deposit is under water, the depth of water over the surface of the marl.

The examination of a marl bed underlying a body of water is much more difficult and less accurate if made when there is no ice covering the surface of the water. Under such conditions, it is generally usual to survey the boundary lines of the lake, establishing stations at measured distances on the banks, and from these points, with the aid of a boat, secure samples and make soundings, in practically the same manner as a hydrographical survey is conducted. The boat is rowed over imaginary lines between the stations on the shore, borings being made and samples taken at intervals over the deposit. If the deposit of marl occurs in a dry state or underlying a swamp, the examination is conducted by laying out meridian lines over an established survey, the borings and samples being taken from the intersection of all lines forming squares.

The next course to pursue is to submit the samples of marl to some competent testing laboratory familiar with the manufacture of cement by whom the samples should be carefully analyzed and determinations made for the following ingredients:

Calcium oxide, silica, combined oxides of iron and alumina, magnesium oxide, sulphuric anhydride, together with the loss on ignition. Determinations can be made for alkalies and other elements, but as they exist in such minute quantities, their determination will not prove of commercial value. The other ingredient to be considered is the clay or shale. Clays throughout the State of Michigan are usually found in a blue color, but when existing in connection with the marls, they usually carry a higher magnesium content than is desirable for the manufacture of Portland cement. On the other hand the suitable shales, though comparatively scarce, are notably free from deleterious elements, and better adapted for Portland cement purposes.

An examination of either the clay or shale deposits should be conducted on the same lines as those pursued for the marl investigation, analyses being made on the samples of clay in order to determine their uniformity and quality. The elements to be determined in the chemical analyses are similar in all respects to those enumerated for marl, with the exceptions of the oxides of iron and alumina should be separated. In all cases after the examination has been made, the data should be collected and a careful computation made of the quantities of suitable marl and clay occurring in each deposit. Then assuming as a conservative unit, that one square yard of marl will manufacture two and a half barrels of cement, it is readily computed the number of barrels of cement that can be manufactured from the deposit and the number of years a mill of given capacity will run.

In general, a marl of good quality should contain over 50% of calcium oxide, with not over 1½% magnesium oxide, and less than 2½% of either silica, combined iron and alumina oxide, or sulphuric acid. Although there are many marls found in the State of Michigan containing less than 50% calcium oxide having the other ingredients in proper proportions, these low lime marls usually contain a high per cent of organic matter which represents so much loss in the available quantity of marl. However, such marls can be used for the manufacture of a high grade of Portland cement, provided a suitable clay or shale is used in conjunction with them. A clay or shale of good chemical proportion should contain in general, not less than two parts of silica, to one part of combined iron and alumina, while the oxide of magnesia should not be over 3%, and the sulphuric acid less than 2%. The clays throughout Michigan usually contain a small lime content, but this is not detrimental to their use for Portland cement mixture, provided care is exercised in correctly proportioning the two ingredients if the magnesia content is low. As a rule it will be found that clays carrying over 10% of lime will be too high in magnesia.

The quality and quantity of the marl, clay or shale deposits having been found satisfactory and the capacity of the mill been decided upon, the services of competent engineers should be engaged to prepare plans and make a final report on the property, and which report is usually used in connection with the prospectus for promoting the financial interests of the corporation.

A matter of great importance, which should be carefully investigated, before the erection of a plant, is that referring to freight rates. This question applies not only to the advantages derived from securing low rates for the shipment of cement to main distributing centers, but also to the careful consideration and selection of a site for the erection of a plant. Generally speaking, it is more desirable to erect a plant alongside of the marl deposit, but in some cases direct water and rail shipment can be made by erecting the factory some distance from the marl and clay deposit, provided a low guaranteed rate can be secured, and the haul is not too great, for the transfer of both the marl and clay from the deposits to the mill site. A plant so located possesses many undisputed advantages.

The cost of a modern rotary Portland cement plant varies largely with the character of the buildings and the mechanical equipment. A plant thoroughly up to date in mechanical equipment, using electricity for the transmission of power, and with steel frame buildings having brick sides, can usually be figured at $50,000 for each rotary kiln completely installed. Each kiln has an average capacity of about 125 barrels per day, but its daily capacity varies with the size of the kiln, skill of the operator, fusibility of the slurry burned, and general conditions of the plant. In general, therefore, it is safe to assume the cost of construction at $400.00 for each barrel of cement to be produced. This, however, does not allow a working capital, which in round figures should be 20% of the total cost of the plant. It represents, however, the entire cost and equipment of a thoroughly modern and up to date plant manufacturing Portland cement by the wet process, either from marl and clay or marl and shale, including such equipment as is needed for excavating and handling the raw material. The most economical process would necessarily embody such machinery as would eliminate manual labor and reduce the cost of repairs to a minimum. Such an equipment is contemplated in this estimate, and would include disintegrators for the marl and clay, tube mills for grinding, and pumps for handling the slurry, sufficient storage capacity for both the clay and marl ingredients, and also for the slurry mixture of the two previous to being transferred to the kilns. These storage tanks to be equipped with suitable agitators in order that the slurry may be kept in a state of constant motion. Kilns 60 feet long by six feet in diameter to be used, equipped with pulverized coal for burning the slurry. Suitable cooling arrangements should be provided for storing and cooling the hot clinker before it is finally ground into cement; the stockhouse so designed that the bins will automatically discharge the finished cement into conveyors which carry it to the packing room, while the packing room would contain automatic packers for both barrels and bags. The plant would be thoroughly equipped with a heavy and durable elevating and conveying system in order to handle both the raw and finished materials.

Most of the plants heretofore erected have utilized shafting for the transmission of power, but experiments made in one or two mills have demonstrated the adaptability of electrical installation, doing away entirely with troublesome line shafts and cumbersome and unsightly piers upon which the shafting bearings necessarily rest.

Several of the modern plants at present under construction in the State of Michigan are installing electricity for the transmission of power. Such an installation costs about 10% more than the installation of shafting for transmitting power, but it effects a considerable saving in the floor area of the buildings, as shafting transmission of power necessarily requires buildings with larger floor space. In maintenance, the electrical equipment is probably less in cost of a cement plant than the shafting, though no accurate data is yet obtainable upon which to base a comparison.

In the matter of engines and boilers, it is desirable to use compound condensing engines with water tube boilers, and if the capacity of the plant is over 1,000 barrels per day, automatic stokers should be provided. Approximately it requires about one horse power for every barrel of cement capacity.

Electrical installation can be made with either the direct or alternating current. Between these two systems there is very little difference in the first cost of installation. The dynamos and motors for the alternating current are more costly than the same machinery built for the direct current, but the saving in the general system of wiring and connections for the alternating current about offsets the extra cost of the wiring and connections of the direct current system. While both systems are equally adapted for direct connected or belted drives, direct current installations with separate motors driving each machine have been most generally used, although there are now in operation two plants, one using alternating current and the other direct current motors, in which each machine is directly connected without the intervention of belt or shafting to the motor driving it.

Between the two systems of power transmission, that is, shafting and electricity, the latter is probably the more economical, but to offset this, it requires more skilled care and attention. Electricity, however, has one great advantage, in that it offers a more flexible plant, wherein power can better be distributed and economy observed by the operation of any combination of machines, under all conditions.

Aside from the correct proportioning, mixing, and burning of the slurry to a proper degree of hardness, the power plant is a department upon which great care and thought should be exercised. As coal represents such a large item in the cost of production, the power plant installed should be such that the highest economy and efficiency can be obtained.

The cost of construction of a rotary plant can be reduced to $300.00 for each barrel of the capacity by the use of steel buildings covered with corrugated iron sides and roof, the omission of electrical equipment and the installation of a less costly power plant. The cost of construction can be still further reduced by the construction of frame buildings and the omission of all labor-saving devices throughout the plant which would necessitate the handling of a large part of the raw, unfinished product by manual labor. Such construction would necessarily increase the cost of production of the finished cement and thereby decrease the profits.

The preceding outlines contemplated the use exclusively of rotary kilns, but there is yet an entirely different system which can be installed, and for which the cost of erection would not exceed $200.00 for each barrel of the capacity. This refers more particularly to the installation of set kilns, together with such machinery for mixing and grinding the marl and clay or marl and shale in a semi-plastic condition, forming same into bricks which are afterwards dried and then burning the raw material in some form of a set kiln. The Dietsch and Schofer kilns, classed as the best of this type, require the expenditure of a large amount of manual labor in order to prepare the raw material, charge the kilns and handle the clinker, after it has been thoroughly burned. Small consideration is given to this method of manufacture in this country at the present time, and it has been almost entirely superseded by the rotary kiln, principally because of the increased production of the rotary kiln over the set kiln, and the opportunities offered with the rotary system of utilizing mechanical devices for handling the raw and finished products, and thus effecting a large saving in the item of labor. Assuming the capacity of a rotary plant at 1,000 barrels per day, it requires about nine months to complete the erection, and about three months thereafter, or one year after starting erection, before it is in full running order, and turning out its maximum capacity of marketable cement.

