The shore lines are relatively regular, especially on the east and north sides, the convex side of the crescent, with banks twenty or more feet high close to the water on the east, while on the west side are two rather deeply indented bays. At either end are three small ponds, parasite, or daughter lakes, and surrounding the entire shore except on the eastern side, and the northeastern, or inlet, end is a cedar swamp which is underlaid by marl. The outlet is through the most southerly of the daughter lakes, and the entire shore of the lake is formed by beautifully white marl, the exposures varying in width from a few feet to three or four rods in width, so that as one overlooks the lake from one of the surrounding hills it seems to lie in a basin of white marble.

There are three small islands in the lake, two relatively near together at the northern end, and one quite near the shore at the south end. These islands are also of marl, covered partly with a thin layer of vegetable matter and a scanty growth of grass, bushes and cedar. There is a visible connection, under water, between at least one of the islands and the shore, and it is probable that all of them are thus connected by submerged banks. The marl on the islands is from twenty-five to thirty feet deep, with sand below.

Explorations in the swampy border of the lake, show that the shore was formerly more irregular than now, and that the marl extends back from the water in some places for at least one-fourth of a mile, gradually becoming more and more shallow until the solid gravel or clay is reached. The marl is frequently thirty feet deep along the shore and at no place was it found to be less than fifteen feet deep at the present shore line, the shallowest places being along the shore where the high bank comes down near the water. The deepest vegetable deposit, or peat, found in one hundred and fifty borings in all parts of the deposit was three feet. The main deposits of marl are about the southeast end and along the western side of the lake, with a body of considerable size, underlying a swampy area at the north end. Of the six daughter lakes, four are very small, an acre or two in extent and entirely surrounded by deep marl, the connection between three of them and the mother lake being shallow and narrow, a few inches deep, and a few feet wide, and only existing at high water, while two of the other three are of much larger size, with marl points extending out from either side of the straits which are still relatively wide and deep.

Of the two bays on the west side of the lake, one is much narrower than the other and at the mouths of both, marl points are extending towards each other to a noticeable degree.

At all points along the shore, the slope of the marl is very abrupt from the shallow water to the bottom, always more than forty-five degrees, and frequently nearly ninety, this steepness being noticeable in the small as well as in the parent lakes, while on the east side of the island, at the south end of the lake, the wall of marl seemed positively to overhang, although this appearance was probably due to refraction.

The texture of the deepest part of this marl deposit is apparently that of soft putty, a sounding rod passed through it with comparative ease, and samples brought up have a yellowish or creamy color, which disappears as they dry, leaving the color almost pure white. At the surface the marl is coarser, slightly yellowish and more compact. Where it lies above the water line it is distinctly made up of granular and irregular angular fragments, resembling coarse sand, but the fragments are very brittle, soft and friable, and may be converted into powder by rubbing between the thumb and fingers.

On the parts of the shores where apparently the wave action is chiefly exerted, there are small rounded calcareous pebbles, mixed with molluscan shells, drift material and considerable quantities of stems, branches and more or less broken fragments of the alga, Chara, all parts of which are heavily incrusted with calcareous matter. This Chara material was often piled up in windrows of considerable extent at the high water mark.

The marl banks of the lake, from a little below the water's edge down as far as could be seen, were generally thickly covered with growing Chara, at the time of the writer's visit and wherever a plant of it was examined it had a heavy coating of limy matter, which was so closely adherent to the plant, as to seem a part of it, and because of this covering, the plants were inconspicuous, and would easily escape notice.

Little if any other vegetation of any character was growing in the lakes at this season. Indeed, from the steep slope of the banks of marl, it would be hardly possible for any considerable amount of vegetation of higher types than algæ, to flourish here, because of the lack of light at the depth at which it would have to grow to establish itself.

As Chara of several species, is known to occur within our limits, at depths as great as thirty feet, and probably grows at even greater depths, where the water is clear and the bottom soil is of the right character, i. e., of clay, finely divided alluvial matter, marl, etc., it is apparent that there must be an immense growth of this type of plants in such a lake as the one under discussion. That there is an abundance of Chara in Littlefield Lake is shown by the amount of drift material, composed of the plant, which had accumulated in heaps at the high water wave marks along the shore at various places.

From even a casual inspection of this drift accumulation, it is evident that it is the source of much of the granular and sandlike marl on the beaches, and in the coarse upper layers of the deposit. This wind and wave accumulated material was dry and bleached, and was very brittle, so fragile indeed, that a mere touch was generally sufficient to break it into fragments and it passed by insensible gradation from the perfect, unbroken, dried plant form at the high water mark, in which every detail, even the fruit, is preserved, to inpalpable powder at, and below the water's edge.

In other words we have in Chara, a plant of relatively simple organization, and one able to grow in abundance under most conditions of light and soil which are unfavorable to more highly developed types, a chief agent in gathering, and rendering insoluble, or precipitating, calcium and other mineral salts brought into the lake from the clays of the moraine around it by the stream, spring and seepage waters. After precipitation is accomplished and the plant is dislodged, or dies, it drifts ashore, where after decomposing and drying out the small amount of vegetable matter, the various erosive agents at work along shore break up the incrusting chalky matter, and the finer fragments are carried into deeper water, the coarser are left along the lines of wave action.

The pebbles mentioned above as occurring on parts of the shore, are also the result of the development and growth of an alga, Zonotrichia or a nearly related genus, a much lower type than Chara, having a filamentous form. The vegetable origin of these pebbles would not be suspected, until one is broken open when recently taken from the water, when it is found to show a radiating structure of bluish green lines, the color indicating the presence of the plants, as it is characteristic of the group to which Zonotrichia belongs.

The relation of the deposits about Littlefield Lake to the direction of the prevailing strong winds of the region, is probably significant.

The area of deposition is at the southeast end and along the whole western side of the lake. The winds which would be most effective in the valley of the lake would be those from the north and northwest, which would drive the surface waters down the lake towards the southern end, and, striking the shore on the eastern side, currents formed thus would be turned across the lake to the west, depositing sediment at the turning area and in slack water beyond. The daughter lakes are not easily accounted for, except in a general way, that they were formerly deep bays, which, by the building out of points of marl on either side of their mouths, were finally enclosed. The tendency, already noted, for existing bays to have points of marl, of spit-form, extend from either side of the mouth would seem to indicate this as a probable method of formation. On the island at the south end of the lake there was manifestly a strong current, which was running southeasterly and depositing fine marl on the east side of the island, the wind at the time the observation was made, blowing gently from a few points north of west.

As has been already noted, the islands consist of marl from twenty-five to thirty feet deep, the bottom on which they are built up being, to judge from soundings, made with an iron rod, of rather fine sand. These foundations of sand have deeper water all around them, if soundings, said to have been made by local fishermen, can be relied upon, so it is possible they represent shallows in the original lake bottom, upon which after Chara had established itself, the marl accumulated, both by direct growth of the plants and by sedimentation. It may be worthy of mention, that the Chara growing on the steep banks, may in part, account for their steepness, by acting as holding agents, bind the particles of sediment in place by stems and the rootlike organs which the plant sends into the mud. It is probable that but a small part of the Chara that grows in the lake, ever reaches the shore wave line, and much must break up by the purely chemical processes, resulting from the organic decay in relatively deep water.

APPENDIX, ON THE SHELLS OF MARLS.

BY BRYANT WALKER.

Detroit, Michigan, Nov. 25th, 1901.

A. C. Lane, Esq., Lansing, Michigan:

My Dear Sir.—I enclose my report on the mollusks found in the seventeen lots of marl material received from yourself and Prof. Davis during the last two years. I have not included the recent species, of which several lots were received from Prof. Davis, as their determination was not particularly pertinent to the marl fauna. I can send you a list of them if you desire. There is, however, nothing of special interest in them and the list of Saginaw Valley shells, which you made use of in your former report,* will include them all.

Taken as a whole the fauna of the marl deposits does not differ from the present fauna of that portion of the State from which they come. Nor have I found in the specimens from any particular locality any special peculiarities, which would indicate peculiar local conditions of environment. Individual variations occur more or less frequently, but no more than is often found in similar collections of recent species. The inference is, therefore, that the marl fauna lived under substantially the same environmental conditions as the present fauna does or at least not sufficiently different to produce any special or characteristic variations.

The one species peculiar to the marl deposits of this State is *Pisidium contortum* Prime. It was originally described from the Post-glacial formation at Pittsfield, Mass. It occurs abundantly in the marl deposits both in Michigan and Maine. It has recently been found living in one locality in the latter State and it is quite possible that it may yet be found alive in this State. But so far as our present knowledge extends it is extinct in Michigan. Why this one species out of the fifteen, to say nothing of the other genera represented in the marl, included in our list, should have failed to survive, while all the others are still abundantly represented in our present fauna is very curious. I have been entirely unable to imagine any adequate explanation.

The characteristic feature of the marl fauna is the great relative abundance of certain of the smaller species. This is especially noticeable in *Planorbis parvus* Say, *Valvata tricarinata* Say and

* Vol. VII, Part III.

Amnicola limosa Say and *lustrica* Pils. The larger *Planorbis bicarinatus* Say and *campanulatus* Say occur in nearly every lot of material, but the number of individuals is comparatively small. *Pisidium* both in the number of species and individuals is also a characteristic feature of the marl as it is indeed of our present fauna. There is probably no district in the United States, in which this genus abounds to a greater extent, both in species and individuals than in the inland waters of this State.

The terrestrial species represented in the marl are few both in number and individuals. This is what would naturally be expected, as those that do occur are the occasional examples that have been washed into the water from the adjacent land. Such as have been found present no peculiarities as compared with recent specimens from the same region.

The almost complete absence of the *Unionidæ* from the collections is also noticeable.

The peculiar variations noted in *Valvata tricarinata* Say from Cement City are of considerable interest. A similar tendency to unusual variation, although in another direction, has been noticed in the same species from a Post-glacial deposit near Niles in this State (Nautilus XI, p. 121). In both instances, however, the variation was not common to the whole colony, but was limited to a very few individuals. It cannot therefore be attributed to any peculiar conditions in the environment for in that case it would undoubtedly be more general in effect.

Yours very truly,

(Signed) BRYANT WALKER.

N. B.—Please don't forget to give Dr. V. Sterki the credit for identifying the *Pupidæ* and *Pisidia*.

NOTES.

Numbers refer to numerals in table.

1. Fragment or fragments only.
2. Young shells, just hatched, undoubtedly recent.
3. Apparently recent.
4. Fragment, possibly *S. avara* Say.
5. Peculiar form.
6. Peculiar form, probably *L. humilis* Say.
7. Peculiar form.

8. Young.

9. Undoubtedly recent.

10. One left valve with teeth wholly reserved, one right valve with anterior laterals and cardinals reversed.

11. One valve with posterior laterals reversed.

12. Two samples with the apertural portion of the last whorl separated from the body whorl. One example with the superior and peripheral carinæ present, the umbilical carina wanting, its position however is represented by a slight angulation of the whorl. This remarkable variety has never been seen before among hundreds of examples examined. So far as I know there is no previous record of its occurrence. Should other examples be found it would be entitled to rank with the varieties already described. But as only single specimens from two different localities have been noticed it may be only an individual variation or "sport."

13. One example with the superior and peripheral carinæ present, basal one obsolete. See Note 12.

14. Deformed.

LOCALITIES.

1. Shell-bearing deposits in digging a well about 100 feet northeast of Sec. 36—13—5 E. A. C. Lane, Coll. No. 1.
2. Marl from A. F. Gorton. Lake near Howell. A. C. Lane, Coll. No. 2.
3. E. ½ S. E. ¼ Sec. 3—11 N.—5 E. A. C. Lane, Coll. No. 3.
4. Cascade near Grand Rapids. A. C. Lane, Coll. No. 4.
5. Cedar Springs. A. C. Lane, Coll. No. 5.
6. Sec. 22, T. 10 N., R. 11 W. A. C. Lane, Coll. No. 9.
7. T. 11 N., R. 11 W. A. C. Lane, Coll. No. 10.
8. Pickerel Lake, Newaygo County. A. C. Lane, Coll. No. 11.
9. Indian Lake. A. C. Lane, Coll. No. 12.
10. Fremont Lake (12 N., 14 W.), Newaygo County, 150 to 200 feet above lake. A. C. Lane, Coll. No. 14.
11. Cut between Sec. 24 and 25, Spaulding Township, Saginaw County. A. C. Lane, Coll. No. 15.

    This is a sand deposit of Lake Algonquin?
12. Marsh north side of Cedar Lake, Cedar Lake Station, Montcalm County. Lane and Davis, Coll.

13. Dry marl bed $\frac{1}{4}$ mile east of Cedar Lake Station, Montcalm County. Lane and Davis, Coll.

14. Marsh on east side of Mud Lake, N. W. $\frac{1}{4}$ S. W. $\frac{1}{4}$, Sec. 3, T. 12 N., R. 4 W. Lane and Davis, Coll.

15. From bank of ditch, N. W. $\frac{1}{4}$ S. W. $\frac{1}{4}$, Sec. 3, T. 12 N., R. 4 W. Gratiot County. Lane and Davis, Coll.

16. Bottom of ditch from Mud Lake. N. W. $\frac{1}{4}$ S. W. $\frac{1}{4}$, sand section, Gratiot County, "possibly washed from marl." Lane and Davis, Coll.

17. Goose Lake. Cement City. J. G. Dean.
This is the marl of the Peninsular P. C. Co.

LIST OF SPECIES.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Polygyra albolabris Say											x 1 ?						
" sp.							x 2										
Zonitoides arboreus Say							x 3					x 3					
" minusculus Binn.							x 3										
Vitrea indentata Say							x										
Euconulus fulvus Dr.																	x
Helicodiscus lineatus Say							x										
Strobilops labyrinthicus Say	x ?																
Bifidaria pentodon Say						x											x
Vertigo ventricosa var. elatior Sterki																	x
Succinea retusa Sea	x													x			x 1 ?
" sp	x 4																
Carychium exiguum Say																	x
Limnæa stagnalis L.								x 1 ?			x 1 ?					x	x 1
Limnæa reflexa Say											x						
" palustris Mull											x						
" desidiosa Say				x 1 ?		x		x		x ?			x	x		x	x
" " v decampii Streng.					x	x		x 5 ?				x					x
" humilis Say													x				x
" sp.	x 1		x 6							x 7			x 14-8	x 14		x	
Physa heterostropha Say						x		x						x			x
" gyrina Say		x									x						
" elliptica Lea											x			x			x
" aucillaria Say																x	
" integra Hald																x	
" brevispira Lea				x ?													
" sp.	x 1				x			x 8		x 8		x 8	x 1				x
Planorbis bicarinatus Say		x		x	x	x		x	x	x	x	x	x	x		x	x
" campanulatus Say		x			x	x		x		x	x	x		x		x	x *
" deflectus Say						x		x						x		x	x
" exacutus Say				x						x				x		x	x 8
" parvus Say	x	x		x	x	x	x	x	x	x	x	x	x	x		x	x
" trivolvis Say											x						
Segmentina armigera Say	x 1																
Valvata tricarinata Say		x				x		x	x			x	x	x 13		x	x 12
" tri. v confusa Walker		x		x	x	x		x	x	x		x	x	x		x	x
" tri. v unicarinata DeKay					x	x		x		x		x		x			x
" tri. v simplex Gld.							x	x		x							x
" sincera Say																	x
Campeloma integra Say											x						
" sp								x 8								x 8	
Amnicola lustrica Pils				x	x	x	x	x		x			x	x		x	x

LIST OF SPECIES—CONTINUED.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Amnicola limosa Say	......	x[1]	......	x	x	x	......	x	......	x	x	......	......	x	......	x	x
" walkeri Pils.	......	......	......	......	......	x	......	x?	......	......	......	......	x?	......	......	x	x
Paludestrina nickliniana Lea	......	......	......	......	......	......	......	......	......	......	......	......	......	x	......	......	......
Pleurocera sp.	......	......	......	......	......	......	......	......	......	......	x[1]	x	......	......	......	......	......
Goniobasis livescens Mke.	......	......	......	......	......	......	......	......	......	......	x	......	......	......	......	......	......
Unionidæ	......	......	......	......	......	......	......	x[1]	......	......	......	......	......	......	......	......	x[1]
Unio sp.	......	......	......	......	......	......	......	......	......	......	x[1]	......	......	......	......	......	......
Anodonta grandis v. footiana Lea	......	x[9]	......	......	......	......	......	......	......	......	......	......	......	......	x[3]	......	......
Sphærium simile Say	......	......	......	......	......	......	......	......	......	......	x	......	......	x[1]?	......	x	x
" striatinum Lam.	......	......	......	x	......	x[9]	......	......	......	......	......	......	......	......	......	......	x
" rhomboideum Say	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	x
" occidentale Pme.	x	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
" sp.	......	......	......	......	......	x[9]	......	......	......	......	......	......	......	......	......	......	......
Calyculina truncatum Lind	......	......	......	......	......	x	......	......	......	......	......	......	......	......	......	......	x
" securis Pme.	......	x[1]	......	......	......	x[9]	......	......	......	......	......	......	......	x	......	x	......
" sp	......	......	......	......	......	......	......	x[8]	......	......	......	......	......	x[1]	......	......	......
Pisidium roperi Sterki	x	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
" noveboracense Pme.	x	x?	......	......	......	......	......	......	......	......	......	......	......	x	......	x[9]	......
" affine Sterki	x	......	......	x	......	......	......	......	......	......	......	x	......	......	......	x	x
" pauperculum Sterki	......	x?	......	x	......	......	......	x[11]	......	......	......	......	......	......	......	x?	......
" variabile Pme.	......	x	......	x	......	......	x	......	......	x	x	......	......	......	......	x[11]	x
" medianum Sterki	......	x	......	......	x	x	......	x	......	x	......	x	......	x	......	x	x
" compressum Pme.	......	......	......	x	......	x	......	......	......	x	x	......	x	x	......	x	......
" scutellatum Sterki	......	......	x	......	......	......	......	......	......	......	......	x	......	......	......	......	......
" contortum Pme.	......	......	x	......	......	......	......	......	......	......	......	......	......	......	......	......	......
" tenuissimum Sterki	......	......	......	......	x	......	......	x	......	......	......	......	......	......	......	......	x
" walker Sterki	......	......	......	......	......	......	......	......	......	......	x?	......	......	......	......	......	......
" peraltum Sterki	......	......	......	......	......	x	......	......	......	......	......	......	......	......	......	......	......
" strengii Sterki	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	x	......
" splendidulum Sterki	......	......	......	......	......	......	......	......	......	......	......	x	......	x[10]	......	......	......
" rotundatum Pme.	......	......	......	......	......	......	......	......	......	......	......	......	x?	......	......	......	......
" sp.	x	......	......	......	......	......	......	x	......	x	......	......	x	......	......	x	x

x Present.
x? Identification doubtful.

CHAPTER VI.

RECORD OF FIELD WORK BY D. J. HALE.

§ 1. Lansing—Summer, 1899.

Before starting on a longer tour of inspection a short trip was made from St. Joseph through White Pigeon, Bronson, Coldwater, Quincy, and several other towns near which marl had been reported. The surroundings of the marl, its location and manufacture and any other points needing investigation were to be noted.

White Pigeon.—The first bed visited was that of Mr. Theodore E. Clapp on Section 17, St. Joseph County, two miles southeast from White Pigeon, and one and a quarter miles from the Lake Shore & Michigan Southern railroad. The following are his figures on the bed. The depth is from six to thirty feet with average depth twenty feet, area 100 acres. The marl at the center of the lake is about twenty-two feet deep, at the edges thirty feet deep, water in shallows two to four feet in depth. The marsh land about the lake is underlain with the deepest marl, and this greatest depth is between the lobes of the lake. The marl is not overgrown sufficiently with marsh grass for cattle to graze upon it safely. For sounding the deposit he used two inch drive well pipe cut into six foot lengths, and fitted with couplings so that they could form a continuous rod. Upon one length an augur was welded. This was the apparatus used to bring up the specimens. Mr. Clapp made fifteen soundings, requiring a force of five men.

Tests were carried on during the winter through ice. The analysis of the marl made at Purdue University was as follows:

Moisture	.81%
Insoluble in Hydrochloric acid	1.46%
Silica	.37%
Iron and Alumina	.56%
Calcium oxide	51.00%
Magnesium oxide	1.02%
Potash	.17%
Soda	.52%
Carbonic Acid	41.10%
Organic matter combined with water	4.01%
Sulphuric acid	trace.
Phosphoric acid	trace.
	101.02

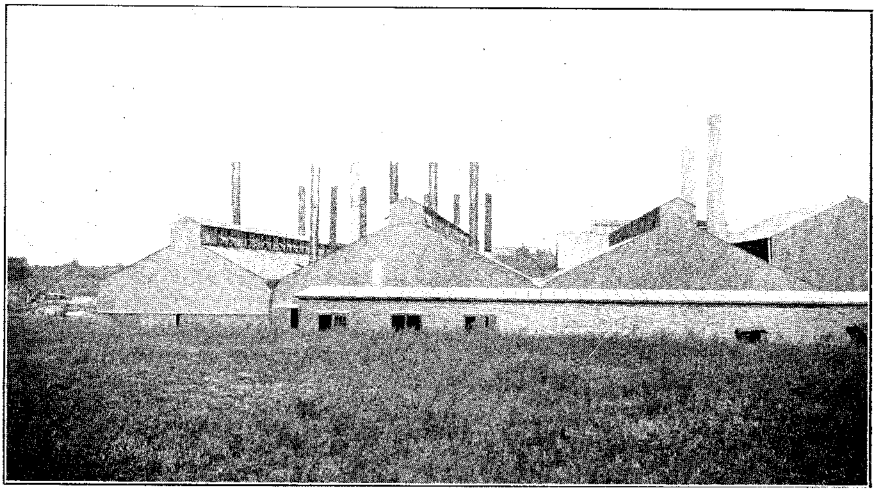
The above analysis would indicate a first class marl. The marl between the lobes of the lake, which was before remarked as deepest, in this instance probably marked the center of the lake. According to Mr. Clapp's soundings the deepest water did not contain the deepest marl, but rather the shallows at the edge of the lake toward the center of the whole lake basin. The lake basin would be the whole depression including the two lobes of the lake, and the low marsh surrounding it.

Bronson, Quincy, Coldwater.

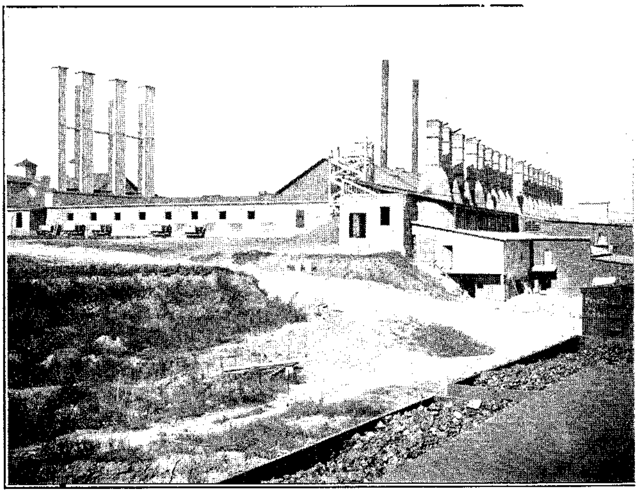
After leaving this lake the old glacial valley or chain of marl lakes extending irregularly through Bronson, Quincy, and Coldwater was examined. It was near Bronson, while sinking piles for a bridge over a creek that a section foreman discovered a marl bed. The whitish or greyish soft mud which he found there, proved upon analysis to be a marl suitable for cement. A thriving factory was started upon this same land, also one at Union City some fourteen miles distant. One is built at Coldwater and another completed at Quincy, these two belonging to the Michigan Portland Cement Co. This constituted the district which was at the time (1899) actively devoted to the manufacture of marl, although factories were in the process of building in many parts of the State.

The bed and factory at Bronson were first examined. The factory itself is located on a sandy island a few acres in extent. These islands are sprinkled through the marl bed, and upon some of them good sized trees are growing. The deposit is one of the old lake valleys above mentioned. In reply to questions asked Mr. Wheeler, the chemist of the factory, the following facts were given. The area of marl is estimated at 1,300 acres. It follows the bed of Swan Creek, and two or three other streams from Spring Lake. The depth varies from one to fifty feet according to measurements made with solid iron rods. Beneath the marl there is a white quartz sand, the outline of which is regularly undulating, which Mr. Wheeler accounts for by the former action of waves. The marl is about thirty to forty per cent water. The lake basin is in the form of an oblong one mile wide and several miles long.

The factory contains seven rotaries and six tanks with an output of 1,000 barrels per day. The occurrence of marl under one part of the marsh does not signify that it will be found under the whole marsh. The bed is thickest at the center. It contains no bog iron ore,



COLDWATER PLANT OF WOLVERTON P. C. CO.



UNION CITY PLANT OF PEERLESS P. C. CO.

and few shells. The well water in the vicinity is rather soft. His analysis of the marl is as follows:

Volatile matter	45.64%
Insoluble matter	1.72%
Iron and aluminum oxides	1.17%
Calcium oxide	49.21%
Organic matter	7.07%
	104.81

Further analyses and descriptive notes will be found in the last chapter.

The marl is dug by an ordinary dipper dredge which scoops out the marl to a depth of twenty-two feet and empties it into small cars in which it is hauled to the factory. The dredge first removes the surface from one to six feet of tough marsh grass, roots, etc., and piles it up at one side or dumps it in place where the marl has already been removed. As the water stands at within from one to two feet of the surface, after a small channel is cleared the dredge has water room to float over the marl which is to be removed. The marl when first dug is much darker on account of being nearly half moisture, but after drying, it becomes about the color of light wood ashes. The next point of interest visited was the clay pit from which the supply of clay for this factory is derived. The pit is on a siding about two miles south of the factory. It is in this vicinity that the great stratum of Coldwater shales is uncovered. In this case the shale does not quite reach the surface, and a shaft seventy-five feet deep has been sunk to penetrate the surface soil, and from the vertical shaft a tunnel with several smaller branches has been dug through the solid shale. A regular mining hoist is used to reach shale and hoist it to the surface. Clay is transferred from the head of the tunnel to the shaft by small cars run on a wooden track. The clay, which is a shale compressed until it shows lines of cleavage, is hard like a rock and is blasted by giant powder as coal is mined.*

The next point visited was Coldwater. Between Bronson and this city the land is rolling and very stony. It does not present the sudden contrast in outlines which characterizes the marl regions further north.

The Coldwater mill is located near several small lakes. The manager of the works who was present during the prospecting

*For analysis see Part I, p. 41 (Clays and Shales by H. Ries).

could not see that there was any regularity in the depth of marl. It showed no greater thickness in the center. The soundings were a succession of sudden changes in depth. Compare the soundings at the lower end of Long Lake in the Cloverdale region. It must be remembered that these lakes were lined with clear marl at the bottom as at Cloverdale and not a completely leveled marsh filled in with vegetation as at Bronson. It is well to notice how the different lakes compare with swamps in increase of depth toward the center of the marl deposit. The marl lands at this point available for cement manufacture were said to aggregate two thousand acres. The beds in this chain of lakes are to be worked by two fourteen-rotary mills, one at Coldwater, and the other at Quincy.

The clay used at Coldwater differed somewhat in appearance from that used at Bronson. It is a surface clay mixed blue and grey in color. Its advantage lies in its easy access and cheap grinding.

