to 30 feet in depth. This bed lies west of the town, and there is said to be a bed of greater area around Kesslar's Lakes north of town.

As mentioned in the early reports there are also marl beds of size in Eckford township.

Near the north line of the county, close to Bellevue at Mud Lake are large deposits. See Eaton County. Also in Convis township, on Kinyon Lake (the Creed farm), is a bed.

On the Torrey farm one and one-half miles west of Albion is a small bed of marl, said to be about 25 acres, at the center over 17 feet deep, and shallowing gradually to the edges, and covered by a foot or two of earth (muck). This is an ideal of a complete and as Mr. Hale calls it sealed bed.

The analysis by W. H. Simmons was as follows:



Silica	00.76	00.82
Iron and Aluminum oxides	1.71	1.86
Calcium as carbonate	87.57	95.18
Magnesia	no trace.	
Sulphurous anhydride	.20	.22
Organic matter	7.91	
Difference	1.85	1.92
Total	100.00	100.00

It is suggested that this was taken so near the surface as to contain an unusual amount of organic matter. The second set of figures is referred to marl free from organic matter.

11. (58) *Jackson County*.—There is said to be a bed, 2.5 feet thick, of white marl underlain by one of blue marl, on the farm of J. Dooley and neighbors, almost a mile long, about six miles northeast of Albion.

The bed in Rives township mentioned by the early survey is extensive, and has recently been tested somewhat.

The Michigan Portland Cement Co., a forerunner of the Wolverine is said to have contracted for about 4,000 acres around Portage Lake, which lies in an old glacial drainage channel, surrounded by extensive swamps, and to have planned a private railroad striking the Michigan Central at Munith.

A bed of bog lime is reported near Kelley's Corners. Also four miles from Jackson.

12. (57) *Washtenaw County*.—Four-mile Lake, between Chelsea and Dexter, on the line between T. 1 and 2 S., and in Range 4 E. is surrounded by bog lime. It is said to average 36 feet deep of bog lime, 96% calcium carbonate. About 1,000 acres are said to have been secured, $20,000 having been paid for 200 acres of land.

Marl is also reported from Mill Lake, J. H. Runciman, owner.

Near Ypsilanti is said to be a bed of 75 acres, 12 feet thick, under 2 feet of stripping.

On Sec. 12, T. 2 S., R. 6 E., is a small bed of 25 acres and others similar near by. Such beds are very common.

13. (56) *Wayne County*.—Wayne County is not likely to contain much bog lime except perhaps in the extreme northwest corner.

14. (55) *Macomb County*.—The same remarks apply to Macomb County.

15. (54) *Oakland County*.—This county being high, and early uncovered by the ice, and full of old lines of glacial drainage, and deep holes occupied by glacial lakes, probably contains much bog lime,—more than has been reported.

W. A. Brotherton says that there is marl 40 feet above the stream on Stony Creek, near Rochester. Large deposits are reported near Clarkston.

I. J. Hiller is said to have a bed of 75 to 100 acres.

A small bed of 20 acres and 6 feet deep is reported at Bloomfield Center, with others near by.

The beds near Holly have already been referred to in connection with the Egyptian P. C. Co.

16. (53) *Livingston County*.—Near Brighton and only a mile from the R. R. are marl beds of about 100 acres and average depth of about 12 feet. Lime Lake, Sec. 36, T. 2 N., R. 5 E.

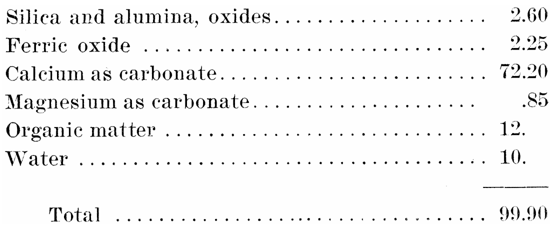
West of South Lyon in Green Oak township are also some bog lime deposits.

Two miles north of Oak Grove is a bed of bog lime, on land belonging to Pierce Elwell and others, on the line of the Ann Arbor R. R. There are other beds on the Ann Arbor line north of Howell.

The deposits around Hamburg and Lakelands, have been mentioned in connection with the Standard Portland Cement Co. There are said to be over 1,600 acres of land underlain by bog lime, which in places is 60 feet deep.

17. (52) *Ingham County*.—There are beds of bog lime near Leslie, one located by H. C. Barden.

Analysis of a Leslie marl is as follows:



Silica and alumina, oxides	2.60
Ferric oxide	2.25
Calcium as carbonate	72.20
Magnesium as carbonate	.85
Organic matter	12.
Water	10.
Total	99.90

There is also a small bed covering about 15 acres, in the northwest quarter of Sec. 24, Vevay, T. 2 N., R. 1 W., belonging to Chester Dolbee. It is now cut through by a stream. On the north side Mr. W. F. Cooper found 6 inches muck, 18 inches marl to sand and gravel; then 20 steps south-southwest, near center of marsh, and gravel; then twenty steps south-southwest, near center of marsh, 9 inches muck; and over 5 feet marl, without reaching bottom. Here the marl was quite white and pure: northwest of this hole a sample full of shells was taken. In general immediately beneath the muck it was full of shells, and deeper down, became a sludge. Under the microscope Chara material appears to be abundant.

18. (51) *Eaton County*.—On the line between Eaton and Calhoun Counties, three miles from Bellevue, there is said to be a bed of bog lime of over four hundred acres, and an average depth of 20 feet. In places it is 37 feet deep and there is but one to two feet of water above it.

There is said to be a suitable clay immediately adjacent.

Around Lacey's Lake, Kalamo township, T. 2 N., R. 6 W., is said to be a large bed of bog lime in places 20 feet thick.

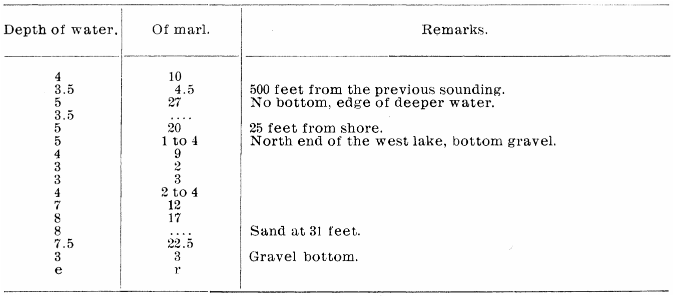
19. (50) *Barry County*.—Mr. Hale has described quite fully the deposits at Cloverdale in Hope township.

Near Prairieville, the township southwest, the bog lime deposits exist, but are said not to be enough to start a cement plant upon.

To the west at Fish Lake, near Orangeville, there are extensive deposits of very good quality as shown by Prof. Fall's analyses. There are 200 acres or more of an average depth of perhaps 20 feet. There is from 0 to 2.5 feet of peat stripping on top. The deepest marl appears to be often close to the water's edge. Though a good bed it is over four miles from the railroad.

Just north in Gun Lake, between towns 2 and 3 N., R. 11 W., the relation between the thickness of the marl and the depth of water is shown by the following table of soundings.

It is obvious that the deeper water does not always have the deeper marl.



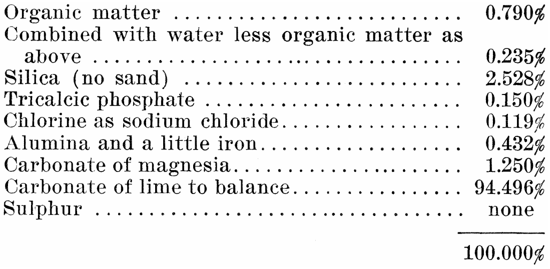
Depth of water.	Of marl.	Remarks.
4	10	
3.5	4.5	500 feet from the previous sounding.
5	27	No bottom, edge of deeper water.
3.5	....	
5	20	25 feet from shore.
5	1 to 4	North end of the west lake, bottom gravel.
4	9	
3	2	
3	3	
4	2 to 4	
7	12	
8	17	
8	....	Sand at 31 feet.
7.5	22.5	
3	3	Gravel bottom.
e	r	

A little farther north. Cobb Lake, Sections 5 and 8, and Barlow Lake, Sections 7 and 18 contain bog lime (said to be 93% calcium carbonate).

21. (48) *Ottawa County*.—A sample of marl from the Lake Shore west of Grand Rapids gave W. M. Courtis, M. E. the following results:

(The sample-loses 6.376% of water and volatile hydrocarbon when dried at 100°.)

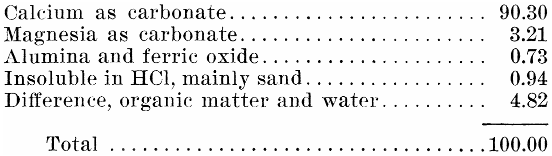
The dried marl contains:



Organic matter	0.790%
Combined with water less organic matter as above	0.235%
Silica (no sand)	2.528%
Tricalcic phosphate	0.150%
Chlorine as sodium chloride	0.119%
Alumina and a little iron	0.432%
Carbonate of magnesia	1.250%
Carbonate of lime to balance	94.496%
Sulphur	none
	100.000%

20. (49) *Allegan County*.

22. (47) *Kent County*.—Beside a number of marl beds in the north part of the county around Cedar Springs, which have been in part described by Mr. Hale, and the insignificant deposits described in the Douglass Houghton reports, there are other large deposits. Mr. Nellist reports 13 deposits many of them first rate, though not convenient. The largest he says is in Wabsis Lake, which is in some places over 100 feet deep (T. 9 N., R. 9 W.) An analysis by A. N. Clark gave:

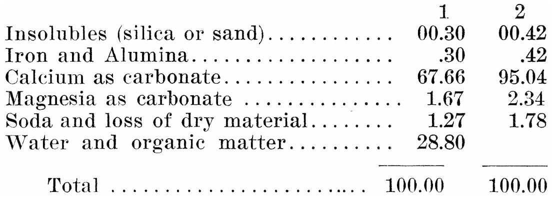


Calcium as carbonate	90.30
Magnesia as carbonate	3.21
Alumina and ferric oxide	0.73
Insoluble in HCl, mainly sand	0.94
Difference, organic matter and water	4.82
Total	100.00

Larnberton Lake, Grass Lake, in Cannon township, and Crooked Lake all contain marl.

There is also marl in a lake on Section 21, Grattan Township, in two little lakes on Section 8, Cascade Township, and in small quantities on Sections 9 and 15, Wyoming Township,

The following is an analysis of a Kent County marl from near Cedar Springs controlled by Stewart and Barker of Grand Rapids. It will be noticed that No. 1 is an analysis of the fresh wet marl, of which we have very few, almost all the analyses being figured to dry marl, or being made on specimens already pretty well air dried.



	1	2
Insolubles (silica or sand)	00.30	00.42
Iron and Alumina	.30	.42
Calcium as carbonate	67.66	95.04
Magnesia as carbonate	1.67	2.34
Soda and loss of dry material	1.27	1.78
Water and organic matter	28.80	
Total	100.00	100.00

The second set of figures are as bog lime analyses are often given, and show that this, except for possibly too much organic matter is a very good specimen indeed. The stripping or top layer contains much more organic matter,—up to 38%. See also Mr. Hale's descriptions in Chapter VI, § 4.

23. (46) *Ionia County*.—Jordan Lake near Lake Odessa, is surrounded by extensive beds of bog lime, which extend into Barry County. The lake lies on the line. They are convenient to the P. M. R. R.

Mad Lake just west of South Lyons also contains bog lime.

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*Chapter VI, pp. 107 to 131.

There is also said to be some near Muir.

24. (45) *Clinton County*.—In the Chandler marsh three and a half miles north of Lansing, T. 5 N., R. 2 W., there is marl; i. e., bog lime, as reported by F. R. Singlehurst.

Merle Beach, significantly named, on Muskrat Lake, T. 6 N., R. 2 W., has also deposits of bog lime over quite a large area under about a foot of peat muck.

25. (44) *Shiawassee County*.—Marl is reported right at Owosso in the Abley Addition, in the southwest corner of Owosso township. Also in the Maple River flats marl is reported in some places over 16 feet thick. Over in Gratiot County around Bannister, Mr. Davis and I did not find any marl along the Ann Arbor R. R. in the extensive marshes there.

A deposit is also reported on the farms of M. Carey, R. F. Kay and J. G. Marsh, in Woodhull township.

26. (43) *Genesee County*.—A number of deposits in this county have already been described in connection with the Detroit, Egyptian, and Twentieth Century Portland Cement plants.

Holden and Buell Lakes, Thetford township, T. 9 N., R. 7 E.

Mud Lake, Arbela township, T. 10 N., R. 7 E.

Marl properties around the above lakes were gathered together by Fred C. Zimmerman and R. Adams of Saginaw. "It appears that the depth of the deposit is anywhere from 10 to 30 feet and deeper. In Holden (Sec. 3) and Buell (Sec. 2) Lakes, where the water is shallow, it can be seen in large quantities. All these lake beds consist of extraordinarily pure marl beds of unusual depth and such consistency that it can be pumped from the bottom.

"Analysis of the material taken from these deposits made at the Ohio State University, gives the following:

Carbonate of lime	89.39
Carbonate of magnesia	1.95
Silica	6.29
Iron and alumina	.99
Organic matter	1.00
	99.62"

The silica is too high if this is a fair sample of the marls, which I doubt.

27. (42) *Lapeer County*.—In the Annual Report for 1901, Mr. F. B. Taylor says:

"There is a considerable quantity of marl in the county, and localities so far determined are shown upon the map. None of them, so far as learned, are of large enough extent to form a basis of cement works in the present stage of this industry. No beds have yet been found having an extent of over 100 acres. Because of their present unavailability mainly, the marls found have not been tested thoroughly to determine their suitableness for cement. The largest swamps in the county in the eastern and northeastern parts, appear not to yield marl. Marl was formerly burned for lime in several parts of the county, most notably in southwestern Hadley, and southeastern North Branch townships. There is marl near Orion."

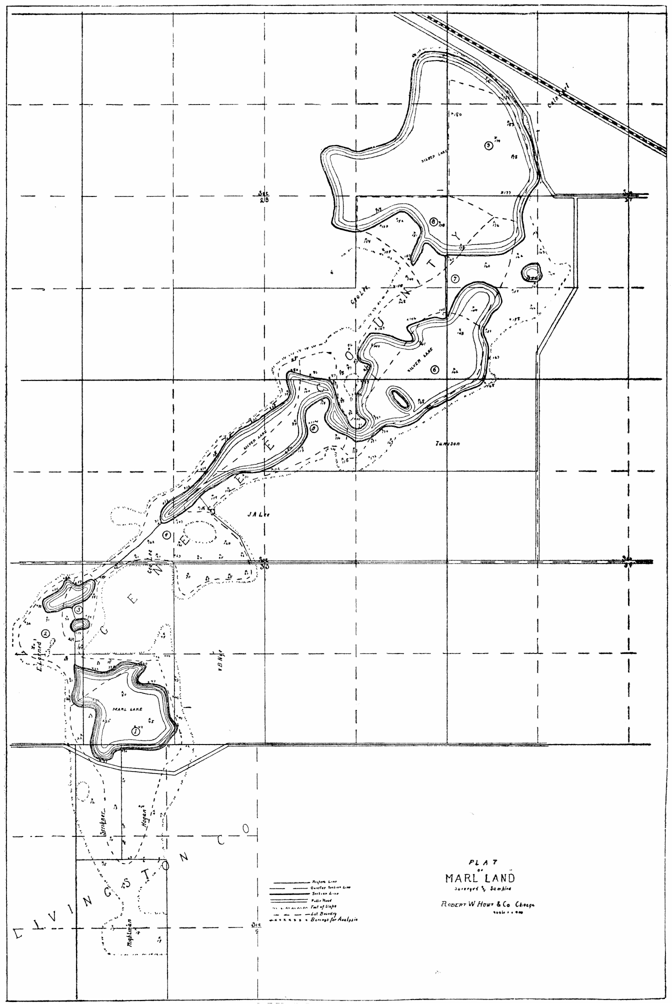

Plate XXI. Silver Lake marl beds.

28. (41) *St. Clair County*.—This county may have a few small beds of bog lime in the western part but none have been reported.

29. (40) *Sanilac County*.—This county was reported in Vol. VII of our reports. Marl probably underlies a good many of the swamps, such as the "Stone wall swamp," in the western part of the county. Some beds have been tested by Cass City parties and are believed to be extensive enough to work. Their proximity to the fine shale exposures of the Lake Huron shore in Huron and Sanilac Counties might be a point in their favor.

30. (39) *Huron County*.—Deposits of marl are described in Vol. VII, and may be sought from Mud Lake northeast to Bad Axe and east to Parisville. It is not likely, however, that there are any very extensive deposits.

31. (38) *Tuscola County*.—Mud Lake in Arbela township has been mentioned in connection with the deposits in Thetford township, Genesee County, just south.

Near Cass City there are said to be big beds of marl 10 feet or more thick. Shale clays can probably also be obtained in this region, as there are exposures of the Michigan series. An analysis of the marl by Prof. Kedzie runs:

Insolubles (silica)	.24
Oxides of iron and alumina	.14
Calcium oxide (as carbonate 94.32)	52.82
Magnesium oxide (as carbonate 2.56)	1.25
Carbon dioxide	39.16
Difference, organic, etc., (2.72)	6.39
Total	100.00

The variation in the items of difference shows how much of the lime is combined as sulphate or with an organic acid.

32. (37) *Saginaw County*.—There is probably no bog lime, i. e., what the cement companies call marl, in Saginaw County, beyond possibly a few inches in swampy hollows.

What has been reported as marl, like that on the Prairie farm, is clay marl,—and only an ordinary surface clay free from grit. For instance, E. Wetzel opened a bed of clay at Zilwaukee, eight feet down and about twelve feet thick, which gave H. &. W. Heim on analysis:

	Top.	Bottom.
Silica and alumina	65.1	63.75
Calcium carbonate	20.4	20.9
Difference	14.5	15.35
Total	100.00	100.00

33. (36) *Gratiot County*.—Five miles west of Alma is a small bed of 30 acres from 4 to 16 feet deep.

Cedar Lake District.

34. (35) *Montcalm County*.—Montcalm County is full of lakes, many of them containing more or less marl. The neighborhood of Cedar Lake, a few miles east of Alma, shows an interesting variety of occurrence of marl and has been somewhat investigated, as shown by Fig. 31 and the following description:

Bass Lake occupies a hollow in the sands. The shore is sandy and there is no outlet. Rock Lake is similar but the surroundings are somewhat more gravelly. Marl Lake has already been referred to by Mr. Davis.* The water is pure, milky white, and this he attributed to the fact that there is a bench about 100 yards wide of pure marl around the lake over which the water is shallow, from two feet down. There is no peat covering over this bed. This we notice in the diagram of soundings (Fig. 31), and we notice too that soundings 5, 9 and 13 outside the shore of the lake show no marl.