With the progress made in the Portland cement industry during the past five years, it is not a profitable venture to install less than three or four kilns on the erection of a new plant, and the plant should be so designed that the buildings can be readily increased and the capacity doubled or tripled without interfering in any way with the operation of the initial plant. The larger profits in the present condition of the cement market are to be derived from large productions.

During the construction of the plant it is absolutely important that careful consideration be given to the selection of a competent superintendent, master mechanic, electrician and chief chemist, in order that they may report for duty during the last stages of construction, and thus become familiar with the plant. These heads representing the executive force at the mill, should be men who have a thorough experience and knowledge in the manufacture of Portland cement, operating under similar conditions. Upon the skill of these men depend in a large measure, the prospective profits to be derived from the investment. Many mistakes have heretofore been made by filling these positions at the mill with men who have had no experience in the manufacture of cement. Upon these men, working in harmony with a careful and efficient higher management, depends in a measure the success of the venture. It is generally conceded by all who have had experience in the manufacture of Portland cement that it is one of the most difficult and trying lines of manufacture. This is due to the excessive wear and tear on the machinery, due to the hard and constant use to which it is put, requiring constant watchfulness in order to detect defects and wearing parts, with skill and judgment, in remedying the same before final breakdowns occur, necessitating the shutting down of the entire plant.

The cost of manufacture varies greatly in each plant, ranging from 80 cents to $1.40 per barrel of cement produced. This variation depends on several reasons, principal among which is the general design and construction of the plant, efficiency of the entire management, daily condition of the machinery, cost of all raw materials delivered at the mill, including marl, clay, and coal, and cost of labor and size of the mill.

A brief summary of the foregoing facts would therefore tend to show that a cement proposition should be carefully handled from the earliest stages of its development, until the plant is finally erected, after which the success or failure of the venture depends in a great measure on the skill and competency of the engineers who have erected the plant and reported on the general conditions favorable to manufacture, together with the general management selected to handle the business of the company.

The views accompanying this article are as follows:

Plate IV. General exterior view of an eleven-kiln plant.

Plate V. General plan of a complete plant having an installation of four kilns with sufficient floor space for installing the necessary grinding machinery to bring the capacity up to 1,000 barrels per day, which would only necessitate the extension of the kiln building.

Plate VI. General interior view, showing a modern slurry department in operation.

Plate VII. General view showing a modern rotary kiln 60 feet long by 6 feet in diameter.

Plate VIII. General interior view showing the front hoods of a battery of eight rotary kilns with hot clinker elevators, pulverized coal bins with apparatus and piping for forcing coal into the kilns.

Plate IX. General plan of a complete plant having an installation of three kilns, without provision for future extension.

Plate XIII. General interior view showing batteries of ball and tube mills in operation grinding Portland cement clinker.

Plate XIV. Four views as follows:

  A. A modern office building with chemical and physical laboratories and a few sleeping rooms for superintendent and his assistants.

  B. View showing section of a stockhouse under construction to have self-discharging bins.

  C. View showing bottom of concrete slurry pits under construction, with piping and valves being set in position for handling the slurry mixture.

  D. View showing a dry marl deposit with car and steel rope attached, for hauling the marl from the bed to the slurry department of the mill.

Plate XV. General exterior of a four-kiln plant.

CHAPTER VIII.

NOTES ON THE ORIGIN OF MICHIGAN BOGLIMES.

BY A. C. LANE.

§ 1. Introduction.

It was the original intention to have this report prepared entirely by Mr. Hale, but the subject grew upon him, just as the Portland cement industry has grown in the State. Moreover, work like that which Mr. Davis, and Lathbury and Spackman have done seemed too large to be incorporated without credit to them as authors. Other information also kept coming in which deserved an incorporation, that I could myself, with less delay than any other, perform, and at the same time insert some comments on the theories of the origin of boglimes, presented by the others, that I could not very well insert into their papers.

§ 2. Origin of boglime, chemical considerations.

It must not be forgotten in discussing the origin of these fresh water lime oozes, limestone doughs, so to speak, that it is perfectly possible for more than one method of formation to produce very similar material. It is possible that the Indiana geologists may be right[1] in their conclusions as to the origin of their deposits, and Davis and Hale also right as to the origin of those boglimes they have studied. But the crucial point in discussing any theory of purely chemical precipitation is this: Is there any evidence of such saturation of ground water with calcium bicarbonate, that any loss of temperature and pressure likely to exist will cause precipitation by purely chemical means? Therein lies the importance of the tests made by and for Mr. Hale, given above[2] and we may also compare, for the hardness of spring water, analyses 52-80 of my paper on the water analyses of this State.[3] In these $CaCO_3$ varies from 0.12 to 0.40 parts per thousand,[4] yet in only five cases is it

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[1] Twenty-fifth Annual Report, p. 48.
[2] PP. 46 and 118.
[3] U. S. G. S., Water Supply Paper No. 30.
[4] Grams per kilogram, ounces per cubic foot nearly.

over .20 of carbonate or bicarbonate. To these analyses may be added one of the Owosso mineral water which is a natural spring, flowing from the side of the hill about 11 barrels a minute, at a temperature of 50° F.

	Parts per M.
Calcium bicarbonate	.367
Magnesium bicarbonate	.273
Iron bicarbonate	.227
Sodium and potassium chlorides	.030
Silica and alumina	.009
	.906

Mr. J. G. Dean of the Peninsula cement plant informs me that the water of Goose Lake, near the mouth of their intake yielded:

CaO	.110
MgO	.044
$(Fe,Al)_2O_3$	tr.
SiO_2	.004
SO_3	.014
CO_2	.108
$(Na,K)_2O$	.004
	.284

This implies .262 parts per thousand of calcium and magnesium carbonate, and if this is saturation for average lake conditions, then about one-third of the ground waters above referred to reach it.

Treadwell and Reuter made no researches on the solubilities of calcium and magnesium carbonates together in the same solution, but as they find that calcium carbonate may exist to the extent of only .238 parts per thousand, if no free CO_2 is present, it must be near the point of saturation.

The solubilities of the carbonates are so important and the paper is so comparatively inaccessible here, and besides has a number of misprints, and misplacements of text, which Mr. Treadwell has kindly corrected for me, that I think it worth while to give the following summary in the hope that some of our cement factory chemists may feel impelled to continue an investigation, in which the survey might coöperate.

Abstract of article "Ueber die Loeslichkeit der Bicarbonate des Calciums und Magnesiums von F. P. Treadwell and M. Reuter" with 11 figures in the text. Zeitschrift für Anorganische Chemie, Vol. 17, p. 170.

It is well known that bicarbonated water gradually becomes cloudy upon exposure to the air, while calcium carbonate separates as a thin crystalline film on the surface of the fluid, and that the separation increases as the absorbed CO_2 escapes. It follows that if calcium bicarbonate was in solution, the solubility of the same stands in relation to the free CO_2. Data as to the solubility of this salt are rare in literature; indeed, its very existence has been doubted. It was accordingly of interest to investigate the existence and solubility in carbonated and non-carbonated waters of bicarbonates especially of the alkaline earths. Calcium, magnesium, and sodium bicarbonate came within the range of investigation. The method employed for the special case of the calcium salt may be briefly sketched.

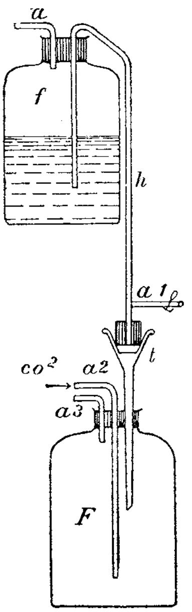

Fig. 16.

Distilled water was saturated with CO_2 and CaO in a closed bottle, the partial pressure of the CO_2 on the fluid being one atmosphere, i. e., the gas above the water was pure CO_2.

Fig. 16 shows the apparatus used for filtering off the water from the upper bottle f, where the quicklime was to the lower F without allowing access of air and loss of pressure of carbon dioxide.

The solution, filling about the half of a large bottle, remained after filtration but without alteration of the partial pressure, clear for days,* and the *per cent of CaO does not alter in the slightest*, as is evident from the analyses below.