Jonesville.

At Jonesville, Mr. Chase Wade was interviewed. A factory was completed at this point. The bed to be utilized has an area of from seventy-five to eighty acres with an average depth of twenty-five feet. The analysis showed from ninety-three to ninety-five per cent of calcium carbonate.*

Kalamazoo.

The return trip from Lansing to St. Joseph was made by way of Hastings and Kalamazoo. At the town of Cloverdale the Chicago, Kalamazoo & Saginaw railroad passes through a cluster of lakes, and on account of the promising outlook it was deemed advisable to make a thorough investigation later, the result of which is given in the description of the Cloverdale district.

Kalamazoo was next visited, and the site of the former cement plant was examined. A chain of three small lakes form a deep valley with a rate of fall so great that a small water flume bringing water about a half a mile from the creek at the headwaters of the lake furnished ample water power for a large mill. The lower of the three lakes was nearly dry and the marl exposed was very light colored with many shells. In this lake there was little or no surface muck. In the upper, however, the depth of marsh surface was

*See report by W. M. Gregory, upon the plant of the Omega P. C. Co.

so great as to render the marl scarcely available for manufacturing purposes. One of the first factories started in the State was built on this marl bed, but with the old kiln process and with the expensive method of handling raw materials, it did not pay.*

The next marl bed reported was in the vicinity of Niles. It was five and a half miles east of the town, and covered about forty acres. Deep wells in the vicinity were said to have very hard water, and the hills surrounding terminated abruptly at the edge of the marsh and were of gravel.

§ 2. Cloverdale.

The peculiar formation of the region about Cloverdale makes a very interesting locality for the study of the formation and occurrence of marls. By consulting a map of Michigan it is seen that the townships of Hope, Barry, and Prairieville of Barry County contain an unusually large number of inland waterways and lakes. (Fig. 3.) The country is a network of deep depressions forming dry channels, gullies, water courses and lake beds. Between channels are high gravel and clay hills. The soil is very heavy but forms a greatly varying mixture. At one place it may be a tough till of clay, gravel and boulders which may be traced a short distance and then may be replaced by fine sand, clay or gravel. A cross section of the land as seen in cuts in side hills, washouts or wells shows as much if not more variation. The bottoms of gullies and kettles left by the receding water generally have a blue, black or red clay bottom hidden by a few inches to as many feet of loam or sand. These dense clays formed the bottoms of numerous lakes and channels, many of which have dried out with the fall of water level, but the largest and deepest of which form the present lakes of the township above mentioned. Within a radius of three or four miles of Cloverdale, Hope Township, on the C. K. & S. there are five lakes and several other holes not entirely dry, a fair sample of the latter class being "Twenty-one Lake" west of Cloverdale. The five lakes examined, all of which contained marl, were Long, Round, Balker or Horseshoe, Guernsey and Pine.

The purpose of the investigation was to study the mode of formation, extent and quality of the marls and clay in and about the lakes, so as to ascertain if possible their origin and their adaptability to cement manufacture. As the marl is supposed to originate

*The quality was very good, as is shown in many places in Kalamazoo, where 20 years has made little impression on the cement. L.

in one of several possible ways from the salts contained in underground waters, the relative hardness of spring and well waters surrounding the lake to the hardness of the surface of the lake and its deep water together with its outlet, was determined. This required the collection of samples of water in small fruit jars, which after filling were shipped to the Michigan Agricultural College for analyses. On page 46 will be found a table and key to analyses with a brief enumeration of results obtained. The surroundings of the beds themselves, the nature of the soil, and general impressions as to the formation of the whole lake may throw light upon the changes which may have brought about these curious deposits. These were therefore noted where possible and the conclusions drawn from these facts have been noted in Chapter IV.

To determine depth and outline of marl beds and to obtain samples at any depth the following apparatus was made. It consisted of fifty-four feet of inch pipe (three 18-feet lengths each cut in two making six pieces each nine feet long). Each piece was threaded on both ends and when a coupling had been screwed upon one end of each pipe the whole could be united into a continuous tube fifty-four feet long.

Fifty-four feet of one-half inch pipe was cut, threaded and coupled as above except that the couplings were turned down slightly in a lathe so that when coupled with the half inch pipe, they would allow it to pass freely within the inch pipe. Two shorter pieces (each four feet) of one-half inch pipe were provided, threaded as the others, but each shod to suit solidity of the material to be penetrated. The lake bottoms investigated in this region varied from a fine almost impalpable mud suspended in very deep water to very sandy or very dense clay carbonate. The very sandy and very muddy bottom would be washed off the worm of an ordinary augur. To obviate this difficulty and to preserve the specimens while being hauled to the surface, one of the short pipes was shod with a device which is somewhat of a miniature of a well driver's sand pump. It consists of a cylinder of iron just the diameter of a half inch coupling hollowed out and chisel pointed. Upon one side of the chisel surface a hole is drilled up the center to the hollow, which hollow is the exact size of the inside diameter of the one-half inch pipe. The hole is stopped on the inside by a ball valve, the ball being retained within the cylinder by a wire passing through the cylinder at right angles to its length threeeights of an inch from the bottom of the hollow. A thread is cut on the inside of the upper end of the cylinder making the end with threading just the size of a half inch pipe when threaded. It must, therefore, screw inside a coupling which joins it to the short piece of the pipe. When chugged down the valve allows the soft mud to spurt up into the cavity but when lifted the ball drops down into the hole drilled through the bottom, stopping the egress of the contents through the hole by which it entered. At each fresh downward thrust of the chisel the content of the cylinder increases, rising in the hollow half inch cylinder to the top where elbow or one-way coupling may be screwed on to direct the outflow which may be received for examination.

The other short pipe was shod with an augur, the worm of which was similar to a ship augur, but the stock of which was hollow so as to allow whatever ascended through the worm to pass up into the half inch pipe as in the previous case. When the marl was somewhat solid as was the case when the chisel was used, an iron poker one-fourth inch in diameter was used to shove the specimens out of the pipes. These are the only means so far seen which serve to bring to the surface a correct specimen of lake bottom from any depth. Specimens of lake marl were brought to the surface from beneath several feet of mud and fifty feet of water. The outer pipe serves solely as a protection and support to the inner pipe which is liable to break loose from the couplings when forced to great depths. This outfit while absolutely necessary for scientific research was not used by me in later soundings. Where the marl becomes nearly as dense as a limestone, as in the several instances in the Northern Peninsula, the chisel of the sand pump with a double tube, the outer being shoved down as the inner cuts its way through, is the best outfit that can be used. But as the marl in two-thirds of the cases seen lies on top about like "butter in summer," and at the bottom like "butter in winter," an ordinary 1½ inch augur welded on to ½ inch pipe will retain the marl and stand the strain necessary for numberless soundings. If one man is sounding alone he may use ⅜ inch or ¼ inch pipe, but is liable to bury the lower half of his rod out of reach in some marl bed.

With the outfit first described, which was fitted up in half a day at a machine shop in Kalamazoo, five lakes were examined in five days with a crew of four section men. A raft was made by slightly fastening two boats together with a framework of boards, the two heaviest boards lying parallel to each other across the boat amidship. These furnished a footing and prevented the tip of the boats from pressure of lifting on their inner gunwhales.

Four men rigged a boat raft from a pair of boats and old lumber in about half an hour. They then rowed to any desired position, anchored at bow and stern and made soundings. Specimens were generally taken from bottom and surface of the marl bed at the same spot. Boats and men were then taken to the next lake by team, about a day's work being expended on each lake.

The first lake examined was Long Lake (Fig. 3, p. 14). It is about three and one-half miles long and very narrow, being nearly cut in two by Ackers Point. The C. K. & S. R. R. runs parallel to it and bounds it nearly the whole length on the southeast side. The town of Cloverdale lies nearly all south of the railroad and at the southwest corner of the lake.

The surroundings of the lake are worthy of notice as perhaps having a remote bearing upon the origin of the lake and its contents. The southwest or upper end of the lake is bounded by an abrupt hill or bluff about seventy-five feet high, consisting of a dense till or mixture of tough clay, gravel, and boulders, and crowned by hard wood timber. This hill is flanked upon the south by lower land than on the north, the only land touching the lake being a heavy blue clay, which has flowing beneath it several springs. That on the south forms a narrow isthmus between Long Lake and Round Lake lying to the southwest. A canal or ditch had at one time been dug through this neck of land to a distance of two to three hundred feet, and the fall of water from Round into Long Lake was 16 feet, furnishing water to drive a mill. The surface of the neck of land, beneath which is clay and quicksand, is sand. The banks of Long Lake are flanked on the northwest and southeast sides by high, rolling, gravelly clay hills, which end abruptly at the shore and through which several cuts have been made by the railroad.

The lake rapidly narrows at the northeast, and to its outlet, which is a small creek flowing through a narrow low land into other holes which have once been lakes but could not be reached in any way with sounding apparatus. When the water was higher the whole must have looked like a large river without low lands, with little current, and abrupt shores.

The first sounding was made in the narrow channel connecting the two halves of the lake at Ackers Point. From here soundings were made at short intervals circling the shore to the right and south side toward the outlet, from thence returning on the west side to place of beginning, and from there on the north side of upper half around the upper end past Cloverdale, and back on south side to place of beginning.

The bottom immediately about Ackers Point was of heavy sand and gravel for some little distance out, probably having been washed down from the point over the bed. The first sounding, 40 feet out from heavy gravel shallows, showed a depth of 30 feet of marl, and at the bottom a fairly solid tamarack log, sample of which was bored and torn out, being brought to the surface by the augur.

See pages 18 to 21 for a list of soundings taken, showing depth of water, depth of marl, nature of bottom and analysis number where a sample was preserved for analysis. This number, upon reference to the accompanying table of analysis, will give the chemical constituents of the sample as far as determined.

The sounding No. 1 at Ackers Point was one of the deepest made and the sample taken was among the purest. As the lake widens from the narrows the shallows spread out and divide, following the north and south shores. The shallows extend out from the lowlands on shore perhaps 200 feet, gradually deepening, when there is a sudden jump into deep water, making a shelf much like a sand bar in a river, but not to be expected in a lake. Where opportunity offered, soundings were made on the edge of the shelf and in the deep water outside to determine exactly what was the relationship of depth of water, marl, bottom and true bottom. For the sake of clearness this relationship is pictured crudely by diagrams, which will be referred to by numbers.

Diagram 1, Plate I, shows the shelf as found by soundings Nos. 8 and 10. It will here be seen that the fall of level of the true bottom is more gradual than that of the marl or false bottom as the layer of marl decreases 10 feet. It is not well to form an opinion upon this one relationship, but to watch if it holds true in further comparisons. It is also noticeable that samples 3A and 3B, or specimens taken from Nos. 8 and 9 on the shelf show more sand than No. 10 (4) taken off in deep water. This comparison was made about half way down the lower lobe of the lake. The shallows finally again covered the bottom and joined, making an extensive flat which continued to the outlet. At the head of this flat, and about the center of the lake, was the next object of interest. This was a rocky islet about 40 feet long and 10 feet wide, formerly a cigar-shaped, stony shallow along the center of the lake. The largest boulders are just above water. All are covered with a thick, very soft, white coating of lime, which is fastened to glacial pebbles, covering them all much like a snow storm, i. e., thickest on top and scarcely at all upon the under side, though the stone may be free from others and exposed to the water. The white coating of lime hardens quickly when exposed and dried in air. A cross section shows two layers of granular friable lime, between which is a layer of green organic matter or chlorophyl revealing the presence of living organisms.

Soundings 13 and 21 were made in the mid channel, 13 to the south and 21 to the north of the island, showing conditions on each side of it. With the depth of water the depth of marl is, respectively, 9 and 23 feet, showing that the north channel was originally much deeper, the marl now filling both and making them very shallow.

The conditions thus shown immediately at the beginning of the large shallows at the foot of the lake are interesting. A rocky islet just reaches the surface of the water. From this islet the depth of marl increases from a coating a fraction of an inch thick to 23 feet thick on the north, 9 feet thick on the south, with a shallow channel 4 feet of water. Soundings Nos. 12 to 14 show the conditions in a line down the lake, 12 before the island is reached, 14 after passing around the island in a line toward the outlet. These soundings show again that the island is surrounded in two other directions by 12 and 33 feet of marl. The increase is not, as the soundings would indicate, sudden, but gradual, the island seeming like a bouldery outcrop of the bottom, which is at No. 12 heavy gravel, at the island bouldery, and at No. 3 at 33 again fine lake sand.

Taken as a whole, soundings 12-22, inclusive, show somewhat the shape of the lake bottom under the shallows to the foot of the lake and as far into its outlet as the raft could be propelled. In no case is the water over 6 feet deep, except in the swimming hole near the north bank. Soundings 14 and 17, taken in nearly a straight line, show a deep channel which narrows and runs into the shallow outlet. No. 16, taken to the north and left of these, shows but a trace of sandy marl with a gravelly bottom. No. 16 is more notable, as it was taken from the foot of a hill from which several springs issue. Prodding 50 feet to the south of 16 shows about the same condition, proving that the bed rapidly narrows, but the sudden jump downward in No. 17 shows that the outlet still remains the old channel, though nearly choked up with marl, with no surface muck. Proddings not recorded as soundings show that southwest of sounding 16, returning to Ackers Point along the north side of the lake, the muck and gravel from steep hills encroach upon the bed. The sudden contrast in the nature of the bottom is shown by comparing sample 6 of table, which is a muck from the narrowest outlet, with Nos. 5A and 5B, fair samples of marl in deep or old channel.

Nos. 21 and 22 (Plate I) are again parallel to Nos. 8 and 10. No. 21, the same referred to as north of Rocky Island, was taken just outside the swimming hole. Diagram 2 shows the relative change in depths of water, marl and true bottom. Here the relation in fall of marl and true bottom is exactly reversed as compared with Diagram 1. The marl bottom or shelf is less pronounced than the original shelf made by the true bottom before marl was deposited because the marl bottom is like a thick bottom before marl was deposited, is like a thick blanket taking away the sharpness of the edge and by its own increase in thickness of 8 feet, making the fall less sudden and the lake bottom more nearly level. Still the increase of water from 4 to 16 feet is so immediate that outline of the white bottom seems to sink suddenly out of sight. The original bottom with an almost immediate fall of (47-23) 24 feet must once have formed a bold precipitous terrace or more likely in this case a small deep kettle..

By the above soundings, together with many proddings and examination of bottom in shallow water by the eye, the following general idea of the broad shallows at the foot of the lake and merging into its outlet is given: The bottom of the deep mid lake suddenly rises to form an extensive shallow. It even shows above the water's surface in the stony islet, but slopes down on either side of the islet to form deep channels, the one on the north being deeper (27 ft.), the one on the south 13 feet. The bottom is somewhat uneven and pebbly where it is shallow. On the other hand there are many holes, the largest of which, the swimming hole, is 47 feet deep below water with the bottom surrounding it 27 feet. Besides holes there is a deep middle channel north of the stony islet and running into the outlet. The bottom rises on each side to a pebbly shore covered toward the outlet with muck or sandy marl in very thin layers.

The shore on the north side has the steep hills and springs back of it. The marl lies upon this original bottom covering it, nearly filling up the old channel and hiding all but the deepest hole, which it helps to fill. It, however, forms but a thin incrustation on the rocky islet, but in the channel thickens again to natural depth. It merges into sand and mucky marl (Analysis No. 6) toward shore, but shows admixture of sand even in the deep channel.

Upon continuing up the lake on the north side, leaving the broad shoal, a layer of sand is found between Nos. 22 and 23. But the shoaling marl again thickens on approaching Ackers Point on north side, showing no unusual features excepting that it can be easily seen that the old channel past Ackers Point has been filled to a depth of 30 feet with marl like the channel described leading out of the lake, and also that the marl is much thicker immediately in the narrows and about the point than along the shore down the lake.

From the point opposite Cloverdale the lake widens with a slight bend reaching out to the north toward the only low land. No. 27 was taken to find if the depth were any greater below the springs which emerge from the heavy clay lowland at the north corner of the lake, but no great difference in depth between that and many other soundings taken in the absence of the springs could be noted. The depth and quality of marl here are just the opposite to sounding 16 at the foot of the lake. In this case a fairly deep layer (25 ft.) of marl, with fine sand bottom, was found, while No. 16 showed 2 feet of sandy marl with gravel bottom.

At the foot of the steep till bluff before referred to as forming the boundary of the head of the lake there was a boxed spring (Sample 1, p. 46, taken here). Below this spring the water was shallow and appeared to be a sand bar, but upon investigation from boat with sounding apparatus the marl was found to run almost up to the bluff at a good depth, but the sand has washed over it to such a depth that it was reached with difficulty by the pipes. In coming down the northwest shore, which was described as mostly sand in places where marl was struck, it was found that the marl was interlayed with sand, the augur first sinking through soft marl, then grinding in sand. This would seem to point toward a washing action of the sand over the marl during the period of deposit of the marl. Nos. 28 and 29 (Diagram 3, Fig. 4) were another parallel set (Plate I), showing the position of the marl overlying the shelf, being made close to shore under the bluff and in shoal water. The soundings were taken as closely as possible to each other and the changes in depth are very sudden. The marl layer again tends to break the abruptness of the descent of the true bottom. The difference in depth of water on and off the shelf being greatest before the deposit of marl, for before deposit the shelf was 24 feet high, after deposit 15.*

Another test opposite Beechwood Point, a short distance below Cloverdale, showed the gradual increase in depth of marl, from deep shoal water in as far as possible toward Beechwood Point, at

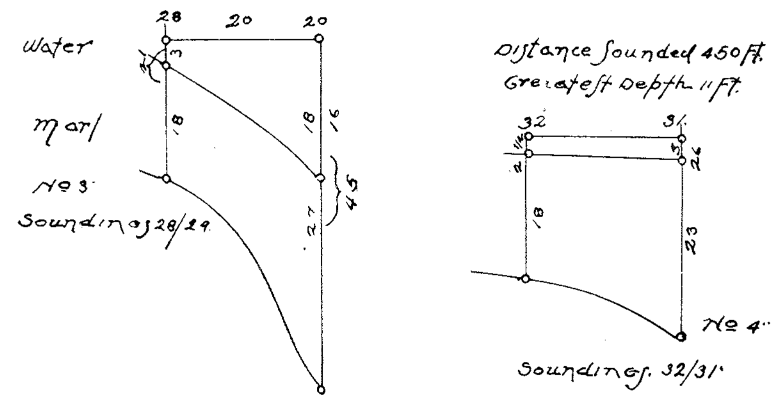


Fig. 4. Diagrams 3 and 4, of soundings 28, 29, 31, 32, Long Lake.

right angles to the length of the lake. In 50 feet the increase of depth of marl is 5 feet to an increase in depth of water of 1 foot (see Fig. 4, Soundings 31 and 32).

The general idea of the lake as given by the foregoing examination is that of a very long, narrow body of water. It consists of two quite distinct parts, the deep water and the surrounding extensive terrace or bar. Over the whole the marl lies as a thick and more or less even deposit which thins toward the shore edges where it is pretty thoroughly mixed with sand, clay or muck. The sudden changes in thickness of the marl layer seem due in greater part to the inequalities in the bottom, which is full of jogs, channels and holes. In all cases excepting Diagram I, the marl in cover-

*(45-21) instead of (18-3), see Fig. 4.

ing the terrace or shelf made by the bottom always lessens its very abrupt descent, being thicker just outside the shelf in deep water than in the shoal water upon the shelf. In this lake variation in the composition of the marl is very marked. In close proximity to the shore the marl is quite thoroughly mixed with sand. This condition extends out one or two hundred feet, as in samples from Sounding 8. Other instances before alluded to show the marl to be layered with sand and next to the very steep hill at the southwest end the sand has washed completely over, hiding the marl.

In this lake the marl layer seems to lie heaviest on the south side of the lake. It covers the whole lake bed, including the bottom 45 feet deep at the center, but lies heaviest over the terrace on the south side and has choked and completely filled holes and channels as deep as the mid lake 47 feet (Diag. 2, Plate I). Compare with sounding 10 mid lake, also No. 14 deep channel. A comparison of their soundings shows the former capacity of the lake. On account of the repeated admixtures of sand and muck the duplicate analyses furnish little data for consideration of difference in depth excepting in the deepest sounding, as 1A and B, 2A and B, 3A and B. These, the most nearly pure samples taken show, if anything, an increase of organic matter with increase of depth. There is no doubt that within a short distance of the bottom sand has worked up into the bed so that a sample, though taken with the greatest care, will show high in sand when taken within two or three feet of the true bottom. Here as in nearly all soundings taken during my experience the deeper soundings and the surface samples differ considerably in appearance, the deeper being fine grained, compact and of a steel-blue tinge, which with a high per cent of organic matter, becomes darker.* The surface samples were generally whiter, more flaky in appearance and lighter. No. 4 (Sounding 10) is of interest on account of its position 45 feet below the surface in Mud Lake. Like the other deep soundings it is high in "organic matter" and matter insoluble in HCl. No. 6 is a fair example of the mucky marl of the lake, little of which was found and that at the narrowed outlet. Notice the increase in organic matter and insolubles which far exceeds all but 3B, which was mostly sand. With this increase of organic matter there is an increase of iron and aluminum as there

*See pp. 16 and 18.

is also in No. 4, the mid lake sounding. This is natural, as organic matter is supposed to aid in the deposit of iron.

All in all, sand and organic matter have penetrated this bed from beneath and from the edges. Only in mid lake in the thickest part of the deposit for some distance from the surface down is the marl free from foreign matter. The bold shores and the manner in which the sand is found constantly washed over and against the beds are perhaps good explanations of this condition.

Organic matter as a constituent of the marl is found in largest percentages in the bottom of the deepest parts of the lake.

Mud or Round Lake, as before described, lies southwest of Long Lake, the two being separated by the high clay and gravel hill. This lake continues southwest, paralleling the railroad for a short distance, then winding to the north. The lobe at Cloverdale and nearest Long Lake was examined for marl. The water of its outlet could not be sampled as it was at the other end of the lake, its waters emptying in a nearly opposite direction from those of Long Lake, the hill forming a divide. The hardness of the water as compared with Long Lake, was as 1 to 16, being nearly as soft as rain water. The bottom was heavy gravel or muck with finer sand. Of all the soundings made but one revealed the presence of marl. This marl of poor quality was found 38 feet below surface beneath several feet of silt and by the deepest sounding made in the lake.

Standing at the divide between the lakes the general contour of the bluffs or shores of the two lakes would show Mud Lake to be much higher, about 15 feet according to the fall of water at the mill. The hills about it are not as bold and upon the whole its waters do not so deeply indent the surface of the country. The springs which do not flow from the hills slip out at the shore line, are softer and probably are not from as low a level as those of Long Lake, being mostly surface drainage.

The wells in Cloverdale and those near the two lakes and on the divide were tested. The deep drive wells of Cloverdale were of the hardest water found. The deeper one on the divide was hard, the surface one soft.

As the people's idea of hardness and softness of waters in a given vicinity are very conflicting some method was sought to obtain a definite comparison of waters upon the field.

A standardized soap solution was made in the laboratory by titrating a known volume against a known weight of crystalized

$CaCO_3$ or marble, so that every cubic centimeter of the solution needed to make a suds with 50 cc. of water, would imply one degree of hardness,—one grain per U. S. gallon of calcium carbonate or its equivalent.

The soap solution was carried in the field and measured against 50 cc. of spring or well water tested. The figures below, opposite the well or spring located, are the number of cc. of the solution required to neutralize 50 cc. of the water and form a comparative test of the hardness of the water in question:

1. Well, Hotel at Cloverdale	20.00
2. Water of Mud Lake	1.00?
3. Water of Long Lake	16.00
4. Deep well on divide between lakes	16.6
5. Ludwigs (box spring at foot of hill)	12.2
6. J. L. Chamberlain's well west of hotel	16.6
7. Simon Dayton shallower well on divide	8.0
8. Deep drive well Southwestern Michigan	13.

From this it will be seen that the lakes contrast sharply. The deep wells (Nos. 1 and 6) are hard, shallow wells on divide, No. 7 medium, and Mud Lake very soft.

No. 5, the deep spring, is quite hard.

No. 8, from non-marl region, is softer than deep well waters of this locality.

In comparison the waters of the two lakes form a sharp contrast. It is the settled idea in this part of the country that a hard water lake means marl and a soft water lake the absence of it. Several instances besides this under my direct observation were given me and I have never in my own experience found a lake which tested very soft water to show anything but traces of marl.*

In the case in question Mud Lake is not cut so deeply into the glacial drift as Long Lake. While there is sand and gravel on the edges, deeper there is a clay hard-pan, while Long Lake is in fine sand bottom. On the divide between the two in the wells driven there is said to be a heavy clay layer. Under these circumstances the only explanation to be seen is that Round Lake receives the surface drainage of soft water and is withheld from seepage into Long Lake by a clay hard-pan. Long Lake cuts deeper into the drift and receives the hard water springs and drainage from the same layer as the deeper wells.

*See analysis of Goose Lake water, of Peninsular P. C. Plant.

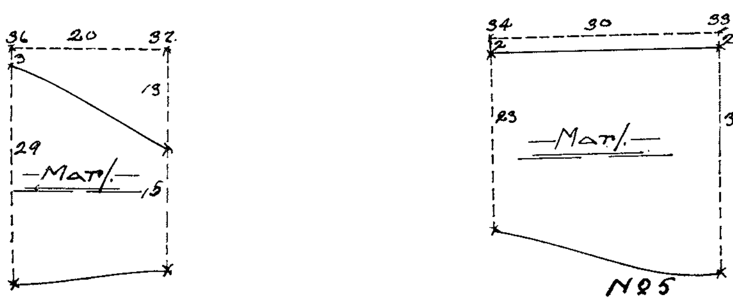
The next lake tested (Pl. II) was Balker or Horseshoe Lake. It lies about two miles east of Cloverdale and a mile in direct line at right angles to the C. K. & S. in the N. E. ¼ of Sec. 22 of Hope Township. It draws one of its names from its shape. It has two lobes or arms and a basin into which both empty and from which issue its outlet. All the attention was devoted to the south lobe and basin as a raft and tools could not be propelled into the north arm on account of the shallowness of the channel which was filled with marl, covered with a few inches of water. The two arms, like the sides of a horseshoe, are surrounded by a low marsh covered with tamarack, a good part of which must have recently been covered with water as it is but little higher than the lake surface. The south arm as it now exists is nearly round or elliptical in form. The east end consists of a large and very shallow flat upon which the first soundings were made. This flat leads into the basin by a narrows almost choked with marl. Here it is well to remark that the marsh vegetation characteristic of marl flats in general is a long cylindrical reed without leaves or branch, which shoots up many feet from a marl bottom or grows in very shallow water, as in this case, where it almost blocks passage of a boat. It is true that this reed* is found to greater or less degree on sandy or mucky bottoms, but it is one of the few practical guides to the location of marl, though like all others never entirely trustworthy.

Except for the shallow flat mentioned the rest of the lake has the shelf-like bottom already noted, the shallows forming a ring but 20 or 30 feet wide about the abrupt descent into deep water. Soundings were made on the edge of the shallows and across the lake from two sight points to determine if possible the profile of the bed or its cross section as cut across the lake. Before describing the various soundings it will be well to notice that the lake proper, which so far as determined is underlaid with a deep deposit of marl does not cover anywhere near all the depression lying between the steep bluffs. The lake as a whole more deeply indents the surface of the country than does Long Lake. The bluffs are steeper and more abrupt, the springs are noticeably larger and more numerous especially near the lake proper, which lies horseshoe shaped, curving around the south and west side of the valley, the remainder of which is covered with low tamarack marsh. The springs are also of harder water.