Mr. Jno. Webster's estimate of marl on this lake is of marl 12 feet thick, 100 yards wide, over a circumference of 5,186 feet, i. e., 6,220,800 cubic feet. It is quite likely 11; at there is two or three times as much as this.

On the other hand, about Cedar Lake, which is slightly higher, the conditions are entirely different. The marl is covered with peat and at the edge, which is the margin of the lake, drops off to 30 feet depth very rapidly. The peat varies, as we see in the diagram of soundings, from one to five feet thick; being generally about three feet thick.

The land south of the railroad rises rapidly 175 feet or more, and the lake lies in a valley in the till. As bearing on the origin of the marl, it is worth noting that an upward pressure of the ground water is shown by three flowing wells on the road from the station to the lake, which penetrate the drift to a depth of 48 feet. The temperature of these wells is for the first one 49° F., and for the one nearest the lake 48.3°F. It is quite likely that Cedar Lake is deep enough to come pretty near to the artesian stratum and allow considerable upward seepage. This is of interest in considering the origin of the marl. An analysis by R. C. Kedzie of clay brought to the surface by one of these wells, is as follows:

Silica, soluble	60.00
Sand	3.00
Calcium as carbonate* ($CaCO_3$)	18.31
Magnesium as carbonate ($MgCO_3$)	3.00
Alumina and oxide of iron	14.80
Difference (water or losses)	.89
	100.00%

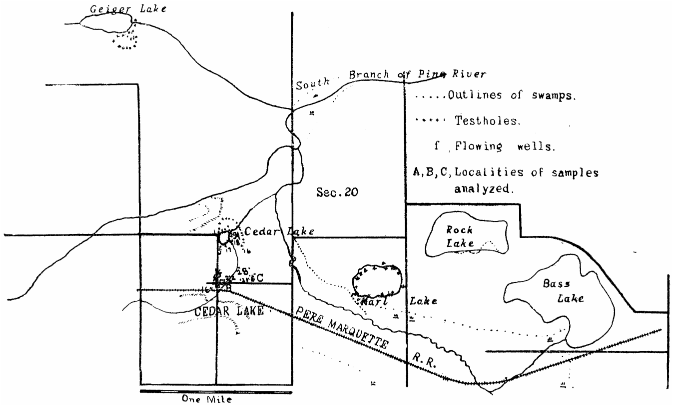

Figure 31. Sketch map of the lakes near Cedar Lake Station of the Pere Marquette R. R., T. 10 N., R. 5 and 6 W.

This would not be a bad Portland cement clay so far as the analysis goes, but it is one of the common surface calcareous clays and it is not likely that the lime would come twice alike.

Cedar Lake is quite a little lower than the railroad station and the water level seems to have been falling. This may have helped the peat to spread more rapidly over the marl, and helps to account for the marl extending considerably above the present level of the lake, a meadow north of the station showing a considerable thickness of marl, analyses B and C. In this latter place it is cut into by the stream. When the material for analyses A and B was taken the marl was 22 feet thick with about one-half foot of muck on top.

Of B, which is near the railroad, a sample barrel was shipped to the H. S. Mould Co., for briquetting, and they report that it can be successfully handled at a cost not to exceed 50c a ton.

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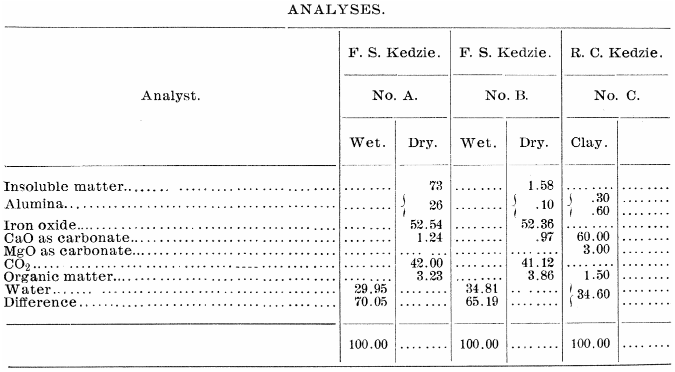
*Page 83.

*It is probable that the lime and magnesia are not all carbonate, hence the difference is too small.



ANALYSES.

Analyst.	F. S. Kedzie.		F. S. Kedzie.		R. C. Kedzie.	
	No. A.		No. B.		No. C.	
	Wet.	Dry.	Wet.	Dry.	Clay.	
Insoluble matter		73		1.58		
Alumina		26		.10	.30 .60	
Iron oxide		52.54		52.36		
CaO as carbonate		1.24		.97	60.00	
MgO as carbonate					3.00	
CO_2		42.00		41.12		
Organic matter		3.23		3.86	1.50	
Water	29.95		34.81		34.60	
Difference	70.05		65.19			
	100.00		100.00		100.00	

Around Cedar Lake, Mr. Webster estimates, see Fig. 31, 13 feet of marl on 20 acres, i. e., 11,325,600 cubic feet, and tributary two acres 11,174,400 cubic feet beside.

Around Geiger Lake (Fig. 31), he finds six and one-half acres 12 feet thick, or 3,136,320 acres. These estimates are certainly very conservative, and as Mr. Webster himself says, a larger amount of time in testing would have materially increased the amount upon which he could surely estimate. Altogether in the region there is said to be some 700 acres of marl lands, options upon which were held by W. S. Nelson and George Reed. Cedar Lake has furnished some of the material for microscopic tests, and for Prof. Davis's experiments.

The Cedar Lake marl is very pure Chara lime, and there is just a small residue, in which angular quartz grains, rarely as large as 0.07 mm occur. There is one well terminated crystal of tourmaline, prismatic with blunt rhombohedral terminations, the two ends slightly different in tint, with appropriate refraction, bi-refraction, and pleochroism.

Riverdale.

Just east of the Cedar Lake district in Gratiot County is Riverdale,—where the Pere Marquette crosses the Pine River. The valley here is much too large for the Pine, being an old gravel filled drainage channel of the ice. Southwest of the village, toward a small pond known as Mud Lake, is a swamp covered with peat, underlain with marl toward the center. The peat cover is thicker toward the margin of the swamp.

This also is in a region where flowing wells occur at a shallow depth (38 feet).

In Mud Lake marl, from near Riverdale, the cell walls appear as dark lines, with more coarsely polarizing matter between as the calcite radiates from them. There are also bodies, fruit op spores (?) with a little greater index than balsam, spheroidal in shape, with yellow polarization colors and a distorted black cross of + character, and a diameter of about 0.04 mm.

Olson Lake and a number of other lakes near Howard City contain bog lime, and some of them have been already described by Mr. Hale.

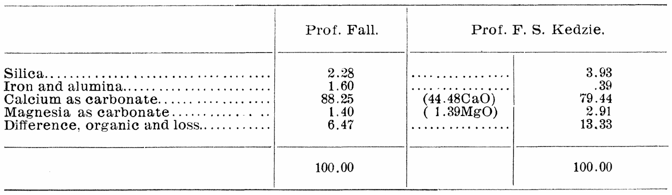
35. (34) *Muskegon County*.—A sample of marl has been sent by Mr. Keating of the Muskegon Board of Trade, but no extensive deposits have been made public. Mr. Hale found nothing pure.

36. (33) *Oceana County*.—H. Kennedy is said to have on his farm in Rothbury, a lake whose bottom is rich in fertilizer (?) of a marly nature.

Marl is also said to have been found near Pentwater.

37. (32) *Newaygo County*.—Some of the deposits of Newaygo County have been quite fully described in connection with the Newaygo plant and by Mr. Hale.

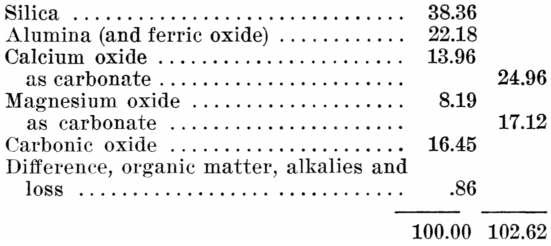
A sample of marl from Fremont Lake gave:



	Prof. Fall.	Prof. F. S. Kedzie.	
Silica	2.28		3.93
Iron and alumina	1.60		.39
Calcium as carbonate	88.25	(44.48CaO)	79.44
Magnesia as carbonate	1.40	(1.39MgO)	2.91
Difference, organic and loss	6.47		13.33
	100.00		100.00

Direct estimate gave Prof. Kedzie 34.54 CO_2 and 15.36 organic matter and loss. Thus the indications are that in this marl the CaO is combined in part with an organic acid.

An adjacent surface clay gave Prof. Kedzie:



Silica	38.36	
Alumina (and ferric oxide)	22.18	
Calcium oxide	13.96	
as carbonate		24.96
Magnesium oxide	8.19	
as carbonate		17.12
Carbonic oxide	16.45	
Difference, organic matter, alkalies and loss	.86	
	100.00	102.62

38. (31) *Mecosta County*.—In the neighborhood of Barryton are said to be marl beds from 20 to 300 acres in extent (T. 16 N., R. 7 W.).

The beds around Pierson are described in § 3. Historical. of CHAPTER VII.

MANUFACTURE OF PORTLAND CEMENT FROM MARL.

39. (30) *Isabella County*.—The Littlefield Lake deposit has already been described by Mr. Davis, and in connection with the Farwell P. C. Co. It is probably the best in the county.

40. (29) *Midland County*.—This county probably contains no large deposits of bog lime.

41. (28) *Bay County*.—The shale clays of this county, developed by the coal mines, have been mentioned in connection with the Hecla P. C. and C. Co. There are probably no large deposits of bog lime, unless possibly in the extreme north.

42. (27) *Arenac County*.—There is not much bog lime in this county, though there is some valuable limestone. There may be a little under the marshes of the west end.

43. (26) *Gladwin County*.—Extensive beds are reported within a mile of the county seat, and there may be others northwest.

44. (25) *Clare County*.—See description of the beds of the Clare Portland Cement Co.

45. (24) *Osceola County*.

46. (23) *Lake County*.—The principal beds here are probably in the possession of the Great Northern P. C. Co., and have been previously described.

A bed is reported on Section 3, T. 20 N., R. 14 W.

47. (22) *Mason County*.—Large beds are reported near Miller-ton on the line of the Manistee and Grand Rapids R. R., near the west line of Lake County.

48. (21*) Manistee County, and region of the Manistee and Northeastern R. R.*

Through the courtesy of J. J. Hubbell, chief engineer of the Manistee and Northeastern R. R. we have the result of their work of investigation which he has superintended, to add to the notes of Mr. Hale on his trip. This region includes:

49. (20) *Wexford; and also Benzie, Grand Traverse and Leelanau Counties.*

The collection embraces some 52 clays and marls of which samples were taken, and turned over to us in their case.

Many of the surface clays, though calcareous as usual, run lower in carbonates than those from other parts of the State as the following group of analyses shows, in which, however, the magnesia is so high relative to the lime as to show that the material is dolomitic. Such clays will hardly effervesce with cold acid, and may thus pass for better cement clays than they really are.

Lab. No.	592	593	594	595
Mark	65	66	67	68
Silica	61.94	56.64	61.10	59.36
Alumina	11.58	12.18	13.91	12.38
Iron (ferric) oxide	3.49	3.59	3.62	3.62
Calcium oxide	5.92	8.17	6.32	5.63
Magnesium oxide	4.85	4.29	3.91	4.62
Sulphuric anhydride	.18	.31	.31	.30
Difference, CO_2, organic, alkalies, etc	12.04	14.82	10.83	14.09
Total	100.00	100.00	100.00	100.00
Calcium as carbonate*	10.6	14.6	11.3	10.1
Magnesium as carbonate	10.1	9.0	8.2	9.7
Total dolomitic matter	20.7	23.6	19.5	20.2
Difference to balance, organic, alkalies, etc	2.11	3.48	1.56	4.14

W. H. Simmons of Bronson, Chemist, Dec. 17, 1900.

The following are some of the clays:

No. 1A. East Lake, Sec. 4, 5, T. 21 N., R. 17 W., 4 feet thick; 1 to 2 feet of sand stripping, a smooth, pink brick clay, surface, high in lime with a trace of sand.

No. 1B. Same location, 5 to 10 acres of it, 2 feet thick; 2 feet muck stripping, with no sand and but a trace of lime. A smooth blue clay.

No. 2. Arendale Hill, Sec. 15, T. 22 N., R.16 W.; extensive quantity, with 2 to 4 feet stripping; very high in sand and high in lime. A pink brick clay, but probably with some small pebbles.

No. 4. Onekama, Sec. 25, T. 23 N., R.16 W.; extensive quantity, with light stripping, no sand, but a moderate amount of lime; in appearance like 1A.

No. 5. Manistee, Sec. 31. T. 22 N., R. 16 W.; moderate quantity, with 3 feet stripping, a trace of sand and high in lime; a laminated, pinkish, fine grained clay.

No. 6. Copemish, Sec. 7, T. 24 N., R. 13 W.; small quantity, with 2 to 4 feet stripping; no sand, and a moderate amount of lime; a smooth, pink plastic clay.

No. 7. Betsey River ("Aux Becs Scies"), Sec. 10, T. 24 N., R. 14 W.; quantity large and stripping light; sand high, and moderate amount of lime; a massive, pink clay.

No. 8. Horicon, Sec. 9, T. 25 N., R. 12 W.; a limited quantity of clay with heavy stripping; with no sand, but much lime; a blue clay, till clay, with small limestone fragments.

No. 9. Carp Lake, Sec. 1, T. 28 N., R. 12 W.; large quantity with light stripping; only a trace of sand, and a moderate amount of lime; a tough, plastic, pinkish clay.

No. 10. Duck Lake, Sec. 26, T. 26 N., R. 12 W.; limited amount with heavy stripping; no sand but high in lime; a pink clay.

No. 11. Cedar Run, Sec. 6, T. 27 N., R. 12 W.; moderate amount with 4 to 6 feet of stripping; no sand, and a moderate amount of lime; looks much like 1A; a smooth, pink clay.

No. 12. Carp Lake, Sec. 15, T. 28 N., R. 12 W.; quantity limited and stripping 5 to 19 feet; with no sand but high in lime; compared with No. 9 it appears smoother and more uniform.

No. 13. Traverse City, Sec. 28, T. 28 N., R. 11 W.; large amount, with no stripping; a smooth, pink clay. Analysis:

Sand	00.00
Silica	29.06
Magnesia	2.07
Lime (carbonate?)	50.02
Alumina	12.03
Iron (oxide?)	5.02
Difference	1.80
	100.00

No. 14. Sherman, Sec. 31, T. 24 N., R. 11 W.; limited amount; too much stripping; sand but a trace, but lime heavy; a cream-colored clay.

No. 16. Platte River, Sec. 14, T. 27 N., R. 14 W.; amount limited, and too much stripping; with no sand, but a trace of lime; a deep red, plastic clay; would be a valuable clay if favorably located.

No. 17. Platte River, Sec. 29, T. 27 N., R. 14 W.; amount limited, but stripping light; only a trace of sand and lime; a red clay, similar to No. 16; a valuable clay, but I suspect that the lack of lime is due to leaching, and would not be found persistent.

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*Calculations below totals are by A. C. Lane and not by analyst.

Plate XXII. General view Newaygo Portland Cement Co’s plant.

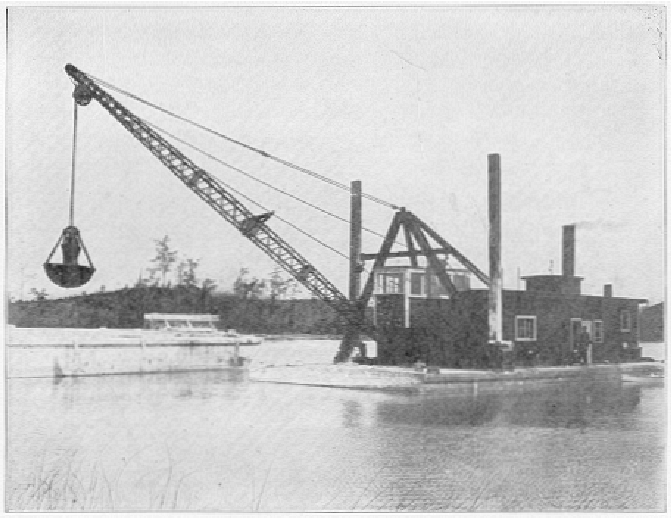


Plate XXII. Method of excavating marl.

No. 20. North and east of Wexford, Sec. 23, T. 25 N., R. 11 W.; amount small, and amount of stripping unknown; high in sand and lime; a buff, brick clay.

No. 22A. Dean’s Mill, Sec. 30, T. 24 N., R. 11 W.; one hundred acres of it, with 1 foot of stripping; no sand and only a trace of lime; a buff clay with roots in it; valuable if not merely a superficial layer.

No. 22B. Dean's, Sherman, same section; a large amount directly under 22A; analysis as follows:

Sand	trace
Silica	41.76
Alumina and iron oxides	17.16
Lime (oxide?)	16.00
Magnesia	5.62
Loss (on ignition?)	19.02
Difference	0.44
Total	100.00

This analysis shows that the clay 22A is probably due merely to superficial leaching, and will be irregular in thickness. No. 22B is a smooth, pink clay with a resemblance to No. 1A, etc.

No. 22C. Dean's, Sherman, same locality and directly under 22B; large amount; analysis as follows:

Sand	trace
Silica	47.68
Aluminum and iron oxides	17.70
Lime (oxide?)	12.50
Magnesia	5.38
Loss	16.42
Difference	0.32
Total	100.00

A drab, plastic clay, a shade bluer than 22B.

No. 22D. Dean's Mill, same section; stripping of 220; amount extensive; with no sand, and only a trace of lime, according to report, but the sample with the survey effervesces freely; apparently the same as 22C.

No. 23. Northport, Leelanau County, Sec. 10, T. 31 N., R. 11 W.; large amount, but 3 feet of stripping; no sand and a moderate amount of lime; a good deal like the clay at Manistee, No. 5.

No. 24. Meesick, Sec. 11, T. 23 N., R. 12 W.; large quantity with light stripping; no sand, and a moderate amount of lime, much like No. 23.

No. 25. Eddington farm, Sec. 25, T. 27 N., R. 13 W.; extensive quantity with light stripping; high in sand, and moderate in lime; a dark red clay, with some small pebbles. Apparently a till clay of little value.

No. 26A. Stanley’s clay, Harrietta, Part I, p. 3, this report, probably, large amount with 2 or 3 feet of stripping; analysis (compare analysis 24 of Part I):

Sand	0.00
Silica	55.60
Magnesia	12.00
Loss on ignition (?)	15.60
Difference (calcium oxide?)	16.80

No. 27. Carp Lake, Sec. 12, T. 28 N., R. 12 W.; amount limited and stripping heavy; no sand but much lime; much like 26A.