A part of the CO_2 above the water was replaced by air, until separation of carbonates was observable. This is the point at which the most possible CaO can be taken up, for the temperature and pressure then prevailing. By successive lessening of the partial pressure of the CO_2 the calcium was more and more separated, until finally when the partial pressure reduced to 0, no further alteration in the lime took place. The water then contained, as was shown by analyses, *calcium and CO_2 exactly in the ratio to form bicarbonate*. Accordingly an aqueous solution of calcium bicarbonate is present.

The problem was then to determine exactly at each time the partial pressure of the CO_2 resting upon the fluid as well as the per cent of CaO and CO_2 in the solution. To this end the apparatus illustrated by Fig. 17 was used.

The bottles F_1 and F_2 contain two of the solutions to be investigated separately. The gas is drawn out through the tubes r_2. These are perforated at distances of about 2cm in their vertical parts (so as to get a fair sample of air), and outside of the neck of the bottle are bent at right angles. The horizontal parts have glass stopcocks, h_1 and h_3, and T pieces, t_1 and t_2, and n_1 and n_3 are pressure level tubes, which can also be closed by stopcocks. Mercury is the fluid that fills them. In their prolongation the tubes open into the common capillary C, which has a small funnel, n_2, above, and below is closed by a thick walled rubber pipe and clamp. The arrangement is to avoid as far as may be, the injurious space between the cocks h_1 and h_3 and the opening of the capillary pipette. If the cocks h_1, h_3 and s are closed and the other cocks open, by raising the level tubes n_1 and n_3, all of the air will be

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*The experiments were performed at a constant temperature and pressure. The mean temperature of 15 degrees Celsius was chosen (59° F.), which it was possible to keep exactly only by placing the apparatus in a room which was not subject to great variations (amounting to 1 to 2 tenths of a degree during the whole investigation).

The slight differences in the temperature could be neglected but the variations in pressure were considerable, so that all the data had to be reduced to the normal conditions of 0 degrees and 760 mm. of mercury pressure.

forced out of the tube system and the same will be gradually filled with mercury. When this has risen to the desired height in n_2, q_4, h_2 and h_4 are closed, and the thick tube at s is fitted over the pipette filled completely with mercury. The suction is applied at O (by a Sprengel pump) while the cocks s and h (or h_3) is opened until the globe of the pipette is full and then s is closed. It is advisable to repeat this operation two or three times. After the last time, first h_1 or h_3 is shut and the capillary of the pipette is filled with mercury by opening the clamp of q_4 a moment. The gas is now ready for analysis, which was done by Hempel's Exacter method. (Gas analytische methode, p. 45.)

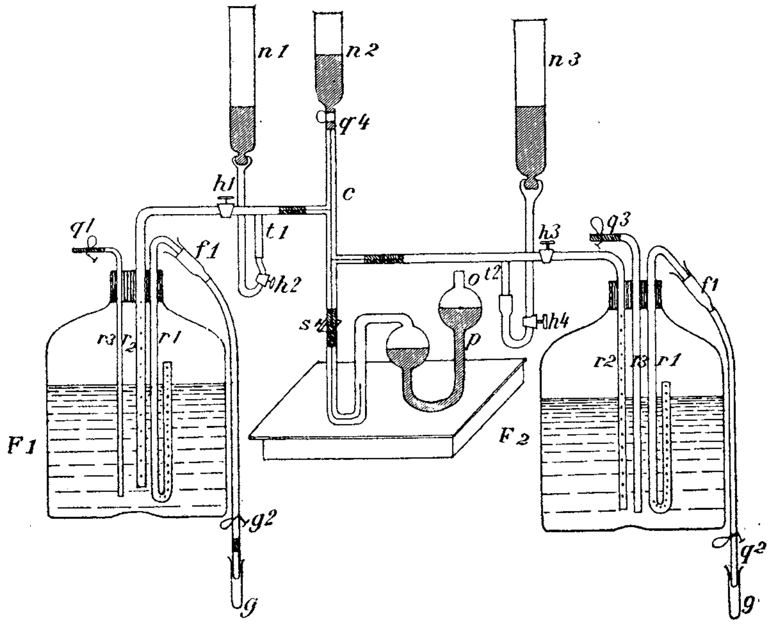

Fig. 17.

The analysis of the solution falls into two parts.

a. Determination of the total CO_2.

b. Determination of CaO and combined CO_2.

Here also it is important to obtain an average sample, for it is clear that the water does not give off its absorbed CO_2 equally in each horizontal stratum. The upper layers lose the most, the lower the least gas. Referring again to Fig. 17, the tube x goes through a perforation in the rubber cork. It is bent inside the tube and perforated in the ascending part at distances of 1cm. It works like a syphon. Any carbonate crystals possibly taken with the fluid are held back in the little filters at f. These are short glass tubes, somewhat expanded at the end, the cone of which is best packed with asbestos. Upon this goes a rubber tube, which ends in a short glass tube, over which, to prevent evaporation, a short test tube is tightly fitted. By light pressing on the clamp, q_2, any amount of water desired can be taken.

The small flask A* (Fig. 18) is exactly gaged by weighing with water filled up to a certain mark, and can be closed by a rubber cork through which goes a λ shaped glass tube (R) which has a side opening a little above the end of one of the forks which is closed. To fill the flask a fine aluminum wire is put into it, the water to be tested is allowed to flow in as quickly as possible along the side, it is corked at once and the tube R raised so that the side opening is in the rubber cork, and the outer air fully excluded. The tube R is thoroughly washed with distilled water, the upper end joined to the graduated tube B and the side fork of R is connected with a reservoir of HCl (S) † by the rubber tube N, which is closed by a clamp. The rubber connections are tightly tied, then the sphere K emptied by lowering the mercury reservoir D and closing the cock L. The air which is now in B, by proper turning the cock L and raising the reservoir P again, may be driven out of the apparatus, after taking away the rubber con-

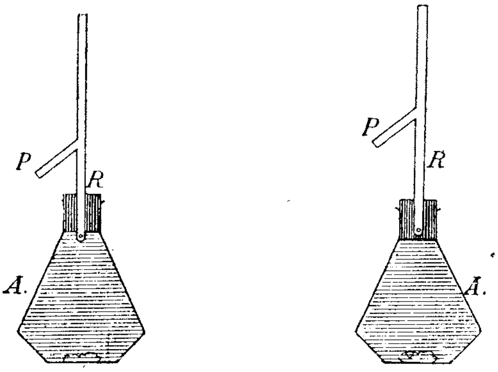

Fig. 18.

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*Treadwell "Analyse der Passugger Mineralquellen."
†This figure is omitted.

nection to the Orsat tube. Repeating this operation several times, K is finally emptied. Now pressing the tubes R carefully into the cork so far that the side opening appears below it, the HCl finds its way into the flask A and there is a lively evolution of gas, and the mercury falls rapidly in B.* When it is about three-fourths full, the reservoir D is suddenly lowered and the cock L closed. In the meantime the Orsat tube O, full of potash (K_2O) has been connected with D and the gas is driven (noting the volume, temperature, and height of barometer) from D into it, by turning L and raising D.

Then the connection between A and B is restored and another lot of gas generated. If the gas comes too slow, the flask A may be warmed, under certain special precautions.

Finally when only a little gas is given off a few c.c. of HCl (1:2) are put into the flask A, and finally, more is added and boiled but with care that no water goes over into B.

After all the CO_2 of the expelled gas has been fully absorbed, and the amount of water vapor subtracted from the sum of the total readings, the volume of total CO_2 is thus obtained. The operation takes one-half to three-quarters of an hour.

Lime. The lime was titrated with 1-10 normal HCl, using methyl orange as indicator.

The partial pressure (amount of CO_2 in overlying atmosphere) is lessened, as was remarked at the beginning by replacing a part of the CO_2 over the fluid by air. The tubes r_2 and r_3 with their prolongations, t_1 and t_2 serve the purpose; these outside the bottles are bent at right angles and closed by rubber tube and clamp, and fit snugly into the hole of the cork, but can yet be moved up and down in the same.

The process is as follows: The ends of the rubber tube at t_1 and t_2 are taken off. The clamps q_1 opened and from t_1 and t_2 the air sucked with an air pump. If one wishes to lessen the partial pressure but slowly, the gas is replaced by air without admitting the air through the fluid. The partial pressure decreases much faster if the air is allowed to enter through the solution, after that diluting the atmosphere charged with CO_2 that rests on the surface of the water. Finally the apparatus is closed and in either case one must wait several days for equilibrium to be established.

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*Care is to be taken that the pressure is less than an atmosphere.