*Scirpus lacustris? L.

The soundings were begun at the approach to the narrows in the south arm. The bottom as at Ackers Point, Long Lake, rises at the mouth of the narrows into a flat shallows. Soundings 33 and 34 (Diag. No. 5) were taken approaching from the center of the lake toward the shallowest place in the narrows leading into the basin. The distance between soundings is about 50 feet, and while the depth of water remains the same, original bottom sinks 7 feet, i. e., the depth of marl increases that much. The real bottom of the lake is the opposite in incline to false bottom. This is paralleled in Long Lake where the narrows at Ackers Point, though choked with marl, were nearly as deep as the remainder of the lake, as the false bottom has a gradual incline, not terraced like the sides, but built up by marl. This is true in the east shallows of the lake, but not true of terraces on north shore. (See Diagram No. 6.)

The next surprise is the relation of 36 and 37. No 36 is taken on the usual terrace and 37 just outside (see for slopes of bottom



No. 6.

Fig. 5. Soundings 33, 34, 36 and 37, Horseshoe Lake, T. 2 N., R. 9 W.

Diagram No. 6). Here the depth of original bottom is less by 3 feet toward the center of the lake than on the shore terrace. As this shore was lined with marsh it is hardly possible that the marl extends in a perpendicular bank against an opposite solid bank or shore, but in all probability the marl layer extends out a great distance under the marsh. This could not be determined, but this must be inferred from a comparison of the soundings of the other terraces before made. I know of no possible explanation of the almost immediate drop of level (29-15), 14 feet in thickness of marl bed unless currents of long ago where different water level and direction of drainage may have cut marl out in some places and filled in others. (See Fig. 5, Diag. No. 6.) From this short point, upon which No. 36 was taken, the line of the soundings was continued straight across a slight neck in the lake to the neighborhood of springs on slightly higher ground. No. 38 showed increase in depth of marl again. At No. 39 a sample of water was taken by lowering a corked jug to the bottom, pulling the string allowing it to fill and at once raising to the surface and putting the water into the fruit jar which was sealed as usual. (Analysis 5, page 46.)

No. 40, the deepest sounding anywhere made, was interesting both from what it revealed and left buried in obscurity. All the pipe in the apparatus was used without touching the original fine sand bottom of the lake. At the depth of 60 feet the sample which was almost fluid was retained by the sand pump and is shown in Analysis 9 of the table on p. 20. This analysis shows the highest per cent of Fe_2O_3 and organic matter of any taken in the lakes. There was no clay and comparatively little sand as shown by the low per cent insoluble. It is also lacking in $MgCO_3$, showing a decidedly lower per cent than the rest of Horseshoe Lake. This, as

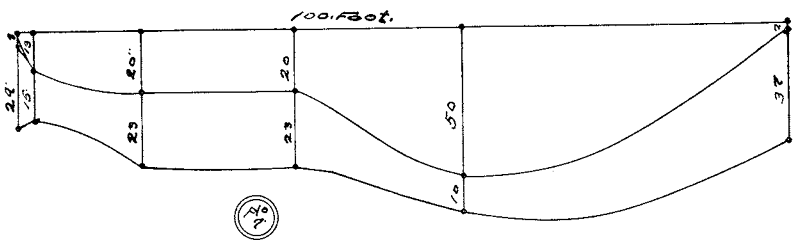


Fig. 6. Section showing Soundings 36, 37, 38, 39, 40 and 42 of Horseshoe Lake.

may be noticed in later soundings, is not the only lake in which the marl of the deeper portions gains greatly in organic matter. But such an increase in iron has not been elsewhere noticed.

Sounding 41 was a little to the east of the foregoing series, at the mouth of a very large spring. This spring emptied from beneath a bank at some distance back from the water's edge and by a small rill into the lake. The boats were shoved in as far as possible and a sounding taken in a few inches of water. The pipes sank with little effort to a depth of 32 feet. The sample from the very bottom was like that at the top, a fine silt with a trifle of lime which could be faintly detected by acid. The spring formed a large reservoir 8 feet across and 5 feet deep. At the bottom was its fountain a foot across and boiling up through black silt. The analysis of this sample of water is No. 4 of page 46. The peculiar phenomenon here witnessed was that one of the largest and hardest springs should show no trace of marl immediately in or at its outlet.

But next comes Sounding 42, made perhaps 50 feet to the west and completing the outline series, the whole of which are set forth, making a cross section of the lake bottom as shown in Fig. 6. Sounding 42, but a short distance from the spring and within 25 feet of solid ground, a bank about 15 feet high, showed marl to 37 feet depth, the deepest sounding anywhere on the lakes.

And here it is well to remark that Horseshoe or Balker Lake had the uniformly thickest layering of marl of any of the five. It in fact was so thick that its nature was difficult to discover on account of the slowness and labor in making deep soundings. Whatever the agents were by which such a bed was laid down they should be apparent in so thick a bed. The springs were large and their water hard, but no visible connection between the water of the springs and the marl of the lake could be discovered. The largest spring and its immediate vicinity were free from all but traces of lime. A very deep layering, about same depth as marl, of silt replaced the marl in and about the spring and at its outlet. The interesting phenomena apparent on the Rock Islet in Long Lake, namely the thick lime coating of the pebbles, was again manifested in a part of the lake at the shallows at the foot of the lake next to the narrows leading into the basin. This shallow area covered several acres and was from 1 to 2 feet in depth. The marl layer as shown by the first two soundings varied from the center in toward the narrows from 23 to 30 feet in depth. In an ordinary marsh, especially in the reeds or rushes, the bottom is black or dark-brown from dead rush, twigs, silt, and other marsh accumulations, but the bottom here, even in the reeds which ought to catch and hold everything that came to them, was gleaming white marl. In fact it was very much lighter in color than the specimens at the bottom which were in almost every case steel-blue in color. This color with a lack of a trace of organic matter at the surface was in this particular case perhaps explained by a more minute examination of the bottom. A branch of a dead tree leaned over and where it touched the water disappeared from sight. Upon following it beneath the water's surface it was found to have become coated with white lime covering, essentially the same in structure and appearance as that of the pebbles in Long Lake. There was the same triple coating of green or chlorophyl between the layers of granular lime. In the distribution the lime reminded one of the limbs of a tree after a snowstorm, the greatest thickness of lime being on top and scarcely any underneath. This coating was not confined to twigs, but included anything that had fallen into the water, all being covered so that they lost their identity and blended closely with the brownish white bottom.

The last portion of the lake investigated was the basin. This basin is nearly circular in form, is shallow and overgrown with round rushes at the margin and increases gradually to about 10 feet depth at center. Its waters, clear as crystal, lie over a very deep bed of marl. It has three arms, one leading from the north arm of the Horseshoe Lake, one from the south arm and lastly the outlet or creek. All are so overgrown with rushes and choked with marl that boats are forced through with difficulty. The soundings made and marked in the list make the average uniform depth of marl about 30 feet. The clearness of the water can perhaps be accounted for by the fact that every particle of foreign matter, organic or otherwise which might find its way into the pool, seems to be surrounded and buried by the lime as described in the case of twigs. Whether the lime or marl be precipitated carrying down the organic matter with the marl or whether the particles attract the lime by the assimilating action of minute animal or plant organisms one result is here obtained. The water is left so pure and clear and free from foreign matter that fish or water plants can be seen entirely across the basin. Here it is well to remark that the bottom was overgrown with a plant much in appearance like a small pine tree. In the middle of the lake sound at 40 feet, a deep water plant was brought us, smelling exactly like a pole cat.*

The best samples of Balker Lake were not analyzed. The very deep samples were tough and steel-blue, were evidently high in clay and organic matter, but on the whole not so sandy as those of Long Lake.

As will be seen by descriptions on page 46, samples of water were taken from two springs, from the deepest part at sounding 41, from the surface and outlet of the basin and it can be easily seen that on account of the intensely marly nature of the lake its waters should reveal something of the marl's origin.

It is impossible to reconstruct the lake as it once existed. Its bold shores and large marsh hint at a far greater depth and volume

*See pp. 56, 89.

of water with currents which may have done something toward disturbing the evenness of so thick a layering of marl.

As in reality a small portion of the whole bed was examined the rest lying under the adjoining marsh, the cross section (Fig. 6) is rather incomplete and the individual soundings do not show the pronounced relations between true and false bottom. Attention is especially called to the sounding mid lake, which shows the remarkable difference in quality of the marl in the deep water, as it contains much iron and organic matter and only about half calcium carbonate. It has been suggested as an explanation that the organic matter of the lake upon account of the dish-like shape of the lake tends to slide into the central or deeper portions, giving them a more highly organic character.

It was especially noticeable that Long Lake contained a more caustic marl than Horseshoe Lake. In Long Lake the hands of the operators were severely chapped and seamed, while this was scarcely noticeable in Horseshoe Lake. The marl did not seem to bite.

A review of the springs of Horseshoe Lake hardly seemed to justify the theory of immediate precipitation of lime. There was no trace of marl in or around them although at a distance of a few hundred feet the deepest marl was found. Upon the whole this lake is very deeply indented in the surface of the country, having high, steep bluffs. The portion covered by water has a steep terrace or shelf, less shallows than Long Lake, with a deeper and larger lake center. It has a thicker, more homogeneous marl with considerable organic matter distributed most-largely toward a somewhat clay bottom.

The next lake visited was Guernsey. This lake lies northwest of Cloverdale about 1½ miles in Secs. 17, 18, 19, Hope Township. Its two long lobes form like Long Lake what might have once been an old river valley. This is continued by a rather narrow marsh and creek forming an outlet. This marsh, several miles away, is said to contain bog iron.

The lower lobe only could be examined, as it was impossible to get the raft through the narrows between the lobes. The lobe examined appeared something like a mitten. The wrist forms the extension, shallows and narrows leading to the north arm the hand. The main body of deep water is fringed with shallows. The thumb to the west was a long lagoon lying in marsh. The south end was all sandy bottom destitute of marl. Yet the usual terrace was there and so close to shore that teams must be careful not to drive in far for fear of suddenly slipping off the shelf into deep water. A spring was found near the south end, of which the water was sampled in jar 9. (See page 46, Chap. IV.) A small deposit of iron was on the vegetation, but no trace of lime could be seen in the vicinity of the spring. As proddings were made from time to time up the east side of the lake a sandy marl was found which increased to a depth of several feet as usual at the approach to the narrows. There were broad flats or shallows which, being covered with marl, gave the neighboring fishermen the idea that there must be an extensive deposit of marl. Upon actual sounding it was found that the flats were covered by 1 to 3 feet of water, beneath which was 3 to 4 feet of marl and below this a tough, almost impenetrable blue clay bottom. The lagoon opening on the west side, described as the thumb, contained nothing but fine silt to a depth of 25 to 30 feet. It seems queer, but is a fact, that upon the west side of the narrow tongue of marsh dividing off the lagoon there should be pure silt of the ordinary marsh or river formation, while upon the east side in lake proper there were 20 to 25 feet of the best marl in the lake, the bottom also in the latter case showing strict terrace formation, which was tested in the usual way by Soundings 49 and 51. In this case the bottom was found nearly level and about the same depth beneath water level as that in the lagoon. West of it the difference in the terrace was, in this, the first instance cited, caused by difference in thickness of marl layer. But this is a very slight terrace. Compared with real ones previously examined there is but a four foot fall. This could have easily been displaced or washed over the sand, which is further south and to which it sinks. An examination of analyses 12A and B, 13A and B, and 14A and B shows a very interesting condition of the bed. The surface samples, 12B, 13B and 14B show by far the higher lime and in every case a much smaller percentage $MgCO_3$, but far the higher percentage organic matter and lower percentage insolubles. In other words the marl is at the surface fair marl but with considerable organic matter, but at the bottom it merges into a blue clay which of course is higher in insolubles, higher in $MgCO_3$ and much lower in organic matter, except in case of 14A. The $MgCO_3$ is not very high, and as the clay is very fine grained, if not too deeply buried, it could be used mixed with the marl for factory purposes.

14B is one of the best samples found in the lakes and was taken in Sounding 32.

To recapitulate the important features of this lake. It is long and river-like, undoubtedly one of the old glacial valleys like Long Lake. The layering of marl lies toward the west side of the south lobe, is underlain by blue clay, is from 2 or 3 to 28 feet deep, is not as uniformly thick as Horseshoe Lake, does not cover the whole lake, is flanked upon the west side by a deep lagoon filled with silt. Its springs show no unusual trace of marl. It does not indent the surrounding hills very deeply, being the shallowest placed lake so far visited.

The next lake examined was Pine Lake. This lake, north of Cloverdale, is in Sections 8 and 9 of Hope Township. The portion covered by water when the lake was examined rendered its outline very different from that given on the county atlas. It consists of three large lobes, the narrows of which were larger and less obstructed than any so far visited. Time permitted only the examination of the south lobe and its connecting narrows. The first sounding was made at the cove or landing where stock and teams are driven and row-boats usually land. The surface of the marl is muddy, which is an unusual occurrence not found elsewhere in the lake. It may be due to the constant roiling at the water's edge. The next sounding was made across that end of the lake at a large boiling spring. This spring was about a yard across and its location was marked by a large number of bubbling fountains which boiled up through the marl 10 feet thick. This is the first case where marl was found in or about a spring. The analysis of this marl (No. 17) shows it to be remarkably free from sand or clay, but quite high in organic matter. Although the bottom from which the spring came was fine sand like the rest of the lake, and although the water was washed up through it and the marl, the ascending stream seems to have no power left to mix the sand with the overlying marl.

As the remainder of the south lobe presented no unusual appearance, a series of soundings were made across the first narrows, which were perhaps 100 feet wide. These soundings are numbered from 3 to 8 on the record sheet. Figure 7 shows the cross section of the bottom as platted from the soundings.

By this it is seen that from Sounding 3 to Sounding 7 there was a deep original channel nearly filled with marl except where gouged out in the center of the modern narrows. On the west side Sounding 8 shows another channel almost entirely filled with marl. As the true bottom shows no sudden terrace or shelf so the marl or false bottom, though it slopes to form the deep depression of mid-channel, does so gradually without the sudden step or terrace formations. To appreciate this compare true and false bottom here and in Diagram 3, Plate I. From the way the marl lies it would appear worn away in mid-channel. It would be unfair to establish this as a fact as the marl might have formed more easily about the side or points forming the narrows and so have built out into the channel.

The samples taken from this lake are analyses Nos. 16, 17 and 18 A and B, 20A and B. They average better than those of other lakes of the group. The first, No. 16 (Sounding No. 1), is the poorest. Though taken about 30 feet from shore and at a depth of 20 feet, the sample contains considerable sand which has evidently

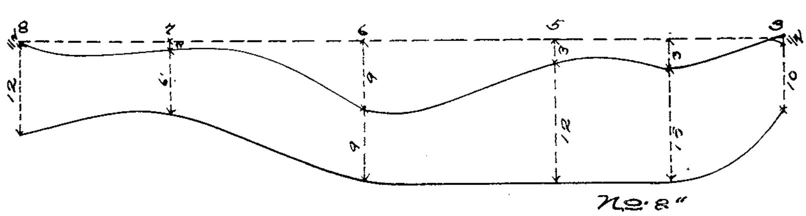


FIG. 7. Section at Pine Lake, soundings 3 to 8.

worked out from the shore. This is shown by a high per cent of "insoluble in HCl." The surface was before described as being covered with organic matter, the only black bottoms on the lake and probably due to the landing.

No. 7, taken in front of the boiling spring at 10 feet depth, shows a very high per cent of organic matter though otherwise light in Al_2O_3, Fe_2O_3, insolubles, and $MgCO_3$. The especially low percentage of insolubles and Al_2O_3, Fe_2O_3 are interesting, as the sounding showed the spring boiled up through a 10-foot bed of marl. At the bottom was fine sand. This sand was not mixed with marl as would appear natural, but the sample taken was unusually free from insolubles as the first column indicates. Again, this sample is the freest from Fe_2O_3, Al_2O_3 of any taken. The spring then left none of its iron in passing through clear marl, but carried it away in solution. Near by there is an outlet to this lake and this outlet, several miles away, contains a large deposit of bog iron ore though within the immediate vicinity there is no trace of it and the samples are free from all but slight amounts of iron and alumina; .8% to 3½%. In 19, 20 and 21 both surface (B) and deep (A) samples were taken. These samples belong to Soundings 5, 6 and 9, respectively. (See Diagram No. 8.) These soundings form part of the cross section of the narrows and are about 20 feet apart. Some investigators have thought that deep samples show higher percentage of magnesia than do shallow, so it was thought advisable to compare analyses of surface and deep samples in order, if possible, to arrive at a conclusion as to the increase in percentage of magnesia. Such a conclusion might assist in tracing the origin of marl. In the three pairs of analyses, 18, 19, 20, the first two show the highest magnesia at the surface while 20 is a little in favor of the deep samples. In two cases out of three, 18 and 20 against 19, the organic content is the greater with the increased depth. In all three instances Fe_2O_3, Al_2O_3 is highest in deep samples. In 19, where the organic matter varies least with depth, Fe_2O_3, Al_2O_3 varies least. This sample, Sounding 6, is, however, but 9 feet in depth, giving the least distance of any of the three soundings sampled, between surface and deep sample. It is noticeable that there is less variation in any of these components than in the soundings where distance between samples is greater. In two out of three the insoluble matter is highest in the lower sounding. In comparison of future samples from different depths it will be well to keep in mind the mutual relation with varying depth of the samples in order to find if possible the constant variation in composition of a marl bed. This would be of little aid to the factory chemist as the dredge makes a clean cut from bottom to top, but may assist in our scientific research for the origin of marl.

For the sake of clearness and to give some system to the perusal of further descriptions it is thought best to review the work upon the five lakes so far discussed.

CLOVERDALE REGION—SUMMARY.

Long Lake is covered with a sheet of marl varying from 20 to 30 feet in depth. The bottom of the lake is not level and even, but has a more or less regular terrace on the south side, a deep channel which runs from mid lake under the marsh at the present outlet, narrowing at the same time to a width of thirty or forty feet. This channel, which forms the deeper portions of the lake, is choked at Ackers Point, about mid-way and the lakes outlet, with a depth of marl of about thirty feet. At a depth of twenty-five feet of water in mid lake there is twenty feet of marl, showing that the bed thins in water of that depth.

Besides the main channel there are many sudden holes in the outline of the original sand bottom, and also a sandy islet where pebbles and stones crop out at the surface. To each side of this islet the channel, while it is not as deep as toward the outlet of mid lake, is filled evenly with marl. The depth from surface of water to original bottom is, on the north side of the island, 27 feet, on the south side 13 feet, while the depth of water is four feet in both cases.

The accompanying map of the lake and cross sections of the bed are made to show the manner in which the marl is deposited upon the terraces. The effect of the marl in all cases is to round over and fill up holes. It deposits sparingly upon the rocky islet and fills the channels to each side. It thins toward the center, but produces a less sudden descent from the terraces than would have been found on the original bottom, before the deposit of marl.

The deposit lies evenly at both ends, and along the southeast shore, but is thin and persistent only at points which project from the northwest shore.

The lake being three miles long and but a few hundred feet wide, and having high gravel and clay hills, is very subject to washings of surface soil. Its composition is heavily influenced by sand and clay rendering it of little use for factory purposes.

The waters flowing into the lake by its springs are very hard, as were also the deep drive wells of the immediate vicinity. The lake adjoining, called Mud or Round Lake was remarkable for its contrast. It apparently received the soft waters of surface seepage, was clearly of higher level, with sand, clay and mud bottom. A trace of marl under several feet of muck was found in thirty-five feet of water. The saying that "hard water makes hard marl" was very well exemplified in these two lakes. From a view of the two so close together, yet so different in their content of marl and the hardness of their waters, it would appear that Mud Lake indented the surface of the country less and did not receive the drainage of the springs from the deeper strata of soil. Its surface is about fifteen feet higher than that of Long Lake and the ditch connecting the two lakes had furnished water fall sufficient to run a mill.

Horseshoe Lake (Plate II) contains the deepest and most actively depositing bed of marl and the deepest of any of the lakes investigated in this region. The lake as it now exists encircles a portion of the whole basin in the form of a horseshoe, the remainder being covered by marsh. The largest and most intensely carbonated springs and lake water were found here.* This lake, running from 20 to 37 feet of marl on shallows. It also shows the same tendency to fill the sudden step made by the greatly increasing depth from the shallow terraces to deep water. In this deposit the greater variation in composition resulting from increase in organic matter, is seen every time a deep and a shallow sounding are taken in the same spot for comparison. The great coldness of the deep water of mid lake is sharply contrasted with the luke-warm water of the shallows. The great abundance of plant life in shallow water and the thick incrustation of every object covered by shallow water are very striking, as are the absence of incrustation plants from deep water.† This is the remainder of a very large deeply indented lake basin, which has held the hard waters of its deep springs for many centuries. Nearly all the basin is sealed by marsh growth. The portion remaining consists of the waters of Horseshoe Lake, which are actively depositing the best grade of marl at the surface of its shallows.

The portion of Guernsey Lake examined is remarkable for its strictly local deposit of marl. The thumb described contains very good marl on its east side and a corresponding depth of loose lake silt on its west side in the lagoon. On the one side the particles of silt are surrounded by the deposit of marl, making a marl bed with 22% calcium carbonate at bottom and 64% calcium carbonate at surface, while on the other side of the tongue of land fifty feet away there is a deposit of twenty to thirty feet of pure silt. At the head of the lake there is no marl at all, though there is a terrace and a spring of water containing 130 parts in the million of calcium carbonate, which is a fair average. It appears from this that conditions are not always favorable for the growth of marl, given the same kind of bottom and the same water. True, the con-

*See Nos. 4, 8 and 5, page 46, Chapter IV.
†Wesenberg-Lund.

ditions are not exactly identical with those of the deep deposit at Horseshoe Lake. The springs are not so plentiful or of such hard water. The sandy spot alluded to is bare and unsheltered.

Pine Lake shows fairly hard water, a good deposit of marl over the entire lake and not as great difference in content of organic matter as Horseshoe Lake or Guernsey Lake. This was a case where a spring bubbled up through ten feet of marl without bringing sand into its composition or otherwise affecting its quality. We must conclude that the immediate locality of springs has no effect upon the position of the marl either in regard to depth or quality.

The samples of water taken are interesting only from one point of comparison. For the whole list of samples and analyses of some, see page 46, Chap. IV.

$CaCO_3$ COMPARED IN PARTS PER MILLION.

Springs.	Wells.	Surface.	Water medium deep.	
Horseshoe 200, 160		70	100	117
Long Lake 100	160, 156	40		
Guernsey 130		40		
Pine Lake 170, 136				80
Mud Lake 80		30		53.6

From these comparisons and those made with soap solution in the field, it appears: that the most intensely marl lakes have the most heavily carbonated waters, the soft water lake showing much poorer in all cases; that in the lake itself, the deep water contains the most gas and carbonates and that they uniformly disappear in every lake at the surface, the gas being lost entirely and the carbonates in a fairly even proportion. These well, spring and lake waters substantiate the idea that the water's hardness is responsible for the presence of the marl in a somewhat direct ratio to the strength of the carbonates it contains.

§ 3. Pierson Lakes.

I visited Big and Little Whitefish Lake, southwest of Pierson three or four miles, Pierson Township, Mecosta County.

The general outline of the land is a rather monotonous level, but in the neighborhood of the lakes it is considerably broken, but not as much as at Cloverdale. Big Whitefish Lake is about three miles long by a mile wide. Its shore level sinks into extensive shallows consisting of somewhere between 20 and 30 feet of marl.

At near the center a "blind island" rises from the very deep water and is covered by about 25 feet of marl. Blind islands are met with often in these lakes. They are small shallows in the deep water of mid lake. There are large flowing springs along the shores of the lake. These springs deposit iron upon the stones and vegetation at their borders, but the marl in the lake below them appears to be unaffected by iron coloring. One spring at the south end gave marked smell and taste of sulphur and was valued highly for its medicinal properties.

At its southeast corner the lake is bounded by a sandy ridge containing gravel with fossils and granite boulders. Beyond this ridge, perhaps 200 yards to the east, is a deep hole or smaller lake, about 200 feet across. This is fed by intensely irony springs and empties by a deeply cut creek into the larger lake. The sudden fall gives about ten feet of water fall for turning light machinery. The creek is very interesting. Its bottom is composed of marl which continues up its steep bank 20 or 30 feet. About half way to the top of the ridge upon the sides the marl is shown on the uprooted stumps of large forest trees.

Between the two bodies of water mentioned is a kettle not as deep, but with sides so steep that there was some speculation as to whether the Indians had not dug it out to make their mound which was on the ridge to the east. Upon examination a crude marl was found in the bottom of this kettle under a few feet of loam, showing that it, with the low ground adjoining, had been under water. It looked as though the three, the larger lake, the hole and the kettle between had once been one and that the creek bed was once but a connecting channel.

A bed of clay was examined on the farm of Mr. Shanklin some little distance from the lake. The clay bed was covered by 2 or 3 feet of red and yellow ochre, which had at one time been dug for paint. An augur was used and the ochre and clay bed beneath penetrated to the depth of 10 or 12 feet. The samples brought up showed a fine clay which reacted feebly with acid, but was in most cases mixed with sand, which seemed to run through the bed somewhat in layers, there being found several samples entirely free from grit.

Little Whitefish Lake, two or three miles from Whitefish Lake, was visited briefly and a few soundings made at the south end. Here there was a swamp at the southeast corner which was probed to a depth of 15 feet without striking anything but silt. The marl upon this side seemed slightly red or brownish in cast, but at the west side it was much whiter. The marl was (28 ft.) deeper upon the points or shallows running out from the shores and of the prevailing consistency. North of the marsh and jutting almost into the lake was a bluff showing 25 to 30 feet of clay which was nearly like rock, of light color and was calcareous.

§ 4. Lime Lake and vicinity.

The lakes about to be described are near Cedar Springs in the northern part of Kent County. The country through which our guide led us showed very distinctly the effects of the glacial action. Steep hills, waterways, creeks and small lakes produced a very undulating surface. The first fact worthy of notice was very strikingly illustrated in the examination of road cuts in several side hills. These hills were generally coarse sand which was thoroughly seeded with small pebbles and boulders. At varying distances up their sides, clay strata projected slightly, or their exposed surfaces were worn down and hidden by sand and gravel from above. These clay banks are typical of half the clay in Michigan. In color it is light or ashy gray. Its texture or grain is ruined by the admixture of fine sand. Upon addition of acid it effervesces more freely than many samples of marl because it contains so high a percentage of carbonates of calcium and magnesium. Upon a further examination of the bank or hill the carbonated condition of the soil is found to continue not only in the clay, but also in the loose and apparently pure sand as, upon contact with acid, the surfaces of the sand grains freely effervesce.