No. 28. Carp Lake, same section as No. 27; large amount and no stripping; no sand and moderate amount of lime; one of the common, smooth red clays.

No. 29. Manistee, Sec. 30, T. 22 N., R. 18 W.; large amount and no stripping; much sand and a moderate amount of lime; contains some small pebbles,—a till clay.

No. 30. Monroe Center, Sec. 6, T. 25 N., R. 11 W.; large amount, with 1 to 3 feet of stripping; no sand and no lime; a greenish, somewhat vari-colored clay, and if the sample is a fair one, it ought to be a very valuable clay.

No. 31A. Russell’s farm, Sec. 22, T. 21 N., R. 18 W.; a very large amount with no stripping; only a trace of sand and a moderate amount of lime; one of the common type of smooth, pink plastic clay.

No. 31B. Russell’s farm, same location; 2 to 3 feet thick with No. 31A as a stripping; with much sand and a moderate amount of lime; these two clays together could be nicely combined in making brick.

No. 32. Sherman, Sec. 31, T. 24 N., R. 11 W.; large amount with light stripping; no sand and no lime; smooth, with a greenish tinge; apparently a valuable clay for cement or other purposes.

No. 33. Near Sherman, Sec. 25, T. 24 N., R. 12 W.; large amount with light stripping; no sand and a moderate amount of lime; a smooth, pint plastic clay.

No. 34. On Manistee River, Sec. 10, T. 23 N., R. 12 W.; amount unknown, but no stripping; no sand and a moderate amount of lime; a smooth, red clay.

No. 35. Bear Creek, Sec. 6, T. 22 N., R. 14 W.; very large amount with very light stripping; no sand and a moderate amount of lime; a very smooth clay, in color between blue and purplish drab.

No. 36. Platte township, Sec. 29, T. 27 N., R. 14 W.; limited amount with light stripping; only a trace of sand or lime; the sample, however, is a common pink clay, probably a till clay, with small pebbles, and free effervescence in acids.

No. 37. State Lumber Co., S. W. quarter of N. E. quarter, Sec. 22, T. 26 N., R. 14 W.; high in sand with a trace of lime; a pink clay.

No. 38. Jas. Case, Homestead P. O.; southwest quarter of northwest quarter, Sec. 22, T. 26 N., R. 14 W.; no sand and moderate in lime.

No. 39. Carp Lake, Sec. 12, T. 28 N., R. 12 W.; see No. 9; large amount, with moderate amount of stripping; a trace of sand and moderate amount of lime; a reddish clay.

No. 40. Carp Lake, same location as No. 39; a large amount with moderate stripping; similar in sand, lime and appearance.

No. 42A. Brosch Estate, Traverse City, Sec. 1, T. 27 N., R. 11 W.; 80 acres of it, 2 feet thick; stripping light; analysis:

Sand	00.00
Calcium oxide	3.15
Magnesium oxide	0.31
Aluminum and iron oxides	32.79
Silica	60.62
Difference	3.13
Total	100.00

No. 42B. Same location as 42A; 80 acres of unknown depth, with 2 feet of stripping; no sand and a moderate amount of lime. This appears to be the main bed of reddish clay, of which A is a superficial layer, produced by leaching. They are very similar in looks.

No. 43. B. Hoke, Sherman, southwest quarter of the southwest quarter, of Sec. 29, T. 24 N., R. 11 W.; moderate amount with light stripping; high in sand, and moderate in lime; a blue clay,

No. 44. Southeast quarter of the southeast quarter, of Sec. 18, T. 24 N., R.12 W.; with a trace of sand and moderate in lime; a pink clay.

No. 45. Corey, Wexford Corners, northeast quarter of the northwest quarter, Sec. 18, T. 24 N., R. 11 W.; with a trace of sand, and moderate in lime; a pink clay.

No. 47A. Lake Bluff, north of Leland, Sec. 4, T. 30 N., R. 12 W.; bluff 200 feet high, with no stripping; free from sand with a moderate amount of lime; a typical pink till clay; the sample is not free from pebbles and sand, though they are not abundant.

No. 48A. Lake Leelanau, Sec. 11, T. 30 N., R. 12 W.; large amount with light stripping; no sand but high in lime; a smooth, pink clay.

No. 48B. Lake Leelanau, layer below 48A; similar in character; very smooth.

No. 48C. Lake Leelanau, layer below 48A; similar in character.

No. 52. Sec. 19, T. 24 N., R. 11 W.; small amount with heavy stripping; a large amount of sand, but low in lime.

No. 53. Clay to be used at Baldwin; a smooth, pink clay, freely effervescing; one of the common surface clays. No. 60 is a calcareous shale from the bay shore near Petoskey. No. 15 was a clay from the foundation of the new pumping station at Detroit, of the water-works; a green sand clay, freely effervescing. The remaining numbers are of marls, many of them not along the line of the road.

No. 54 was a very fine specimen of almost pure calcium carbonate, bog lime, or marl, from Baldwin.

No. 55 was supposed to be an average sample, perhaps not quite so fine, showing some root marks and some shells.

No. 56. Bronson Lake, Sec. 4, T. 26 N., R. 13 W.; a widening of the Platte River; dark blue with quite a number of shells.

No. 57 is from Newaygo.

No. 58. This is from the "Bigmarsh," a filled lake connected with the Betsey ("Aux Becs Scies") River, Sections 1 and 2, T. 25 N., R. 13 W.; said to cover 988 acres, varying from 6 to 35 feet in depth, and (as a result of 600 soundings) to contain about 23,000,000 cubic yards. The sample has a slight bluish tinge, and a good many shells, and appears quite as good as most commercial marls, that of the Peninsular plant, for instance.

No. 59. From Carp Lake, Sec. 24, T. 30 N., R. 12 W.; at the narrows; a good-looking, bluish marl.

Besides these deposits of bog lime, there are in this district:

Mr. Farr's deposit at Portage Lake, Onekama, already described by Mr. Hale.

A deposit in the south end of the lake at Arcadia.

A deposit in Little Platte Lake, Sec. 36, T. 26 N., R. 15 W.

The deposits in Upper Herring Lake, controlled by the Water-vale P. C. Co., already described.

A deposit at the head of Carp Lake, Sec. 10, T. 28 N., R. 12 W., as well as that at the narrows, already mentioned.

On the north side of Olen Lake, Sec. 26, T. 29 N., R. 14 W.

In Traverse Lake and perhaps Lime Lake, T. 29 N., R. 13 W.

50. (19) *Missaukee County*.

51. (18) *Roscommon County.*

52. (17) *Ogemaw County*.—Beside the extensive deposits of bog lime described in connection with the Hecla cement plant, and the projected plant at Lupton, the same is reported from:

Gamble Lake, Sec. 11, T. 23 N., R. 3 E.

Devore Lake, Sec. 11; same township.

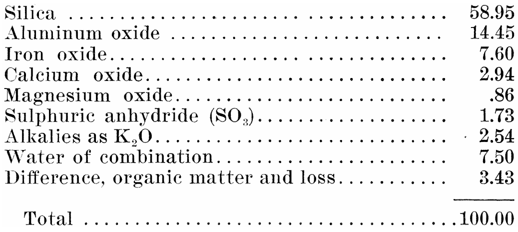
Sage Lake, a large lake in the south central part of T. 23 N., R. 4 E.

As there are probably outcrops on the Rifle River of the Michigan and coal series, it is likely that good shale clays may be found in the county, although as already remarked, the Hecla plant plans to go to the coal measure shales of Bay County for theirs.

53. (16) *Iosco County*.—Valuable marl beds are said to have been found near East Tawas by H. C. Bristol.

The Michigan series of outcrops in this county at Alabaster, and up the Au Gres River, and exposures of argillaceous limestone, suitable for rock cement and probably of shale clays for mixing in Portland cement occur.

The following analysis, is I think, from one of these clays, taken from near Alabaster and Sherman, and analyzed for R. A. McKay of Bay City by F. S. Kedzie:



Silica	58.95
Aluminum oxide	14.45
Iron oxide	7.60
Calcium oxide	2.94
Magnesium oxide	.86
Sulphuric anhydride (SO_3)	1.73
Alkalies as K_2O	2.54
Water of combination	7.50
Difference, organic matter and loss	3.43
Total	100.00

Its freedom from lime or grit, and high per cent of silica are valuable qualities.

54. (15) *Alcona County*.—In the annual report for 1901 some details are given regarding the bog lime deposits of this county I pp. 60 to 65) as follows. The deposit north of Harrisville about three miles, near what is known as Ludington's Spring, received some attention in the summer of 1899.

"Marl deposits in Alcona County, so far as examined, were found to be too thin to be utilized in the cement industry. There is from 6 to 10 feet of rather impure marl in the lake on the township line a mile west of Lincoln. About 6 feet of marl, apparently of good quality, was found on the border of Tubb's Lake in Sec. 31, T. 26 N., R. 7 E., forming a platform 10 or 12 rods wide. Marl deposits 1.5 to 2 feet thick are exposed in a railway ditch in a swamp one-half mile north of Harrisville station, and a similar depth in railroad ditches south of Greenbush on the west side of Cedar Lake.

"Deposits of what is popularly known in Michigan as marl, but is nearly a pure calcium carbonate, occur at a number of points, at Springport (South Harrisville), Kirk Ludington's, Shabno's, four miles south of the Presbyterian church in T. 27 N., R. 9 E., etc.

"A very interesting deposit in some ways is one that is crossing the lake road about three miles and a half north of Harrisville.

"It covers probably not less than 20 acres. I do not know how deep it is, though it has been tested.

"The interesting thing, however, is its mode of occurrence, which is directly in front of the bluffs worn by the lake at a higher level, with no ridge or barrier between it and the present lake. It is wasting away, but the upper part is redissolved and precipitated and passes into a firm and hard calcareous tufa, while as one goes down, it becomes granular and then soft. It appears to be a genuine Chara lime formed by the precipitation of lime by the lake weed known as Chara, but it can hardly be supposed to have been found in such purity directly on the beach of a great lake, and we are forced to assume that it is the relic of a small lake, the rest of which has been eroded away.

"There is enough, perhaps, for lime kilns, but hardly, I think, for a cement plant; and, beside, it is so hard and granular on top that the advantage of marl, its fine sludgy character suitable for mixing, would be lost.

"In general, clay deposits of fine and uniform texture are rather rare in Alcona County, but in the southeast part there is considerable clay that carries but few pebbles, an area of several square miles being found around Mikado and northward from there between Gustin and Killmaster. Although an unsuccessful attempt has been made to burn a kiln of brick at Mikado, it seems probable that the surface clay will in many cases prove suitable for brick or tile. It will at least be worth while to experiment further with the clay, for that part of the county would be greatly improved by underdraining with tile, and it will be an advantage to manufacture the tile where it is to be used.

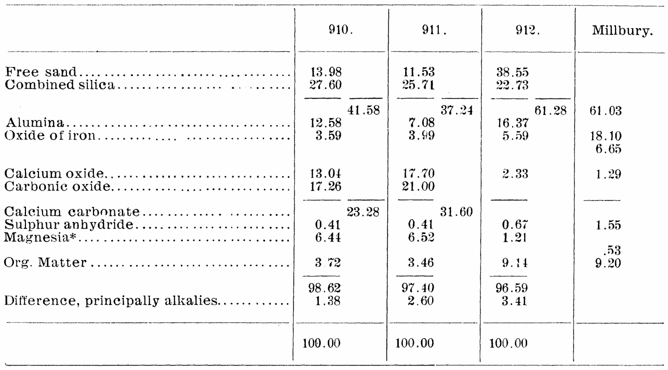
"At South Harrisville, Sec. 32, T. 26 N., R. 9 E., some brick has been made of glacial clay. It Is not entirely free from pebbles, effervesces somewhat and makes cream-colored brick. Some brick has been made also at Mikado (West Greenbush) of a similar quality. All the clays of the county are Pleistocene or surface clays, and it is the almost universal rule that such clays have more or less calcium and magnesium carbonate. Generally the top of the bed is free from carbonates, which have been leached out.

"Just at Harrisville the stream falls over a smooth, well-bedded clay, apparently an old lake clay free from pebbles. If not, it could easily be washed free by the stream.* Back of Sturgeon Point, on Sec. 25, T. 27 N., R. 9 E., are fields where a similar clay appears to be present, but it is particularly well exposed where the Black River opens out from the hilly moraine country to the swampy land of the old lake bottom on Sec. 3 of the same township and Sec. 34, just north. Here a calcareous clay is extremely well exposed in the bed of the stream, appearing almost as though it were bed rock. But probably the same bed of clay also appears in the bluffs of the outer valley above the flood plain and at least 10 feet above the river. Here it is light reddish in color, does not effervesce with acid, lies close to the abandoned track of an old logging railroad, and could be readily worked. I should think it would make unusually good brick and tile (see analysis below), though it is quite possible that farther working and testing with auger would show that in going deeper more lime was encountered. Still it is quite likely that an important top layer may have been leached free.

"There are indications that similar clays occur all the way along, but somewhat below and nearer the shore, the highest former shore line of Lake Huron (645 to 655 A. T.).

"The Au Sable River also flows at several points over firm, well-bedded pink clays, apparently free from pebbles but full of lime. A good place to observe them, however, is in a little side stream at Bamfields, Sec. 11, T. 25 N., R. 5 E., where they are well exposed.

"Three typical samples of the clays were sent to the McMillan Chemical Laboratory, Albion, for analysis, and the following reports were received from Prof. Delos Fall:



	910.		911.		912.		Millbury.
Free sand	13.98		11.53		38.55		
Combined silica	27.60		25.71		22.73		
		41.58		37.24		61.28	61.03
Alumina	12.58		7.08		16.37		
Oxide of iron	3.59		3.99		5.59		18.10
							6.65
Calcium oxide	13.04		17.70		2.33		1.29
Carbonic oxide	17.26		21.00				
Calcium carbonate		23.28		31.60			
Sulphur anhydride	0.41		0.41		0.67		1.55
Magnesia*	6.44		6.52		1.21		
							.53
Org. Matter	3.72		3.46		9.14		9.20
	98.62		97.40		96.59		
Difference, principally alkalies	1.38		2.60		3.41		
	100.00		100.00		100.00		

"No. 910 is the ordinary calcareous clay or marl of the district from Black River near the water level, and is free from pebbles or grit. It will be seen that it is composed of about one-third very fine sand or rock flour, one-third clay proper, and one-third dolomite. It may be used for making brick, but will yield a light brick that will not stand hard burning.

"Samples of clay from the Au Sable valley appear to have similar composition.

"No. 911, from the old brickyard southeast of Harrisville, is a typical tile clay and contained some small limestone pebbles. It will be seen that it contains even more lime, nearly half. Neither of the clays appear to be suited to the higher uses for clay.

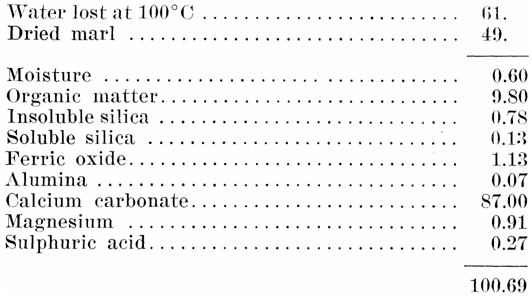
"No. 912, the third clay, which lies over No. 910 and may be derived from it by solution of the calcareous material, is of an entirely different character. If the silica is finely divided enough, and I think it is, it would make an excellent clay to mix with Portland cement for the manufacture of marl. I have given an analysis of the Millbury, Ohio clay, which is largely used in the State for cement manufacture, for comparison.

"It would also make an excellent grade of red brick, and very probably also paving brick. It remains to be seen by a series of borings how much of this clay there is, but in all probability field tests showing whether it effervesces with muriatic acid will be sufficient to show this."

55. (14) *Oscoda County*.—There are probably considerable beds of bog lime, but little is as yet known of them. Some is reported about 5 miles west of Luzerne, near Tyrrell, T. 26 N., R. 1 E.

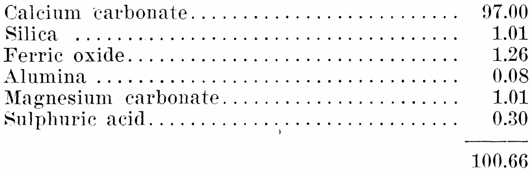
56. (13) *Crawford*.—There is a deposit of bog lime close to Grayling. The analysis given in the Agricultural Bulletin, No. 99, is in error.

An analysis of the Grayling marl by W. M. Courtis, M. E., is as follows:



Water lost at 100°C	61.
Dried marl	49.
Moisture	0.60
Organic matter	9.80
Insoluble silica	0.78
Soluble silica	0.13
Ferric oxide	1.13
Alumina	0.07
Calcium carbonate	87.00
Magnesium	0.91
Sulphuric acid	0.27
	100.69

Same sample figured without the organic matter is:



Calcium carbonate	97.00
Silica	1.01
Ferric oxide	1.26
Alumina	0.08
Magnesium carbonate	1.01
Sulphuric acid	0.30
	100.66

57. (12) *Kalkaska County*.

58. (11) *Grand Traverse County*.—Some of the beds of this county have been described in connection with the Elk Rapids Portland Cement Co., and the work of Mr. Hubbell for the Manistee and Northeastern R. R.

59. (10) *Benzie County*.—The beds of this county have been largely described in connection with the Watervale plant, by Mr. Hale, and in connection with the Manistee and Northeastern R. R.

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*As at Sebewaing, see Vol. VIII, Part I.

*There is not enough CO_2 to combine with all the lime and magnesia, hence there is probably some hydrous magnesian silicate present. L.

A bed of 100 acres is reported near Aral.

60. (9) *Leelanau County*.—Some beds of this county have been referred to in connection with the explorations of the Manistee and Northeastern R. R.

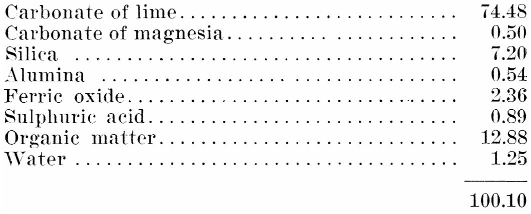
61. (8) *Antrim County*.—The Elk Rapids factory is located in this county. Beside this company the "Lake Shore Cement Company" (G. W. Davis of Mt. Pleasant, S. B. Daboll of St. Johns, and others), have obtained options on the lime deposits of Intermediate (which Mr. Hale has described, p. 142, as Central Lake), Grass and Clam Lakes, some 600 acres in all it is said. The shores of this county contain, as I believe, valuable exposures of shale clay.

63. (6) *Otsego County*.

64. (5) *Montmorency County*.

65. (4) *Alpena County*.—There is marl, limestone and clay, abundant in this county. See the description of the Alpena Portland Cement Co, and the Annual Report for 1901. The limestones I believe to be especially valuable.