1. Calcium bicarbonate.

For the details of process of formation and filtration without change of pressure from quicklime and water charged with CO_2, reference must be made to the original Experiment 1. Solution was kept in a room of constant temperature 24 hours. The solution which stood under the pressure of one atmosphere CO_2 was analyzed four successive days and the total CO_2 and CaO found constant, to wit: 2.854 parts per thousand of CO_2 and 1.156 Ca CO_3, of which 0.509 is CO_2 equivalent to 1.872 CaH $(CO)_3$ with 1.018 CO_3.[*]

The lime was not quite pure, conatining in 100 ccm water, in grams:

0.0005	$CaSO_4$
0.0006	SiO_2
0.0010	Fe_2O_3
0.0021	impurity

Experiment 2 was conducted with a CO_2 pressure of 67.9 mm mercury.[‡] On the surface of the solution was to be observed a faint inappreciable crystalline secretion of calcium carbonate. It follows that from the partial pressure of 70 mm (when CO_2 is 9% of the atmosphere) up, the solubility of the bicarbonate increases too slowly to be determined in this interval with present apparatus.

Below this the separation of carbonate begins when by dilution of the CO_2 with air the pressure of CO_2 is lessened, and depends on the evaporation of the CO_2 from the water into the air. This reaction ceases when no more calcium is precipitated and the gas analyses show no increase in partial pressure. Numerous tests have shown that to determine equilibrium, the gas analysis is

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[*] The detailed figuring is as follows:
(a) CO_2, 92.67 cc. water used,

4 or 5 times repeated boiling gave	177.3 ccm. gas
After absorption with K O H	42.6
CO_2	134.7
Pressure 724.7 mm. mercury temperature	10°.4 C
Reduced to standard pressure (740mm.) and temperature 0°C=	121.74
Equivalent in 100 cm. of water	131.40
Milligrams CO_2	258.4
A repetition gave	258.8

(b) Ca. In all four cases, per 100 ccm. water 22.34 cc. 1-10 normal HCl of coefficient 1.0346 was used; i. e., 23.11 cc. 1-10 HCl corrected, corresponding to 115.6 $CaCO_3$ with 50.9 CO_2 or 187.2 $CaH_2\ (CO_3)_2$ with 101.8 CO_2.

100 cm. solution evaporated to dryness gave	.1180 gCO_3
By titration above	.1158
Indicating	.0025 impurity.

A fair correspondence.

[‡] 9.98% CO_2 in the air at t=12.50 and 726.1 mm. pressure.

surest, for a slight decrease in calcium in solution corresponds to a relatively great change of partial pressure, and if two successively performed gas analyses are alike, the solubility of the bicarbonate is alike, as test 3 showed. At the beginning of the test the atmosphere above the water contained 8.94% CO_2. Air was sucked in and the gas above the water at once tested. The CO_2 was but 3.47%. After a while a second sample of the gas as well as one of the water was investigated. The CO_2 had risen to 6.23%, nearly double, while the bicarbonate has dropped off about one part per liter. After this point the CO_2 and lime remained constant.*

Ca.	Per 1000.		% CO_2	Pressure.
	Ca.	Bicarbonate.		
Experiment 2	.462	1.872	8.94	
	.463	1.876	3.47	
	.439	1.776	6.23	67.9
Experiment 3	.433	1.755	6.04	
	.433	1.755	6.02	

Treadwell and Reuter give the following other observations on the solubility of $CaCO_3$ in carbonated waters.

Grams $CaCO_3$ in liter.	Tem.	Authority.
.7003	0°	Lassaigne Journ. p. Chem. 44, 84.
.8803	10	Lassaigne Journ. p. Chem. 44, 84.
.6700		Bergmann Arch. Pharm. (1874) [3] 4 : 145.
1.8000		Bischoff Jahr. Chem. phys. geol. (quicklime).
2.8000		Bischoff Jahr. Chem. phys. geol. (quicklime).
2.5000		Marchand, 2.64, (pure) from Caro.
1.0 to 1.5		Struve, 2.64, (pure) from Caro.
3.0		Caro inaugural dissertation.
.9852	21°	Warrington p = 7.483 mm.

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*Details of figures are as follows:
Partial pressure P = p (percentage reduced to normal) × 7.60

Experiment 2. Zero point 2.2.	Height of mercury in barometer tube of apparatus.	Temperature in degrees centigrade.	Barometer in mm.
Initial volume	58.0	12.5	726.1
After absorption of CO_2	127.7	12.5	726.1

Tension of water vapor at 12.50 5′ = 10.8.
Initial volume stood under the pressure 726.1—(55 8 + 10.8) = 659.5.
Gas — CO_2 stood under the pressure 726.1 — (121.5 + 108) = 593.8.
Therefore percent air = 659.5 divided by 593.8 × 100 = 90.02 and percent CO_2 = 9.98.

According to these data the solubility of calcium carbonate in carbonated waters varies from 0.7003 to 3.0 grams per liter. The statements of Bischoff that the solubility of $CaCO_3$ is dependent on the purity of the material which furnishes the CaO or CO_2 can not be confirmed, but at 15°C, saturated calcium bicarbonate solutions gave, whether made of pure or impure limestone, from 1.13 to 1.17 grams per liter of $CaCO_3$. At 13.2°C. the solubility was 1.31 grams per liter for the $CaCO_3$ from common quicklime, and 1.30 grams per liter for the pure material. At a temperature of 2.8°C there was 1.45 $CaCO_3$ in the liter, showing a greater solubility at the cooler temperature. Long standing produced no increase in calcium.

A study of the solubility of calcium carbonate from an analogous point of view is presented by a work of Schloesing Compt. Rend. 74:1552. His table is as follows, but he does not describe how the partial pressure was computed:

Pressure of CO_2 in atmospheres, t = 16°.	Total $CaCO_3$ per thousand.	Total CO_2.
0.000504	.0746	.06096
0.000808	.0850	.07211
0.00333	.1372	.1230
0.01387	.2231	.2184
0.0282	.2965	.3104
0.05008	.3600	.40863
0.1422	.537	....
0.2538	.6334	1.0720
0.4167	.7875	1.500
0.5533	.8855	1.8460
0.7297	.9720	2.2700
0.9841	1.0860	2.8640

We may also add as of interest to us in this connection the following extracts from Roth's Chemical Geology.

Vol. 1, p. 44, solubility of gases and other substances in water.

Baumert found in the air absorbed by rain water (t=11.4°C; after a long rain) 1.77 volumes CO_2, 33.76 O, 64.47 N, while in atmospheric air there is but 1 vol. CO_2 to 628 of O.

Bunsen says that 1 volume water absorbs at 760 mm (atmospheric) pressure (i. e. about 1 atmosphere):

	At 10° C.	At 15° C.	At 20° C.
O	1.03250 or 1	0.02989	0.02838
CO_2	1.1847 36.4	1.0020 or 33.5	0.9014 or 31.8
N	0.01607 or 0.50	0.01478 0.49	0.11403 or 0.4

Thus more CO_2 is absorbed at low temperatures. The air free from CO_2 absorbed at 23°C consists of 34.91 volumes N and 65.09 O.

Bunsen estimates from the power of absorption the ratio of the gasts in rain water, supposing atmospheric air to be 20.951 O and 79.007 N and 0.042 CO_2, as follows:

	5° C.	10° C (50° F.)	15° C. (59° F.)	20° C.
CO_2	2.68	2.46	2.26	2.14
O	33.97	34.05	34.12	34.17
N	63.35	63.49	63.62	63.69

Under otherwise similar relations the amount of absorbed gas is proportioned to the pressure. Peligot found in 1857 2.4 per cent CO_2 by volume in the air absorbed by rain water.

P. 45. According to Boussingault and Levy 100 volumes of air from a soil not rich in humus and not manured for a long time, contain at least 25 times, that from humus rich soil 90 times, and that from recently manured soils as much as 250 times, as much CO_2 as atmospheric air,—the maximum in 100 volumes of air 9.74.

Pettenkofer found in the ground air of Munich down to 4 meters depth a maximum of 1.838 per cent CO_2.

P. 48. Solubility of Ca CO_3.

Fresenius: 1 part in 10,600 cold or 8,834 boiling water; Graham, 0.0343; Bineau, 0.016 to 0.02; Cruse, 0.036; Peligot, 0.020; Schloessing, 0.0131 in 1,000. If at 15°C water takes up 1 volume of CO_2 (i. e. about 0.2% by increase of pressure and lower temperature more), the amount of carbonate dissolved increases. In water saturated with CO_2 (which does not occur in nature) is dissolved in 1,000 parts of water, according to:

Bischof of chalk	9 to 10
Cossa of chalk of Luneburg (18°,740 mm)	.835
Carrara marble (7.5° to 9.5°, 753 mm)	1.181
Cossa Carrara marble (20.5—22°, 741—746 mm)	.9487
Cossa Carrara marble (26—28°, 737—742 mm	.855
Calcite 12° 754.2 mm	1.217
Iceland spar 18°, 735.1 mm pressure	.970
Precipitated $CaCO_3$ at 18° and 735.1 mm.	.950
Boutron and Boudet (several atmospheres pressure of CO_2)	1.16

According to Warrington at 13° and 747.3 mm. pressure water with 1% ammonium chloride dissolves 1.050 $CaCO_3$.