Parallel with the stratum of clay are often found small ledges or boulders of a matrix of coarse sand in which are cemented small pebbles. The upper surface is even as if smoothed by the leveling action of water, although the rock, as it has now become, is fifty feet above the level of a stream and buried in a hill. The lower surface of this rock or tufa is uneven and jagged. Upon the addition of acid to this rock it also, as in the case of the sand and clay, bubbles with escape of gas, and the particles of sand and the pebbles fall apart showing that the matrix or binding element is not the insoluble sand, but the very soluble carbonates.*

A comparative test for hardness was made upon the springs and creeks of this region during the trip and all were found to be very

*A similar recent sandstone occurs beneath the clay bed at Harrietta. L.

hard. Lime as a carbonate was found to permeate very thoroughly the soils of the whole district, and the soil mixing effect of glacial action was very marked.

Lime Lake.

The first lake visited in this region was Lime Lake. An old kiln was still to be seen marking the place where marl from the lake had once been burned for lime. The lake as a whole made a very sharp and deep indentation or circular hole in the plain of the surrounding country. The shallows on its shores formed a white but narrow margin ending in an abrupt terrace and very deep water toward the center of the lake. The shallows, the dry land of the valley, and the broad entering valley of a small creek, formed a solid body of very white marl from fifteen to twenty-seven feet in thickness. Shells, large and small, constituted nearly the entire body of marl even at the greatest depth and they preserved their form perfectly. This is certainly one instance, at least, in which shells can furnish nearly if not all the excuse for the origin of marl.

Several samples of marl taken a few feet below the surface, upon drying, turned from nearly white to a pronounced red. This was very likely due to the oxidation, upon exposure to air, of the ferrous or nearly colorless iron to the ferric state in which the color is red. The valley opening into the lake from above was very large and probably once formed an old glacial valley. It connects Lime Lake with several higher ones and is a pure marl bed with but slight covering of surface soil.

Twin Lakes.

These lakes were remarkable for their great contrasts with each other. They had no visible union, but they were said to connect with each other by an underground channel. The lower one was shallow and sandy, the upper one was a hole between huge banks which, in cuts made by washouts, were almost identical in nature with the sand hills before described. Its banks or bluffs, fifty feet high, descended with but a step for a shore line, directly into water, making no shallows whatever. So abrupt was the descent to the bottom that one standing on shore could shove a pole out of sight in the water without touching bottom. The lake is said to be one hundred and seventy feet deep, according to the measurements of the Fish Commission. The springs emptying into the lake formed a glistening scum of iron. This lake is a very good example of the hundreds of holes made by glacial action and without which we could not have the conditions necessary for the formation of marl.

§ 5. Fremont District.

Fremont Lake and the town of Fremont are situated on the Pere Marquette railroad in the northern part of Sheridan Township, Newaygo County. The country surrounding the lake is rather level and the lake makes but a slight indentation in the surface. In sharp contrast to this the lakes in the hilly country before examined seemed to depend for the depth and extensiveness of

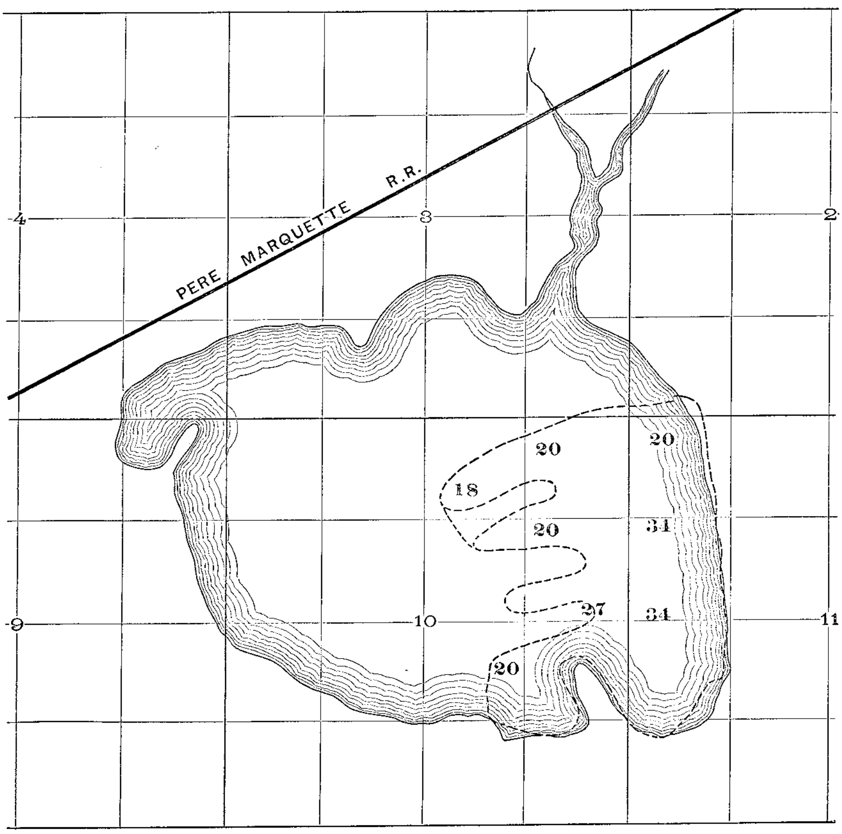


Fig. 8. Fremont Lake, Newaygo County.

their deposits upon the comparative depth at which their basins were sunk below the level of the surrounding country. Fremont Lake has a very shallow basin and it therefore differs entirely from the regions before mentioned.

The lake is to be the site of a fourteen-rotary cement plant to be run by power transmitted from the other factory to be built at Newaygo.

The map of Fig. 8 represents Fremont Lake or the portion of its basin covered by water. The dotted line encloses that portion most available for cement purposes. The depths of marl soundings are shown by the figures. The drawings together with the accompanying analyses were kindly loaned us by Mr. John Cole.

The lake examined closely on the side toward the town shows marl shores covered partly with sand. The shallows which are very extensive extend out toward the center of the lake as long, parallel peninsular shallows. The change from shallows to deep water is very abrupt, even between the peninsulas. These abrupt changes are very similar to those at Cloverdale. The soundings in this lake show the shallow marl toward deep water. Soundings of eighteen and twenty feet are found toward the center as contrasted with thirty-four feet at the inside edge. There is a blind island in the center of the lake which brings within reach much valuable marl.

The peninsulas above mentioned are covered with from one to three feet of water, the marl has no covering of organic matter and supports a thick growth of the cylindrical rush known as marsh-rice which is so prevalent as to be almost characteristic of marl beds.

The analysis of the sample of marl by Prof. Delos Fall of Albion was as follows:

Silica	2.28%
Aluminum and iron oxide	1.60
Lime	88.25
Carbonate of magnesium	1.40
Organic matter and undetermined	6.47
Carbonate of lime after the removal of organic matter	94.85

Beneath this marl lies a blue clay which was analyzed to determine whether it would be of proper composition to mix with clay in the manufacture of cement. It was found that the clay directly underlying the marl contained over seven per cent magnesium oxide, which was considered unsafe. The startling fact from a scientific point of view is the sudden variation in content of magnesia in the marl and in the clay immediately beneath it. 1.40% magnesium carbonate equals .7% magnesium oxide and the proportion of the oxide in the marl to the oxide in the clay beneath is then, as .7 to 7. For this reason either a totally different agent or the same agent, with greatly varying power, must have controlled the deposit of magnesia in the marl and that beneath it in the clay of Fremont Lake.

Mr. Cole showed me another clay from a different part of the country, which was to take the place of that just mentioned. It appears as a dense blue shale and the following is the analysis as given to me by Mr. Cole (chemist not known):

Silica	42.94%
Alumina (Al_2O_3)	12.94
Oxide of iron	5.73
Calcium oxide (CaO)	12.93
Magnesia	2.97
Loss by ignition	18.94
Alkalies (sulphuric acid, etc.)	4.07

There were said to be numerous hard water springs in the vicinity. A drive well near the station was examined and showed very hard water. A well bored near the lake failed to strike anything but marl till at a depth of thirty feet it penetrated a limy clay. The clays of this region are very calcareous.

§ 6. Muskegon District.

Bear Lake just north of the mouth of the Muskegon River, was visited and probed for marl. It appeared after investigation that Bear Lake was but the old mouth of a river. Muck and silt to the depth of 35 feet was found, but no marl, excepting at one place. Near its outlet was a streak of clay at right angles to the outlet and to the mouth of the Muskegon River. This clay was found to run under the lake and above it and beneath the silt was a foot or two of genuine marl. Several soundings were made at the mouth of a creek emptying into the lake and also in the rushes at the head of the lake. The bottom was in every case a foundation of fine sand covered by many feet of silt.

The Muskegon River flats were said to contain marl and several samples were submitted to me by Prof. McClouth of the Muskegon High School, but nearly all of them showed an intimate mixture of clay, sand or muck with the marl demonstrating nicely what has usually appeared, that marl generally loses its individuality and becomes an admixture of marl with sand, clay or muck in the neighborhood of running water.

§ 7. Benzie County.

Benzie County contains a number of marl lakes, several of which are drained by the Platte River.

Also a company was formed to work the marl in Herring Lakes, five miles south of Frankfort. These two lakes are connected by a stream which has a waterfall of 15 feet. This is to be obviated by cutting a canal through a bend in the creek partly draining the upper lake. This lake contains a deposit of marl about 30 feet in depth. It is fed by numerous springs, which form a network of creeks. To the east the lower lake is very deep and is connected with Lake Michigan by a short channel which is to be deepened for the entrance of large lake boats.

The bluffs of clay about Frankfort were examined for a cement clay, but none was found. Some clay was quite free from grit, but all was highly calcareous. On a farm north of Frankfort there was a sink hole, some 300 feet from the lake. There was no visible drainage, but upon the bluff opposite the hole there was a seepage of water from between the clay and the sand lying above, showing that the water might in part be held in and turned lakeward by a dense underlying stratum of clay. This may also explain the drainage of some marl lakes which have perfectly fresh water but no visible outlet. Crystal Lake was examined but showed no signs of marl. It had a very gradually increasing depth and pebbly beach like Lake Michigan and was unlike most marl lakes in formation and slope. The Lake Michigan bluffs, which are here very high opposite the lake, suddenly sink to within 15 or 20 feet of its level. The sharp well-defined channel with abrupt banks on each side seemed to show a former connection between the two lakes. A comparative test of hardness of water showed them about alike.

In Frankfort River, south of the town, there is a large elbow or basin formed by the river bottoms which broadens into a large marsh to the south. This marsh looks as if it could easily have been a shallow basin or lagoon. It is said that several thousand acres are underlain with 2 to 3 feet of marl. That examined was under 2 to 3 feet of muck and was very white.

§ 8. Harrietta.

In the trip from Frankfort to Cadillac the clay banks of Harrietta were passed.* It was near this point, the highest in that part of the State, that marl was reported as lying in a creek and upon its banks. Marl is deposited everywhere regardless of elevation.

§ 9. Escanaba.

The country about Menominee is largely limestone. A lake in Sec. 6, T. 24 N., R. 26 W., is said to be marly. No marl lakes were popularly known around Escanaba.

*See Part I, p. 53.

At Escanaba a light prospecting outfit was made consisting of the following:

40 feet of $\frac{3}{8}$-in. pipe, cut in 4-foot lengths.

Couplings for the above.

$1\frac{1}{2}$-in. common wood augur bit welded to short piece of $\frac{3}{8}$-in. pipe.

1 alligator wrench.

This could be loaded into a sack, strapped up and checked from one station to another.

It is found that for soundings in deep water for marl $\frac{1}{2}$-inch pipe is the safest, although the smaller $\frac{3}{8}$-inch pipe is lighter and can be raised or lowered in the marl easier, but is liable to bend out of shape and tear out at the couplings.

A 2-inch bit is a good medium size. A larger one requires too much work to raise it through the marl. A smaller one does not hold the marl in its coil. For practical purposes this is the most serviceable outfit for the average marls of Michigan. But in the Upper Peninsula marl was found too hard to penetrate by this means and in the Lower Peninsula marl and mud are sometimes too soft to be held in the worm of the augur. For all round sampling we find the outfit at Cloverdale very good though bulky. At Little Lake, the junction of the Chicago and Northwestern and the Munising R. R., Marquette County, Upper Peninsula, several lakes were examined. Their water showed in comparison as 2.7 to 11-13 as contrasted with that of Lake Michigan. This was quite soft and bore out the result of investigations at Cloverdale. The lakes were in a low, level country themselves, had very low banks, and nothing but seepage springs. Upon sounding they gave depths of marsh silt varying from 12 to 25 feet upon a fine sand and gravel bottom.

§ 10. Munising.

At Munising no marl lake was found in the immediate vicinity. I was informed by the superintendent of the road of a marl lake once discovered in sinking a shaft. The boring was carried through 20 or 30 feet of muck, when the drills passed through about 30 feet of marl and then into sand and rock again. The well filled and the liquid marl was pumped up as it constantly filled the hole and prevented progress. Finally the upper layer of denser muck sank like a flap till it shut out the liquid marl and the boring was completed, no ore being found.

§ 11. Wetmore.

At this village there was a large creek fed by a mass of boiling springs in its bottom. This bottom consisted of a very dense white marl covered by a few inches of silt. When the augur penetrated with the greatest difficulty and was pulled out with a specimen, a new spring boiled up in the puncture of the crust made. This point is near the divide of the Upper Peninsula upon the side which drains into Lake Superior. The creek is bounded on either side by somewhat low hills. The marl obtained was half way in consistency between marl and limestone. It was rather granular, though the particles themselves examined under microscope cannot be distinguished from those of dried marl. The marl is an almost pure white and very heavy considering its volume in comparison with ordinary marl. The creek is said to drain several lakes nearly upon the divide.

§ 12. Manistique.

Here lime kilns were visited. The whole country is limestone and there are no lakes or flowing springs or wells in the immediate vicinity. The limestone itself is over 30% $MgCO_3$ but burns well, making a good lime. A sample of marl from a dried up lake-bed some 30 miles distant was shown me. Its analyses revealed 95% $CaCO_3$ and it seemed one of the purest samples seen in my trip, being, with the exception of a little darkening organic matter, pure white. The analyses showed but traces (slight) of MgO and this too in a country noticeably abounding in magnesian limestone. The lake-bed from which this came showed a basin-shaped depression of about 37 acres filled with purest marl from a shore depth of 1 to 2 feet constantly increasing to a center depth of 29 feet. This is a good example of a completed lake.

§ 13. Corinne.

A spring creek was examined and a small bottle of water taken.* Most of the bottom of the creek was underlain as at Wetmore with a very hard granular marl 2 to 3 feet deep with clay beneath and one or two feet of muck on top. There were no indications that this had been a lake bed in very recent times, though the ground which formed a small swamp had very likely been under water for differing lengths of time. A lake about three miles farther south was visited and had a peculiar history. It was said that it increased in size during the spring months, but in summer, July and August, it suddenly disappeared and it was wondered if it found some crevice in the marl and suddenly emptied itself. It is prob-

*Sample of water taken from large spring. See (No. 2).

able that the lake filled up from spring rains and then gradually dried and by summer it had got so shallow that when steady hot weather came the thin sheet of water left evaporated quickly and the shore line advanced very suddenly. When the lake was visited in late July it had 3 or 4 feet of water upon it and was one great shallow of marl one mile or more long and a quarter mile wide. The marl was the purest seen, but was so dense and granular that the augur did not penetrate over five feet. The marl, however, formed rather dense layers. As the augur penetrated it it would sink easily for a foot or two and then strike an almost impenetrable layer which seemed like sand, but the specimen obtained would be very hard marl. It is probable that this stratified condition or layering of different density is caused by the sudden drying and baking given the crust during the annual drying of the lake. The lake was in an extensive forest bottom and I was informed that it was fed only from the surface waters which collected in the wetter portions of the year.

I could hear of no marl in the region of Trout Lake, but near St. Ignace there were deposits of marl and dolomite. No marl could be located in the neighborhood of Mackinaw City. Little Traverse Bay had marl underneath the sand as shown by driving of spiles for piers.

At the straits and for many miles inland the immense area covered by limestone scraped bare of glacial drift perhaps shows where the lime of our marl once originated no matter how subsequently deposited in the lakes. The immense number of small, smoothly rounded limestone pebbles show that a great body of lime must have at one time been washed away by the action of water, being removed in the form of either a fine sediment or a solution.

§ 14. Grand Traverse region.

The district about Traverse City was next visited. The marl upon a low basin on the asylum grounds was examined and found to contain an underlining of marl about 2 or 3 feet deep. Here it became evident as at Frankfort that an originally greater depth of water lying over the marl did not imply a greater depth of marl, but rather the opposite. This is considering the water level of Michigan as a whole. This, together with the thin bed at Frankfort and others very near the water level of Lake Michigan, showed unusual thinness. In this case a large basin had been grown over with muck and covered with debris to the depth of 4 to 5 feet and only showed where a large ditch had been dug. The marl was very hard and dense, very white.

The lakes about Interlochen were next visited. Duck Lake had been dammed to allow the floating of logs so that the marl being under greater depth of water was more difficult to examine. The effects of sand washing over the marl were very noticeable in this lake, probably on account of the increase of water depth. No marl was found in the immediate vicinity of the opening of any spring or creek into the lakes. In the bay or lagoon on the east side, made by the peninsula, water and marl were shallow enough to permit of sounding with the result of a gradual increase in depth of marl from shore to center. (Fig. 9.) Hard sand prevented a like test upon the opposite shore. The marl was in no case exposed close to shore excepting on the shore of the peninsula, which was very low and overgrown with trees and may have been but recently lake bottom, though upturned stumps showed no traces of marl. Upon the point itself there was a shallow coating of marl which increased but slowly at greater depths of water. The deep marl

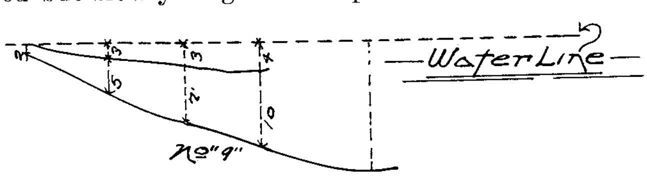


Fig. 9. Section showing soundings at Duck Lake.

extended to a greater depth than 20 feet of sounding pipes and lay to the east of the peninsula where it joined mainland. Upon the west shore of the lake there was a coating of sand with no marl in or about the outlet. There is marl in the deepest parts of the lake. Lake rice reeds in 6 feet of water were coated with marl deposit. No Characeæ were visible. This was long known by the logging men, who in raising the weights let down to pull rafts, brought to the surface the gray mud. In general this lake as viewed seems to be a very marked case of the washing of sand from shores onto marl. The marl was undisturbed, was at the center and upon the peninsula where it thinned toward shore.

The lake opposite Duck Lake, into which Duck Lake emptied, showed nothing but sand, shallow sand shores and seepage springs.

§ 15. Central Lake.

Central Lake, also called the Intermediate Lake, being one of a series or chain, extends for some distance along the coast and very nearly at a level with Lake Michigan. The bold terraced shores and the sharply contoured hills that run down at right angles to the course of the lake are very striking to the eye. These contain a mixture of every kind of soil from pebble to fine clay. The lake itself can scarcely be called more than a river, though the ratio of fall is so slight that it has no perceptible current. Below the village of Central Lake sand is in some cases washed over the marl. But its presence underneath the lowland was shown in a startling manner. It was desired to raise the bed of the railroad which passed within 30 or 40 feet of the water's edge, and to do this a heavy grading of sand and gravel was loaded into the lowland. One night this suddenly sank with the land supporting it about 20 feet. There is no doubt the semi-liquid marl beneath the lowland was forced by the greatly increased weight of the grading out into the lake, when the land above with railroad and all sank to solid bottom.

The lake was examined mostly about midway and from there to the south end. The first series of soundings was made on the

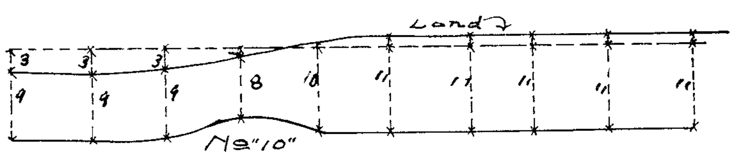


Fig. 10. Central Lake, Antrim County. See also Plate I.

east side, out a hundred feet in shallow water, from a steam launch and from there in, and then along a slight creek about 200 feet in. The accompanying diagram (Fig. 10) will show relation of water, marl and land level. It will be seen that the large woods which had but a few inches of muck covering gave a very steady depth of marl. This marl while it contained no real sand or grit was very intensely granular and of a very brownish tinge. I should say that it had little organic matter, much iron and was decidedly different in grain from that usually met.

The marl also showed well at points and beyond one of these to the south we examined the marl islands in the south lobe of the lake.

These are very interesting as they are islands of solid marl nearly in a center line and about ½ mile apart.

North Island* is very small, has upon it but few trees, is 30 or 40 feet long, 20 feet wide, and has its longest axis from east to west.

Soundings were made first from the south, approaching from the median line of the lake to the small strip of dry land forming North Island. The following is a table of soundings on and about North Island (see Fig. 11 and Diagrams 11, 11A and 11B of Plate I):

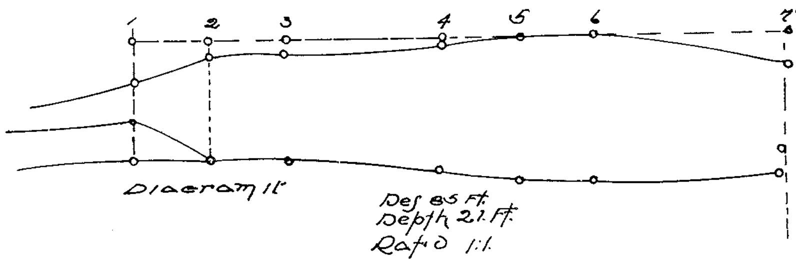


Fig. 11. Section across North Island, Central Lake. See also Plate I.

No. of sounding.	Depth of water.	Depth of marl.	Location.
1	5	5	50 ft. S.
2	2	14	40 ft. S.
3	2	14	30 ft. S.
4	6 in.	17	10 ft. S.
5	Dry land	19	On S. shore.
6	Water's edge	20	North shore.
7	Dry land	21	East end.
8	Dry land	21	West end.
9	Water, 4 ft.	15	25 ft. N.

The regularity of increase and decrease in depth of marl, the steady variation in the relation of true bottom, marl, and water depths, is very striking and has been met with in but few other lakes.

The island was about 40 feet long by 10 feet wide at the center and was oval shaped. A shallow of weeds extended north and south about 50 feet at right angles to the greatest length of the island, making an oval-shaped island, surrounded by an oval-shaped belt of shallows, the ovals being at right angles to each other. The island itself was barely above the water's edge and was solid marl except for an inch or two of loam on top. Several trees grew on the dry ground which could be crossed easily on foot as the marl island seemed quite solid, which is not usual with marsh islands of this kind.

Upon the shores, especially the north shore, the light shells had been sifted at the water line by the action of the waves, so that the

*See Plate I, Diagram 11B.

shore was a mass of shells of all sizes from a pin-head to an inch in diameter, and also intermixed with the shells were pebbly accretions something like those forming the coarse grained marl beneath the woods to the north, before mentioned.

Here it is very easy to see how shells could be broken into fine particles and merge with a bed of marl, losing their former identity. Several large clam shells were noticed lying just under the water's surface, upon the marl. These crumbled when grasped between the fingers though they had once been very strong hard shells. It is very easy to see that if this is the condition of a large clam shell,

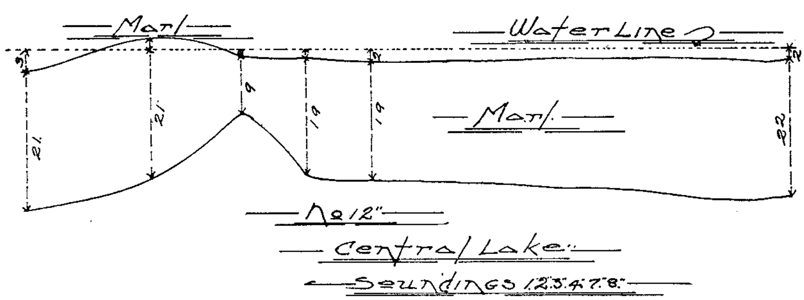


Fig. 12 Section across South Island, Central Lake.

the more delicate shells would be crushed by a much smaller pressure.

South Island,—considerably larger and lying ½ mile south—was next examined.

It was one or two hundred feet long, oval-shaped and with its axis north to south, or at right angles to that of North Island, but in a line with the axis of the shallows of North Island. From the south end of South Island, shallows run to the south end of the lake. These shallows, the deeper channels on each side and the approaches to South Island on all sides, are all solid marl of fair quality with no surfacing of muck or silt whatever.

The soundings taken about South Island and on to the south end of the lake are as follows:

No.	Depth of water.	Depth of marl.	Location.
1	1	9	Close on S. E. shore S. Is.
2	1	19	10 ft. S. No. 1. Away from shore.
3	2	19	10 ft. S. E. No. 2.
4	2	22	70 ft. S. E. of 3.
5	5 ft.	20	Mid-channel S. E. of lake.
6	1	27	At extreme S. end of lake.
7	3	21	West side of island.
8	Light muck 2 in.	21	Center of South Is.

By consulting this table and the figure (12) accompanying it, it will be seen that the outcropping of the island of marl is produced not by an added depth of marl, but by a rise in the true sand bottom of the lake. This rise in level is sharp but uniform, the depth of marl being greater if anything away from the island. It helps to solve no problem concerning the formation of marl excepting to show that the marl behaves like any thick layer either of chemical deposit or sediment. It lies like a thick sheet over projections such as this, making them less pronounced than they would be without the covering.

Also notice that the soundings of South Island are deeper than those of North Island, not on the island, but immediately around it. The island is larger and judging from the size of the trees and thickness of the muck, has been first exposed by the slowly receding waters and has probably had somewhat more of the marl washed off of the higher parts on account of its longer exposure to wave action of the lake and leveling influence of water. The two series of soundings show a gradual increase of depth of marl from the north to the south end of the lake, where in tall pipe-stem reeds and one foot of water, the deepest sounding of marl (27 feet) in the lake was made. These two series as compared with that made in the woods and immediately west are deeper and show a whiter, more finely divided marl toward the south where in the deeper parts it loses almost entirely its granular character and brownish trace of oxides of iron.

The north end of the lake a mile and a half or more north of Central Lake was visited and a brief attempt made to examine the conditions there. They were strikingly different. While at the south end there was no sign of muck or any organic covering, here there was found everywhere 2 to 8 feet of very fine river silt. Beneath this was 6 to 10 feet of marl, the deepest having a bluish tinge.

The striking features of the lake were the granular appearance of a few beds, the gradual change in depth of marl and lack of sudden irregularities in bottom. Perhaps the whole can be traced to the slight fall of level of the lake, there never having been any current to disturb the original bottom of the marl deposited upon it. There is but 3 feet fall in eight miles in this chain of lakes.

There are many good springs of hard water flowing into the lake. The samples, 8 to 11 inclusive, represent the waters of this region (p. 46).

A mound spring examined, of which there are said to be several, is very peculiar, seeming to be formed by the water issuing from a side hill with a sloping clay bank, down which the water finds its way to pile up for itself a mound, and to boil from the top of this. The mound, four or five feet high by six broad, consisted to the depth sounded, about 10 feet, of a sandy bog iron ore mixed with clay below, making it withstand the seepage of water, and above with muck. The water itself carried up with it as a fine sediment a marly clay. (See Analysis 28, page 21.)