We have also an analysis of an Alpena County marl, by W. M. Courtis:

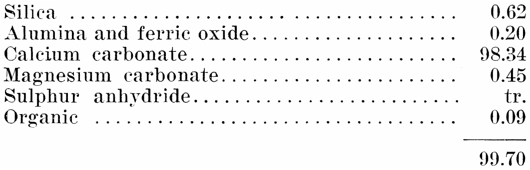


Carbonate of lime	74.48
Carbonate of magnesia	0.50
Silica	7.20
Alumina	0.54
Ferric oxide	2.36
Sulphuric acid	0.89
Organic matter	12.88
Water	1.25
	100.10

66. (3) *Presque Isle County*.—The conditions of Alpena County are repeated here.

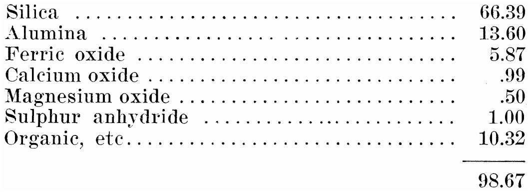
The following are analyses of a limestone and yellow clay shale south of Rogers City, which I owe to Mr. J. G. Dean of Hassan, Tagge, and Dean of Detroit:

Limestone.



Silica	0.62
Alumina and ferric oxide	0.20
Calcium carbonate	98.34
Magnesium carbonate	0.45
Sulphur anhydride	tr.
Organic	0.09
	99.70

Shale Clay, Yellow.



Silica	66.39
Alumina	13.60
Ferric oxide	5.87
Calcium oxide	.99
Magnesium oxide	.50
Sulphur anhydride	1.00
Organic, etc	10.32
	98.67

There are said to be marl beds half a mile from the court house. Only about two feet of stripping are said to be needed.

67. (2) *Cheboygan County*.—Very extensive deposits of marl are reported on Black (otherwise called Cheboygan) lake. The little steamer Eva of the Onaway-Cheboygan mail line is said to plough through acres of it in the bed of Lower Black River, between Stony Point and Taylor's Landing. Limestone also occurs frequently.

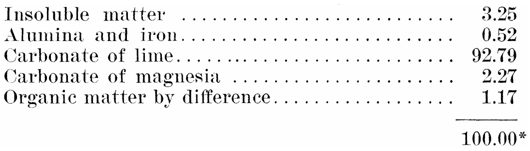
Beds are reported 5 miles from Mullett Lake, and at other places. A sample has been sent me, said to come 7 miles from Wolverine, close to the county line, west and a little south, T. 33 N., R. 3 E., probably near the Cobb and Mitchell lumber R. R., extending over 160 acres, and said to be enough to make 16,000 barrels of cement.

This deposit or another near by has been described as occur ring in a dried up lake which has a trout stream flowing from it, but no distinct inlet in an area perhaps 40 rods by 160 rods, and in thickness 7 feet or so. It is bluish, effervesces freely, but not as rapidly as many marls, and appears to be clayey or magnesian. Turns the acid somewhat amber, mainly from a little organic matter.

68. *Emmet County*.

69. *Upper Peninsula*.—The marls of the Upper Peninsula have been relatively little investigated. Beside the account given by Mr. Hale of beds near Munising, Wetmore, Manistique, Corrine, we have the following notes:

At the World's Fair in Chicago Dr. W. H. Tucker made an exhibit of the marls from Naubinway, Mackinac County. He reports them to exist in large quantities, lying in a bed some 10 feet in thickness, which is overlain by but 6 inches of a mixture of marl and vegetable mould. The analysis is reported by him to be as follows:



Insoluble matter	3.25
Alumina and iron	0.52
Carbonate of lime	92.79
Carbonate of magnesia	2.27
Organic matter by difference	1.17
	100.00*

Compare the deposit at Corinne near by described by Hale, p. 140.

A large deposit of marl is said to exist close to St. Ignace, discovered by John Prophet.

Near Manistique large deposits of marl are said to be controlled by the White Marble Lime Co.

North of Menominee, T. 34 N., R. 26 E., there are said to be lakes with marl, and near Stephenson.

A very good sample has been sent in by W. B. Rosevear from Drummond's Island.

Houghton, Houghton County.—A small amount of marl was found in making some excavations at West Houghton.

Mr. W. V. Savicki gives the section of a deposit shown in Fig. 32, perhaps the same, not far from the old Atlantic Mill, but in the thickest place exposed only about a foot thick. It was exposed in a ditch dug in 1899 for the Houghton water supply.

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*Report of the Board of World's Fair Managers.

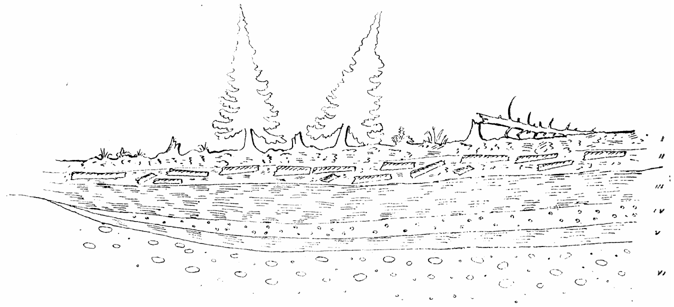
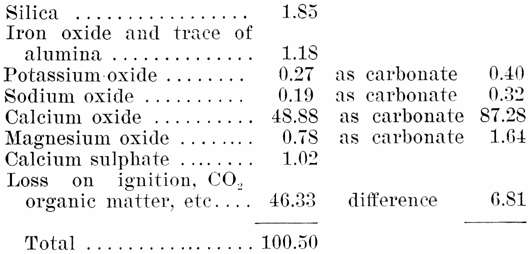


Figure 32. Section of marl deposit at Houghton.
I. Ordinary forest swamp surface, ground covered with grass.
II. About 2 feet of old rotten timbers fairly well compressed.
III. About 6 feet of very fine peat, pretty solid.
IV. Marl full of small shells.
V. Fine clay.
VI. Glacial drift.

Mr. Geo. L. Heath made the following analysis:

The marl was first dried at 105°C. As the organic matter is determined by difference and as it is not altogether certain that the lime is combined as carbonate, or the potash and soda as carbonate instead of silicate the difference 6.81 may be less than the real amount of organic matter by a trifle.



Silica	1.85		
Iron oxide and trace of alumina	1.18		
Potassium oxide	0.27	as carbonate	0.40
Sodium oxide	0.19	as carbonate	0.32
Calcium oxide	48.88	as carbonate	87.28
Magnesium oxide	0.78	as carbonate	1.64
Calcium sulphate	1.02		
Loss on ignition, CO_2 organic matter, etc.	46.33	difference	6.81
Total	100.50		

Concluding Remarks.

It will be easily seen that the foregoing notes are a very uneven and imperfect account of the deposits of bog lime in the State. Yet they are enough to show why they are so imperfect. Deposits of bog lime are everywhere present in the State, though most often probably in the higher parts. They are often covered by swamp, and often difficult of access, being neither water nor yet land. The resources of the State Survey are entirely inadequate to make a systematic study of them, and we have depended largely upon the investigations of private parties, incidental observations, and the hasty summer's work of Mr. Hale.

Enough has been learned to bring out some salient points, however, and show that there is no lack of marl which should be more properly called bog lime, in most of the State. It is much higher in lime, and has but few transitions to the calcareous clays, which are abundant in the State, and have just as good title to the name marl, but usually run from 30 to 40% of carbonates. Deposits of surface clays which run low in carbonates are rare, and there is usually a fair percentage of magnesia. An important exception are the clays which are but weathered shales.

I have concluded to append together instead of scattered through the text according to locations a group of analyses which are due to Prof. Delos Fall of the Board, and at the same time reprint a valuable paper which he presented to the Michigan Society of Engineers, with the permission of the Society. Other* analyses by Prof. Fall will be found scattered through the report, having been received at various times from the various parties for which he has executed them. It is apparent that he and his pupils have been connected with many of the successful enterprises in the State.

MARLS AND CLAYS IN MICHIGAN.*

BY DELOS FALL, SC. D., ALBION COLLEGE.

Portland cement is a chemical compound resulting from the burning at a temperature of about 3,000 degrees Fahrenheit, of an intimate mixture of a certain definite proportion of pure limestone and clay of a definite condition and pure quality. The limestone may be of a solid and crystalline form or in a finely divided condition, in which it is found in the so-called marl beds of Michigan. The clay may be solid shale or the plastic variety that has resulted from the disintegration of the parent rock. What constitutes a pure quality for clays and marls, and what the proportion in which they are to be mixed is a question which the chemist alone can determine.

Marl

The term "marl" from the mineralogical standpoint, is a mixture in any proportion of limestone and clay. In certain parts of our country, notably in the southern states, but not to my knowledge in Michigan, this mixture approximates very closely to the proportion required for a high grade Portland cement. As the term is used with us, it applies to a comparatively pure calcium carbonate with a certain very small proportion of clay, and it may contain a small percentage of magnesia and sulphuric acid.

Deposits of marl are found in the beds of those lakes in Michigan, which, owing to their past histories, are now surrounded by marsh lands, the marl being found in the bottom of such lakes, and extending out under the overlying muck or peat. These beds vary in depth from a few inches at the edge of the deposit to 30 or 40 feet in the center. In places they are almost entirely uncovered, and are exposed to view in such a way that they can be immediately utilized without any expense for the stripping process which must be employed in all cases where there is a covering of muck or peat. Occasionally a layer of greater or less thickness is found, consisting of decayed organic matter lying in the center of the depth of the bed, indicating that in the process of the deposition of the marl, the level has alternately risen and fallen. In some cases it has been found possible, by

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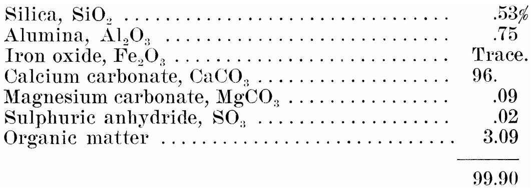
Namely: pp. 136, 154, 304, 305, 336.

*From Michigan Engineer, 1901, pp. 124, 133.

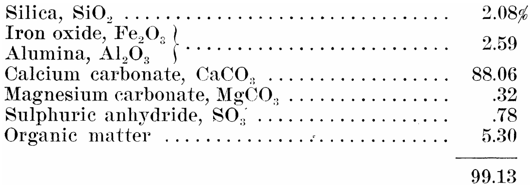
draining off the water of the lake, to uncover rich and extensive beds of marl with no other expense attached to this stage of the work. The composition of the marl in the various beds in Michigan varies to a considerable extent. One bed, which has been exhaustively examined, gives, on analysis, average of fifty samples, a composition as follows:



Silica, SiO_2	.53%
Alumina, Al_2O_3	.75
Iron oxide, Fe_2O_3	Trace.
Calcium carbonate, $CaCO_3$	96.
Magnesium carbonate, $MgCO_3$	.09
Sulphuric anhydride, SO_3	.02
Organic matter	3.09
	99.90

This is extremely pure. Marl is rarely found running so high in calcium carbonate, and so low in clay, magnesia and sulphuric acid.

An average of eighty-four samples from another bed resulted in the following composition, which may be taken as fairly to represent the marls of Michigan:



Silica, SiO_2	2.08%
Iron oxide, Fe_2O_3 Alumina, Al_2O_3	2.59
Calcium carbonate, $CaCO_3$	88.06
Magnesium carbonate, $MgCO_3$	.32
Sulphuric anhydride, SO_3	.78
Organic matter	5.30
	99.13

Exclusive of the organic matter, the 84 samples average 93.10% of carbonate of lime.

The above bed is characterized by a strain of blue clay accompanying the marl. This is not a serious adulteration of the marl, except that it will require more constant attention from the chemist in order to produce a mixture of constant composition.

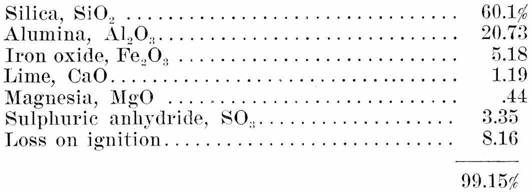
The main points of interest concerning prospective value of marl for manufacturing purposes are the proportions existing in the raw material of carbonate of lime, magnesia, sulphuric acid, and organic matter. It is desirable that the carbonate of lime should run as high as possible, in order that there may be the largest percentage available of this, which is the most important contribution to the final composition of Portland Cement. Too much organic matter will lower the percentage of carbonate of lime, and clog the rotaries in the process of burning, and, because of this fact, will diminish the amount of the finished product which the rotary furnace is capable of producing per day. With excessive amount of organic matter present in the marl, the total output of a sixty by six rotary furnace might be as low as seventy-five or eight barrels per day, when, with the marl containing less organic matter, say from two to not more than five per cent, the product should be from 120 to 130 barrels per day.

The presence of magnesia in the cement must be considered deleterious to the quality of the cement, from the fact that it refuses to unite with the clay at the temperature required for the burning of the cement, and is left at the end of the process in the form of caustic magnesia MgO. When water is added it takes up that water to an extent which produces a hard product of increased volume, and hence produces a cracking or disintegration of the proposed structure. In general, it may be said that a percentage of not more than two per cent is not considered harmful. The presence of sulphuric acid in the marl and clay, and its effect upon the finished product, does not seem to be appreciated as it ought to be, for it is noticeable that most of the reports of chemists as to their analytical findings give no mention of sulphuric acid in the marl. The chemical analyses should always state the presense or absence of this ingredient, and the proportion in which it occurs. Sulphuric acid generally occurs in the form of calcium sulphate or gypsum, and it is well known that the presence of it in considerable percentage, say more than two per cent, retards the setting quality of the cement. At the same time, it possesses no hydraulic qualities, but will in the presence of water partially dissolve and thus lead to the final disintegration of the proposed structure.

Michigan Clays.

Originally it was supposed that the difficult problem for the initiation of a Portland Cement industry was to discover sufficiently large beds of pure marl; indeed, it is true that that feature of the problem is not so easy a task as many suppose, the number of beds in Michigan being somewhat limited as to quantity, accessibility, and quality. On the other hand, it was supposed that an inexhaustible supply of clay of proper quality could be found adjacent to any marl bed. Farmers and others would point to large deposits of clay which they were sure would prove of sufficient purity and quality for the purpose. By this general tradition, promoters and investors have been led into the establishment of large plants, only to find that they must seek long and sometimes unsuccessfully for clay of the proper material. Not all clay will make a good Portland Cement.

Clay is essentially a silicate of aluminum but rarely occurs without the admixture of iron oxide, calcium carbonate, or sulphate, and sometimes magnesia. While calcium carbonate must be used in the mixture for cement making, its presence in the clay complicates to a large degree the problem of the chemist in making that mixture, and more especially maintaining the mixture in a uniform and constant composition. Many of our clays run too high in alumina, making, upon burning, a quick setting cement, not so durable and permanent as that produced from a clay containing a less amount of alumina. The following analysis of a Michigan clay will aptly illustrate this point:



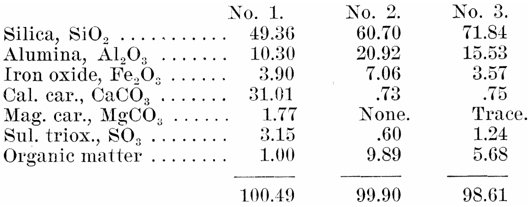
Silica, SiO_2	60.1%
Alumina, Al_2O_3	20.73
Iron oxide, Fe_2O_3	5.18
Lime, CaO	1.19
Magnesia, MgO	.44
Sulphuric anhydride, SO_3	3.35
Loss on ignition	8.16
	99.15%

This analysis illustrates another bad feature existing in some Michigan clays, namely, the too large percentage of sulphuric acid.

The 3.35 per cent of sulphuric anhydride present in this clay represents 5.6 per cent of calcium sulphate, and this in the mixture with marl would bring the percentage very near to two per cent, which might be considered to be the limit permissible for that ingredient. The analysis above given would be almost ideal if the alumina ran at from six to ten per cent, and the SO_3 was lower or altogether absent.

Clays should contain very little free sand, iron oxide, or organic matter. It should have a tendency to gelatinize when treated with acids. The silica must be combined and not tree, for the reason that at the temperature at the command of the cement-maker, free silica will not combine to form a silicate of lime which is the essential ingredient in Portland cement. About sixty per cent of the clay should be silica.

Three classes of clay found in Michigan are illustrated by the following analyses from my laboratory note book:



	No. 1.	No. 2.	No. 3.
Silica, SiO_2	49.36	60.70	71.84
Alumina, Al_2O_3	10.30	20.92	15.53
Iron oxide, Fe_2O_3	3.90	7.06	3.57
Cal. car., $CaCO_3$	31.01	.73	.75
Mag. car., $MgCO_3$	1.77	None.	Trace.
Sul. triox., SO_3	3.15	.60	1.24
Organic matter	1.00	9.89	5.68
	100.49	99.90	98.61

No. 1 possesses the great disadvantage of a variable quantity of calcium carbonate, the fact that the relation of this to the clay itself is that of a mere mixture growing out of accidental and therefore varying conditions making it very certain that no two samples of the same bed would show the same composition. The clay is also imperfect from the presence of a high percentage of calcium sulphate. The temperature at which proper calcination would take place can scarcely be inferred; but it would probably be high. Clay No. 2 is a good clay; it will burn at low temperature and be economical of fuel. It is rather high in alumina and would make a quick setting cement. Its setting quality could be retarded by the addition of a small percentage of gypsum.

Clay No. 3 is too high in silica; the temperature required for the calcination would necessarily be very high, the excessive temperature being hard to acquire arid very disastrous to the life of the rotary.

Discussion.

Mr. Lane.—There are many kinds of marl in the State,—one kind and another, and the question of clay is an important one. One advice I should give—if I were to give advice—would be to call in the services of a chemist; but before starting to get your chemist, it might be well to make a few preliminary tests yourself. Now there are two simple tests, which, if applied might prevent two-thirds of the samples sent to my office from ever being sent. In the first test, if yon can feel grit when yon chew the clay, feel the clay in your teeth, probably it is not worth investigating. In the second place testing it with hot acid, if there is a good deal of lime, it is likely to mean more or less magnesia, and certainly a good deal of trouble for the chemist. Ordinary vinegar or anything hot and sour, is not bad to test it with, if you happen to be in the woods. These two tests will rule out a good many clays. Another point is the question of coal to be used, which certainly is important. I think there is Michigan coal that ought to be good enough to answer the purpose. I have seen samples of Michigan coal, taken from near Saginaw, which show very little ash and very little sulphur, and I think ought to be quite good.