If to a solution of $CaCO_3$ in CO_2 water $MgCl_2$ is added the solution will stand weeks and can even be boiled without clouding. By continued evaporation magnesium carbonate is precipitated.

According to T. S. Hunt the solubility of $CaCO_3$ is increased also by addition of sodic or magnesic sulphate, because bicarbonates of soda respectively magnesia form.

According to Northcote, 1,000 parts of saturated salt solution contain 1.77 $CaCO_3$.

P. 50. *Magnesia carbonate* is somewhat more soluble in carbonated water than calcium carbonate. Merkell's results are:

In 1,000 parts at 50° C. under a pressure of CO_2 of:

1 atmosphere	2	3	4-5	6
1.31	1.34	7.5	9.0	13.2

Cossa 18°, 750 mm pressure, from magnesite.....	.115
Bischof, 750 mm, pressure from magnesite.......	.049
from pure magnesia............	.135

P. 51. Fresh precipitated magnesia carbonate is quite soluble in a solution of the sulphate and precipitates Ca CO_3 from solution in carbonated waters.

Vol. III, p. 417 Engel and Ville, under pressure of 1 atmosphere CO_2, the solubility varies with the temperatures, 19.°5′ C. 29°.3 C. 82° C. as follows: 257.9, 219.95, 49.0; the presence of alkaline chlorides, sulphates, and carbonates and magnesia salt increases the solubility of magnesium carbonate.

Dolomite. Vol. I, p. 52 Cossa at 18° C. 750 mm. pressure, 1,000 parts of water dissolve:

of dolomite ($CaMg\ (CO_3))_2$...............	.310
Of mesitine $FeMg\ (CO_3)_2$....................	.075
At 16° C, 758 mm carbonated water dissolves of ($Mg\ Fe_3C_4O_{12}$).........................	.115
A. Kupffer, of dolomite	.2967
Siderite $FeCO_3$. Wagner, at 4 or 5 Atm. pressure of CO_2 $FeCO_3$.......................	.725
Cossa 18°, 760 mm.........................	.720
Bischof	.60755
K. von Hauer, usual pressure, iron dust of precipitate	.91

Carbonates of alkalies lessened solubility.

Iron Carbonate.

III, p. 417, J. Ville found in carbonated water..	1.39
E. Ludwig Wilhelm's quelle water............	0.9648

Schloesing worked thus: crystallized pure calcium carbonate was suspended in water and through the fluid air charged with CO_2 passed until gravimetrically no increase in calcium carbonate could be detected. But there is probably an error in calculation, for Schloesing in the strongly carbonated solution, assumes carbonate together with bicarbonate to be present. For instance, he computes:

1. $CaCO_3$ (neutral) according to special tests of solubility	.0131 g in liter
All calcium as carbonate.....................	.360
Difference calcium carbonate existing as bicarbonate	.3469

Accordingly he refers to the three following parts of CO_2:

CO_2 in the neutral calcium carbonate..........	.00576
CO_2 in the bicarbonate......................	.30530
CO_2 free	.09757
	.40863

Caro denies the existence of calcium in carbonate, from the following test. A solution of calcium bicarbonate with excess of CO_2 was allowed to stay exposed to the air until calcium carbonate began to form at the surface, and then the CaO and CO_2 of the clear solution determined. Caro gives the following figures: 5 cm. solution contains:

0.00270 $CaCO_3$ = 0.0015176 + 0.0011924 CO_2, or in grams per kilogram:

0.540 $CaCO_3$ = 0.35352 plus 0.23848 CO_2.

"Total CO_2 was determined by precipitation of 5 ccm. with ammonical $BaCl_2$. The computed CO_2 is 0.0142 gr. (.142 gr. per 100 cm.).

Caro's result is thus: Combined CO_2 = 0.0011924 g., half combined and free = 0.0142 g.

The ratio of two numbers is 1 : 10, which certainly points to the presence of *calcium bicarbonate* and much free CO_2.

A series of tests, Nos. 3 to 12, showed that the three values, partial pressure in per cent at 0° C. and 760 mm. pressure, amount of calcium bicarbonate and free CO_2 decrease together so that when the first and last become zero the total CO_2 is just equal to the amount needed for calcium bicarbonate. From this the conclusion is justified that calcium bicarbonate is a permanent salt in solution, whose solubility is for the mean barometric pressure at Zurich and the temperature of 15° 0.38509 per liter. Two tables and curves are given, showing the solubility of this salt, first as a function of a partial pressure, and second, as a function of the amount of free CO dissolved. We do not repeat the curves, which can be constructed from the table below, of the original figures 5 and 6.

SOLUBILITY OF CaO IN BICARBONATED WATER AT 15° C.=59° F. AND 760 mm. PRESSURE.

In Air.			In Water (parts per thousand).						
Test.	% CO_2.	Pressure of CO_2.	Free CO_2.	Calcium bicarbonate.	Fixed CO_2.	$CaCO_3$.	Ca.	Total. CO_2.	CaO.
1......	100.00	760	1.574	1.872	.509	1.156	.462	2.587	.647
2......	8.94	67.9	1.574	1.872	.509	1.156	.462	2.587	.647
3......	6.04	45.9	.863	1.755	.477	1.083	.433	1.817	.606
4......	5.45	41.4	.528	1.597	.434	.986	.394	1.396	.552
5......	2.18	16.6	.485	1.540	.418	.951	.380	1.321	.533
6......	1.89	14.4	.347	1.492	.405	.921	.368	1.157	.516
7......	1.72	13.1	.243	1.331	.362	.822	.329	.967	.440
8......	0.79	6.0	.145	1.249	.339	.771	.308	.823	.432
9......	0.41	3.1	.047	.821	.223	.507	.203	.493	.284
10......	0.25	1.9	.029	.595	.162	.368	.147	.353	.206
11......	0.08	0.6	....	.402	.109	.248	.099	.214	.139
12......	....	....	....	.385	.105	.238	.095	.211	.133
13......	....	....	....	.385	.105	.238	.095	.211	.133
14......	....	....	....	.385	.105	.238	.095	.210	.133

The data given above lead to the inference that calcium bicarbonate may exist in very dilute solution.

In consequence, it was of interest to determine the electric conductivity of this salt, for Kuster says* that the bicarbonate in very dilute solutions is hydrolytically separated since its solution colors phenolphthalein feebly red. This was found true, but the result of electric tests was that "the conductivity reached no maximum, even in the greatest dilution, as is usually the case with salts that are hydrolytically broken up," and bicarbonate of potash behaved in the same way.

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*Z. Anorg. Chem. 13, 127.

Calcium bicarbonate in solution with NaCl.

From Kippenberger's tests it appears that calcium carbonate is about three times more soluble in concentrated salt solutions than in water. This greater solubility is probably dependent on the formation of double salts. Therefore it was to be expected that these double salts, like Karnallite, would be fully decomposed in dilute solution, so that the solution of calcium carbonate in dilute solutions of salt would be similar to that in pure water, and a similar behavior should be found for the bicarbonate.

Tests performed as for pure water on dilute saline solutions charged with CO_2, which contained 5 grams per liter NaCl, result as follows:

ABSTRACT OF TABLES 3 AND 4.

				0.41	0.50	3.16	6.07	11.47	16.95	%CO_2 at 0° and 760 mm in gas
				3 4	3.8	24.0	46.1	87.2	128.8	pressure of CO_2
.082	.081	.083	.086	.121	.182	.292	.368	.529	.539	Ca
.090	.089	.092	.095	.133	.201	.321	.405	.582	.593	CO_2 corresponding to $CaCO_3$
.205	.203	.208	.216	.303	.456	.730	.921	.1323	1.348	$CaCO_3$
.332	.329	.337	.349	.409	.739	.1183	.1492	.2143	2.184	Bicarbonate
				.003	.027	.135	.235	.1101	1 325	Free CO_2

From this (comparing with tables 1 and 2), it is apparent that the solubility of calcium bicarbonate is but little influenced by the salt.

Figures 7 and 8 of the original paper showed the solubility as function of partial pressure, and as function of percentage of CO_2.

II. Magnesia bicarbonate.

No new principles involved. (Details of experiments omitted.)

1. Without alteration of the partial pressure (of 1 atmosphere CO_2) the CO_2 and MgO remained constant down to experiment 4, when the amount of CO_2 ceased to be enough to form bicarbonate of magnesia with the MgO present.