This mound spring may be of interest perhaps as showing what a limy water will form upon being stopped and allowing to deposit upon issuing from a spring. No pure marl was found in the vicinity. A very interesting fact was its absence.

The clays of the vicinity were next examined.

The hills west of the town were in some cases strewed with glacial boulders and were more largely of sand and gravel than those on the east. On the east side was a brickyard that showed very nicely the thorough mixture that the clays of the vicinity had undergone. The clay as dug for use was somewhat moist and capable of being picked. A lump upon drying and examination showed a very fine grain, and was full of carbonates. On slicing a section of clay the different color of the fine layers gave it a highly streaked or stratified appearance, and these layers were rumpled and bent almost like the grain of curly maple, showing that the bed must have undergone great disturbance after being laid down. An inspection of the whole cut showed an upper layer of sand, a fine much rumpled layer of fine dark clay, then beneath this a fine bluish sand, hardly distinguishable from clay at first sight.* The whole hill looked as if it had been scraped together by some great power, and just before the mixture of layers became intimate, and they lost their identity, the movement ceased. This was the one of the lowest of a series of low hills, the highest of which was at an elevation of between 100 and 200 feet above the village.

The clay hills above Mr. Crow's farm were next visited. It was found that the clay anywhere near the level of the lake showed a strong heavy admixture of carbonates, but the shales higher up in the hills were freer from them. On the farm in question clay en-

*The same contortion of the clay laminae may be noted at Clippert and Spaulding's yard in Lansing (Part I, page 56), and at the location described by Dr. C. H. Gordon, in the Annual Report for 1902. It appears to be due to a readvance of the ice sheet, after the clay had been laid down just in front of it. L.

tirely free from carbonates was found, but mixed with shaly pebbles, which were very heavy in iron and somewhat gritty. There is no doubt that in the hills about the town a genuine shale of fair quality for cement manufacture could be found.

§ 16. East Jordan and vicinity.

The marl lying at the head of the south arm of Pine Lake* and about the mouth of the East Jordan, in the large valley once forming a continuation of the lake, was next examined. The bed was reached by steamer from Charlevoix. At Charlevoix, where the railroad crossed the outlet of the lake, marl was noticed nearly worn away by washing of the water and in most cases buried by sand, but is seen in streaks where it is exposed on the bottom. Its only significance is its presence in this part of the lake in a very thin layer.

Along the shores of the south arm of the lake layers of marl of a few feet in thickness were seen cropping out under the banks washed away sharply by the action of the waves.

The general appearance of the valley examined was very similar to that of Central Lake. Sharp hog-back ridges from high hills ran down somewhat parallel to each other and at right angles to the length of the valley, which is clearly the result of glacial action. A series of soundings were made to determine the manner in which the marl was deposited. So far as found the marl lay in the form of a basin showing 2 feet at the edges to 20 feet in the center, the center of the basin corresponding somewhat to the center of the valley. Upon the whole the marl lacked the granular appearance found at Central Lake, but was not of as uniformly great thickness and was covered with from 5 to 10 and 15 feet of muck and swamp growth and in most places with heavy forest growth or its remains.

The disturbing action of a current of water was here noticed, for at the mouth of the river and at the head of the lake the marl was covered with many feet of silt and mixed more or less with sand.

As a rule the whole of this bed was underlain with blue clay. A large area of land suitable for tillage, forming a rather dry tableland with the old deeper channel of the lake surrounding it, was covered with a light muck, 1 to 3 feet of marl and then very tough reddish or blue clay. In the above instance if marl has any value as fertilizer it should, upon the admixture of muck, marl and clay, produce splendid crops, as was already shown in one or two in-

*See reference in Davis' paper.

stances where the land was utilized. It is a significant fact worthy of notice for its bearing upon the origin of marl that these clays at or below the level of marl beds are nearly always heavily impregnated with carbonates. One sounding that showed well the condition upon the table-land was as follows: One or two inches of surface soil, 2 feet marl, 3 feet tough red clay, 15 feet black clay, water and gravel bottom.

Upon the whole the marl of this section lay in a basin shaped depression nearest the water, but spread in a thin layer over nearly the whole valley. It is covered with forest or thick layers of muck in most instances and in others mixed with the debris of silt and sand brought down by the rapidly flowing river. It is, therefore, scarcely available for cement manufacture, but may some day be used to mix with and make more tillable the tough clays of the valley.

The clays of this region, however, were of greatest interest. They were of two somewhat distinct types. Those before mentioned were a fine-grained sediment laid down at or below the level of the marl. Black, blue and red were distinct colors noticed. They were all very tough and dense. In a drive taken 8 or 10 miles south and on the west side of the valley the clays of every color and condition from fresh sediment to a heavy shale in place were examined.

Those examined rather low down the bluff nearer the valley, always showed carbonates and more or less admixture of grit, probably brought down by water. As we ascended in the cuts, clay in various stages of weathering from an almost compact shale to completely disintegrated soil could be seen. The color also varied, being of a yellowish or greenish tinge. These were in a number of places quite free from carbonates, but the shales were always coarser grained and would, while being more compact, dig and grind hard.

Finally an old mine shaft, where an attempt had been made to find coal, was visited. A heavy black, coarse-grained shale had been pierced by a shaft to a depth of 75 feet. The shale was nearly like rick and cropped out at the surface, breaking up and seaming where exposed to the weather. It reminded me very strongly of the Coldwater shale visited in the southern part of the State.* In the seams the shale was reddened by oxidized iron and it was said

*It is, however, the Devonian black shale. L.

that occasionally pockets of iron pyrites were found in it, although none could be seen at the time.

A brickyard was then visited on the east side of town which contained strata of different colored clay and sand, much as at Central Lake, except that the level of the layers was not disturbed. All this clay, however, showed the presence of carbonates in very large quantity.

§ 17. Manistee Junction.

Lakes about Manistee Junction were next visited. This part of the country shows very well the condition of the lakes and the outline of country prevailing in a large part of the marl districts of the north part of the State, to-wit: an almost level pine plain in which suddenly occur drops below the level of the surrounding country without the slightest warning, much like a hole upon a level plain.

A small lake was examined. This was circular in form and contained the deepest marl (20 feet) at upper end. This marl was bare of muck and covered only by water. Upon the west side a test was made of a shelf like those found in other lakes, these shelves probably corresponding to the bare shelves found about Central Lake and East Jordan, which marked the recession of the ice. Near the shore were ten feet of marl and shallow water, while out 12 feet there were 12 feet of water and muck. At the lower end the conditions were the opposite of those at the upper. Here were found 26 feet of muck, beneath which were 4 feet of marl. Fine sand was the bottom in every case where soundings were made. The quality of marl was poor, being much mixed with organic material and sand. Notice the parallel case of Central Lake where silt and fine muck deposit shifted toward the outlet, marl being thinner. The water of this lake and others visited in this vicinity was tinged deep brownish red, lacking the remarkable clearness of most intensely marly lakes.

Long Lake next visited was cut deeper into the surrounding country. The marl did not show upon the water's margin which was of compact sand, but farther out, away from the shore, was a fair quality of marl and a good extent of shallows. Soundings were not made as no way could be devised to get upon the water.

Calhoun Lake could not be reached in its deep parts where the marl, if any, was located. A marsh near here drained by a creek and practically dry showed good marl 15 feet thick, below one foot of muck. It was as usual in the form of a basin. No distinctive marks could be found to separate it from numerous marshes in which marl has not been found.

Marl was also reported in hills between Reed City and Clare. This appeared to be a high clay country and rolling, quite distinct from the sand plains.

§ 18. Rice Lake.

This lake is situated in Newaygo County, Town 11 North, Range 12 West. The greater part of the marl examined belongs to Messrs. John H. Kleinheksel, Henry Beers, and Dr. M. Veenboer. The above map was prepared by Prof. Kleinheksel, who accompanied me during the survey of the bed.

The lake abruptly breaks the level of the pine barrens and on account of the present condition of its bottom affords especial advantages for the study of its marl. From the appearance of the large lowland or marsh the water has not for some time occupied the whole depression indicated on the map by the double traced outer line "A," and a later limit is well defined by the presence of a thick growth of scrub oak which encloses the area covered by the recent lake. This older water line is shown by the outer single line marked "B," and the more recent one by the inner line "C." Between these two shore lines, the old and the new, is found a considerable thickness or accumulation of marl ranging from two to twelve feet and lying under an overgrowth or accumulation of solid land some six or seven feet in thickness. This land is covered as before mentioned by a thick growth of scrub oak.

By a system of large ditches the lake is still further drained till it has shrunk within the inside shore line to its present limits as marked on the map* (Fig. 13).

With the above understanding, the first notable fact revealed by the numerous and carefully located soundings is that as far as could be discovered, the center of the marl basin is not exactly under the center of the water basin, nor the present lake. The center of the marl basin is very clearly shown to be in the northeast quarter of the southeast quarter of Section 10. Around this deepest portion the gradually decreasing depths group themselves. The sounding of twenty feet in the above-mentioned section forbids an increase of depth toward the water as do the soundings of twelve feet and twenty-two feet in the quarter section adjoining it on the right. The soundings made up the center of the present lake still

*The original U. S. Land-office Survey in 1838, was made in January, and no lake was recognized. The re-examination in 1854, sketched in a rather small lake. In hardly any two maps has the lake the same shape.

further deny the presence in mid lake of any marl center. The fact is then established that in the case of this lake the greatest body of marl does not lie beneath the deepest portions of the lake. Furthermore the marl as sounded extends in its location toward the large north and east lobes of the lake as marked by the line of bluffs forming the original depression.

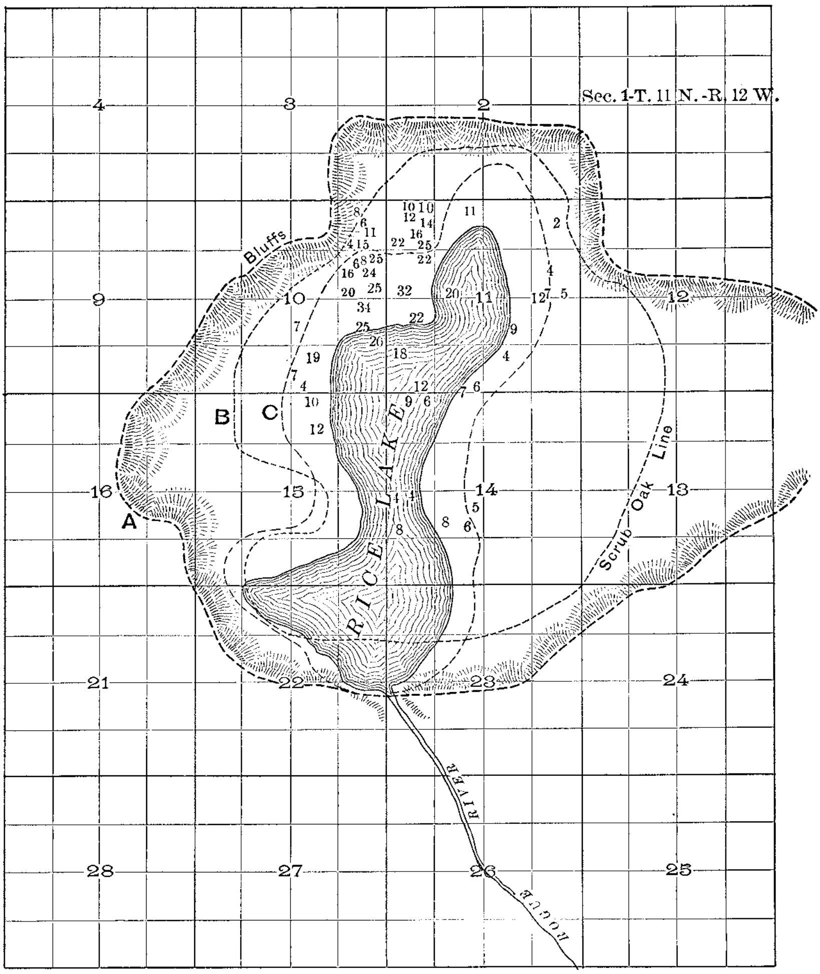


Fig. 13. Rice Lake.

The next point of interest is the rapidity with which the surface has overgrown and sealed up the present deposit. This deposit is covered by some three to five feet of tangled roots of marsh growth, forming a layer which jars for yards around with the weight of one's tread. This growth, though light and easily penetrated, is thick and must have nearly all formed in the few years since the lake has been drained. It leads us to beware how we judge of the age of a marl bed or the length of time since it has ceased depositing by the depth of its covering or surface.

The material underlying the marl was in all cases found to be a fine lake or quartz sand, such as has been met with in the majority of lake soundings. One peculiar feature here was that just as the augur passed from the marl into the sand, it brought up a greenish layer which contained little sand, and was a grade between organic matter and marl. This is the foundation upon which the marl started its growth, and should be of the utmost importance in the study of the method by which it is laid down.

Having noted the surroundings of the marl, the final matter of consideration is the marl itself. The marl which was studied most closely in regard to quality was taken toward the center of the marl basin in deeper soundings. Though the examination carefully covered two quarter sections, the quality of the marl throughout remained surprisingly uniform. From the accompanying analyses by Prof. Frank Kedzie of the Michigan Agricultural College, and those selected by Prof. John Kleinheksel and analyzed by Prof. Delos Fall of Albion, it will be seen that the marl is rather high in insoluble matter and low in carbonates. Of this insoluble matter a small and constant part is quartz sand met with in many marl lakes and seemingly independent of the sand washed in by drainage. The organic matter though high is steadier than in most lakes, remaining the same through all the deep soundings. The analyses by Prof. Kedzie, Nos. 1 and 2, are at surface and 35 feet deep respectively. The variation in organic matter and magnesia is slight. These analyses illustrate the fact that the deeper parts of the bed vary but slightly, probably owing to the distance from hills and surface washings of all kinds.

Following are the results of analyses:

Agricultural College, Nov. 25, 1899.

	No. 1
Insoluble matter	6.66
Oxides of iron and aluminum	1.34
Calcium oxide (equivalent to 71.66% Ca CO_3)	40.12
Magnesium oxide	1.10
Carbonic acid gas	32.50
Organic and undetermined	18.28

(Signed) FRANK S. KEDZIE.

Agricultural College, Nov. 14, 1899.

	No. 2
Insoluble matter	4.36
Oxides of iron and aluminum	2.36
Calcium oxide (equivalent to 76.82% calcium carbonate)	43.01
Magnesium oxide	.97
Carbonic acid gas	34.24
Organic and undetermined	15.05
	100.00%

(Signed) FRANK S. KEDZIE.

Albion, Mich., June 22, 1900.

Prof. J. Kleinheksel, Holland, Mich.:

	No. 3	No. 4
Silica, SiO	2.84*	8.67†
Alumina, Al_2O_3	2.76	3.55
Iron oxide, Fe_2O_3	none	trace.
Carbonate of lime, $CaCO_3$	79.55	65.67
Carbonate of magnesium, $MgCO_3$	none	none.
Sulphuric acid, as SO_3	3.15	2.50
Organic matter, etc.	11.70	19.58
	100.00	99.97

DELOS FALL.

§ 19. St. Joseph River and tributaries.

In and about the mouth of the St. Joseph River there are beds of marl. Very small creeks have in the meadows surrounding them, small beds 1 to 3 feet thick of marl. Hickory Creek and Paw Paw River, which has a large marsh near its outlet, have marl along their course.

§ 20. Onekama.

Portage Lake (Fig. 14), on which is situated the Town of Onekama, is about eight miles north of Manistee and opens by a short but very navigable channel into Lake Michigan. It is surrounded by high hills on all sides and on account of the deep depression made by the lake the springs which issue from beneath the hills are numerous and large. One spring contained a considerable percentage of sodium carbonate, but the marl in the immediate vicin-

*This is a marl containing over 5% of clay and running rather low in carbonate of lime. After the organic matter is excluded the percentage of carbonate of lime amounts to 90.09.

†This is a sandy marl. Excluding the organic matter there is 81.65% of carbonate of lime.

ity in which the spring emptied showed no unusual trace of alkaline salts. This is only another illustration of the fact that the agency at work in the deposit of the marl has a power of discrimination, refusing certain salts from the water and depositing others. Such was shown to be the case of the sulphur and iron springs mentioned in the description of Big Whitefish Lake. Portage Lake is fed entirely by a network of springs and spring creeks and the water is very clear.

The shallows of the lake are not all marl. Strips of marl from three to four feet in thickness alternate with sandy beach around

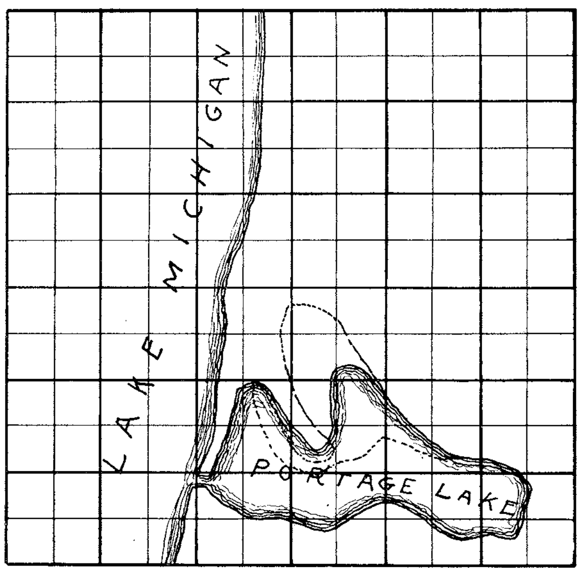


Fig. 14. Portage Lake, Manistee County.

the whole lake, but the deepest marl and that which engaged our attention lay to the north and northwest shores toward Lake Michigan. It lay in a lobe of the smaller lake forming its northwest corner and reaching beyond the water up to the low sand hills bordering on the Great Lake. It is only thought necessary to mention certain features which will illustrate the general ideas already gathered as to the location of marls.

As before stated the deeper marl was confined to the large lobe or lagoon of the lake. Lines of soundings were run in different directions and the following conclusions reached: The marl decreased in depth with increase in depth of water toward the center of the lake. There was also an increase of content of organic matter as the center of the lake was approached. In the lobe above mentioned, considered as a whole, the marl deepened rather evenly toward the center of the whole basin. Here the marl was 21 to 22 feet thick with little or no surface covering. As the parallel lines of soundings approached the borders of the basin the depth of marl decreased rather evenly to 19, 17, 15 and 13 feet. The last named depth remained nearly constant as far as followed through the thick undergrowth to the northwest toward Lake Michigan.

The marl on the whole was little contaminated with foreign matter such as sand and clay. There was a very small content of the fine quartz sand often found in deposits. The ditches and small creeks emptying into the lake over the bed had carried down sand which had mixed with the marl in their immediate vicinity. The marl was deposited upon a fine pepper and salt sand which formed the lake bottom. In the marl basin or lagoon before mentioned soundings revealed a peculiar condition. The bed contained a small layer of intervening organic matter alternating with the marl. The material was well preserved and seemed to consist of driftwood and marsh growth pressed firmly into a layer a foot or so in thickness. The layer was about fifteen feet below the surface of a firm pure marl deposit.* Its presence might indicate that the marl had ceased to deposit for a time, and with the return of favorable conditions had again deposited, burying the layer of drift and marsh growth which had accumulated.

A large part of the lobe examined was not under water at the time. A part of it had recently been covered by water before a new outlet into Lake Michigan had been dredged for the lake. When it was drained the surface of the marl had been left dry. This left the marl more or less dense and dry and as a consequence there was nothing but a slight growth of grass and the consequent "surface" was only a few inches to a foot in thickness. This was a great contrast to Rice Lake which had been drained about the same length of time, but was left very wet. The marsh growth had become luxuriant and the "surface" is from three to five feet of marsh growth. Beyond the dry portions of Portage Lake and forming the fringe of real marsh was the portion which had always remained wet. Here the growth of soil and roots reached five feet or more. From these comparisons it can readily be seen that it is impossible

*This may indicate a lower level for Lake Michigan at one time. L.

to judge the age of a marl bed from the depth of surface growth covering it.

Sixty-nine soundings were made varying from 13 to 22 feet. The bed covered about 125 acres, not including a large area along the shores containing marl from seven to ten feet. The marl is of fair quality and its variation in quality is shown by the following analyses:

	No. 1.
SiO_2	2.81
Al_2O_3 and Fe_2O_3	.65
CaO as $CaCO_3$ (47.89)	85.63
MgO as $MgCO_3$ (1.47)	3.08
Phosphorus	.014
Total organic matter	6.96%

	No. 2.
Silica	3.64
Oxides of iron and aluminum	1.35
Calcium oxide	45.37
Magnesium oxide	.63
Carbon dioxide	35.86
Organic and undetermined	11.85

Submitted by A. W. Farr.

Samples No. 3 and No. 16, or Nos. 1 and 2 above, were taken at the respective depths of three and sixteen feet by the owner, Mr. Farr, and the latter was evidently mixed with sand as a careful examination of the whole basin showed no such amounts of sand, the sand being in all cases, excepting in the presence of flowing water, fine quartz sand and in small quantity. The remaining samples show a fair marl with no harmful compounds in proportions too large for manufacture.

CHAPTER VII.

MANUFACTURE OF PORTLAND CEMENT FROM MARL.

§ 1. Introduction.

The purpose of this chapter is not to give a full technical description of the process of cement manufacture. This may be found in any one of a number of large volumes written upon the subject.*

In a later chapter, prospecti from various cement plants in the State are cited and will furnish farther information. In order to connect these details and to give compact description of the process and to emphasize important points, this chapter is written.

§ 2. Definition of terms.

The name "Portland" was derived from the name of a popular building stone used in England at the time that our present cement was given its name. The cement was thought by some to somewhat resemble this natural rock, hence was named after it.

Portland cement is an artificial mixture of calcareous matter with silicious (generally clayey) matter, which is properly proportioned and burned to a point just short of vitrification or melting. The resultant slag will, upon grinding, set with the addition of water to form a cement.

Natural cement differs only from Portland cement in that nature has mixed the calcareous and argillaceous ingredients in nearly the proper relations.

Slurry is the properly ground and mixed clay and marl or limestone suspended in enough water so that the mixture can be pumped from one reservoir to another.

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*See also 25th Annual Report of the State Geologist of Indiana; 22nd Ann. Proc. Ohio Soc. of Surveyors and Civil Eng., p. 18; 21st Proc. Indiana Eng. Soc., several papers; American Engineering Practice in the Construction of Portland Cement Plants, by B. B. Lathbury, 1902; A Rotary Cement Kiln for use in the Laboratory, by E. D. Campbell; Jour. Am. Chem. Soc., March, 1902; various papers, especially those by the Newberries in the Cement and Engineering News, and other pamphlets issued by the same press. Beside Lathbury and Spackman, Robert W. Hunt & Co., of Chicago. The Osborn Co. of Cleveland, and Hassan, Tagge and Dean of Detroit, may be mentioned as designers of cement plants. See also report by Prof. I. C. Russell in the 21st Annual Report of the Director of the U. S. Geological Survey.

The gradual perfection of Portland cement to-day is owing to the application of raw material and high grade machinery to the development of one chemical principle which is and will remain at the foundation of the cement industry, that two elements or groups, lime on the one hand, and silica or alumina on the other, when properly proportioned and intensely heated, have the power to combine with each other and then later with water such strength that after the combination once occurs, fire, water, acid or salts, have little power to disturb them or weaken their hold upon each other. The first group is calcareous. We see it purest in lime or calcium oxide, in an amorphous rock as calcium carbonate of limestone, as calcium carbonate in chalk, and in the purest state as crystallized rock or marble. The second group is silicious. This forms a large part of the earth and is found purest in quartz sand and fire clay. When these two groups, the calcium carbonate of the marl on the one hand, and the silica and alumina on the other, are finely ground and mixed and subjected to a temperature of between 2,000 and 3,000 degrees Fahrenheit, the calcium carbonate loses its carbon dioxide becoming calcium oxide and the silica becomes soluble. When the slag is ground to powder and mixed with water the nascent compounds recombine to form a tricalcic silicate and aluminate, an insoluble, non-combustible rock which becomes harder if anything, with age.

§ 3. Historical.

Before the discovery of the principles which govern the setting of cement, the Romans and they who followed them used slaked lime and a volcanic dust called pozzuolana. It contained the above mentioned substances in the right proportions to form a fair cement.

About the year 1756, Smeaton, an English engineer, made experiments to find a mortar which could be used under water in the construction of the Eddystone lighthouse. About the year 1818 Pasley in England and Vicat in France began experimenting upon cement materials to ascertain the proportions necessary to produce an artificial cement.

"In 1824 Joseph Aspedin, a bricklayer of Leeds, discovered and patented a method of making a hydraulic cement and named it 'Portland,' from its fancied resemblance in color and texture to the oolitic limestone of the Island of Portland, well known and in great favor in England as a building stone."

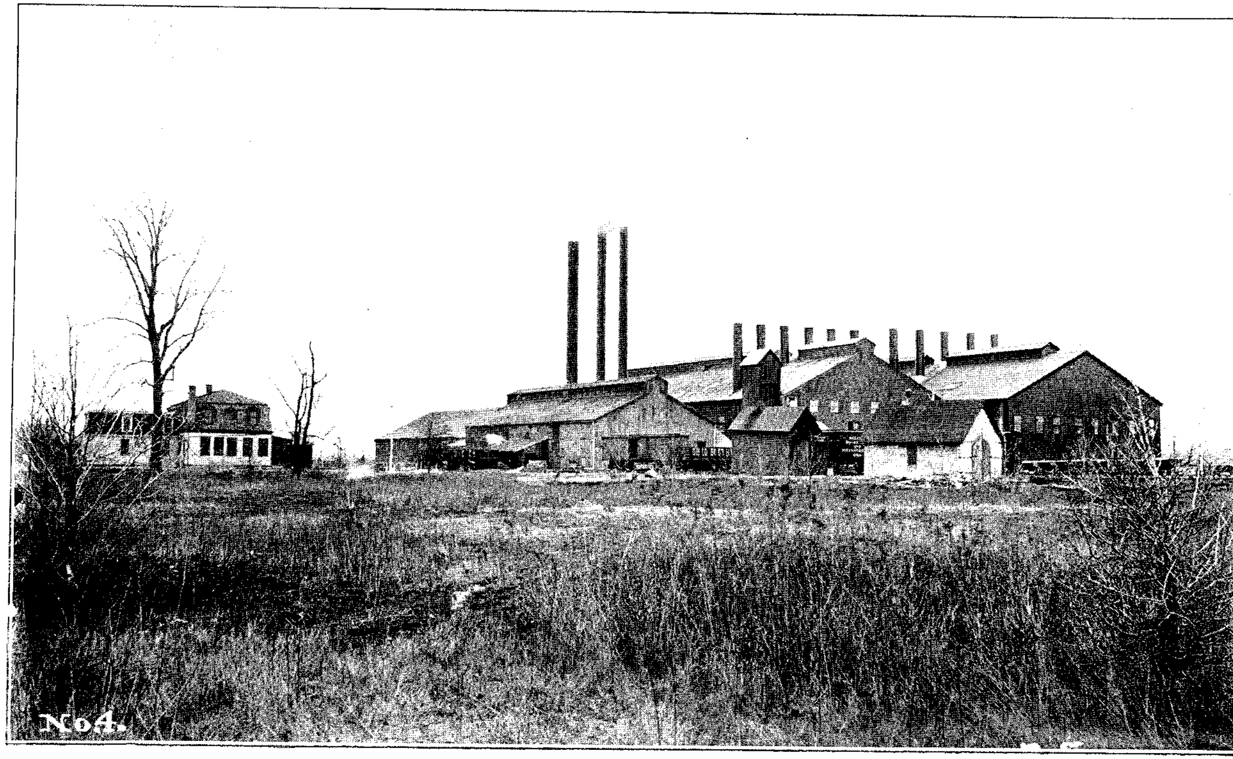
§ 4. Materials for Cement.