Professor Campbell.—I will say that in our own work here we have undertaken in the past couple of years to do a little work on cement, though our experiments have not taken us far enough along to draw any reliable conclusions. We are trying to study a few of the conditions which exist. In the course of that we have analyzed a number of samples of clay and marl, and in the synthetic work that we are trying to do, we are trying to control the different factors which determine the property of the cement. The chemical composition is only one. It is well known that the proportions are very close between the different elements which have to be maintained in the mixture, but this is only one of the various factors which we are working on. One factor is the time limit, the time for which the material is subjected to a given heat, say 2,300 degrees Fahrenheit, will give the same result as a shorter time at 2,700 or 2,900 degrees.* These are some of the problems on which we are trying to throw a little light; but it will be necessary to make longtime tests. One of the great troubles that we find in studying the tests that are made, is the short-time tests that are used in making cement tests. They are usually from 24 hours to 28 days, most of them not exceeding 28 days in time, which seems like nothing to me to determine the property of cement. We have had a few from three to six months, and a year, and some that we had kept longer. Cement will change very much after three months, and after six months. We have had cement that would gain steadily up to three months, then drop off at six months, after that gain again, so it is almost impossible to draw conclusions from a short-time test. Now this question of magnesia is a vital one. In one ease, for instance, we have made cement with as high as 6.90 per cent and after six months' test, the cement has been gaining with no signs of deteriorations as yet. Whether this will continue, or whether it will commence to deteriorate after a year or two, time will tell. I do not feel like expressing much of an opinion on the clay that is best adapted to cement work, because the longer we work on it, the less I feel we know or are able to pass an opinion on. I have had occasion two or three times to change my own opinion after working awhile. While some experiments will lead to the idea that clay should have a certain proportion of aluminum, silica, etc., other clays that at first are thought to be not at all satisfactory will give equally good results. So I do not feel like expressing my opinion very strongly as to what an ideal clay or marl should be.

Mr. Lane.—I would like to ask if you have made any experiments as to the influence of the fineness of grinding.

Professor Campbell.—We always try to grind to the same degree of fineness and test the fineness. To give an idea of a single property of the cement, the time of setting, for instance. I think there are not less than six different factors that determine the time of setting, and every one of these may vary, so that it is hard to get at the exact benefits of a single factor. It will undoubtedly be years before we can get at the true nature of what cements are, and the influence of the different factors on the properties of cement. Portland cement is extremely sensitive to water, and quite a difference will be produced by the addition of a little water.

Mr. Russell.—By the addition of a little water when you have reached the turning point, it is remarkable how the strength runs down. The man who works for a dollar a day says, "Turn on more water," and "That is enough" and it is impossible to induce people to see that their structure would be very much better if they would understand that there were quantitative relations between the water and the cement, and that they might learn that lesson from those who are able to give it, and their work would be very much bettered by it.

Mr. Brigden.—What is the least amount of water possible to make a good mixture?

Mr. Russell.—Well, you can work with a trowel a neat cement with something like 22 per cent, can you not, Professor Campbell?

Prof. Campbell.—That is as low as you often get. If you go much beyond that, say 23 per cent, it will run the tensile strength down to a remarkable degree and impair the structure.

Mr. Brigden.—I think the man with the hoe has the better end of the argument in almost every case, whether the work is done by the contract or by the day; you can stand and watch him, and you will occasionally hear from the bottom of the trench, "This is too stiff," or "This is too wet," etc. I know but little about the matter of cement or its development. I can hardly understand what Mr. Greene meant when he said there seemed to be a large opening for the manufacture of water pipe from cement. I had supposed, and I think I have good authority for that supposition, that the use of cement-lined pipe (if that is what he means) was going entirely out of date, and that cast iron was used for water mains, and I think that is true of every portion of the United States east of the Mississippi River.

Mr. Rogers.—I would like to ask Prof. Campbell something about the practical methods for the engineer to determine whether there is too much magnesia in the cement or not, if he has only a few days or a month or so to test the cement before he has to use it.

Prof. Campbell.—I cannot give a method that would be entirely satisfactory, because a great many of the difficulties that are often attributed to magnesia in the way of expansion, I think are not due to magnesia at all; so I do not as yet think there is any entirely satisfactory test. Of course, the chemist's analysis wilt show the per cent of magnesia in the cement; but then the old question comes up again as to what per cent is allowable. That is the question that we are working on at the present time.

Mr. Whitney.—In regard to this question of mixing cements, I think one feature that is often overlooked, and it may be because of the contractor's haste or tendency to save, is that long mixing has a good deal to do with the strength of the cement, that is, after the water is put on to the cement and mixed with the sand, the mixture grinds the cement finer and makes the water appear milky, and when that condition prevails, you will find the strength of the cement is a great deal more. I want to say a word about marl beds. I have had some experience the last two years, and have probably made something like fifteen hundred soundings. In the question of sounding marl beds, there are two or three points of interest that may be brought out. They vary as to their depth where sometimes we would least expect it, and the bottom of them is so irregular that sometimes it is necessary to take soundings quite close together. Another thing is that there is a good deal of difference in the appearance of marls. Some will be yellow as ordinary corn meal, and very mealy and be very poor marl, and there will be some that is nearly white, and some that yon will first feel like throwing out, when, upon a careful examination, you will find that it is pure marl, but not so finely disintegrated. Then again you will run across sand that is a little closer to the surface than you hoped to find it, and you have got to be rather particular to know when you strike it. Often you will find marl in the condition of nodules*, and the person sounding will be almost sure he has struck gravel; he can hear it grate, and it is almost impossible to turn an augur through it; it takes a pretty good job of well-driving, sometimes, to get through a small layer of it. There is one other fact I might mention, that of course would be easily observed, and that is that around the mouth of streams flowing into lakes where there are marl deposits, there is apt to be a layer of organic matter over the marl, sometimes very deep, sometimes quite deep, and sometimes mixed with the marl and extending quite a way. I would also say that in sounding with .augurs, it is sometimes quite desirable to have two sizes of augurs, as there is often a good deal of suction which pulls off the material at the bottom, and gives you, when you pull it up, the material from the top. Of course the use of a go-devil is something by which you can take up samples from any depth, and is quite valuable. Where there is a mixture of clay it is quite apt to be found toward the bottom, and one can rapidly detect it by the color or by the feeling or the appearance of the augur when it is pulled up, and of

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*See "Some preliminary experiments upon the clinkering of Portland Cement," by E. D. Campbell, Journal Am. Chemical Society, Vol. XXIV, No. 10, Oct. 1902.

course the per cent of clay can be actually determined by a chemical analysis.

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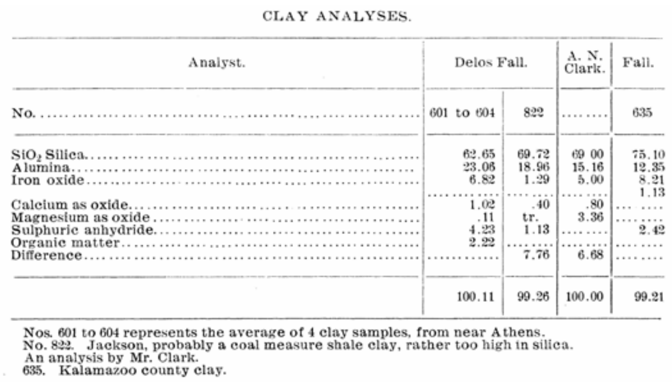
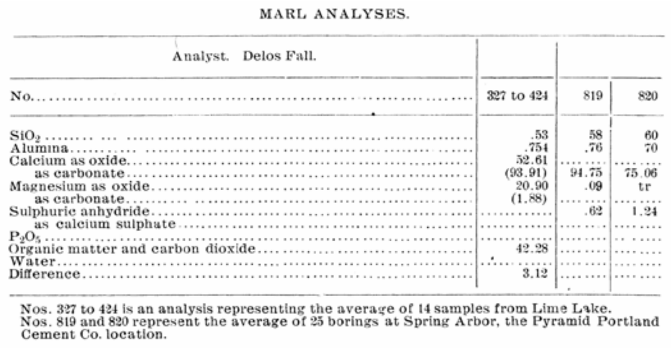
*Probably Schizothrix. elsewhere described, p. 90.



CLAY ANALYSES.

Analyst.	Delos Fall.		A. N. Clark.	Fall.
No.	601 to 604	822	....	635
SiO_2 Silica	62.65	69.72	69 00	75.10
Alumina	23.06	18.96	15.16	12.35
Iron oxide	6.82	1.29	5.00	8.21
	....	....	....	1.13
Calcium as oxide	1.02	.40	.80	....
Magnesium as oxide	.11	tr.	3.36	....
Sulphuric anhydride	4.23	1.13	....	2.42
Organic matter	2.22	....	....	....
Difference	....	7.76	6.68	....
	100.11	99.26	100.00	99.21

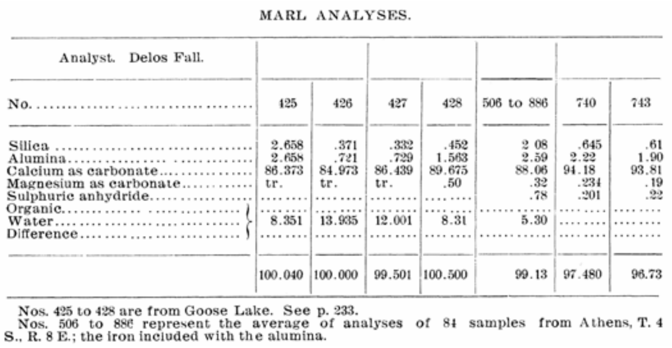
Nos. 601 to 604 represents the average of 4 clay samples, from near Athens.
No. 822. Jackson, probably a coal measure shale clay, rather too high in silica.
An analysis by Mr. Clark.
635. Kalamazoo county clay.



MARL ANALYSES.

Analyst. Delos Fall.			
No.	327 to 424	819	820
SiO_2	.53	58	60
Alumina	.754	.76	70
Calcium as oxide	52.61	....	....
as carbonate	(93.91)	94.75	75.06
Magnesium as oxide	20.90	.09	tr
as carbonate	(1.88)	....	....
Sulphuric anhydride	....	.62	1.24
as calcium sulphate	....	....	....
P_2O_5	....	....	....
Organic matter and carbon dioxide	42.28	....	....
Water	....	....	....
Difference	3.12	....	....

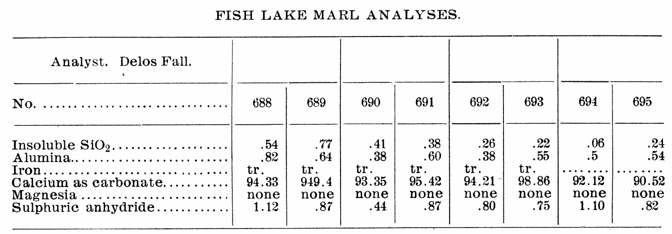
Nos. 327 to 424 is an analysis representing the average of 14 samples from Lime Lake.
Nos. 819 and 820 represent the average of 25 borings at Spring Arbor, the Pyramid Portland Cement Co. location.



MARL ANALYSES.

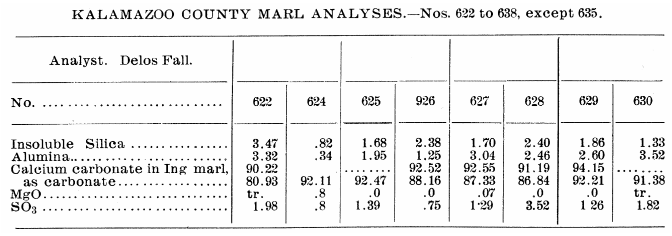
Analyst. Delos Fall.							
No.	425	426	427	428	506 to 886	740	743
Silica	2.658	.371	.332	.452	2 08	.645	.61
Alumina	2.658	.721	.729	1.563	2.59	2.22	1.90
Calcium as carbonate	86.373	84.973	86.439	89.675	88.06	94.18	93.81
Magnesium as carbonate	tr.	tr.	tr.	.50	.32	.234	.19
Sulphuric anhydride	....	....	....	....	.78	.201	.22
Organic }	....	....	....	....	....	....	....
Water }	8.351	13.935	12.001	8.31	5.30	....	....
Difference }	....	....	....	....	....	....	....
	100.040	100.000	99.501	100.500	99.13	97.480	96.73

Nos. 425 to 428 are from Goose Lake. See p. 233.
Nos. 506 to 886 represent the average of analyses of 84 samples from Athens, T. 4 S., R. 8 E.; the iron included with the alumina.



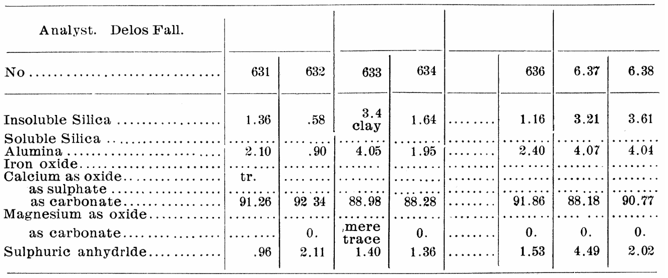
FISH LAKE MARL ANALYSES.

Analyst. Delos Fall.								
No.	688	689	690	691	692	693	694	695
Insoluble SiO_2	.54	.77	.41	.38	.26	.22	.06	.24
Alumina	.82	.64	.38	.60	.38	.55	.5	.54
Iron	tr.	tr.	tr.	tr.	tr.	tr.	....	....
Calcium as carbonate	94.33	949.4	93.35	95.42	94.21	98.86	92.12	90.52
Magnesia	none	none	none	none	none	none	none	none
Sulphuric anhydride	1.12	.87	.44	.87	.80	.75	1.10	.82



KALAMAZOO COUNTY MARL ANALYSES.—Nos. 622 to 638, except 635.

Analyst. Delos Fall.								
No.	622	624	625	926	627	628	629	630
Insoluble Silica	3.47	.82	1.68	2.38	1.70	2.40	1.86	1.33
Alumina	3.32	.34	1.95	1.25	3.04	2.46	2.60	3.52
Calcium carbonate in Ing marl,	90.22		....	92.52	92.55	91.19	94.15	....
as carbonate	80.93	92.11	92.47	88.16	87.33	86.84	92.21	91.38
MgO	tr.	.8	.0	.0	.07	.0	.0	tr.
SO_3	1.98	.8	1.39	.75	1·29	3.52	1 26	1.82



Analyst. Delos Fall.								
No	631	632	633	634		636	6.37	6.38
Insoluble Silica	1.36	.58	3.4 clay	1.64	....	1.16	3.21	3.61
Soluble Silica	....	....	....	....	....	....	....	....
Alumina	2.10	.90	4.05	1.95	....	2.40	4.07	4.04
Iron oxide	....	....	....	....	....	....	....	....
Calcium as oxide	tr.	....	....	....	....	....	....	....
as sulphate	....	....	....	....	....	....	....	....
as carbonate	91.26	92 34	88.98	88.28	....	91.86	88.18	90.77
Magnesium as oxide	....	....	....	....	....	....	....	....
as carbonate	....	0.	mere trace	0.	....	0.	0.	0.
Sulphuric anhydride	.96	2.11	1.40	1.36	....	1.53	4.49	2.02

CHAPTER X.

METHODS OF, AND COMMENTS ON TESTING CEMENT.

BY RICHARD L. HUMPHREY.

Structures of masonry or concrete owe their stability almost entirely to the character of the substance which binds or cements together the brick, stone, and other materials used in their construction.

From the earliest times, therefore, there has been an almost constant endeavor to obtain some material which would attain great strength in a very short period of time and which would resist the forces which tend to disintegrate or decompose it. Such a material must harden rapidly, equally well in air or water and have great adhesive qualities.

The material used in the earlier structures consisted of a mixture of sulphate of lime (gypsum) and sand (the latter usually of a volcanic origin) or a mixture of lime and volcanic ash or trass and sand.

Such mortars required considerable time to harden and also protection during the initial stage of hardening from rain and frost, which readily dissolved and disintegrated them.

It was necessary therefore to frequently renew the mortar in masonry by pointing, unless sufficient carbonic acid had been absorbed from the air to convert the lime into a carbonate, in which form it offered greater resistance to the weather.

This material proved very unsatisfactory even when carefully used and protected from the weather during the early stages of hardening, and at best was only meagrely hydraulic.

The most satisfactory results were obtained with Roman Cement, a mixture of fat lime and a volcanic ash. With the downfall of the Roman Empire the art of making this cement was lost and subsequent experimenters endeavored to recover and to equal or excel this Roman Cement. As these efforts became fruitful of results and the quality of the mortar improved, it became necessary to devise some means by which the relative value of different mortars could be determined.

The present system of testing may be said to have begun with the experiments of John Smeaton in 1756, in connection with the rebuilding of the Eddystone Lighthouse. Smeaton in his endeavors to obtain a cement which would harden under water made cements from various materials and tested their hydraulic qualities by immersing small pats or cakes, made of the cement, under water.

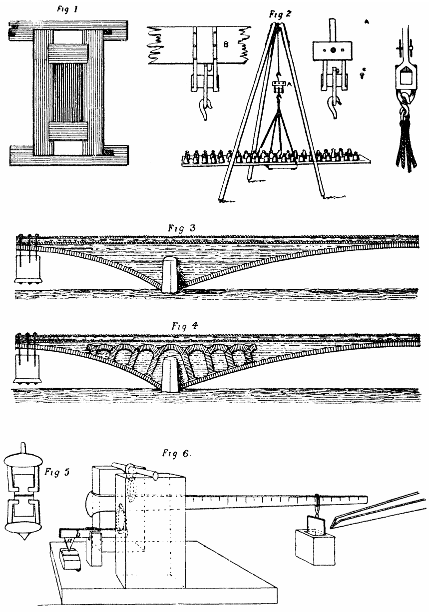


Figure 33. Apparatus for determining the adhesive strength of mortars.

Later Pasley measured the adhesive qualities of mortars by sticking two bricks together and determining the force required to pull them apart. See Fig. 33 (2).

He also determined this same property by building out from a wall, horizontally, as many bricks as possible in a given time. See Fig. 34 (1).

This test was more properly a test for determining the rate of setting.

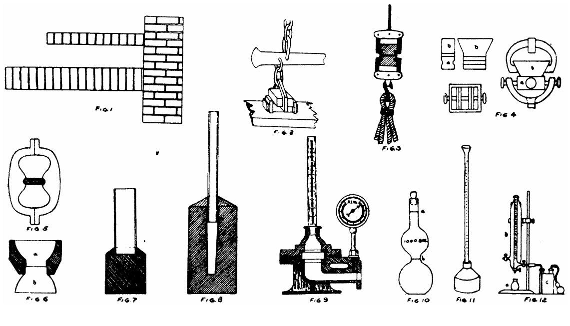


Figure 34. Illustrations of apparatus in cement tests.

Vicat gauged the relative hardness of his mortars by measuring the penetration of a weighted needle falling from a given height.

The apparatus which he devised for this purpose is shown in Fig. 35.