Fig. 9 and Fig. 10 (should be 8 and 9) showed the solubility of the bicarbonate as function of partial pressure and total CO_2 8 in mg.

The result is that magnesium bicarbonate does not exist by itself without a marked excess of free CO_2 dissolved in the water. The partial pressure needful thereto, corresponds to between 2° and 4° CO_2. If the partial pressure is less, the solution loses all of the free CO^2 with a part of the half combined and a mixture of carbonate and bicarbonate results. When the partial pressure sinks to 0 at

ABSTRACT OF TABLES III. AND IV. (SHOULD BE V. AND VI.).*

.....	....	....	....	....	.003	.014	.021	.033	.060	.062	1.07	1.35	1.54	4.45	.547	18.86	CO_2.............
.....	....	....	....	....	.03	1.1	1.6	2.5	4.6	4.7	8.2	10.3	11.7	33 8	41.6	143.3	pressure.
.518	.511	.520	.529	.536	.545	.566	.594	.655	.788	.865	1.224	1.492	2.016	2.016	2.016	2.016	Mg.
.859	.847	.861	.877	.888	.9 3	.938	.983	1.084	1.305	1.433	2.028	2.471	3.339	3.339	3.339	3.339	MgO.
.935	.923	.939	.955	.968	.983	1.022	1.072	1.181	1.4.2	1.561	2.210	2.692	3.639	3.639	3.639	3.639	CO_2 combined.
.601	.602	.613	.589	.611	.612	.652	.670	.791	1.027	1.101	1.789	2.293	3 236	3.639	3.639	3.639	CO_2 half combined.
.....	....	....	....	....	....	....	....	....	....	....	....	....	....	.035	.866	1.190	CO_2 free.
1.536	1.525	1.552	1.544	1.579	1.595	1.674	1.742	1.972	2.449	2.662	3.999	4.985	6.875	7.3 3	8.144	8.468	Total CO_2......
1.954	1.954	2.036	1.960	2.035	2.036	2.169	2.229	2.632	3.417	3.663	5.952	7.629	10.766	12.105	12.105	12.105	Mg bicarbonate.
.641	.616	.6 5	.702	.685	.711	.710	.771	.748	.758	.701	.807	.765	.773	....	....	....	Mg carbonate.

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* p. 200 of the Zeitschrift.

average pressure and at 15° C, we have 0.6410 grs. magnesium carbonate and 1.9540 grs. magnesium bicarbonate per liter.

References to the solubility of magnesium bicarbonate are very rare. Cossa and Kippenberger assume its presence only when there is much free CO_2. Merkel is cited in Roth.

IV. Sodium bicarbonate.

To close the investigation, the presence of sodium bicarbonate in dilute solution was tested. The phenolphthalein test shows that the bicarbonate little by little gives off CO_2 and the solution becomes stronger in carbonate.

Referring to Kuster's work indicating that sodium bicarbonate, by its effect in turning phenolphthalein red, is decomposed at moderate temperatures, the effect vanishing at 0° F, it is to be remarked that solutions of bicarbonate left long standing do the same, and the effect does not disappear at 0°, which leads to the inference that it has lost CO_2, and a series of four tests show this to be true.

We have given above, all the data we have been able to find on the solubilities of the carbonates for different temperatures and pressures. Now for the actual temperatures and pressures, the map figured herewith (Fig. 19), gives some data as to the mean annual temperatures by the isotherms or lines which have the same annual temperature. Upon the map are also placed the temperatures of certain flowing wells, in degrees Fahrenheit.

It appears that the temperature of ground water is usually not far from 49°, increasing according to the depth of the source quite irregularly, but at times as much as 1° in 40 feet. The farther north a place is, other things being equal, the lower the temperature. But it probably goes hardly below 45°, being more or less above that according to the amount of blanketing effect that the snow exerts, and the depth of the source.

The water of all our deep lakes is cool, and in the bottoms of the deeper lakes it will often be permanently cooler than the ground-water temperature. Hence chemical precipitation can never occur in the lake more than half the year, and it will not occur at great depths. Boglime, however, occurs more in lakes originally deep, than in lakes originally shallow. Still it appears to be generally true that in Michigan the marl is thicker in the shallow water at the margin, and Wesenberg-Lund reports the same to be true in Denmark. This can, however, be easily explained under either theory, that of organic or chemical precipitation. But it is curious to remark that in Indiana the geologist reports* not only a deepening of the marl towards the deeper water, but a more widespread

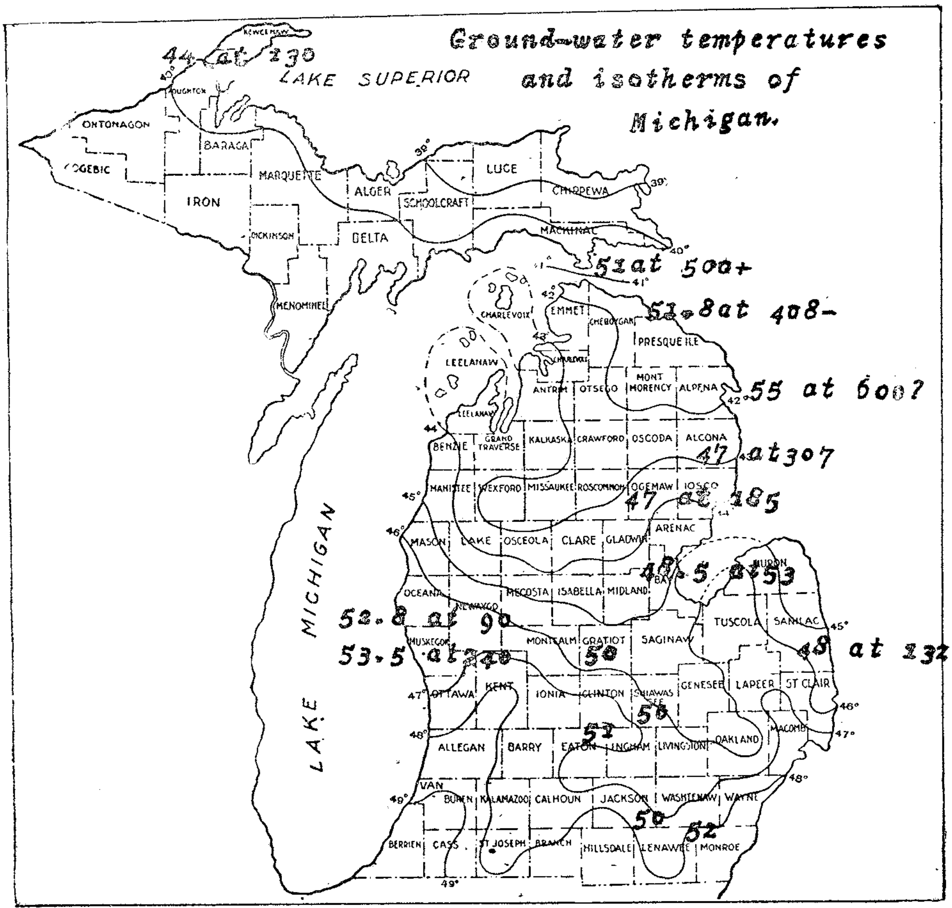

Fig. 4.—Distribution of average mean temperature in Michigan.

Fig. 19. Reproduced from Water Supply paper No. 30, Fig. 4, with some observations on the temperatures of flowing wells.

distribution, a fact which hardly agrees with their theory of the origin of the lime.

Not only will the spring water that enters the lake be cool and under pressure at the bottom so that it will not lose its carbon dioxide nor calcium carbonate there, but as it approaches the sur-

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*25th Annual Report, 1900, p. 45.

face it is liable to be diluted with rain and surface water, which as all tests and[*] analyses show, are far from saturated with bicarbonates[†] and a dilution with only 10% of rain-water would keep in solution all the calcium carbonate of any ground water of which we know. Mr. Hale has pointed out that marl is liable to occur most in the uppermost of a series of lakes, into which presumably less surface water would enter, and this is a distinct point in favor of the theory of chemical precipitation. But it is by no means confined to such lakes. Davis' observation, that in certain lime depositing lakes, the outflow is practically equal to the inflow, does not necessarily mean that the evaporation is too small to be noticed,[‡] but merely that it is nearly balanced by subterranean springs and direct rainfall. It does, however, make it almost certain that there is enough dilution of ground water springs to prevent direct chemical precipitation.

All winter again, the water under the ice is colder than the ground water, and the escape of CO_2 is prevented. There can be no direct chemical precipitation. In the spring the influx of snow water must dilute the spring water and prevent precipitation.