It will not be of profit to follow the development of natural cements. They are produced by grinding and burning a rock having cement materials in nearly the right proportions mixed to some extent by nature. As the proportions always vary the product is more or less unstable, is liable to crack and warp more than Portland cement and never stands as high tensile tests. It is therefore untrustworthy in those portions of great engineering works where great soundness and durability are required. It is produced more cheaply than the Portland cement and is very satisfactory for low grades of work. It is manufactured in large quantities in the United States and supplements largely the use of the more costly Portland cement. As the State of Michigan is supplied with extensive deposits of marl and clay suitable to the production of the highest grade of artificial or Portland cement it is well to notice the different ways in which material and machinery are manipulated to produce the same result.

It is a common idea that but one or two materials may be used for the production of cement, but this is erroneous. Anywhere where lime and clay constituents can be found sufficiently near each other and pure enough, Portland cement may be manufactured. In England, much of the cement is made from chalk, which is a calcareous formation similar in composition to marl, but dry, and a dense blue clay. In the United States chalk is used so far only at Yankton, S. D. Limestone and clay are the favorite materials in most parts of the world and it is only within the past few years that marl and clay as raw materials have come into any great prominence.

Several methods of burning and mixing the raw materials are used in Europe and the United States, adapting themselves somewhat to the nature of the raw materials used.

In England, in the Medway district on the Thames, marl and clay are ground and mixed with 120 per cent to 140 per cent of water. The finer particles are then flushed off by water passed into "settle backs," where the mud settles and the clear water is drawn off. When this sediment has dried to the consistency of a paste, it is gathered up and deposited on floors where it is dried still more rapidly by waste heat from the kilns. It is then mixed with



GENERAL EXTERIOR VIEW OF AN ELEVEN KILN PLANT.

charcoal and burned in kilns. The remarkable feature about this method is the thorough manner of mixing. It is the most thorough method known as the particles of clay and calcium carbonate are suspended together in water and allowed to settle somewhat as in a natural sedimentary deposit. It requires a month to dry the material, and the method is therefore too costly in time and is giving way to more rapid methods.

Mixing by the semi-wet process is probably most widely used throughout the world. When limestone and clay are used they are mixed with about 30 per cent or 40 per cent water, by means of sludge mills or similar contrivances. The mixture is then ground, passed to a drying floor, subjected to waste heat from kilns and burned as before. The mechanical mixture of the particles is not as perfect as in the first method but the drying occupies but 20 hours.

Sometimes the materials are mixed nearly dry and formed into bricks which are burned as before, with coke in a kiln. This is done in the dome kiln or dry method, which has been used to some extent in our own State at Union City and Kalamazoo, and will be described later.

The method of burning differs somewhat. Where a dome kiln is used the layers of mixed cement material alternate with layers of charcoal. In the continuous kiln, charcoal and unburned and partly dried cement materials are fed in at the same time at the top and the whole ignited at the bottom. The portion of heat not used in burning the cement at the bottom escapes upward and helps to raise the temperature of the half wet material above. In this way much more heat is said to be saved than in the dome and rotary kiln process.

Cement could be manufactured using sand to furnish the silicious elements instead of clay. Briquettes of cement made in this manner seem to have stood very good tests. Yet in practice, sand in any form is dreaded in cement manufacture, from the fact that it is so expensive to grind it to a sufficient degree of fineness for the purpose. The clay* is preferred instead because it is divided much more finely than sand, being already ground on account of the breaking down processes of nature.

It can be readily seen that the materials used and the processes relied upon vary widely in different districts although the finished

*What is commonly known as clay is often very largely only extremely fine particles of quartz, mineralogically the same as common sand. L.

product must be almost the same in all cases, as Portland cement has a narrow range of standard composition, which must be approximated in all methods of manufacture. The process used in Michigan depends mostly upon the materials at hand. The silicious element used is either a surface sedimentary, or a shale clay, depending upon which one having the best composition is at hand. The method of burning in nearly all cases is the rotary kiln process. There are few lakes or marshes that can be sufficiently drained so that the marl can be treated by the dry or semi-wet process and for this reason a more detailed description of the rotary or wet process will be given. From the foregoing it must be clearly understood that the factories of Michigan have not only to compete with those using their own process, but also with the remainder of the manufacturies by the limestone process, which alone furnishes more than half the cement produced in the United States. It must always be borne in mind that 40 to 60 per cent of the marl is water and nearly a half of the remainder carbon dioxide, a gas which is driven off in burning. The cost of handling and drying this great bulk of material must never exceed the cost of quarrying and grinding the limestone. When this happens, Michigan factories will be undersold by those of the limestone district. Besides this competitor there is the natural cement. This will take the place of Portland cement in many cases where the price of the better cement rises too high.

§ 5. Kiln process of cement manufacture.

The two methods so far employed in this State are the dome kiln and the rotary process. The former of these two processes is fast going out of use in this part of the country as it does not seem to fit the materials used as well as the rotary process. In 1872 a plant of this kind, the first cement plant in Michigan, was started at Kalamazoo. The marl beds which were used are described in Chapter VI. Another plant of this kind is erected at South Bend, Indiana, but was not in operation when visited. The process which was employed at Union City, Michigan (See Plate III), may be briefly described, as follows:

The marl was scooped up wet from the marsh and is thoroughly mixed with dry clay. The mixture, now of a doughy consistency, is pressed through a square orifice and is cut about the form and size of building bricks. These marl clay bricks are laid on flooring of T rails to thoroughly dry, when they are then ready for the burning, which is accomplished by kilns.

A kiln resembles a mammoth hollow cigar, cut off at both ends. It is built of fire-brick, and is about forty feet high by eight to ten feet in diameter. Beneath is a fireplace of about five feet to furnish a thorough circulation of air.

At the base of the kiln, above the open air space, an arched layer of these bricks is packed, a layer of lumps of charcoal, then another layer of bricks till the kiln is one-third or one-half full. The mass is then fired, and burns for about forty-eight hours; the bricks fuse into lumps of heavy, black slag, perforated by the exit of the carbon dioxide, which is expelled by the fierce heat. The whole mass shrinks and collapses and cools, and is then raked out. Then the slag is sorted by hand into two grades of cement, and is ground by mills into fine, dark brown powder which we know as Portland cement. This is an extensive process, requiring large buildings for drying, many kilns for burning (for a kiln burns only seventy-five barrels at a time) and many men to transfer and sort.

This process is not as exact as it should be. Part of the bricks are overburned and part underburned and must be sorted by hand, requiring great expense in time and labor. It has been displaced at Union City by the rotary process, and all the new factories in the State are employing the latter.

§ 6. The rotary process.

The rotary process, in order to be successful, should be carried on upon a large scale. The buildings which protect such a factory generally cover several acres (Plate IV). The prevalence of disastrous fires which have wiped out several large factories in the past year, causing great delay in the work as well as the financial loss, should emphasize the construction of durable and fire-proof buildings. The latest are being built largely of steel and cement. The machinery is so grouped (Plate V), that the raw material is transferred by machinery from one step of the process to the next, till it enters the storing bin a finished cement. The following is a brief description of the whole process, as seen at Bronson, Michigan.

The marl is scooped up by an ordinary dipper dredge and is drawn a few hundred feet to the factory on small dump cars, where it is stirred and screened and then pumped into a large funnel to measure it.

Meanwhile, the clay, which is mined several miles away and drawn to the works by rail, is elevated to the second story by machinery, is weighed by the wheelbarrowful and dumped into a hopper which drops it to a cluster of revolving millstones, which at the same time receives the semi-liquid contents of the huge marl funnel. When both have been ground and mixed with each other, this mixture drops into a second reservoir, where it is thoroughly stirred and mixed for some time by revolving paddles. From this reservoir the mixture, now termed slurry, is pumped into huge tanks, where it awaits the burning process.

Grouped with each tank is a huge cylinder about 40 feet long and four or five feet in diameter. The cylinder lies with the end that is farthest from the tank a little below the horizontal. The end opposite the tank is closed by a cupola.

The cold, wet slurry flows in at the tank end, the whole cylinder revolves, and the liquid mixture, caught on its inner surface, runs slowly towards the cupola at the further end. Here a falling stream of crude petroleum is ignited and blown by air blasts into the end of the cylinder. The solid sheet of flame penetrates six or seven feet, being under control. The slurry, slowly approaching, is first dried, then heated, and by the time it reaches the end of the cylinder is fused into liquid nodules about the size of pebbles, and falls through a slit at the base of the cylinder. Here it is received by an endless chain of wheeled trays, and, having cooled, is borne to the mills. These mills are very efficient, grinding it to a powder, ninety-nine per cent of which will pass through a sieve with 10,000 meshes to the square inch. It is then finished cement and is stored in bins. In this process, as in the kiln process, the fine powdering and mixing of the crude material is carefully accomplished, and, by burning, the carbon dioxide is driven off and the mass thoroughly fused. This process is almost entirely accomplished by machinery. The machinery is expensive, but only requires the labor of fifty men to run the whole plant.

It is economical, as the burning is performed with exactness, and there is no charcoal to fuse with, and impair the strength of, the cement, nor is any hand sorting necessary.

In the latter case the quality of the cement and cheapness of manufacture is unrivaled.

§ 7. Preliminaries.

1. *Digging.* The raw material, marl, is in nearly all cases found in a lake or a swamp or both. In this condition it may be covered by a few inches to several feet of water, may be bare, or be covered with a surface of grass or rushes which must be "stripped" before the marl can be dug.

In many parts of the State there are extensive marshes covered with a growth of timber which must be cleared and grubbed before the marl becomes available. In such cases it is noticed that nearly all the roots follow the moist surface of upper soil which has been deposited on the marl, and do not penetrate deeply. This renders clearing much less expensive and the clearing can nearly all be done by burning. It is best in selecting sites for factories to avoid as much as possible the marl lands covered with a thick surface of swamp growth or forest. There is much marl land available in the State that does not require expensive surfacing, which should be chosen in preference to the less available territory.

The content of moisture will often vary much according to the position of the marl below or above the water line of the lake or marsh. In the same lake basin there may be marl in mid-lake containing 60 per cent to 75 per cent moisture, and at the same time marl on higher marsh land, at the sides, which will not contain over 25 per cent.

The expense of surfacing is of course somewhat governed by the thickness of the bed and the depth to which it may be dug or dredged. A bed ten feet thick will be much more wasteful in digging than one thirty feet thick, for in each case the surface soil or growth is mixed with the marl in dredging, and must be burned out in the rotaries, involving cost of fuel in drying and time in handling the surface material, which is in the end burned, forming only an ash. Not only is there expense in handling and burning the material that becomes mixed with the marl from the surface, but also there must be a certain margin or remainder of the marl at the bottom of the bed which cannot be dredged on account of admixture with sand or unsuitable clay, of which the true bottom may be composed. It can then be easily seen that there is a greater proportion of the marl in a thick bed, available for use, than there is in a thin deposit, for the waste must be the same in both cases. With the present large supply of deep beds the shallow deposits will not be immediately used. If there are but a few inches of grass and loam above the marl, no appreciable cost will be incurred, excepting to increase the organic content of the upper scoopings of the dredge. If there are several feet of dense marsh growth, sometimes as high as six, it may cost $75 an acre for surfacing,—quite a handicap.

2. *Draining.* In many lakes it is found expedient to drain by a short channel and thereby lower the water level, bringing the deeper parts of the lake within working depth of the dredge. Not every lake is located so as to be easily drained. Also it will be found, if attempt is made to so utilize marl that has laid at any great depth under water, that the quality of such marl will be much poorer, being higher in organic matter and lower in the essential calcium carbonate.

When the lake or marsh has a level of several feet above the stream or lake which empties it, it may be possible to drain it so that the semi-wet or even dry method of mixing may be used. This was to have been done at Watervale and was contemplated by the Hecla Cement Co.

3. *Dredging.* On account of the semi-fluid condition of most of the marl of the State, and its location partly in or adjacent to water, the easiest method of digging the marl has been by the ordinary steam "dipper" dredge. This is a barge or scow floating on the water and operating a large scoop or dipper, which can work to a depth of about twenty-two feet, as was claimed at Bronson. The rubbish or surface growth of a marsh is piled to one side, and the dredge makes a channel for itself as it digs the marl. It can be seen that this method is best adapted to the greater part of the marl in Michigan, which lies either under water in shallows or flats or in a marsh which is at or near water level.

Another proposed machine may come into general use. It is also built on a scow and consists of a movable crane carrying an endless chain of buckets. This chain can be lowered to greater depths by the crane and will perhaps be able to dredge to a depth of thirty feet, though, as the quality of marl decreases and the expense of power in digging will rapidly increase with great depths, it will not be found economical to dredge to the bottom of deep beds. In many factories in the State the marl is dredged and then piped to the factory.

There is one more method of transporting the marl. This is by digging or dredging and then pumping to the factory.* When the marl is pumped it must be mixed with slightly more water, which must in turn, be dried out in burning in the rotary. The increased expenditure for fuel will likely offset the cheaper transportation. The pumping plan is only considered where the marl is adjacent to the factory. Where the marl is several miles away,† a railroad must, of course, be employed, as hauling by wagon is entirely out of the question as being too expensive. Where it is near, an overhead trolley bearing cars or a narrow guage road, in which steam or horses are the motive power, can be used.

Clay must be quarried or dug according as it is a shale or a clay. For quarrying see the account of Bronson in Part I, and elsewhere in this report. Out of 14 factories where the raw material could be located, all but one had the marl deposit within two or three miles of, or directly on the site of the factory, while but four had their clay near the factory, most of them getting it long distances away, in some cases in Ohio‡ or Indiana. The estimated cost of putting the material at the factory therefore, varied from eight cents to seventeen and one-fifth cents per barrel of finished cement, being greatest in the case of the Hecla works, who were to transfer their marl about thirty miles from bed to factory site.

§ 8. Estimates on raw material.

One factory in the State was running about 2,000 pounds of marl to the cubic yard, while it was said to require one and one-half cubic yards of liquid marl to a barrel of cement.

Now a barrel of Portland cement weighs 380 pounds. An average of 65% of this is calcium oxide; 65% of 380 equals 247 pounds of calcium oxide required for a barrel of cement.

Taking a wet marl, which has 40% moisture, and 90.3% calcium carbonate in the dry residue the available calcium oxide would figure as follows:

100% less 40% equals 60% dry matter.

90.3% of 60 equals 54.18% calcium carbonate.

100% calcium carbonate less 44% carbon dioxide equals 56% calcium oxide.

56% of 54.18 equals 30.3% of original weight as available calcium oxide.

*As at the Woodstock and other plants.
†As is the case in the Hecla Plant at Bay City, 30 miles from the bed.
‡Millbury.

At the above factory estimate of raw material 1½ cubic yards of marl would weigh:

1½ times 2,000 equals 3,000 pounds.

30.3% of 3,000 equals 909 pounds available calcium oxide, whereas it really furnishes but the 247 pounds necessary for the barrel of cement. This means that the deposit which was worked must have had a higher content of organic matter and moisture than we have assumed.

Notice the effect of increased per cent of moisture and decreased percentage of calcium carbonate on the percentage of available calcium oxide. Take for instance a marl 60% moisture and 75% calcium carbonate.

100% less 60% equals 40% dry matter.

75% of 40 equals 30 of original weight as calcium carbonate.

56% of 30 equals 16.8% of original weight as available calcium oxide.

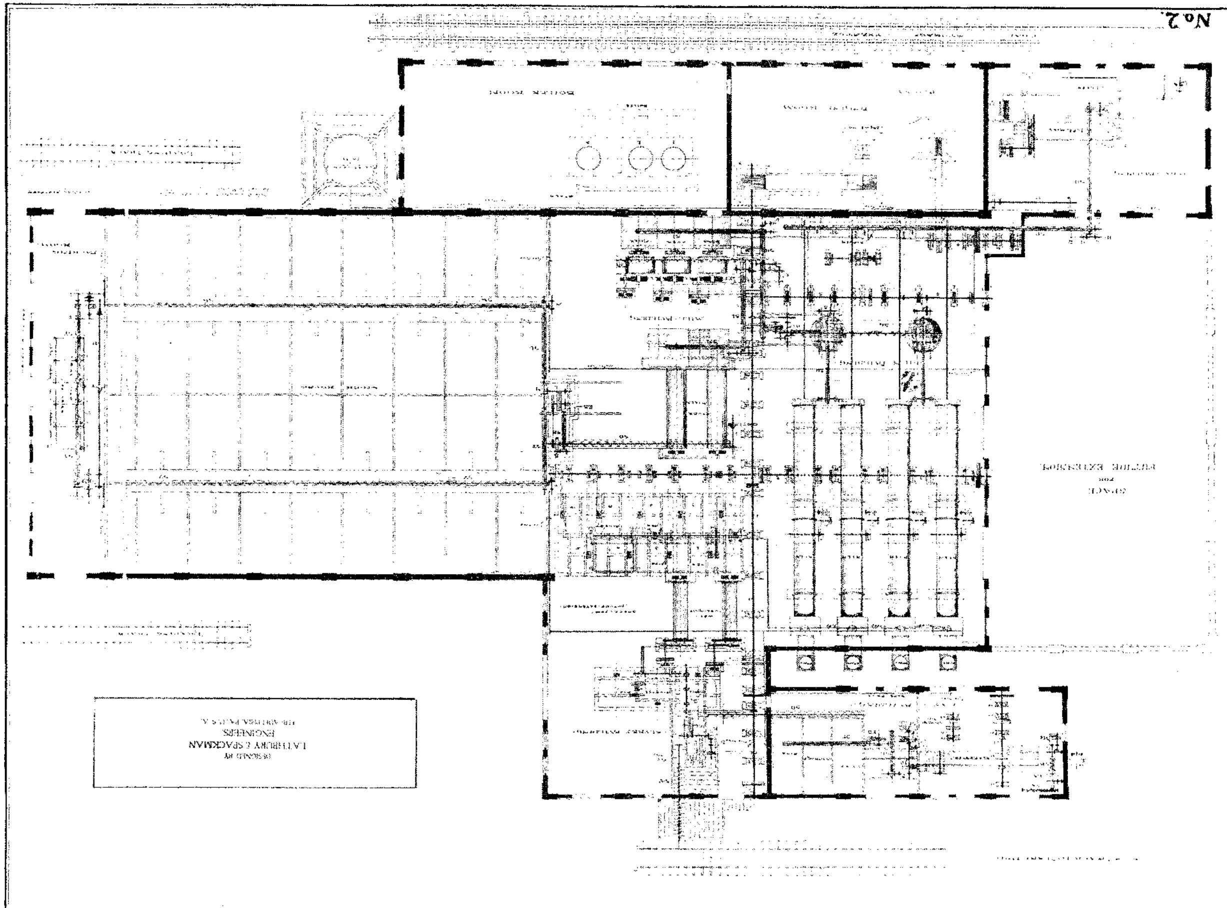
In this case but 16% of the original weight of the marl as dredged and transported to the factory, contributes to the active elements of the cement. It can thus be seen that the actual supply of raw material is greater or less per acre, according to the condition in which it may be found.

No exact volume of marl to the barrel of cement can then be given, as it varies in each bed, but for a high grade marl of medium moisture, probably 10 cubic feet to the barrel would be an average. It is *estimated* in the Clare bed with 94% to 96% calcium carbonate, and 50% to 70% moisture to be from 7.5 to 12.5 cubic feet. At Zukey Lake, the Standard Portland Cement Company, with calcium carbonate 93.92%, estimates 9 cubic feet of marl to the barrel of cement.

The clay is much more compact and free from moisture. The volume of clay of the Omega Cement Company required for one barrel of cement was estimated to be 1.12 to 2.12 cubic feet, according to the per cent of calcium carbonate contained in the clay.

The question as to the requisite acreage of marl is discussed by several cement plants, and the estimated acreage varies widely, being from 262 acres to 2,000 acres. The favorite plan is to show an acreage which will run a factory of the desired size for 100 years. Several factories have been projected upon 75 or 100 acres, but have evidently given up from lack of material.

No. 2.



GENERAL PLAN OF FOUR KILN PLANT WITH PLACE FOR EXPANSION

§ 9. Requisites for marl deposit.

Taking the consensus of opinion as laid down in the prospectuses of the different factories built or building in the State, and the relative merits of beds as viewed in various parts of the State, the requisites of marl are as follows:

Surfacing.

There should be little or no surfacing and the water covering the marl should be as shallow as possible, not over six or eight feet. The amount of raw material in the State does not necessitate the use of beds covered with any great depth of muck or other useless matter which requires surfacing. The marl must be located on or near railroads, but better than all, on the Great Lakes. See freight rates, under shipping.

Necessary composition.

The prospectuses so far examined do not give any analyses of marl lower than 90% calcium carbonate. They vary all the way from this to 96%. It is doubtful in some cases, whether this is the highest sample found, or the average of samples in the bed. One prospectus which gave a sample analysis in its prospectus of 95.73% calcium carbonate gave in two samples taken and analyzed by two reliable chemists, when its bed was sampled as fairly as possible, 83.04 and 77.05% calcium carbonate respectively. In the majority of beds the marl varies with the depth, and when it is 90% $CaCO_3$ near the surface it is likely at 20 or 30 feet to be only 75 or 80% calcium carbonate, as explained in previous chapters.

It is very safe to say that if an average of all samples taken, whether deep or shallow, and irrespective of the choicest location, reaches 90%, the bed is safe as regards calcium carbonate. This will imply unless the bed is exceptional, that many samples will run as high as 95%.

Depth.

The depth of marl used or counted upon in the State varies from as low as 15 feet to depths which no scow of the present kind in use could possibly reach. It is fair to say that marl seems to be used anywhere from 15 to 25 feet below water level, with the restrictions as to water mentioned in the paragraph on surfacing. Low calcium carbonate means high organic matter, which is undesirable from the greater bulk of useless matter transferred to the factory to be burned.

The dangerous constituents are sulphuric acid and magnesia.

Sulphuric acid.

This does not appear to be troublesome according to the analyses seen in the various prospectuses, being given from .08% to .58%. It could go considerably above this, depending upon the amount in the clay. It is not often very troublesome in pure marls, but should be watched.

Magnesia.

This is very much more troublesome, as a strain of magnesian clay in the marl may cause it to vary dangerously. The cement prospectuses giving analyses, show from 1.41% to 1.79% magnesium oxide, which is a very safe limit.

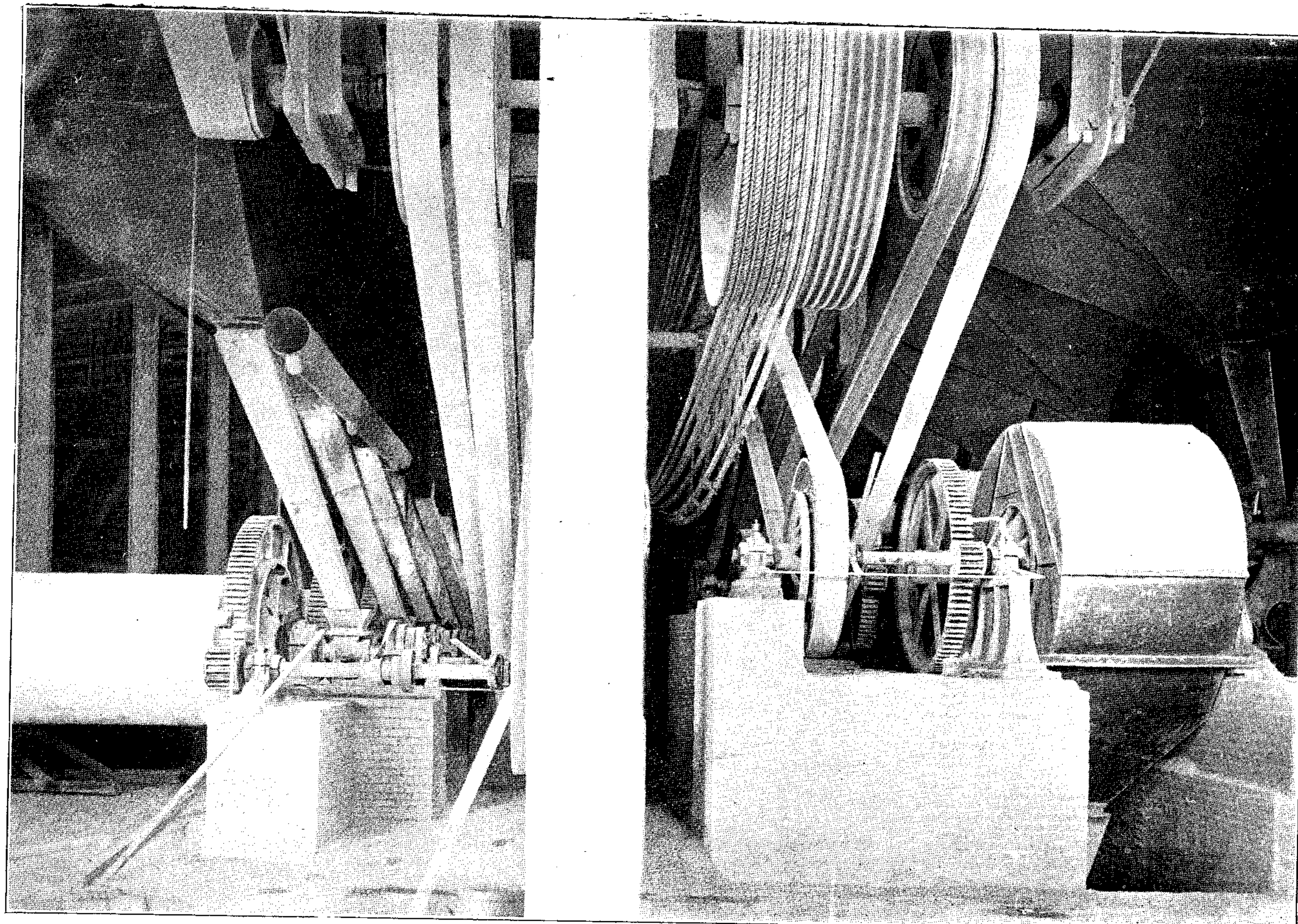
Grain.

Some of the marls of our State are very fine and rival the finest grinding of any material by machinery. One case was noted where there was but 4% left on a 200x200 sieve, or 40,000 meshes to the square inch. This is certainly wherein marl excels all other raw materials for cement manufacture. It need hardly be said that an excess of shells or pebbly accretions somewhat increase the power necessary to grind finely and are a drawback. A marl with above 3% or 4% coarse or fine sand, must be ruled out. Effects will be noticed further on. For analyses of marls for factory purposes, see p. 32 and the descriptions of different plants.

§ 10. Clay.