It was not, however, until 1858 that a definite system for testing was evolved. In that year John Grant, the Engineer in charge of the London Main Drainage System proposed the tests by which the cement used in this work was inspected.

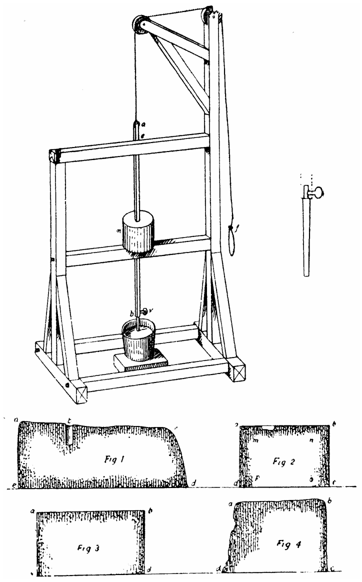


Figure 35. Vicat needle as originally designed.

This marked the beginning of systematic tests of cement. The evolution from these few simple tests has been rapid; at present there are numerous tests in use, all more or less rational, many impractical and none entirely satisfactory.

It is to be noted, however, that the extreme methods formerly in vogue are becoming less used, and the better informed engineers are adopting less radical and more simple tests.

During this period in the development in the methods for making tests, the manufacturer has been forced to meet tests of constantly increasing severity. As a result the quality of the cement, particularly of the American Portland, has been so greatly improved that today the manufacturer is able to produce a material, capable of attaining great hardness in a few hours and exceeding in a few months the strength attained by ancient mortars after 2,000 or more years.

Indeed the quality of the modern Portland Cement has improved so considerably that it has engendered a greater confidence on the part of the Engineer, resulting in a rapid extension of its field of usefulness. So great is the varied application of cement in construction that some one has truly said, "We are on the threshold of the Cement Age."

In Fig. 44 is shown the relative strengths of the modern high grade Portland Cement, cement of the time of Grant, common lime mortar etc., which illustrates the marked superiority of the modern cement.

While it is true that the quality of cement has been vastly improved, the methods for making the tests are still crude and leave much to be desired. Nor are the tests sufficiently defined to enable the novice to follow them with satisfactory results. It is only after considerable

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*In accordance with our custom all illustrations printed with the text are figures. In this paper a number of the figures are reduced from plates containing a number of figures, the numbers referring to which are placed in parentheses experience that sufficient skill is acquired which permits of even approximately satisfactory results.

To define a system of testing which will serve as a reliable guide for novice and expert alike in determining the qualities of cement is a problem of no little difficulty.

The object in testing cement is first to ascertain whether the quality is up to a certain prescribed standard (the specifications), and second for purposes of research.

The inspection and testing of cement is an art requiring considerable experience and much skill. The difficulty in making the tests lies almost wholly in the "personal equation" of the person who makes the tests, a variable which renders the results of such tests not only relative but inaccurate.

Another difficulty in the inspection of cement is the fact, that a cement having passed satisfactory tests at the place of manufacture is no guarantee that the cement will yield the same or even as satisfactory tests at the place of consumption, even should the same person make the tests. From the moment the clinker is reduced to an impalpable powder until it is made into a mortar or concrete and becomes a part of the structure, its physical and chemical properties are constantly undergoing changes which affect its value as a building material. It is doubtful whether these changes ever cease. The cement being to a greater or less extent affected by external influences tending to decompose the mass or by internal influences tending to disintegrate it.

The selection of methods for testing is not so easy as it would at first appear. The system should not depend on cumbersome methods or expensive apparatus. The number of tests should be few and simple in execution.

The inspection of cement may be divided into two classes (1) the mill tests or those made at the place of manufacture, and (2) tests of acceptance or those made at the place of consumption. The latter can be further subdivided into field and laboratory tests.

In the first class are those made by the manufacturer to check the quality of his product and are usually as severe as it is possible to make them, especially as regards constancy of volume.

This is due to a desire on the part of the manufacturer to thoroughly test the quality of his cement before it is shipped.

The methods for making the tests in both classes are, however, the same. The tests in general use are for the determination of fineness, time of setting, tensile strength, neat and with a standard sand, for 24 hours, 7 and 28 days, together with the cold water pat test, and some form of accelerated test, usually the so called "Boiling test." In addition to these, the determination of specific gravity and a chemical analysis of the finished product are made at the mill at regular intervals; most mills make at least one complete analysis of the product each day in order to check the composition.

Where analyses are required on work not possessing the requisite facilities they should be made by some well established chemical laboratory.

While the methods used by the consumer or manufacturer are the same the number of tests made are modified to suit the time available for the purpose and the facilities.

The standard for gauging the results of the tests of acceptance for determining the value of a cement for the purposes for which it is to be used is the specifications. The requirements of this specification should be based on the results obtained by the persons who make the tests. Before fixing these requirements it should be first ascertained what results can be obtained from well known brands of cement by the persons making the tests. Upon these results should be based the requirements of the specifications.

The scope of the tests to be made will depend on the facilities and the importance of the work. In permanent laboratories the testing should be systematic and thorough. Such a system will now be described in more or less detail, indicating where it may be modified to suit other conditions.

SAMPLING.

The selection of the sample from which the tests are to be made while apparently a very simple matter is one of considerable importance and should therefore be carefully done.

At the time of sampling a note should be made of the condition of the cement, i. e., whether cement is lumpy, caked or otherwise damaged.

The sample should be taken from the heart of the package as the outer portion is sometimes more or less impaired.

About one barrel in every ten should be sampled.

Where the cement is delivered in barrels the sample can be drawn through a hole made in one of the staves midway between the heads by means of an auger or sampling iron similar to the ones used by sugar inspectors, Fig. 36 (9.) if the shipment is in bags, the sample is taken from the heart of the package with the hand, or a scoop.

When the sample is taken at the place of manufacture it should be done regularly as it comes from the mill and goes into the bin.

Where cement is held in storage pending the result of the tests, it should be protected from the weather, in order to prevent its being damaged.

The samples should be passed through a sieve having twenty or thirty meshes per lineal inch in order to remove the lumps and foreign matter. This is also a very efficient means of mixing the individual samples in case an average sample is desired; where time will permit, the individual samples should be tested separately in addition to the test on the averaged samples.

CHEMICAL ANALYSIS.

Systematic chemical analyses of cement should be made in all permanent laboratories, not with a view of eventually introducing into specifications chemical requirements (other than those for sulphuric acid and possibly magnesia) but in order that we may have some data pertaining to the composition of the cement when studying the results of the long time tests.

Chemical analyses are chiefly valuable to the manufacturer. The determination of silica, of iron and alumina and of lime is of little value as an indication of quality. They furnish valuable aid in detecting adulterations with inert material in considerable quantity and in determining the quantity of certain deleterious constituents as magnesia and sulphuric anhydride.

The following scheme of chemical analysis is recommended:

One half gram of the finely pulverized sample, dried at 100° C., is thoroughly mixed with four or five times its weight in sodium carbonate, and fused in a platinum crucible until carbon dioxide, CO_2, no longer escapes; the crucible and its contents is placed in a beaker and twenty or thirty times its quantity of water, and about 10 cubic centimeters of dilute hydrochloric acid (HCl) is added; when complete solution is effected, it is transferred to a casserole and placed on a water bath, and evaporated to dryness several times. The mass is taken up with dilute hydrochloric acid, HCl, and water, heated for a short time and filtered, washing the residue on the filter thoroughly with hot water. The filter is dried, ignited and weighed. This weight (less ash) gives the amount of silica, SiO_2.

The filtrate is brought to boiling, and ammonia is added in slight excess; the boiling is continued until the odor of ammonia is no longer perceptible. Filter and wash, re-dissolve in hot dilute HCl, again precipitate with ammonia and filter through the previous filter and wash with boiling water. The precipitate dried, ignited and weighed, less ash gives the amount of alumina, Al_2O_3, and ferric oxide, Fe_2O_3.

The iron is determined volumetrically by fusing the ignited precipitates of alumina and iron with de-hydrated potassium sulphate in the platinum crucible, it is then dissolved in sulphuric acid and titrated with potassium permanganate.

The filtrate from the iron and alumina is heated to boiling, and boiling ammonium oxalate is added until a precipitate is no longer formed. After boiling for a few minutes it is set aside for a short time, when the precipitate has settled perfectly, decant the clear liquid through a filter, wash by decantation, dissolve the precipitate in hot dilute hydrochloric acid, HCl, using as small a quantity as possible to effect a complete solution; heat to boiling and add ammonia, heat on a water bath for a few minutes; when the solution clears filter through the previous filter, wash thoroughly with hot water. Dry the precipitate, ignite to constant weight, and weigh as CaO; or dissolve with sulphuric acid and determine the lime volumetrically by titration with potassium permanganate of a known strength.

The thoroughly washed precipitate of calcium oxalate is dissolved in hot dilute sulphuric acid and the solution is titrated with standardized potassium permanganate.

The filtrate from the calcium oxalate is made alkaline with ammonia and 30 cubic centimeters of solution of hydro-disodium phosphate is added; the whole is set aside in a cool place for twenty-four hours; it is then filtered and washed about fifteen times with ammonia water solution (1:5). Dry the precipitate on the filter, brush on to a large watch glass, burn filter on the lid of the weighed crucible. When the carbon is consumed transfer the precipitate to the crucible and ignite to dull redness, keeping the crucible covered. If the precipitate is not perfectly white on cooling, moisten with a few drops of nitric acid, evaporate and ignite to dryness; weigh as magnesium pyrophosphate and calculate to MgO.

Sulphuric acid.—This is determined in a separate portion. Weigh out about five grams and treat as in the regular analysis, separating the silica; the filtrate is heated to boiling, acidulated with hydrochloric acid, and boiling barium chloride is added; the boiling is continued for ten minutes; when the precipitate has subsided, filter. The precipitate is thoroughly washed in hot water, dried, ignited and weighed as barium sulphate and calculated to sulphur trioxide, SO_3.

Carbonic acid.—This can be determined with sufficient accuracy by means of the ordinary extraction apparatus.

For routine work where quick results are desired the above scheme may be shortened in the following manner:

The first solution may be effected by treating the finely pulverized sample with concentrated HCl diluted with an equal portion of water to which a few drops of concentrated HNO_3 has been added. Evaporate to dryness on the sand bath until all odor of HCl has disappeared. The residue is then treated with concentrated HCl boiled a few minutes diluted with water and filtered. The silica is separated by filtration and ignition as above, or the residue after taking up and boiling with concentrated HCl can be treated with sodium carbonate and the solution effected with concentrated HCl and water as above described.

While other short cuts could be suggested, it is not deemed advisable since the saving in time is not commensurate with the accuracy.

SPECIFIC GRAVITY.

The determination of specific gravity or true density is of questionable value except in the hands of an experienced operator.

In as much as the differences in the results are very small, considerable care must be exercised to obtain accurate determinations.

It is perhaps useful in detecting underburning or adulteration with material of low specific gravity. The adulteration must, however, be in considerable quantity in order to materially effect the results.

A better means of detecting adulteration is through the use of a liquid of heavy gravity and not capable of affecting the cement.

Le Chatelier's apparatus is the best means for making determination of specific gravity.

This apparatus consists of a flask D Fig. 36 (3) of 120 cubic centimeters capacity, the neck of which is about 20 centimeters long. In the middle of this neck is a bulb C, above and below which are two marks engraved on the neck, the volume between these marks, E and F. being exactly 20 cubic centimeters. Above the bulb the neck is graduated into 1-10 cubic centimeters. The neck has a diameter of 9 millimeters. Benzine free from water is used in making the determinations.

The specific gravity can be determined in two ways: (1) The flask is filled with benzine to the lower mark E, and 64 grams of powder are weighed out; the powder is carefully introduced into the flask by the aid of the funnel B. The stem of this funnel descends into the neck of the flask to a point a short distance below the upper mark. As the level of the benzine approaches the upper mark, the powder is introduced carefully and in small quantities at a time until the upper mark is reached. The difference between the weight of the cement remaining and the weight of the original quantity (64 grams) is that which has displaced 20 cubic centimeters. (2) The whole quantity of cement is introduced, and the level of the benzine rises to some division of the graduated neck. This reading + 20 cubic Centimeters is the volume displaced by 64 grams of cement. The specific gravity is then obtained by dividing the weight in air by the displaced volume.

The flask, during the operation is kept immersed in water in a jar A, in order to avoid any possible error due to variations in the temperature of the benzine. T he cement in falling through the long tube completely frees itself from all air bubbles. The results obtained agree within .02.

FINENESS.

The degree of final pulverization which the cement receives is exceedingly important. It has been found that the coarser particles in cement are inert and have no hardening qualities. The more finely a cement is pulverized, all other conditions being the same, the greater will be its cementing properties or what is usually known as its “sand carrying" capacity.

The test for fineness consists in determining the percentages of grains of certain sizes. By our present methods this is accomplished by separating the particles with standard sieves.

These sieves are of brass wire cloth having a circular frame 6 to 10 inches in diameter about 2½ inches high and usually provided with a top cover and bottom pan, figure 36 (8.)

What are known as the No. 100 and No. 200 sieves are generally used. These sieves should have theoretically 100 and 200 meshes per lineal inch and the wire should have diameters of .0045 inch and .0023 inch respectively. As it is impossible to obtain sieves having exactly this number of meshes on account of the impossibility of weaving the wire cloth with sufficient uniformity by hand methods, the specifications should state the approximate number of meshes and the size of the wire of the sieves to be used in making the tests.

The sample for sieving should be thoroughly dried at a temperature of about 212° F., since in this condition the cement sieves much more readily. One hundred grams make a very convenient quantity to sieve.

The manner in which the sieving is done determines to a large extent the time required for the operation. After the fine flour has passed through the sieve the coarser particles pass through very slowly; and since the final operation determines the fineness, it is important that it should be done thoroughly.

The cement is best sieved by moving the sieve forward and backward with one hand in a slightly inclined position and striking the side of the sieve gently with the palm of the other hand at the rate of about 200 strokes per minute.

The cloth of the sieve should be carefully watched, as it is liable to break and produce abnormal results.

The introduction of large pebbles or gravel, retained on a screen having ten meshes per lineal inch, into the sieve, accelerates the operation of sieving.

The sieving can be considered complete when not more than one tenth of one per cent passes through the sieve after one minute of continuous sieving.

NORMAL CONSISTENCY.

The percentage of water to be used in making tests of setting, briquettes and pats is of the greatest importance, for upon this depends the results obtained. The paste used in these tests should be of definite or what is called a standard consistency. The same consistency should be used for all tests.

The best consistency is one so wet that mortar cannot be compressed in molding and not so wet as to make a sloppy test piece which would shrink.

The best method for estimating the proper percentage of water to be used is by means of the Vicat apparatus.

This apparatus illustrated in Fig. 36 (1), consists of a frame K, bearing the movable rod L, having the cap A at one end, and the piston B, having a circular cross-section of 1 centimeter diameter at the other. The screw F holds the needle in any desired position. The rod carries an indicator which moves over a scale (graduated to centimeters) attached to the frame K. The rod with the piston and cap weighs 300 grams; the paste is held by a conical hard rubber ring, I, 7 centimeters in diameter at base, 4 centimeters high, resting on the glass plate J, 15 centimeters square.

Trial pastes are made with varying percentages of water. The paste is of proper consistency when the piston gently applied to the surface of the paste (confined in the hard rubber ring) sinks to a point a given distance above the upper surface of the glass plate J. (about 28 mm.).

Having determined the requisite percentage of water for neat pastes the percentages required for sand mixtures can be determined from the following table:

PERCENTAGES OF WATER FOR STANDARD MIXTURES.

Neat.	1 to 1.	1 to 2.	1 to 3.	1 to 4.	1 to 5.
15%	11.0	9.3	8.5	8.0	7.7
16%	11.3	9.6	8.7	8.1	7.8
17%	11.7	9.8	8.8	8.3	7.9
18%	12.0	10.0	9.0	8.4	8.0
19%	12.3	10.2	9.2	8.5	8.1
20%	12.7	10.4	9.3	8.7	8.2
21%	13.0	10.7	9.5	8.8	8.3
22%	13.3	10.9	9.7	8.9	8.4
23%	13.7	11.1	9.8	9.1	8.5
24%	14.0	11.3	10.0	9.2	8.6
25%	14.3	11.6	10.2	9.3	8.8
26%	14.7	11.8	10.3	9.5	8.9
27%	15.0	12.0	10.5	9.6	9.0
28%	15.3	12.2	10.7	9.7	9.1
29%	15.7	12.4	10.8	9.9	9.2
30%	16.0	12.7	11.0	10.0	9.3
31%	16.3	12.9	11.2	10.1	9.4
32%	16.7	13.1	11.3	10 3	9.5
33%	17.0	13.3	11.5	10.4	9.6
34%	17.3	13.6	11.7	10.5	9.7
35%	17.7	13.8	11.8	10.7	9.9
36%	18.0	14.0	12.0	10.8	10.0
37%	18.3	14.2	12.2	10.9	10.1
38%	18.7	14.4	12.3	11.1	10.2
39%	19.0	14.7	12.5	11.2	10.3
40%	19.3	14.9	12.7	11.3	10.4
41%	19.7	15.1	12.8	11.5	10.5
42%	20.0	15.3	13.0	11.6	10.6
43%	20.3	15.6	13.2	11.7	10.7
44%	20.7	15.8	13.3	11.9	10.8
45%	21.0	16.0	13.5	12.0	11.0
46%	21.3	16.1	13.7	12.1	11.1
Cement	500	333	250	200	167
Sand	500	666	750	800	833

E=2-3 N A x 60 where

N=weight of water (in grams) required for 1,000 grains of neat cement.

A = weight of cement (in kilograms) in 1,000 grams of sand mixture.

E = weight of water (in grams) required for sand mixture.

TIME OF SETTING.

The determination of the time required for a cement to set or the time which elapses before the paste ceases to be fluid and plastic is of considerable practical importance. The beginning of this state is called the "initial set" and the moment when the paste offers a given resistance to change of form is called the "hard set." After the cement has set the process of crystallization or hardening begins.

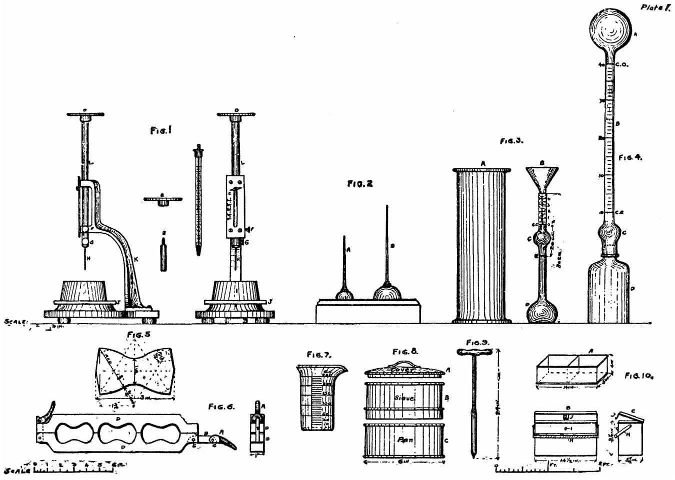


Figure 36. Modern form of Vicat needle and other testing apparatus for Portland Cement.