Only after the hot dry weather of summer has evaporated and heated the lake to saturation point could, if ever, precipitation begin, but it seems doubtful if it could get that far.[§]

Considerations like the above had made the origin of the boglimes by chemical precipitation very doubtful to me, even before Messrs. Davis and Hale made it so clear that organic life was the precipitating agent in some cases, at any rate. In fact such doubts led me to suggest to them their lines of work.

Mr. Davis' discovery of calcium succinate $Ca{=}O_2{=}(C_4H_4O_2)$, in Chara, and its lime secretions yield a new test of the origin of the fresh water limes.

Until this very peculiar salt is shown to be formed in some other way, it is a safe presumption that chara, or at least plant life has contributed largely to lime deposits containing it. It is

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[*] See also Water Supply Paper No. 31, analyses 35 to 45, and ante pp. 46 and 118.

[†] While as shown above rain-water selectively absorbs considerable CO_2 from the air.

[‡] If we look at the figures given in the "Meteorological Chart of the Great Lakes for the Season of 1899," Vol. II, No. 9, of the Weather Bureau publications, p. 21, we see that the evaporation must be between 20 and 36 inches, and the precipitation is from 4 inches to 20 inches more.

[§] Yet the number of facts that must be known, accurately, evaporation, ground water supply, surface water supply, temperatures, and co-solubilities under a large range of conditions, prevent our saying absolutely that it could not occur. In fact, in such a case as the marl referred to by Mr. Hale at Corrinne, where the whole lake dries up, it must.

also found that, as Hale has remarked, organic matter always accompanies even the purest marls. Moreover, it seems to be true that in a marl analysis, in which the CaO, MgO, and CO_2 are separately and independently determined, there is never enough carbonic acid to satisfy the caustic lime and magnesia,* even after making all allowance for the presence of calcium sulphate. While in clayey marls it might be supposed that calcium and magnesium silicates were present, in many of the purer ones the effect is too great to be thus explained, and we are forced to believe that we have the lime united to an organic acid, probably this succinic acid.

It is not uncommon in commercial marl analyses to figure from the CaO and MgO the amount of carbonates, and for many purposes this is sufficient, but in such cases the chances are that the amount of carbonates is overestimated and the amount of organic matter underestimated some 2%.

§ 3. Microscopic investigations.

Although it might seem that the subject of the origin of boglime had been pretty thoroughly threshed out, it must be kept in mind that, in view of the number of causes that are competent under proper conditions to throw down lime, no available light should be neglected. It seemed possible that a study of the microstructure of the lime with the petrographic microscope might be an aid. For comparison with them, some artifical precipitates were made for study.

(a) Microscopic precipitate by loss of CO_2 and heating.

I took a sample of water from the flowing well at the end of Hazel street, Lansing, close to the bank of Cedar river.† This well flows into the air about six feet above the usual river level and has about two feet free jet. The depth is 340 feet, but the water doubtless comes in mainly at much less depth. Within half an hour of the time of taking the water, it was heated to the simmering point, when of course the CO_2 was practically lost. A film was seen floating on the top,—not a continuous coating, but a lot of calcite crystals. With an enlargement of 150 diameters their crystalline character was very apparent. Hexagonal outlines were plain. They were not all simple forms, nor always the same form. Rhomb faces and hexagonal outlines were common (Fig. 20), but

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*For instance, the average amount of CO_2 which Prof. F. S. Kedzie found by analysis in thirty marl analyses in which CO_2 ranged from 27.13% to 44.60% was 36.28% while the amount of CO_2 required by the weights of CaO and MgO in the marl was in each case higher, the average being 38.30%, a good 2% more.

†Temperature 50.8° F.

simple rhombohedra were not the prevalent form. In relative dimensions and habit they resemble often Fig. 21 of the Appendix to Part II of Vol. VI of our reports, or figures 11 and 13 of the calcite illustrations in Dana's System of Mineralogy. Though they are too small (about 0.02 mm) to be exactly determined, the prism or a very long scalenohedron, and the terminal rhombohedron—½ are quite probably present. The optical properties leave no doubt that they are calcite. When transmitting the ordinary ray they

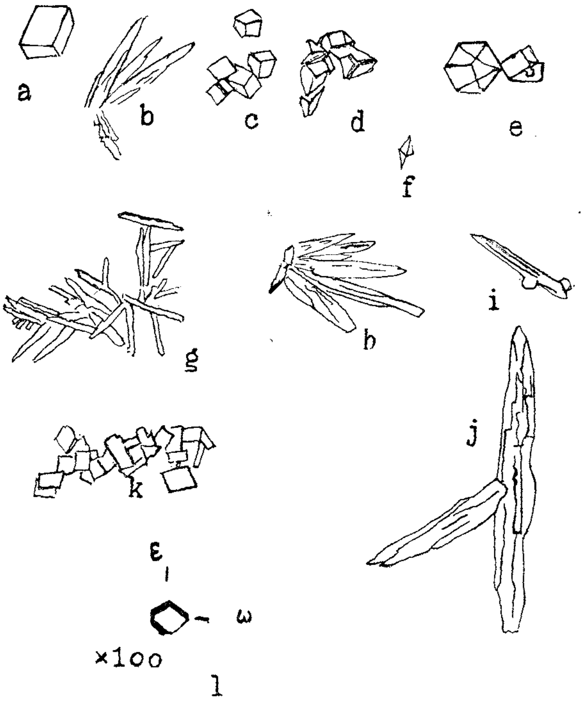


Fig. 20. Crystals produced by evaporation.

have much higher refraction than that of the balsam used for mounting (n=1.521), while with the extraordinary ray their index is very close to that of the balsam,—just a shade less, as it should be. (1.49) The directions of + and — extinction parallel to the diagonals of the rhomb faces are characteristic (Fig. 20). One twin with the twinning face probably—½ was observed. In mounting these crystals a second crop was formed as the water around them evaporated, considerably smaller, being half or quarter the size, and spindle-shaped, like dog-tooth spar (Fig. 20f), and the forms illustrated on Plate XI of the Appendix to Vol. VI, Part II, and Dana's figures 15 to 20.

No marl seen consists to any considerable degree of similar material. Had it been present in quantity, I do not think I could have failed to recognize it. It must be said, however, that every marl had been more or less dried, and therefore a certain amount of secondary chemical precipitation from the hard water of the lakes was to be expected. As a matter of fact, I noticed no material that need necessarily be ascribed even to this source.

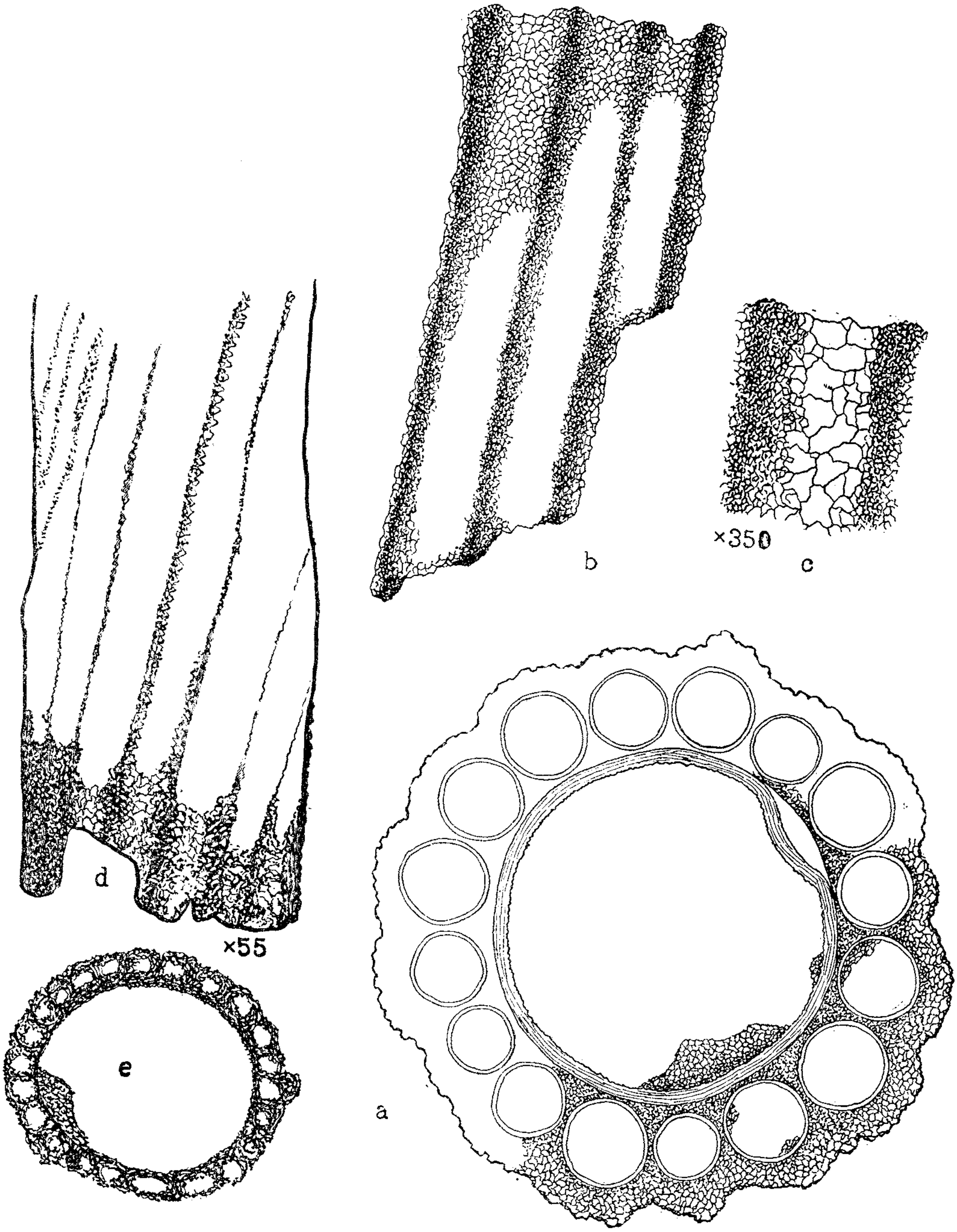
(b) Precipitate by evaporation.