We have in this State two kinds of clays, one being shale, which is often very hard to grind, but is steady in composition, and generally most free from carbonates. The other class are not of the nature of rock, but have been more recently laid down by the action of water and are not compressed. The grains are more easily separated, and grinding is effected with less cost in power. A good cement clay analysis is that of Millbury, O., being the average of 50, as given by J. G. Dean; SiO_2 61.06, Al_2O_3 18.10, Fe_2O_3 6.65, CaO 1.25, MgO .53, SO_3 1.05, organic matter and water 9.20.* The principal points about clays are the relations of silica and alumina and the proportions of lime, magnesia and sulphuric acid. If there is much lime the clay will not go as far with the same amount of marl. Hence, if it is to be carried by railroad any distance, there is the resulting disadvantage of increased cost of transportation. Organic matter and moisture are of course a dead weight. The above clay is a

*See also Prof. Fall's paper.



GENERAL INTERIOR VIEW OF SLURRY DEPARTMENT.

fairly good sample of surface clays used for cement manufacture, the same bed from which this was taken, being used by two factories in this state. A surface clay, if of the right composition, is much better because easier to dig and grind than shales. Often in the neighborhood of shale outcrops there is found a good surface clay, which is the broken down and decomposed shale, and makes a very suitable clay.

The great body of Michigan clays are too high in magnesia and in alumina in proportion to silica.*

An average result from six factories giving their clay analyses was the following analysis:

Silica, 59.90.

Alumina, 22.76.

Magnesia, 1.47.

Sulphuric acid, 1.04 (but two out of six stated).

§ 11. Admixture of raw materials.

This of course depends upon the exact amount of moisture and the percentage of calcium oxide in the marl, on the one hand, and the percentage of silica, iron and alumina in the clay, on the other. It can never be correctly determined without a careful analysis of both raw materials. A good clay is less variable than the marl. At Bronson, it was said that the clay was analyzed once a week and the marl was analyzed every day. The slurry is analyzed frequently to see if it continues in the right proportions, showing at once whether the measurement of the raw materials is carried on exactly and whether the raw material is varying much from the last analysis. If it does, one raw material or the other must be added to preserve the correct balance for the production of a cement of even composition.

Lathbury and Spackman, who write the article on cement making given below, say in their magnificent triglot on American Engineering Practice in the constructing of Rotary Portland Cement Plants:†

"A glance at the analyses of the standard brands of cements, both American and Foreign, will show a great uniformity, and it can be stated that in a good cement, the amount of the different ingredients will only vary within very narrow limits, as shown in the accompanying table.

*See Part I of this volume, i. e., Ries' report on shales and clays of Michigan, and the analyses of shales in the descriptions of various plants.

†Published by G. M. S. Armstrong, Harrison Building, Philadelphia.

	Minimum.	Maximum.
Silica	19%	26%
Alumina	4	10
Iron	2	5
Lime	58	67
Magnesia	0	5
Sulphuric Acid	0	2.5
Alkalies	0	2.8

Le Chatelier, after long study of the composition of cements, concluded that the two important compounds existing in the clinker were a tri-calcic silicate ($3CaO \cdot SiO_2$), and a tri-calcic aluminate ($3CaO.Al_2O_3$). The hardened cement consists of hexagonal plates of calcium hydrate $Ca(OH)_2$ imbedded in a white mass of interlaced crystals of hydrated calcium mono-silicate ($CaO. SiO_2\ 2\frac{1}{2}\ H_2O$). The chief reaction which takes place during the setting of cement, according to Le Chatelier may, therefore, be represented as follows:

$$3\ CaO.SiO_2 + xH_2O = Ca(OH)_2 + CaO.SiO_2.2\frac{1}{2}\ H^2O.$$

Assuming that three equivalents of lime and no more can enter into the combination with silica and alumina in a cement, then assuming magnesia to act the same as lime, the proportion of lime should not be less than that required by the formula $\frac{CaO+MgO}{SiO_2+Al_2O_3}\ 3$ or greater than $\frac{CaO+MgO}{SiO_2-Al_2\ O_3-Fe_2O_3}\ 3$

"The Messrs. Newberry in a series of researches as to the constitution of cement, determined by synthesis:

"First, that lime can combine with silica in the proportion of three molecules of lime to one of silica ($3CaO.SiO_2$) and give a product of practically constant volume and good hardening properties. With more than this proportion of lime the product is not sound.

"Second, that lime can combine with alumina in the proportions of two molecules of lime to one of alumina ($2CaO \cdot Al_2O_3$) giving a product which sets quickly, but shows constant volume and good hardening properties. With more than two molecules of lime the product is not sound. Thus Newberry gives as the formula for a cement with the maximum amount of lime, $x(3CaO \cdot SiO_2)+y(2CaO. Al_2O_3)$ x and y being variable factors, dependent on the relative proportions of the silica and alumina in the clay.

"In practice, cements contain a slightly less quantity of lime than the above formula requires, because of the difficulty of securing perfect mixing and burning and the danger of over liming if the formula is exceeded."

§ 12. Mixing and raw grinding.*

The marl is dumped into a large tank or vat and is generally screened to relieve it of gross organic and foreign matter, useless to the process. As before mentioned it may arrive at the factory in little dump cars, by means of an overhead trolley or cable working from factory to bed, by horse or mule power, by scow towed in the lake, or by pumping from the dredge where it is scooped up directly to the factory by pipe. In all but the last method the marl becomes somewhat dried during transportation. The marl may be pumped into a large hopper and estimated by volume, while the clay is weighed directly, the right weight of it being added to each hopper of marl, when the two are then mixed and ground together. Sometimes the clay and marl are said to be ground separately. At Bronson, millstones were used to grind the raw materials in the wet, and at Omega they were ground as a slurry in tube mills (Fig. 15). The devices used to handle the raw

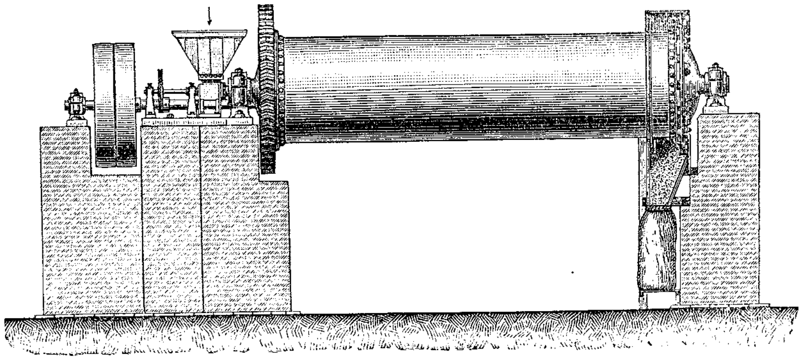


Fig. 15. Tube mill.

materials at this stage of the process vary much. The idea should always be to handle the resulting slurry with as low a percentage of water as possible and yet make a perfect mixture of the two materials. Screw conveyors and sludge mills are used for mixing and conveying from vat to vat and to the tanks which supply the rotaries. The slurry in the tanks must be kept in motion as it is

*See Plates V, VI, and IX.

fed out, because the more solid material settles by gravity to the bottom and would, if allowed, disturb the equality of the mixture.

The expense of the raw grinding department was estimated for a 2,400 barrel plant at Lupton, as follows:

Raw grinding department (two shifts).

2 millers at $2.00	$4 00
4 scalemen at $1.50	6 00
1 electrician	1 75
Oil and grease	3 00
Total	$14 75
125% repair account	18 44
Grand total	$33 19

Cost per barrel 1.4 cents.

Other plants, planned to manufacture from 600 to 1,000 barrels, show four to six cents cost per barrel for this step. No expense should be spared to do this step thoroughly. The whole success of the process depends upon the fineness of grinding and intimate mixing of every particle of clay and marl so that each particle of silica and alumina shall have its portion of calcium oxide ready to satisfy it. The larger the lumps of raw material left unground, the more unsatisfied and harmful material remains.

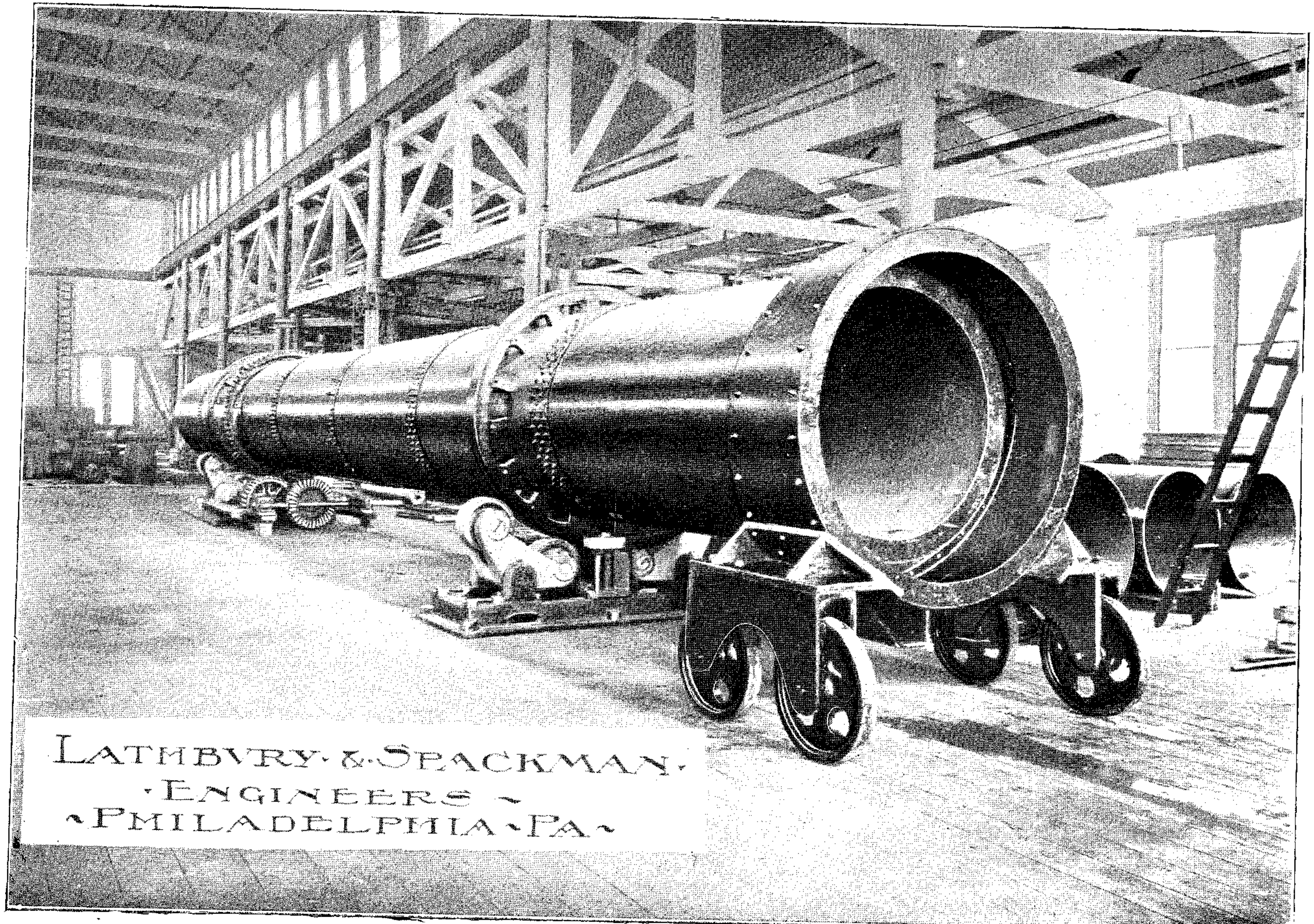
§ 13. Burning.

Every factory now going or projected in this State uses the Ransome rotary kiln process (Plate VII of Lathbury and Spackman's illustrations). It was invented by F. Ransome, an English engineer.

"It consists essentially of a revolving furnace (cylindrical in form), constructed of an outer casing of steel boiler plate lined with good refractory fire brick, so arranged that certain courses are set forward in order to form three or more longitudinal projections, finns or ledges. The cylinder is rotated slowly by means of a worm gear and wheel driven by a pulley upon the shaft carrying the worm. The cylindrical casing is surrounded by two circular rails or pathways, turned perfectly true, to revolve upon steel rollers, mounted upon suitable foundations. Gas, oil or pulverized coal may be used for fuel."*

The kilns are usually arranged in a row (Plate VIII), with the

*Cement and Engineering News.



VIEW OF ROTARY.

supply tanks or reservoirs back of them. The kilns lie side by side with their longest axes parallel so that the motive power may be applied over as small space as possible. In a fourteen rotary plant as at Coldwater or Quincy, there are two rows of rotaries, seven kilns each with the rows facing each other. Petroleum, gas or pulverized coal is used as fuel. This depends somewhat upon which can be delivered most cheaply at the factory. The price of petroleum, of course, is in the hands of a few and is liable to vary more or less, while coal may be had on the grounds in many parts of the State. It is therefore coming into use more generally. According to Stanger and Blount, its ultimate success is dependent upon the method of injecting the stream of coal dust into the rotaries.*

The Ransome kiln has been modified much to get around some of the difficulties encountered, and has been used with success in America, though it proved unprofitable in England. The chief trouble in the wet process, as employed in nearly all the factories in this State, is the cost of fuel. This is considerably greater than it should be when the actual heat is figured out theoretically. The weight of coal necessary to be consumed to produce clinker has been estimated as 23.28% of the weight of the clinker produced. If a portion of the heat of the waste gases is used and they are allowed to escape at 200 degrees C., the percentage is reduced to 17.1% of the weight of clinker in coal. In wet process, 40% moisture, with escaped gases at 200 degrees C., 49.3% of the heat is required to dry the mixture.*

The upper end of the kiln is metal while the lower end toward the flame is lined with magnesia or aluminum brick, to withstand the great heat. While the bricks are as nearly pure as possible, the lime of the slurry acts upon them, producing fusion to such an extent that it has been estimated† that three kilns did about the work of two, because of the break downs and delays caused from the fusing of the lining. A way is suggested and looks very feasible, of lining the fire brick with a coating of cement, packing it down so as to afford a protection to the brick below. This method is employed at the Atlas Cement works as described by Stanger and Blount.

*Engineering News, October 24, 1901.
†A. H. Cederberg.

Analysis of kiln brick, Stanger & Blount.

Silica	55.82%
Alumina	37.98
Ferric oxide	4.02
Calcium oxide	
Magnesia	.78
Soda	.88
Potash	.37

In the furnace the slurry is first dried, then as it travels further toward the flame the different materials become oxidized. The 50 or more per cent of water is driven off in the form of steam. The organic matter is reduced to ash, the carbon being driven off in the form of carbon dioxide. The calcium carbonate loses 46 per cent of its weight as carbon dioxide driven off as a gas. The silica and alumina are made soluble and brought into a nascent condition with the calcium oxide. If there is much sand in the slurry, it is not as easy to grind nor as likely to be ground fine, and the sand, resisting the heat, delays the point of semi-vitrification and increases the cost of burning besides being hard to grind at any stage of the process.

As the heat necessary to clinker cement material is between 2,000 and 3,000 degrees F. the blast of air coming in with the coal or petroleum and the gases driven off, must carry with them an immense amount of heat.

The amount of heat necessary to produce clinker for one barrel of cement is estimated by S. B. Newberry as follows:

Intermittent or vertical kiln (coke)	76	to	95	lbs.
Continuous vertical kiln	42	to	46	lbs.
Rotary kiln, dry material	110	to	120	lbs.
Rotary kiln, wet material (50% water)	150	to	160	lbs.

It is also estimated by Fred W. Brown, E. M.* that an additional 3 gallons of oil or 30lbs. of coal is consumed where wet material is used in a rotary kiln instead of dry. These figures tally rather closely and show the increased expense at this stage of wet marls over dry limestone as a raw material. In case the marl contains a large per cent of organic matter this is nearly as expensive as water because it calls for a large draft of cold air which must be heated to the furnace temperature in oxidizing the useless organic matter. The question is then, how to utilize the immense amount of heat which is wasted. This is roughly estimated as of 175 horse

*Cement and Engineering News.

power intensity when but about 100 horse power of energy is used in clinkering the material.

Mr. Brown makes the following suggestions for improvement.

1. Recovery of heat from clinker produced.

2. Reduction of radiation of heat to a minimum.

3. Reduction of surplus air over that used in combustion to a minimum.

4. Reduction of temperature of escaping gas to a minimum.

5. Development of the efficiency of the melting chamber to a maximum.

He further recommends an induced draft to control the rate of combustion and the removal and cooling of the gases engendered in burning.

There is no doubt that this could be done and also that the hot clinker could help to heat the air entering the rotary. The idea also of using the super heated air and gases to generate steam to furnish motive power, and packing or lining the surface of the rotary to prevent undue radiation of heat is promising, but their application must hinge on the ingenuity of inventors.

There is no doubt that in many parts of the State the waste heat could be used to aid in evaporating the brine of salt wells so that salt could be produced in connection with cement.

The two weak features of wet marl as a raw material come out in the portion of the process employing the rotaries. High organic matter is said to "clog" the rotaries and if not that, it must be dried and then oxidized so that there is another expense added to the extra cost of conveying it and handling it as slurry. The increased amount of fuel necessary to accomplish this and to drive off the moisture of about 50% in the form of steam is one thing that makes the process expensive as compared with handling dry and compact limestone. It is of course counterbalanced by the extra cost of grinding limestone because the marl is already finely divided by nature.

ESTIMATES OF COST.*

A. 2,400 barrels per day.

Coal Grinding.

4 feeders at $1.50.............	$6 00	
2 firemen at $1.50.............	3 00	
2 general men at $1.40.........	2 80	
8 tons coal at $1.50..........	12 00	
Oil and grease.............		$25 80

Burning Department.

2 electricians at $2.00.........	$4 00	
2 headburners at $3.33.........	6 66	
24 underburners at $1.80......	43 20	
100 tons slack at $1.60........	256 00	
2 oilers at $2.00...............	4 00	
8 general men at $1.30........	4 50	$328 76
		$354 56
10% repair account		35 45
		$390 01

B. 1,200 barrels per day.

Coal Grinding (one shift).

2 feeders at $1.50.............	$3 00	
2 firemen at $1.50.............	3 00	
2 general men at $1.40........	2 80	
4 tons of coal at $1.50........	6 00	
Total		$16 30

4 feeders at $1.50..............	$6 00	
2 firemen at $1.50.............	3 00	
2 general men at $1.40........	2 80	
8 tons coal at $1.50............	12 00	
Oil and grease............	2 00	
		$25 40

*For some of these detailed estimates Mr. Hale is indebted to Mr. Cederberg.

Burning.

2 electricians at $1.75.........	$3 50	
2 headburners at $3.00........	6 00	
12 underburners at $1.80.......	21 60	
80 tons slack coal at $1.60......	*128 00	
2 oilers at $1.50...............	3 00	
2 general men at $1.50.........	3 00	$171 14
		$206 14
10% repair account.........		18 74
Grand total		206 14
Cost per barrel................	17.2	

The cost of burning is estimated by different factories as from 3 to 25 c per barrel, the lowest being that of Hecla cement company, which contemplates mining its own coal on the site of the factory.

One great virtue in the rotary kiln is that by careful watching the control of fuel being perfect the amount of over or under burned cement may be reduced to a minimum. For a view of the clinker end of rotaries with arrangement of coal feeders, see Plate VIII.

§ 14. Clinker grinding.

When the clinker drops from the rotary it must be cooled for grinding. It may be allowed to lie until cool or the process may be hastened. A blast of cool air may be passed over it and this air used as a hot blast in feeding coal into the kiln. For elevation of the whole process see Plate IX (Lathbury and Spackman's Plate I.)

The clinker is gathered in nodules the size of a pea to the size of the fist. When broken across, a nodule shows a steel-like lustre, said to be due to crystals of some soluble silicate. If it is a dead black it is overburned, if of a light gray it is underburned, in either case being worthless. A new scheme of cooling the cement is devised by the Atlas company, which it is said aids in "curing" the cement. It is first passed over hollow rollers through which

*The Omega and Alpena factories use coal dust as will the Hecla.

cool air is passed. This air goes to the rotaries warmed, to feed the coal blast passing into the rotary. The clinker then falls on crushing rollers which break up the larger lumps. These rollers are housed, and fed with a spray of water which dampens the cement and is said to satisfy the calcium oxide not taken up by the silica and alumina and so hasten at once the curing of the cement.*

The whole philosophy of the grinding process is to get a cement ground as finely as possible so that the cementing surface, which will increase with the smallness of the individual particles, will be as great as possible. For this reason the finer the flour to which the cement is reduced the more efficient the brand. The great end of manufacturers is, therefore, to obtain a cement which will be ground finely enough to pass all requirements.

For tests, see table on pp. 681 and 682 of Prof. I. C. Russell's article in the Twenty-second Annual Report of the U. S. Geological Survey, Part III and at the end of Mr. Humphrey's report.

The three different classes of machinery used for cement grinding may be described as millstone, tube mill, and rim roller.

The power consumed by the machinery of the process as reduced to the production of one ton of cement per hour is approximated by Henry Faija, as follows:

	Per ton per hour.
For millstones....................	30 to 32 I. H. P.
Ball principle.....................	16 to 18 I. H. P.
Edge runner......................	12 to 14 I. H. P.

Millstones are expensive from the fact that they must be redressed so often as to render the process too costly. They are also the most expensive of horse power.

Plates X and XI are illustrations of the Griffin mill, which seems to be the most popular type of the rim roller class.

Plate X shows a battery of Griffin mill at the Alpha Portland Cement Works, Phillipsburgh, N. J. Notice that they are mounted upon concrete foundations and as closely together as possible, for an economical application of power.

Plate XI shows a 30-inch Griffin mill arranged for dry pulverizing. This shows the interior and it is shown how the material is fed down between the roll and its ring or die. These mills deliver a finely ground and crushed grain and are used in over fifty mills in the United States.

*For detailed description see Engineering News, October 24, 1901.

The Griffin mill is undoubtedly one of the best of its class, but does not seem to have been adopted very generally in Michigan.*

Probably the best illustration of the ball principle as manufactured in this country is that represented by F. L. Smidth & Company, 66 Maiden Lane, New York, as given in Plate XII.

This principle, as far as can be learned, is adopted in most of the factories of Michigan and is well adapted to both wet and dry material. It is rather economical of power and turns out a very fine product. Greenland chert pebbles of a very peculiar appearance are used. They are smooth, rather flat, generally ovate or elliptical in shape and have a small groove or indentation in one of their flat surfaces. They are said to withstand the wear of grinding better than anything yet found and are rather widely used for this purpose. The element of cost in this class of grinding is in replacing the pebbles which wear out and contribute to the siliceous content of the ground cement. It is claimed for this class of machine that it does its work quicker than, and turns out as fine a product with as little wear and tear and expense of power as any class of grinding machinery. It would appear that the wear on the machinery would be less than for any other class. For estimate of percentage of cost of grinding for this class of machinery, see the itemized expense of grinding clinker by this process at the close of this section.

The finer the cement is ground the more rough material it is supposed to cement together, as of course, the finer a given piece is the greater surface it will present to cement other materials together. It thus follows that the finer a cement is ground the more it can be adulterated with coarse materials, such as sand. This fact has been taken advantage of in the manufacture of what is called "silica cement." Sand is ground very finely, and mixed with Portland cement, thus going much further than the neat cement, when mixed with coarse sand. For more details see Cement and Engineering News, February, 1899.

It will be of interest to mention here some experiments conducted under Prof. A. P. Hood at the Michigan College of Mines, in regard to fineness of grinding. The following are the statement of the purpose and the final results obtained by the experimenters.

1. Test A. Effect of fineness of grinding on tensile strength

*The illustrations were given us by the Bradley Pulverizer Company, 92 State street, Boston, Mass.

of briquette. The experimenter concludes that it makes little difference whether the cement is finely or coarsely ground. The finer and coarser ground being weaker as compared with the medium. This he continues is directly contrary to practice and to all current literature on the subject, and thinks perhaps if the briquettes had been molded better the results would have been different.

B. Effect of different percentages of water used in mixing Wolverine cement. Results. At seven days 15 per cent water* gives highest tensile strength. At 28 days, 20 per cent water gives highest strength.

C. Influence of different grades of sand on tensile strength. Normal sand shows highest strength. With increase of coarseness strength decreases. Standard crushed quartz shows about the average between coarse and normal sand.

D. Effect of different amounts of working of mortar. Working fourteen minutes gives highest tensile strength with a gradual decrease with eight and two minutes working.

E. The comparative strength of four cements were in the following order: Wolverine, Lagendorfer, Bronson and Milwaukee.

The strengths of the cements increase with age, the difference between the seven day test and the twenty-eight day test showing an increase of twenty-five per cent.

Cement mortars, one part cement and one sand, the order of strength is W, B, L, M.

With one part cement and two parts sand, the order of strength is the same as above stated, and the increase of strength from the seven to the twenty-eight day test is about fifteen per cent as compared with the neat.

With one part cement and three parts sand, B has but slight advantage over W, while L and M in order are much weaker, the last named being weakest. Average increase of strength with age not appreciable at twenty-eight days.

In general, Wolverine has greatest strength for all purposes, especially when hardened under water. Bronson has next strength and is very quick setting and can be used to advantage in a damp place. It makes a strong mortar. L comes next and Milwaukee,

*See remarks after Fall's paper, printed in the Mich. Engineer, and at the end of this report.

a natural cement, has a disintegrating tendency under water with but a slight increase in strength.

F, G. Test for compressive strength of the above brands.

Neat cements with compressive strength decrease in the order, W, B, L, M. Mortars: three sand, one cement, decrease in order, B, W, L, M. This test nearly checks that of tensile strength which showed B as best used in mortar. From this the experimenter concludes that tensile strength checks very well with compressive strength, so that the latter tests need not always be made.

These experiments are very interesting indeed, and are a good illustration of one very marked need in the cement business. There is imperative need of tests* along two lines: (1) To determine exactly the best methods to be used in making tests; (2) to find just what is responsible for imperfections in our cements, so that when a cement is tested in the laboratory and found to be good, that it will be sure to prove good when used in a building.

Test A of the above tests, differs radically in its conclusions from the present day practice. We would suggest a test here to supplement that, which will perhaps throw some light upon the reason why the finely ground cement did not prove as useful in giving high tensile strength. If the finer particles are fractured in grinding to a dust, rather than worn down to smoothness, the fractured material should give a higher strength. This idea arises from reasoning by analogy and therefore may be wrong. In a mixture of cement with coarser material, the best results are generally obtained with crushed rock, not rounded pebbles. In testing cement mortars, a crushed quartz gives the highest results for tensile strength. It would seem that there is room for experiment right here to determine if different methods of grinding produce different shaped cement particles with a resulting variation in the tensile strength.

The cost of clinker grinding is estimated by four factories at from 7c to 12c. The grinding and the rotary departments are the ones which experience the most wear and tear and hence should have the greatest expense account. The following is a detailed statement of clinker grinding as estimated at Lupton:

*Compare those reported by Prof. Russell in the 21st Annual Report of the U. S. Geol. Survey, pp. 679 to 682, and the report by R. L. Humphrey.

ESTIMATE OF COST.