To add water and again mix a cement which has set is called "retempering." As a cement loses a great deal of its initial strength by "retempering" it is necessary to determine the length of time required for the cement to set in order to avoid "retempering" the mortar on the work.

Tests for the time of setting are made on pastes of neat cement only, as in sand mortars the grains of sand impede the free penetration of the needle.

Vicat devised the original apparatus (Fig. 35) for determining the rate of hardening of lime mortars. In the tests as recommended by Vicat, the weighted needle was allowed to fall into the material under test. In the test as now used, the needle is applied carefully to the surface and allowed to sink into the mass under a given weight, Fig. 86 (1). This apparatus has been described under Fig. 36, two pages before. In this test the cap A is replaced by the cap D, and the piston B is replaced by the needle II. The rod L then weighs 300 grains. The hard rubber ring containing the paste of normal consistency is placed under the needle which is gently brought in contact with the surface and allowed to sink into the mass under the load of 300 grams.

For neat pastes the setting is said to have commenced when the polished steel needle weighing 300 grains, does not completely traverse the mass of normal consistency confined in the rubber ring, and the setting is said to be terminated, when the same needle gently applied to the upper surface of the mass does not sink visibly into it.

A thermometer C graduated to 1-5° C. is stuck into the mass and the increase of temperature of mass during setting can be thus observed.

Care should be taken to keep the sides of the needle clean as the collection of cement on the needle retards the penetration of the needle, while cement on the point of the needle reduces the area of needle and tends to increase the penetration.

The test specimens should be kept in moist air during the test. This is best accomplished by placing the specimens on a rack over water contained in a pan covered with a damp cloth kept away from the specimen by a wire screen. The specimens can also be kept in a moist closet.

TENSILE STRENGTH.

The setting of cement is the change from a condition of fluidity to a solid state. When cement has set, the process of hardening is said to commence. The relative degree of hardening at any age is measured by determining its transverse, compressive, adhesive or tensile strength in pounds per square inch.

Of these tests the tensile test is universally used and has met with great favor on account of the convenience with which the test is made and the cheapness of the apparatus required.

The test piece is of one inch section and is shown in Fig. 36 (5). For convenience in molding and removing the briquettes from the molds, the sharp corners should be rounded off with curves of one half inch radius, the briquettes to be of the form shown in Figure 36 (6).

Molds.—The molds should be made of brass or some equally non-corrosive material and, can be either of the single or gang-type, the latter is preferable since the convenience and facility for molding several briquettes at one time is greater than in the case of the single mold. The greater quantity of material which can be mixed at a time tends to produce more uniform results.

The convenience in cleaning, compactness and facility with which they can be handled are also arguments in favor of the gang type.

There should be sufficient metal in the sides of the mold so as to prevent spreading of the mold when in use.

The molds should be wiped with an oily cloth before using, this prevents the cement sticking to the mold and damaging the briquette during the removal from the mold.

Mixing.—About one thousand grams of cement makes a very convenient quantity of material to mix at a time and will make about eight or ten briquettes.

The French system of weights and measures because of the relation between the gram and the cubic centimeter is the most convenient to use. The proportions should be stated by weight.

The mixing should be done on some non-absorbing, non-corroding surface, preferably plate glass, although marble or slate would do.

If the mixing be done on a surface of marble or of slate it will be advisable to keep this surface covered with a wet cloth when not in use, or thoroughly wet the surface previous to being used. A surface of this character when not in use, becomes quite dry, and absorbs some of the water from the first few batches mixed on it; this renders the mortar much dryer and materially affects the results, especially with sand mixtures.

The cement is weighed out and placed on the mixing slab and formed into a crater into which the proper percentage of clean water is added.

The material is turned into the crater with a trowel and when the water is absorbed, the mixing is completed by thoroughly kneading with the hands; the latter process being similar to that used in kneading dough. The duration of the kneading should be about one minute. During this operation the hands should be protected with rubber gloves.

An inexperienced operator should mix for a definite length of time; a one or more minute sand glass is a very convenient guide.

If the person making the test is very inexperienced, it may be necessary to use one half the quantity of material.

When the moisture begins to disappear from the surface and the paste becomes meally and does not stick together, the cement has begun to set and should be thrown away.

Paste which appears to be of the proper consistency at first, becomes quite wet after thorough kneading, while pastes which appear at first quite dry become plastic.

In sand mixtures the mixing should be thorough in order to insure coating each grain of sand with cement. This is a very important feature in sand tests and is often the reason why one person obtains so much higher results than others.

The temperature of the room and of the water used in mixing should be kept as near 70° F. as practical. The air of the room should be kept moist.

A high temperature and dry air in the room in which the tests are made, tends to dry out the test pieces, thereby checking the proces of hardening, resulting in low strengths and often in cracking of the test pieces and in some instances disintegration.

Molding.—The mortar having been mixed to the proper consistency is placed at once into the molds with the hands.

The molds are filled at once, the paste is pressed in with the fingers and smoothed off with a trowel on both sides. This should take about two or three minutes for 8 or 10 briquettes. The mortar should be heaped upon each mold and then pressed in by drawing the trowel over the surface of the mold, holding the blade of the trowel at an angle of about 5°. The mold is turned over and the operation repeated.

The briquettes are marked in the head with steel dies while still soft, or with a large soft lead pencil just before removing from the molds.

An excellent idea of the uniformity of the mixing and molding is afforded by weighing the briquettes upon removing from the molds. The variations in the weight of briquettes should not exceed 3 per cent.

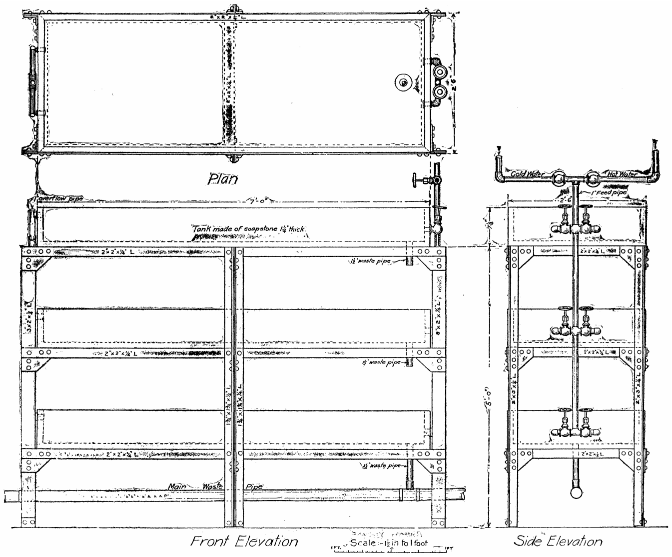


Figure 37. Box for preservation of briquettes.

Preservation of briquettes.—After the completion of the molding, care should be taken to keep the briquettes in moist air; this prevents them drying out thus checking the process of hardening, and prevents the production of checks and shrinkage cracks.

The most convenient way to preserve the briquettes prior to immersion in water, is by means of a moist box or closet. (Fig. 37.)

This may be of soap-stone or slate, or a metal lined wooden box, covered with felt on the inside; the closet should hold water in the bottom and be provided with shelves on which to place the briquettes or the molds containing the briquettes.

For the twenty-four hour tests the briquettes should be placed in the moist closet immediately after molding and kept there until broken; briquettes to be broken at longer periods should be immersed after 24 hours in moist air, in water maintained as near 70° F. as practical.

For preserving the briquettes in water either pans or large tanks are used.

The former should be of the agate ware type, since they do not corrode and are easily cleaned.

A very convenient arrangement for tanks is shown in (Fig. 37). The tanks are in tiers, the supports can be framed of angle iron or wrought iron pipe. Each tank is provided with a hot and cold water supply pipe and a waste pipe; the inlet being at the bottom and the overflow at the top of the tank. These tanks can be built of soapstone or slate, or they can be enamelled iron sinks.

Where pans are used the water should be renewed once each week. Care should be observed to keep the briquettes covered with water.

When running water is used, care should be observed to maintain the water as near 70° F. as possible.

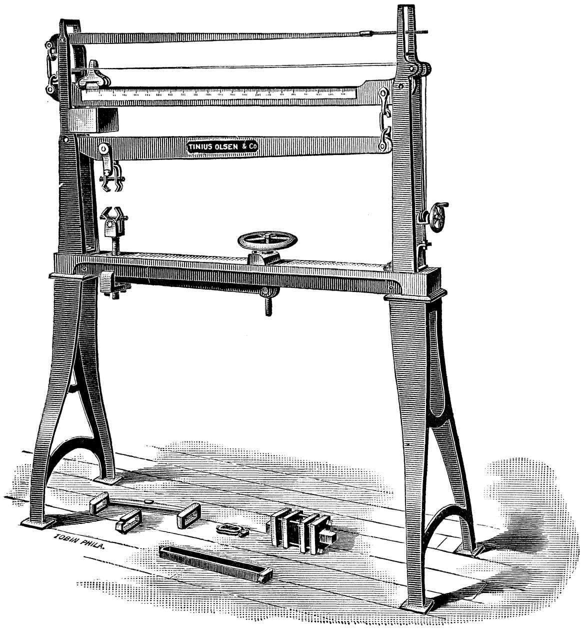


Figure 38. Olsen testing machine, hand driven.

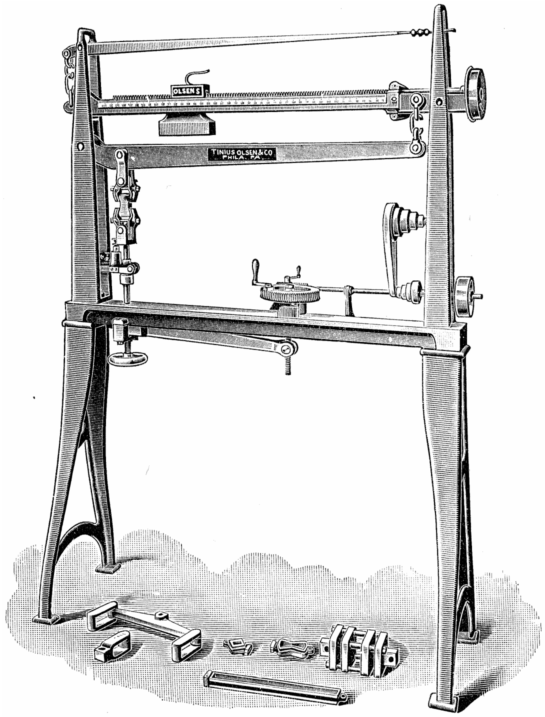


Figure 39. Olsen testing machine, power driven.

Breaking briquettes.—Briquettes should be broken as soon as they are removed from the water. Care should be exercised in centering the briquettes in the testing machine, as cross strains are liable to result from improper adjustment, producing cross strains which lower the results of the tests. The breaking load should not be applied too suddenly, as the vibration produced, often snaps the briquettes apart before the full strength is developed.

Figs, 38 and 39 show one form of testing machine.

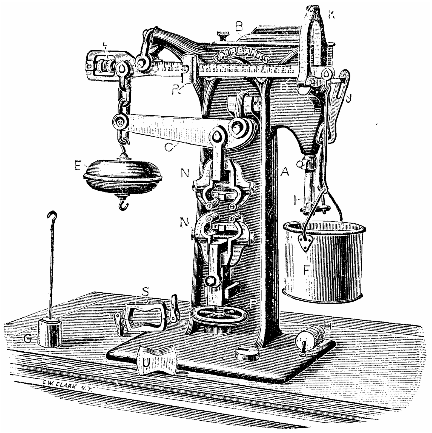


Figure 40. Fairbanks testing machine.

The clips should be kept clean, and the briquettes free from grains of sand or dirt which would tend to prevent a good bearing.

Care should also be observed in applying the initial load; this is particularly the case with the Fairbanks machine Fig. 40 and constitutes the chief objection to this machine. In long time tests the initial load must be very great, and as there is no way of regulating this load satisfactorily, the variations in the results are often largely due to variations in the amount of the initial load applied. In order to regulate the application of this initial strain, it is the practice in some laboratories to place weights in the shot pan at the commencement of the test, the amount of the weight being dependent upon the age and character (natural or Portland) of the cement under test, the weight increasing with age—it being greater for Portland than for natural cement, and also greater for neat than for sand tests.

It often happens that the last molded and usually the densest briquettes are broken at twenty-four hours or seven days and the first molded or less dense at twenty-eight days or longer. This difference in density may be considerable, in which case the tests may show an apparent falling off in strength. Again, the cement may begin to set before the last briquettes is molded, and should these briquettes be broken at the long time period, a loss of strength might be again apparent, or even indications of disintegrations appear. All these facts tend to emphasize the necessity of uniformity in mixing and molding in order to secure uniform density in the briquettes, and thus avoid the resultant apparent losses in the tensile strength.

CONSTANCY OF VOLUME.

One of the most important tests to which cement is subjected, and one which is the most difficult to make, is that which pertains to the soundness. The methods that have been suggested are legion. This test cannot be used by a novice with safety, and even in the hands of an expert all tests for soundness must be made with extreme care.

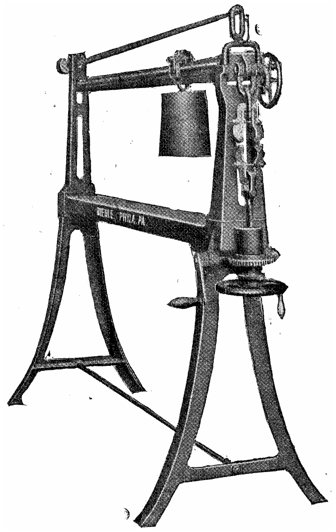


Figure 41. Riehle testing machine.

The object of the test is to determine whether the cement will maintain a constant volume, and develop no evidence of unsoundness or loss of strength. It is exceedingly important that cement should not only develop strength but it should also maintain this strength.

Tests of this character can be divided into two classes: (1) normal pat tests and (2) accelerated tests.

The former consists in immersing a pat of neat cement after hard set in water maintained at a temperature as near 70° F. as possible. To successfully meet this requirement it should remain firm and hard and should not check, become distorted or show other evidence of unsoundness.

Months and even years are requisite to develop evidences of unsoundness by this method unless the cement be of very poor quality. The accelerated tests are for this reason in greater favor, because results can be obtained in considerable less time—in a few hours as a matter of fact.

Of the latter class of tests one best adapted to general use is to immerse the pat (after twenty-four hours in moist air), for three hours in an atmosphere of steam coming from boiling water contained in a loosely covered vessel. The pat to satisfactorily pass this test should remain firm and hard and show no signs of checking, cracking, distortion or disintegration. A more reliable test, but one which is more expensive and which requires considerable care in maintaining the water at a fixed temperature, is to immerse the pat (after twenty-four hours in moist air) in water maintained at a constant temperature of 170° F.

One of the difficulties encountered in these tests is in making the pats; these are usually made of neat cement, about three or four inches in diameter, from one-quarter to one-half of an inch thick at the center and tapering to thin edges at the circumference. The pats should be made with the same percentage of water as in the case of the other tests. Simple as the making of these pats may appear to be, it is extremely difficult for inexperienced persons to make them correctly. Pats may be so trowelled as to give initial strains which develop cracks during the test. A good plan is to strike the glass on which the pat is made after molding; this rearranges the mass, drives the moisture through the pat and makes the density of the pat more uniform. Care should be taken that the pats do not dry out—this produces shrinkage cracks, which give a false impression of unsoundness. Most pats leave the glass, and unless this is accompanied by swelling, curvature of the pat, or cracking at the edges, it should not be taken as evidence of unsoundness. In some cases the cement may set before the pat is finished, and when placed in steam or hot water, the outer edge may lift off. This to the inexperienced is also misleading.

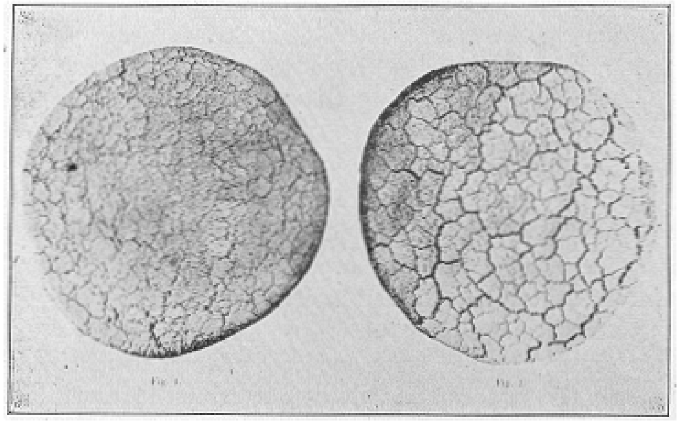


Figure 42. Result of tests of constancy of volume.

Cements should not be condemned on the results of the accelerated tests alone, nor should a cement be considered sound because it has passed such tests.

The results of such tests are shown in Figs. 42 and 43.

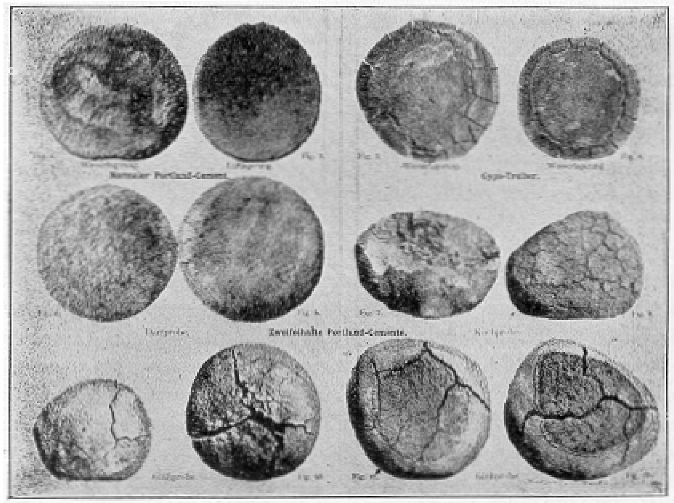


Figure 43. Result of tests of constancy of volume.

CONCLUSION.

The tests just described constitute those most essential for general purposes in determining the value of cement delivered for use. Tests for determining the compressive, transverse, adhesive or abrasive strength, together with those for determining the effect of frost, action of sea water and the porosity, furnish information having a value for the purposes of research, or where the conditions render such data desirable. Permanent laboratories where work of this kind can be carried on, should be equipped for such tests. Tests of still greater importance, which cannot be used as tests of reception, are those made on the work. These consist in tests of briquettes made from mortar taken from the mixing box or cubes of concrete.