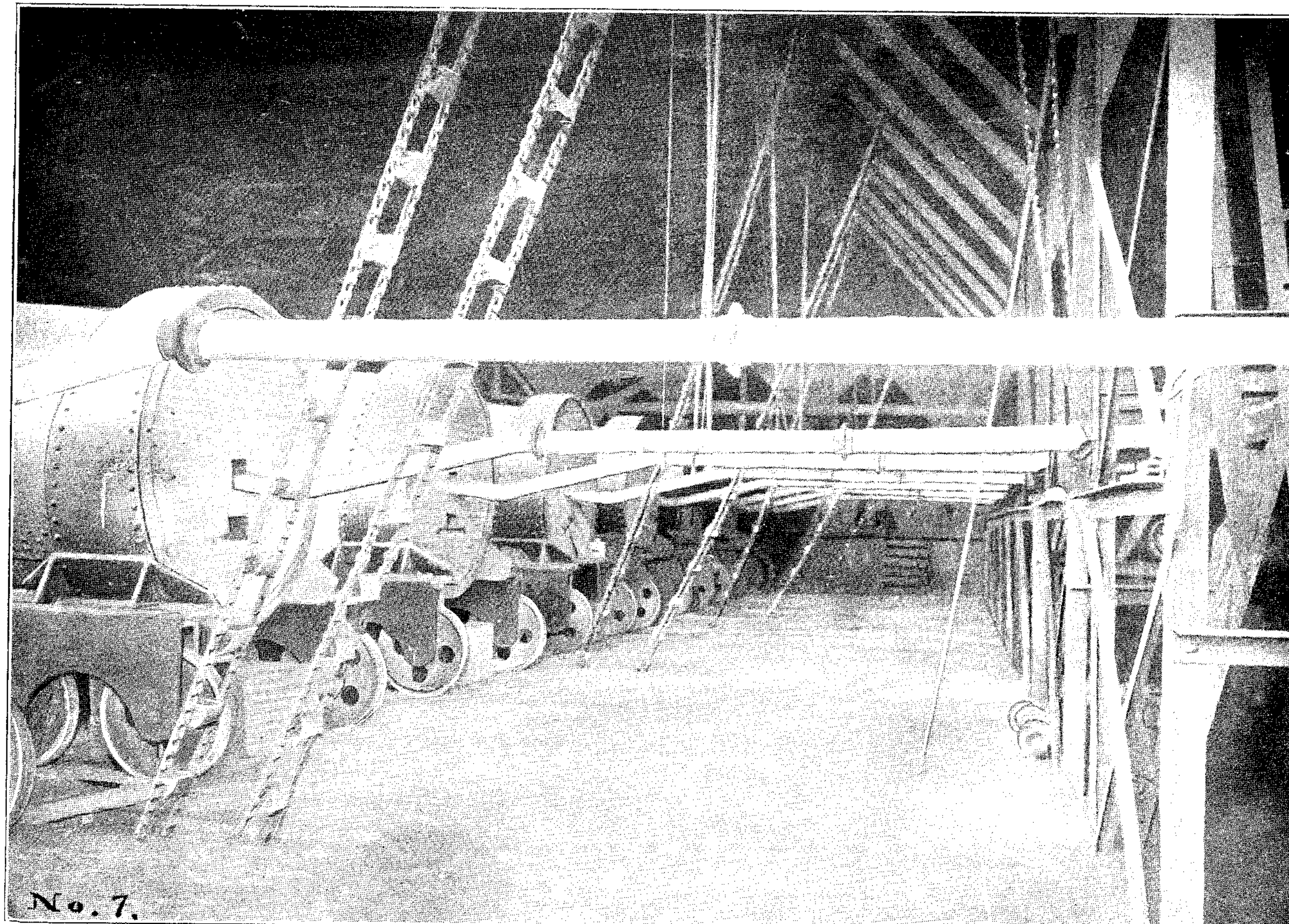
Clinker grinding department (Two shifts), 1,200 barrels.

2 electricians at $2.00..........	$4 00	
2 grinding bosses at $2.00......	4 00	
4 millers at $1.75...........	7 00	
12 feeders at $1.50............	18 00	
6 tons plaster at $10.00........	60 00	
Oil and grease...............	3 00	
Total		$96 00
10% repair account		9 60
Grand total...............		$105 60
	Cost per barrel.	
2,400 barrels	8.8c	
2 electricians at $2.00..........	$4 00	
2 grinding bosses at $2.00......	4 00	
4 millers at $1.75...........	7 00	
24 feeders at $1.50...........	36 00	
10 tons plaster at $10.00.......	100 00	
Oil and grease...............	4 00	
Total		$155 00
20% repair account.........		31 00
Grand total..............		$186 00
Total	7.8c	

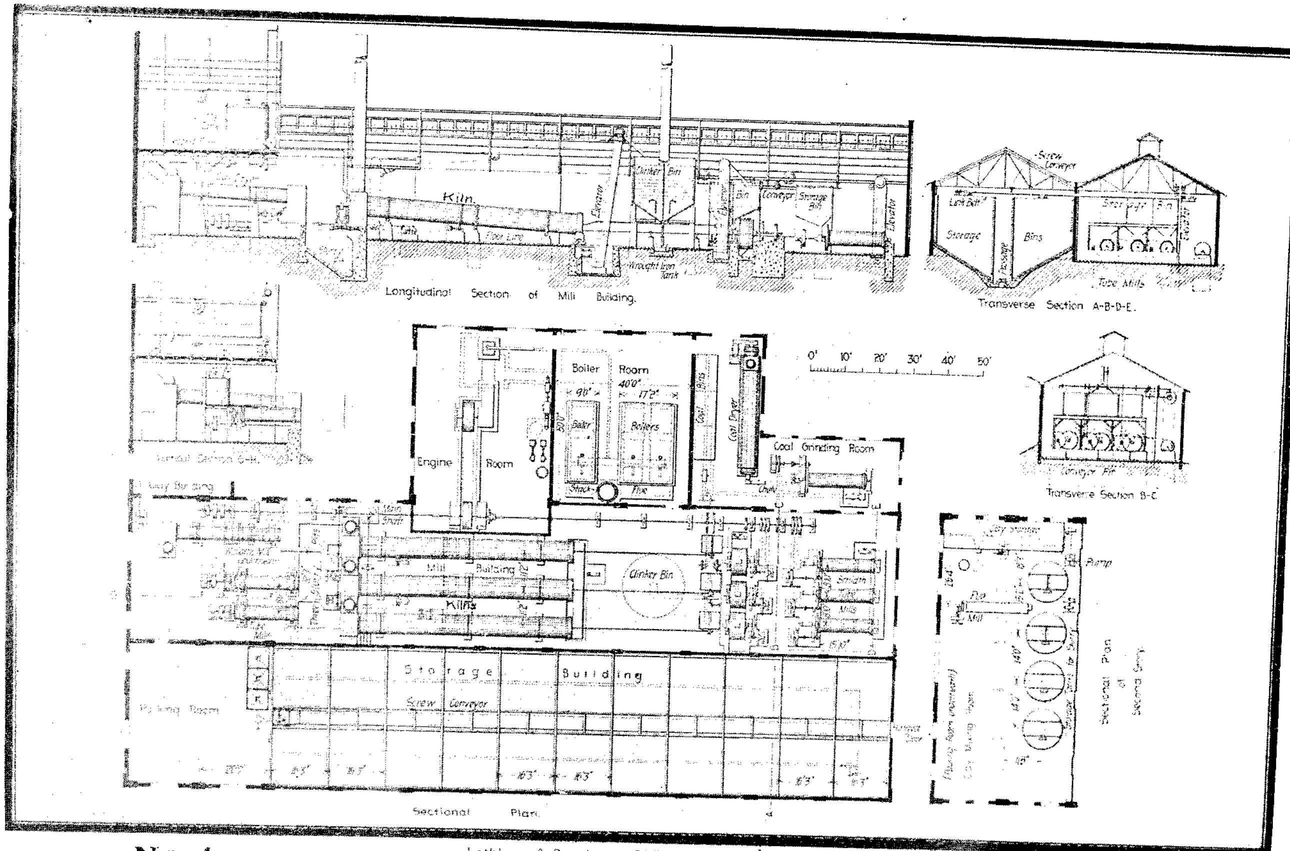
Notice large cost of plaster per day. A company might manufacture its own plaster if located favorably for quarrying the raw material. For location of clinker grinders in general plan, see Plates V and IX. For interior view of coarse and fine grinding department, see Plate XIII.

§ 15. Motive power.

This is an important part. The motive power required is great and must be steady, as any breaking down of the main engines stops the whole plant, checks the grinding and cools the rotaries. To be perfectly sure that this will not occur sometimes, as at the Atlas plant, a second engine is fully prepared, so that at any time it may be hitched to the rotaries and cooling apparatus, and the vital part of the process thereby will continue. The storage tanks of slurry are sometimes made large enough to hold a supply of slurry for running the kilns forty-eight hours, so that all but the



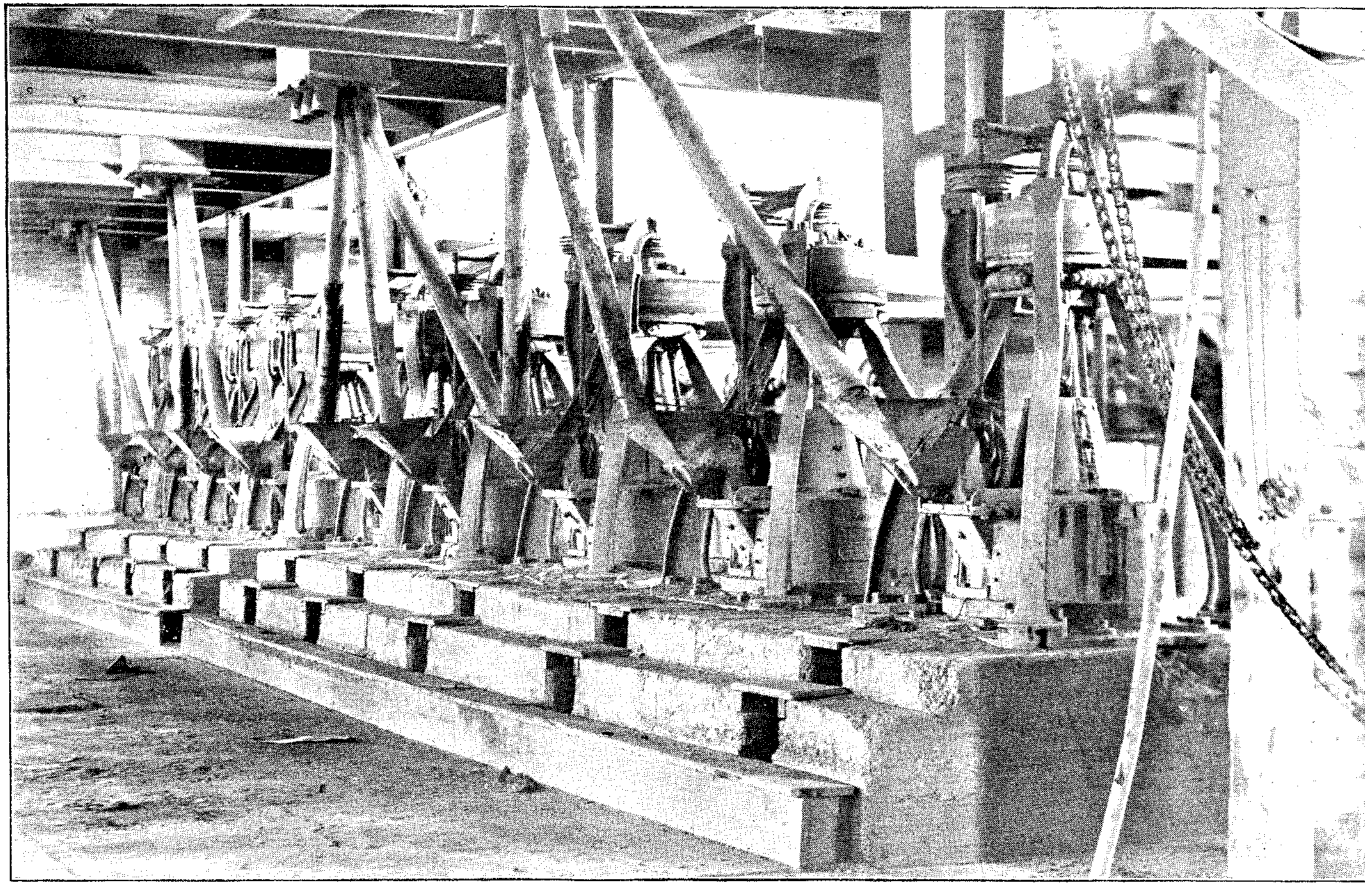
FRONT HOODS OF ROTARY KILNS AND CLINKER ELEVATORS



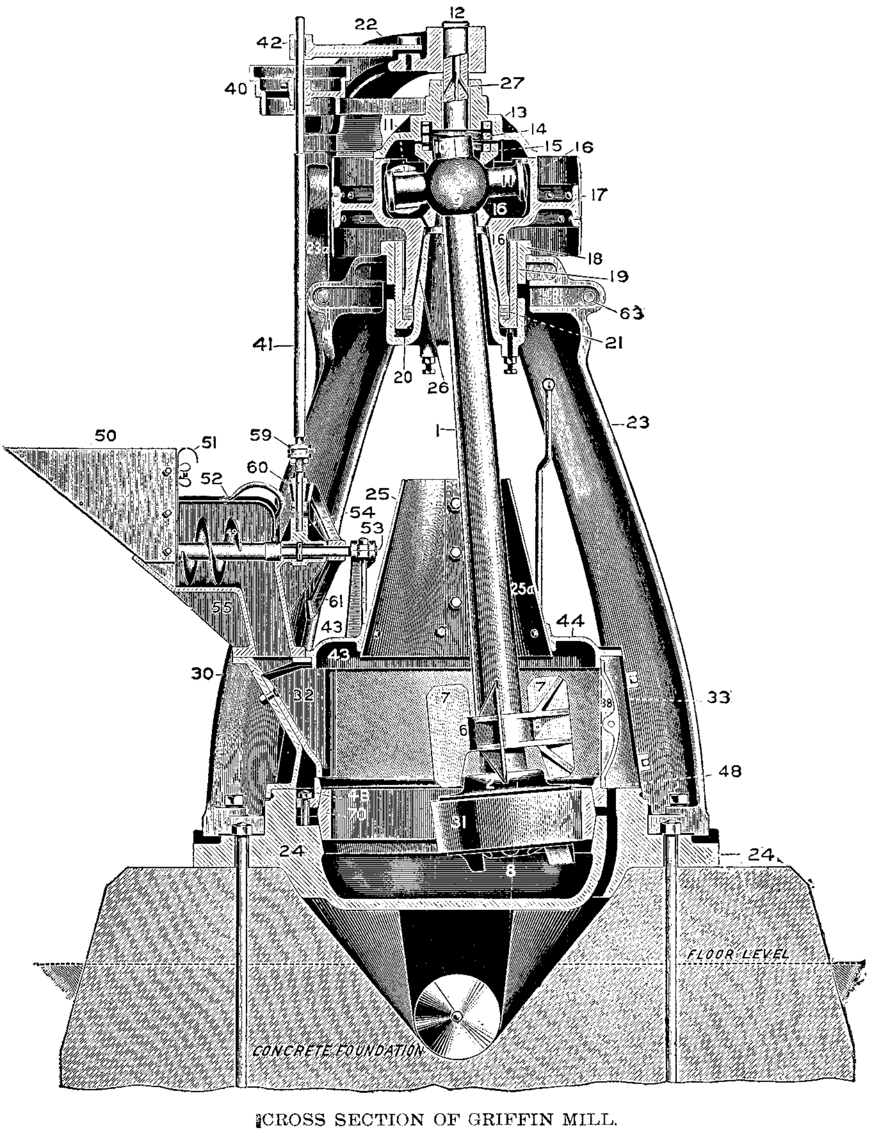
No. 1.

Lathbury & Spackman, Philadelphia, Pa., Engineers.

GENERAL PLAN OF A THREE KILN PLANT WITH ELEVATIONS



BATTERY OF GRIFFIN MILLS GRINDING CLINKER.



CROSS SECTION OF GRIFFIN MILL.

rotaries may be stopped Sunday. There are several new and interesting features to be embodied in the factories of this State relative to power and fuel. The Hecla Cement Company propose to mine their own coal near the site of the factory, thereby reducing their power estimate to 1.28c per barrel, and their burning to 3.25c per barrel. This of course, is the lowest figure given on either step of the process. Another admirable feature would be the use of water power to drive the machinery of the process. This is accomplished by the Newaygo plant. A plan now generally adopted is to transmit the power to the various parts of the process by electricity, making each portion more independent of the others and saving a large waste of power in the transmission.

ESTIMATED COST OF POWER.

The itemized statement of power for the Lupton 1,200 barrels per day, was as follows:

A.

Boiler room:		
4 firemen at $1.60	$6 40	
50 tons of coal at $1.50	75 00	
		$81 40

B.

Engine room:		
2 chief engineers at $2.75	$5 50	
2 assistant engineers at $2.00	4 00	
2 switchboard men at $2.00	4 00	
2 wipers at $1.50	3 00	
Oil, etc	3 00	
		$19 50
Total		100 90
10% repair account		10 09
Grand total		$110 99
Cost per barrel	9.3c	
For 2,400 barrel plant it would be	8.2c	

§ 16. Storage and packing.

Generally a large space should be given for the storage of cement as it is much improved by "curing." If there is any free lime not taken up and the cement is used at once in building, the satisfied compounds set, leaving the unused calcium oxide to absorb carbon dioxide and to swell, causing the cement to crack. The purpose of storage bins is to give the calcium oxide time to absorb before the setting takes place, and it also furnishes a supply for large orders, or allows the plant to run when orders are slack and do not call for rush work. The Lathbury and Spackman plans for a seven rotary plant show a storage capacity of 150,000 barrels of cement. So saying that such a plant produces on an average 500 barrels a day, this would allow it to run 300 days without orders, to fill the bins. It pays to have large storage bins as, especially in our State, the factories shut down often from one cause or another, or perhaps to make extensive changes or to enlarge the plant. This large storage prevents the cement leaving the market. It must also be remembered that the demand for cement is greatest only at certain times of the year, and the safest place to store cement is right at the factory, for nothing is so dangerous to its quality as a leaky or damp warehouse. For ground plan and cross-section of warehouse, see Plates V and IX. The interior section of storage bins under construction is also given in Plate IX. This shows the shape of the floor, which is something like an inverted A, so that the bin helps to discharge itself by the force of gravity.

COST OF PACKING.

This is not itemized by most factories, but by the Lupton Cement Company prospectus is carefully shown as follows, for 1,200 barrel plant:

Regular contract rate....................	2.55c
For 2,400 barrels same rate.	
In addition,	
1 foreman	$2 00
Paper, nails, liners, labels, paste, making average cost	3.5c

§ 17. Specifications for cement.

The standard specifications for cement for the Navy Department are as follows:

The cement to be of the best quality of Portland cement, freshly ground, and delivered in canvas sacks, each sack to contain not less than 95 pounds of cement. The sacks to be carefully secured to prevent waste or loss in handling. Sacks to be returned to the contractor from time to time as they are emptied for use in the work. The cement to be delivered at the navy yard in lots of 400 bags each on or before the expiration of ten days notice in writing to deliver each lot. The first delivery to be made within ten days after the date of the contract.

Cement of which a constituent part is derived or manufactured from "slag," or which has not been used in the manufacture of concrete in heavy foundation work for more than three years prior to the time of awarding of this contract, will not be acceptable.

Bidders will be required to submit with their bids certified statements that no "slag" has been or will be used in the cement to be delivered under this contract; also a certified statement of the engineer or architect of buildings or structures wherein this cement has been used in the manufacture of concrete in heavy foundation work, and has proven satisfactory in every respect for the period of three years prior to awarding of this contract. Failure to produce either of the above mentioned certified statements will be sufficient cause to reject the cement delivered by the contractors, without further test, and all rejected cement will be immediately removed from the yard by the contractor and replaced with other cement to fully meet these and all other specified requirements and tests, without cost to the government.

A certified chemical analysis of the cement to be delivered under this contract must be supplied by the contractor prior to the first delivery of said cement.

All cement as delivered will be immediately subjected to the following tests by the civil engineer in charge of the work; failure of the cement to fully meet each and all of the hereinafter described tests will cause rejection of the cement, which must be immediately removed by the contractor and replaced by other cement of a quality to meet the requirements and tests, without cost to the government:

Specific gravity and fineness—Portland cement shall have a specific gravity of not less than 3.1, and shall leave, by weight, a residue of not more than one per cent on a No. 50 sieve, 10 per cent on a No. 100 sieve and 30 per cent on a No. 200 sieve. The sieves being of brass wire cloth, having approximately 2,400, 10,200 and 35,700 meshes per square inch; the diameter of the wire being 0.0090 inches, 0.0045 inches and 0.0020 inches, respectively.

Constancy of volume—Pats of neat cement, three inches in diameter, one-half inch thick, with thin edges, immersed in water after "hard" set, shall show no signs of "checking" or disintegration.

Time of setting—It shall require at least 30 minutes to develop "initial" set; this being determined by means of needles from pastes of neat cement of normal consistency, the temperature being between 60 degrees and 70 degrees Fahrenheit.

Tensile strength—Briquettes of cement one inch square in cross-section, shall develop the following ultimate tensile strengths:

Twenty-four hours (in water after "hard" set), 150 pounds.

Seven days (one day in air, six days in water), 450 pounds.

Twenty-eight days (one day in air, twenty-seven days in water), 550 pounds.

Seven days (one day in air, six days in water) one part of cement to three parts of standard quartz sand, 170 pounds.

Twenty-eight days (one day in air, twenty-seven days in water) one part of cement to three parts of standard quartz sand, 240 pounds.

The cement depends for its quality upon the amount of soluble silica and the right proportion of lime to supply the same, alumina being also in correct proportion. The finished cement must always be within a very few per cent of a certain standard, the variation being slight. For detailed statement of same and tests applied, see R. L. Humphreys' report on cement testing*. The curing and setting properties of cement are hastened by the addition of gypsum, which counterbalances the effects of over liming. This should not be carried too far, as the sulphates are more or less soluble. It is perhaps owing to the manipulation of tests that many have begun to manifest a distrust of cement tests in general. If the tests as a whole are not conclusive as to the merits of the cement tested, they can not be relied upon, and measures should be taken to remodel the tests, if they are at fault. Averages like the following, if fairly representative, should certainly inspire the greatest confidence in our finished product.

Average of four Michigan factories: seven days, neat 710 pounds, three parts sand 235 pounds; twenty-eight days, neat 824, three parts sand 358.

To compare with this we have the new standard specifications for the navy given above.

§ 18. Buildings.

They should be as nearly as possible fire proof and built of brick, cement or steel. The notices of loss of cement mills by fire are

*For discussion of Hydraulic modulus and cement mixtures see Cement & Eng. News, Aug., Sept., 1900; June, 1901. Also pamphlet from their press by S. B. Newberry.

very frequent, and it is not alone the loss of the mill, which may be partly covered by insurance, but the loss of time and the cost of delay in rebuilding to those who have money invested and should have it earning interest on the investment. Furthermore, the cement runs out of the market and much time is lost in getting new contracts and building up the trade again. On this account, the mills that are now building, are using fire proof material as much as possible. At Lupton, corrugated steel buildings, with a supporting wall of six or seven feet of brick, are recommended. In Newaygo, cement was to be used largely. For views of plants and detailed ground plan of same, see Plates III, V and IX.

As near as can be ascertained, to October 4, 1901, the following is the condition of the cement industry in Michigan:

Eight factories are running a total of 48 rotaries, which is an average of six rotaries per factory.

Nine factories, three in addition to those mentioned, intend to put into operation 132 rotaries. There are seven other factories silent upon the subject of output, which are incorporated under the laws of the State. There are 25 factories in the State which have issued prospectuses or become incorporated, either under the laws of this or other states.

Of 20 factories whose capitalization could be ascertained from prospectuses or other sources, the lowest capitalization was $20,000, the highest $5,000,000. The average was $1,004,500.

For statistics showing the condition of cement mills and market at any given time, consult the reports of the Michigan Commissioner of Labor.

The proposed cost of the Newaygo plant is to be about $500,000, the buildings are to cover five acres, and to hold at least 14 rotaries. The Standard Portland cement plant will be equipped with an outfit costing $350,000, and with a working capacity of 1,000 barrels per day. F. L. Smidth & Co., 66 Maiden Lane, New York, estimate the cost of buildings and apparatus for a 500 barrel plant at $125,000 to $150,000, depending somewhat upon location. This seems much lower than the equipment of the plants which are actually building. The Elk Rapids plant cost about $200,000.

§ 19. Review.

In review of this chapter a most apparent fact is, that there will be, in the near future, severe and destructive competition in Michigan. The editor of the Cement and Engineering News is authority for the statement that in the spring of 1901, contracts were closed for Portland cement at 80 cents per barrel, f. o. b. The Michigan factories are in a comparatively limited area and must nearly all compete in the same markets. At the average estimated cost of the cement as given by the various prospectuses (68c), the addition of very high freight rates will destroy the profits and limit the area of markets. With 48 rotaries going and 132 to be running in the near future, the actual output of well established factories will be shortly trebled.

In considering these figures it must be further remembered that a factory just started must generally introduce its brand by offering it at considerable below the market price, to obtain a foothold in the market at once.

A brief enumeration of the points which will win in this competition are as follows:

The purest raw materials.

The largest plant with the strongest machinery purchasable. A. H. Cederburg estimated a decreased cost of 10c per barrel upon doubling the output.

Cheap power, either through available water power, or coal mined on site.

Most suitable location as regards raw material, fuel and market.

The more of the above requisites possessed by any one factory, the higher will be its profits.

*At present (last reading of page proof, Oct. 1902), however the price of cement has risen again and is over $2.00 a barrel, the low prices mentioned having stimulated a demand for cement in many new directions, with which the supply has not kept up. Especially in constructional work, for bridges and buildings, as well as sidewalks and cellars, a field for the use of cement has opened to which it is at present hard to set limits. L.

APPENDIX TO CHAPTER VIII.

THE DEVELOPMENT OF MARL AND CLAY PROPERTIES FOR THE MANUFACTURE OF PORTLAND CEMENT.

BY B. B. LATHBURY.

The exploitation of a marl or clay deposit involves a large amount of labor, and with it the necessity of an accurate and careful investigation of the quality and quantity of the materials, their general conditions, together with their advantages characteristic of the site from both an engineering and an economic standpoint. During the past few years, which might aptly be termed the construction period of the Portland cement industry in the State of Michigan, the investigation of such deposits have been conducted on purely scientific lines. Briefly described the method of procedure, in order to secure accuracy in the results and reliable figures upon which to base financial calculations for exhibiting the proposition as an attractive investment, is as follows:

The marl deposits should first be carefully surveyed and soundings located at convenient points over the entire deposit, from which samples of the marl should be secured, and the depths ascertained for each sounding. The most suitable time for such an investigation is the winter, when the water over the deposits, if located in a lake bed, is usually frozen. This permits meridian lines being laid out over the entire surface, thus forming squares of known size, at the corners of which holes can be bored in order to ascertain the depths and quality of the material. Field notes are usually kept of such an investigation, and the samples are carefully preserved with the number of the hole from which they are taken. The distance apart of each sounding or bore hole depends in a great measure upon the uniformity of the material and the variation in depth of the deposit, but generally speaking, on a plat laid out in measured squares, the lines of which are located by a transit, bore holes can be made every 300 or 200 feet. The survey should then be accurately platted, a map made showing the boundaries of the deposit, together with the location and depth of all bore holes, their consecutive number on the plat, and if the