Data obtained from such tests is valuable, inasmuch as it furnishes information concerning the strength of the concrete or mortar taken from the mixing of the mortar or concrete.

There should be some system under which the tests are made, that is, there should be a regular number of briquettes made from each sample, and they should be broken at regular intervals; whenever possible these tests should be extended beyond the regular twenty-eight day period, as it is very desirable to know what the strength is at the end of several years. In addition to the tensile tests, each sample should be submitted to all the tests usually employed. The data obtained from these tests should be carefully recorded in a book kept for the purpose.

Having made the above tests, the interpretations of the results obtained is the next and most serious difficulty which confronts the inspector. It is impossible always to insist on a rigid compliance with the requirements of the specifications, since the failure to meet these requirements may be due to faults in the testing.

It often happens that the person who makes the tests does not use the same amount of energy in each test; this is particularly the case where the number of tests made is large, or the test pieces may dry out or they may be affected by the conditions under which they are preserved.

In cases where the cement fails to meet the requirements, it should be given a re-test before condemning it.

It may be well at this point to call attention to the falling off in tensile strength which occurs at the end of one, two or more months. Just what causes this action has not as yet been satisfactorily explained.

All cement as it acquires hardness becomes brittle, the length of time required varying from a few months to several years.

In the early stages of the process of hardening, the mass is tough and in a more or less amorphous condition; but as the crystallization proceeds, the mass becomes brittle. It would seem that the loss in tensile strength can be attributed to crystallization.

The modern rotary kiln process is such that we can obtain artificially, in a very short space of time, a result that nature requires centuries to accomplish.

We are required to make tests of a material, which for all practical purposes can be considered a stone; it would seem logical therefore to apply those tests usually applied to tests of stone, i. e., compressive tests.

This would seem to be a proper method for ascertaining the real strength of cement especially for long periods of time.

Tension tests should be used for the purpose of determining the relative value of shipments of cement, and should be confined to tests not extending over 28 days.

When small compression machines, capable of crushing one inch or one and a half inch test pieces, can be built to compete with the present tensile machine, then we will be able to retire the tension tests.

Passing judgment on the quality of a shipment of cement, is one of the most difficult problems that confronts an engineer. You are dealing with a material subject to numerous conditions, any one of which may affect its value as a material of construction. It should be borne in mind that cement is manufactured in one form, tested in another and used in a third. Abnormal behavior in the tests does not necessarily indicate its probable action in actual use.

When we consider the ancient structures which were built with materials of inferior quality (when gauged by our present standards) we are impressed with the hardness and durability of the mortars.

Again it is very rare that we see cases of failure that can be ascribed to the bad quality of the cement. Our facts are not sufficiently established to enable us to state just what qualities or ingredients are requisite for a good cement.

We know, however, as far as our knowledge extends, that the modern rotary kiln product possesses the property of acquiring great strength and hardness in a very short period of time and has thus far been able to resist all normal forces tending to destroy it. What the future will develop only time will tell.

Our system of testing under the best conditions is very imperfect and leaves much to be desired.

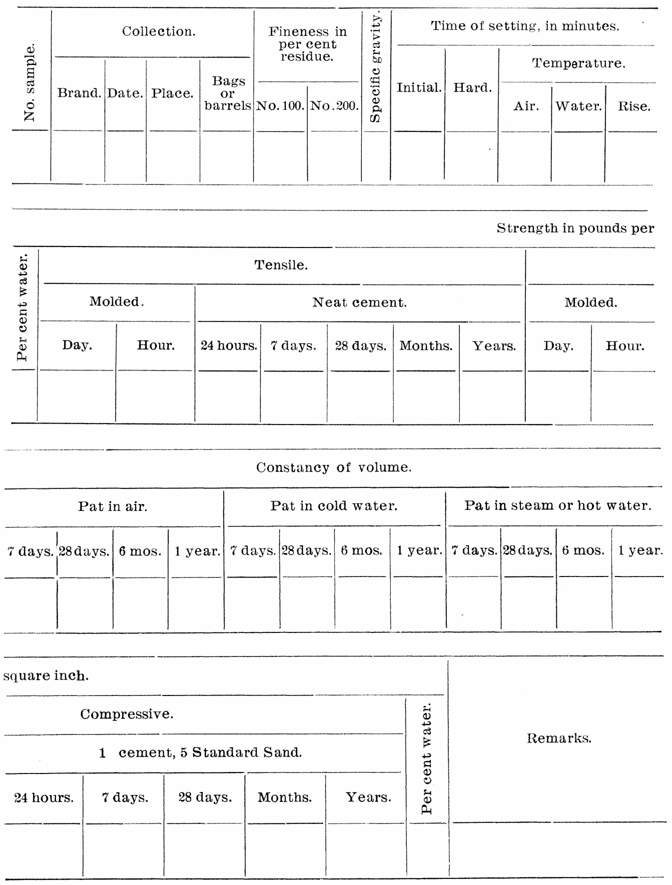
Without positive information as to what is required of a good cement, and under an imperfect system of testing it does not seem fair to be too rigid in our requirements.

Testing cement and the interpretation of the results obtained, requires the liberal application of common sense and good judgment, mellowed by practical experience.

No better rule can be observed by the person acquiring his first experience in testing cement than, "When in doubt re-test the cement."

The future alone can prove the correctness of our present theories, and in the meanwhile, in lieu of something better, we must accept our present cements with faith in their high excellence as a building material.

An excellent record book is shown in the following form:



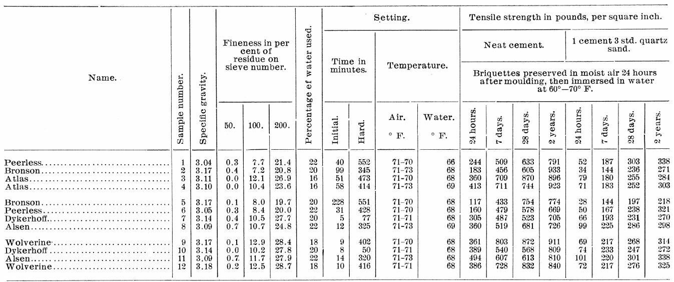
No. sample.	Collection.				Fineness in per cent residue.		Specific gravity.	Time of setting, in minutes.			
										Temperature.		
	Brand.	Date.	Place.	Bags or barrels	No. 100.	No. 200.		Initial.	Hard.	Air.	Water.	Rise.

	Strength in pounds per								
Per cent water.	Tensile.								
	Molded.		Neat cement.					Molded.	
	Day.	Hour.	24 hours.	7 days.	28 days.	Months.	Years.	Day.	Hour.

Constancy of volume.											
Pat in air.				Pat in cold water.				Pat in steam or hot water.			
7 days.	28 days.	6 mos.	1 year.	7 days.	28 days.	6 mos.	1 year.	7 days.	28 days.	6 mos.	1 year.

square inch.						
Compressive.					Per cent water.	Remarks.
1 cement, 5 Standard Sand.						
24 hours.	7 days.	28 days.	Months.	Years.		

CEMENT TESTS BY RICHARD L. HUMPHREY.



Name.	Sample number.	Specific gravity.	Fineness in per cent of residue on sieve number.			Percentage of water used.	Setting.				Tensile strength in pounds, per square inch.							
							Time in minutes.		Temperature.		Neat cement.				1 cement 3 std. quartz sand.			
											Briquettes preserved in moist air 24 hours after moulding, then immersed in water at 60°—70° F.							
			50.	100.	200.		Initial.	Hard.	Air. ° F.	Water. ° F.	24 hours.	7 days.	28 days.	2 years.	24 hours.	7 days.	28 days.	2 years.
Peerless	1	3.04	0.3	7.7	21.4	22	40	552	71-70	66	244	509	633	791	52	187	303	338
Bronson	2	3.17	0.4	7.2	20.8	20	99	345	71-73	68	183	456	605	933	34	144	236	271
Atlas	3	3.11	0.0	12.1	26.9	16	51	473	71-70	68	360	709	870	896	79	180	255	284
Atlas	4	3.10	0.0	10.4	23.6	16	58	414	71-73	69	413	711	744	923	71	183	252	303
Bronson	5	3.17	0.1	8.0	19.7	20	228	551	71-70	68	117	433	754	774	28	144	197	218
Peerless	6	3.05	0.3	8.4	20.0	22	31	428	71-70	68	160	479	578	669	50	167	238	321
Dykerhoff	7	3.14	0.4	10.5	27.7	20	5	77	71-71	68	305	487	523	705	66	193	231	270
Alsen	8	3.09	0.7	10.7	24.8	22	12	325	71-73	69	360	519	681	726	99	225	286	298
Wolverine	9	3.17	0.1	12.9	28.4	18	9	402	71-70	68	361	803	872	911	69	217	268	314
Dykerhoff	10	3.14	0.0	10.2	27.8	20	8	50	71-71	68	389	540	568	809	74	233	247	272
Alsen	11	3.09	0.7	11.7	27.9	22	14	320	71-73	68	494	607	613	810	101	220	301	338
Wolverine	12	3.18	0.2	12.5	28.7	18	10	416	71-71	68	386	728	832	840	72	217	276	325

In the test for soundness and constancy of volume, *all the pats* (which were preserved in moist air for 24 hours, then immersed in air at 60° to 70° F., in water at 60° to 70° F., in steam for three hours and in water at 180° F. for 24 hours) of the brands tested proved perfectly sound.

The above table shows results on samples of Portland cement collected by D. J. Hale and sent to Richard L. Humphrey for testing (not samples which were submitted by interested parties) taken from warehouses where cement was sold every day by retail dealers.

Each sample and each duplicate of a sample were packed separately, first in a paper sack then in a cloth sack, then in a small oblong wooden box just containing the package. Each box then contained but one sample and the sacks could not possibly mix by breaking or sifting.

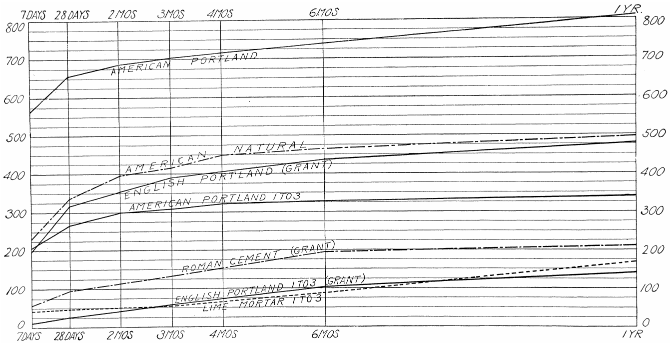


Figure 44. Diagram illustrating the strength of cement at various epochs, for different intervals after setting.

About 10 or 12 pounds of cement was taken at a time. It was taken as nearly as possible at the center of a sack or barrel, no sack being sampled which by caking showed the effect of moisture, a leaking roof or a situation exposing it to moist draughts of air as between doorways. The duplicate sample was selected in as nearly the same spot as possible to the one in which the first sample was taken. That is, it was selected from the center of the same barrel or sack.

Numbers 3, 4, 7, 8, 10 and 11 were collected at Meecham & Wright's warehouse, 98 Market St., Chicago, Ill. Numbers 1 and 6 Peerless, was sampled from Stevens, Hobbs & Co., Benton Harbor, Mich. Numbers 2 and 5 Bronson, was sampled from Jno. Wallace & Co., St. Joseph, Mich.

The following are the numbers and names of the samples taken:

No. 1. Peerless.
No. 2. Bronson.
No. 3. Atlas limestone cement, made at Coplay, Pa.
No. 4. Atlas—Duplicate of No. 3.
No. 5. Bronson—Duplicate of No. 2.
No. 6. Peerless—Duplicate of No. 1.
No. 7. Dykerhoff.
No. 8. Alsen's Portland Cement, from Jtzehoe, Germany.
No. 9. Wolverine, taken at Thomas Moulding's warehouse, 40th and Wentworth Sts., Chicago, Ill.
No. 10. Dykerhoff—Duplicate of No. 7.
No. 11. Alsen—Duplicate of No. 8.
No. 12. Wolverine—Duplicate of No. 9.

The samples were submitted to Mr. Humphrey with the number only and not the name of the manufacturer or statement of which were duplicates.

NOTES BY D. J. HALE.

Upon consideration of these results the following comments appear to be suggested.

The specific gravity checks the closest of all the tests and would serve to identify the duplicates as such. The specific gravity of well made cements does not vary greatly, and in the case of these cements the total variation is only 14 per cent. The duplicates, however, vary from each other very slightly indeed, three sets agreeing and three varying, one duplicate from the other, one per cent (Nos. 1 and 6, 3 and 4, 9 and 12).

Fineness seems to have agreed best with the 50 mesh sieve. In this test three out of six pairs gave identical results. This was not paralleled in the tests on the 100 and 200 mesh sieves, the divergence between brands in several instances not being as great as that between duplicates.

Duplicates only can be compared as to setting, since different percentages of water were used, duplicates, however, receiving the same. It will be noticed that the greatest divergence in initial set between duplicates 2 and 5 occurred when the air temperature varied. However, in 3 and 4 there was the same difference in air temperature with a difference of only seven minutes in the initial set. It can be seen that even with the careful effort here made to keep temperatures as nearly as possible equable the time of setting is very difficult to keep even, and as a source of comparison between respective brands would scarcely be reliable, as the divergence between samples is in many cases not as great as that between duplicates.

The tensile strength appears from a comparative point of view the most unsatisfactory of the tests. In the 96 tests made there were but two instances in which duplicates gave the same number of pounds breaking test, 3 in which they varied 2 pounds from each other, 3 in which they varied 3 pounds from each other. The greatest variation between duplicates was 159 pounds. On the other hand so often do the duplicates differ more from each other than from other brands that it does not seem as if this test could show which was the sounder of two brands. For example take 1 and 6, 24 hours neat. The difference is 80 pounds; between 6 and 5 which are not duplicates but rival brands, 57 pounds; between 6 and 2, rival brands, 23 pounds.

There can be no doubt that this set of tests was made as carefully as they could be made by our present methods of testing. In a general way some test higher than others but in such an uncertain manner that excepting for the specific gravity test it would scarcely be possible to pick out by means of the record here shown, those samples which were duplicates from those which were different brands. It can scarcely be fair to allow one set of experiments no matter how carefully carried out to settle the question of whether or not our present methods are an actual test or not of the quality of our cements. This series seems to accentuate the emphatic declarations of Mr. Humphrey and many who are called upon to investigate the merits of different cements by present methods, that these methods are of small value as an actual test. They cannot, however, be totally condemned until a better system is devised. It is also not to be forgotten that the water and steam test showed all to be first-class cements. While this test does not serve to distinguish between good cements, it should certainly not be discarded because it is valuable in detecting a worthless brand.

GEOLOGICAL SURVEY OF MICHIGAN. VOL. VIII, PART III, PLATE XXIII.

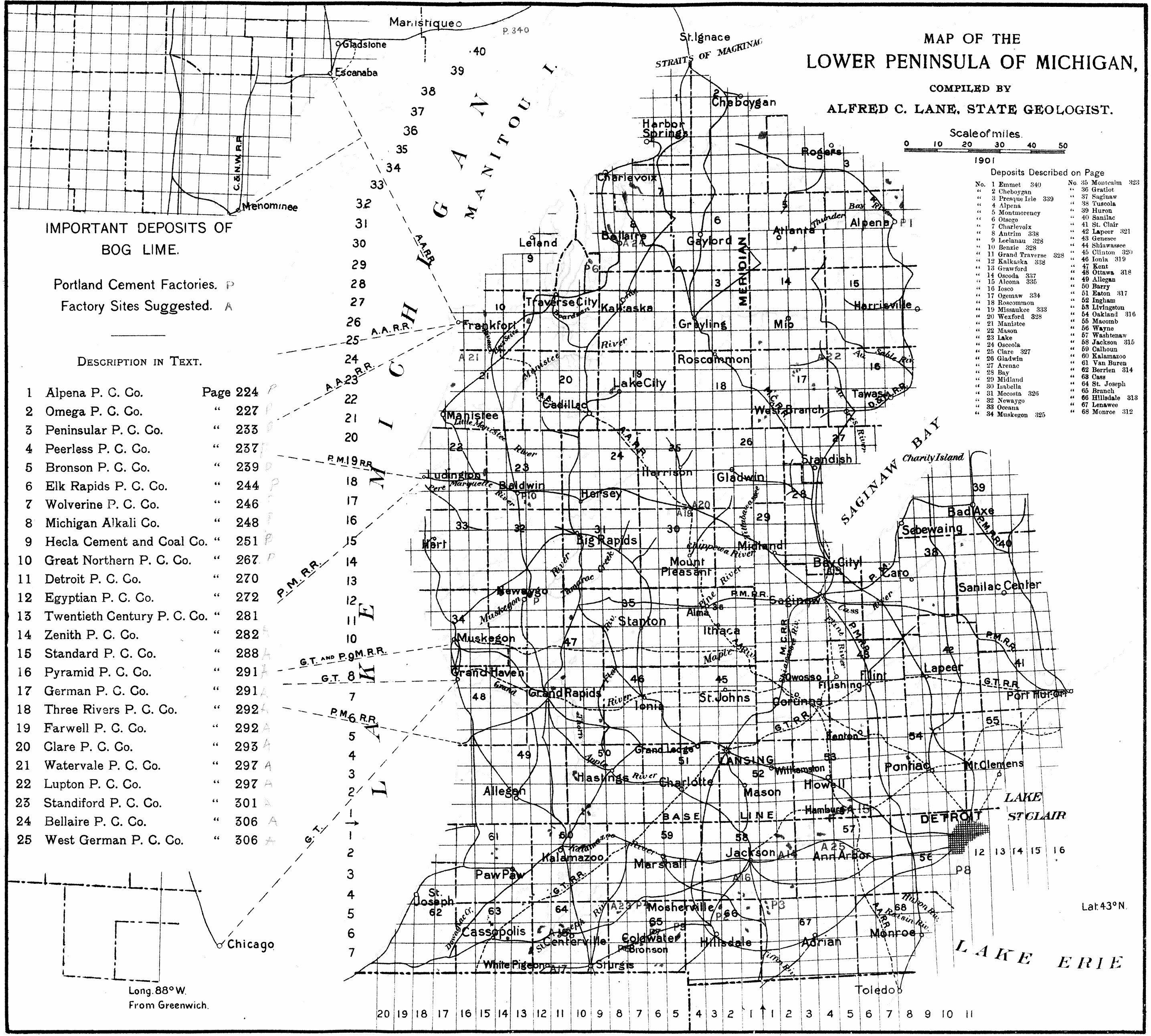


Plate XXIII. Index map.

ERRATA.

Page 190, line 18, for Cederburg read Cederberg.

Page 277, the figure 35 is inverted.