I also allowed drops of water of the artesian well used in the Hollister block (which is 150 feet deep in white sandstone of the coal measures and probably similar in chemical character to the previous well and analyses Nos. 238 and 239 of U. S. Geol. Sur. Paper No. 31), to evaporate. In one drop the dimensions of the larger crystals are about 0.005 mm and less, about a three hundredth of a millimeter. In so minute crystals it is hard to measure angles accurately, but it appeared that a termination of the fundamental rhombohedron was combined with prismatic or acute scalenohedral faces.

In Figure 20, groups a to j were drawn by C. A. Davis from some Alma well water. I think that b and g, h, i, and j, are groups of gypsum crystals, while a, c, d, e, and k, appear to be mainly rhombohedral calcite, and f is plainly a scalenohedron. In l we have a crystal drawn by myself with the cameralucida with some pains to get the angles right, and the optical orientation indicated. The contrast in relief brought out by rotating the crystals immersed in balsam above a single nicol is very striking and characteristic.

(c) Chara fragments.

The calcareous Chara stems have a hollow core surrounded by a single slightly twisted row of elongate cells. The diameter is commonly about half a millimeter. The lines between the cells are continuous and produce the effect of slightly spiral ribs. This is shown in Fig. d of Plate XVI. Fragments of chara therefore, like figures b and c appear ribbed. Close to the ribs the granulation of the calcareous aggregates is very fine, while between it grows coarser,—up to 0.02 mm. The boundary between the various areas or patches of uniform polarization color appears vague or crenulated. This interdigiting effect or crenulation is especially shown



MICROSCOPICALLY ENLARGED FRAGMENTS AND SECTIONS OF CHARA.

in c, and sometimes needs the use of crossed nicols to bring it out. Even very small fragments show patches of different polarization colors. Sections a and e are cross-sections of chara stems drawn by Mr. B. O. Longyear and myself. Such sections are hard to prepare and seem never to occur accidentally. The other sections b to d are such as will ordinarily be found in looking at a sample of marl.

(d) Blue green algae.

The apparently calcareous pebbles which are really concretions of calcium carbonate thrown down or out by Schizothrix, have already been described by Davis. Similar pebbles are noted as occurring in the marl in certain horizons at Goose Lake, from which the Peninsular plant take their marl. The pebbles in marl referred to in the discussion of Prof. Fall's paper before the Engineering Society are probably similar, and the calcareous coating on dead branches and shells also. The "pebbles" on the southeast side of Zukey Lake at Lakelands, which turn brown on the side exposed to the light, are of the same nature.

A cross-section of such a "pebble" or concretion shows a faintly radiating structure. Under the microscope I have not been able to discern this, but instead, there appears to be a cloudy aggregate of irregular calcite, not sharply crystalline nor coarse grained, not over a hundredth of a millimeter at the outside.

There is not very much that is characteristic about it, and very much of the commercial boglime deposits is precisely similar.

Near the Cottage Grove Higgins Lake resort, not only are the upper sides of pebbles overgrown with warty deposits of these algae, but the bottom sand is cemented in a layer about 3 mm thick, brown on the upper side and greenish on the lower.

(e) Shell structure.

The shells which occur in the boglimes are as Walker's list shows, mainly (bivalves) pelecypods or gastropods (snails). Whatever the genus, and whether the structure be foliated or prismatic, aragonite or calcite, the ground up shells should show, and do as a matter of fact show a fibrous structure under the microscope. Larger pieces are commonly composed of bundles of fibres, more or less opaque, owing to the interlamination of material of different refraction. The direction of extinction is usually either parallel or varies according to some law, and there is a pronounced organic structure which can hardly be mistaken, but which varies of course, according to the species. I do not think, however, that any considerable amount of such material could escape detection under the microscope. It generally forms an unimportant part of the commercial marl or boglime deposits.

(f) Limestone flour.

What is called clay in Michigan, is, so far as the glacial clays are concerned, more properly rock flour, and contains a great deal of finely divided quartz and other minerals, being by no means merely a hydrous alumina silicate. Inasmuch as the limestones and dolomites form a large part of the subsurface or bedrock of the State, and of Canada to the northeast, the almost universal presence of lime in the clays, which are thus rendered properly marls, is quite natural. Now it is not inconceivable that, as Mr. Parmelee has suggested, in a region of limestone rocks sedimentary clay-like deposits might form, aided perhaps by the greater weight of the carbonates, in which lime would predominate to almost any extent. Such clays as the following analyzed by Prof. Fall, from Alcona county are very largely limestone, though in them magnesia is present in quantity, and this we should expect would be generally true. A typical till clay from the old brickyard southeast of Harrisville, Alcona county, containing some small limestone fragments, is composed as follows:

Free sand	11.53	11.53	Sand.
Combined silica	25.71		
Oxide of aluminum	7.08		
Oxide of iron	3.99		
Organic matter, basic water	3.46		
Difference chiefly alkalies	2.60	42.84	Clayey matter.
Calcium oxide	1 .70		
Magnesium oxide	6.52		
Carbon dioxide	21.00	45.22	Limestone.
Sulphur anhydride	0.41	0.41	In pyrite or gypsum.
		100.00	

Examined under the microscope, such clays, which as we see are nearly half limestone flour, show a good deal of material which is almost indistinguishable from the alga deposits or the commercial marls. But the material is in general, more brown and opaque, contains more or less angular quartz, and almost always fragments of limestone which are over 0.01 mm in diameter,—frequently 0.05 to 0.08 and larger. Such fragments are absent in the marl, and this is the best distinction I can at present make. This is not very satisfactory. It seems quite possible that there might be quite an amount of sedimentary lime material in a bog lime, before we could separate it microscopically from materials of another origin, organic or otherwise. It seems likely that the rise in magnesia to which Hale refers is fully as sensitive a test of the admixture of clay marl in a boglime as microscopic examination. The calcareous clays become much harder when dry, and even when wet again, only very slowly break down.

§ 4. Conclusions.

It appears, therefore, that any appreciable mixture of lime sediment does not produce the quality of bog lime which is desired for Portland cement manufacture. While a continual accumulation of boglime or marl requires a continual supply of lime which is furnished in the hard water of the springs, yet the animal and vegetable life of the lakes never allows this to accumulate to the point of chemical precipitation of the bicarbonate, but it is deposited through organic processes. In this the Characeæ play a conspicuous part, especially in the purer marls. More minute algae may have, collectively, greater and more widespread importance. In fact, microscopic examination seems to indicate this. The role of animal life is usually quite subordinate.

Notes on the microscopic examination of the different marls will be found in connection with the description of the different deposits in the next chapter.

CHAPTER IX.

LIST OF LOCALITIES AND MILLS.

§ 1. Introduction.

The object of this chapter is to give as full a list as conveniently could be made both of the Portland Cement mills actually at work and the materials that they use, and also of the plants that have been planned and materials prospected as well.

In description of the manufacturing plants, it must be remembered that the interest of the geologist is in the first place in the raw materials, and for farther discussion of the details of manufacture we must refer to Lathbury and Spackman of Philadelphia on engineering practice, the Detroit Journal of Wednesday, April 16, 1902, the nineteenth annual report of the Labor Commissioner, and professional journals like Cement, Cement and Engineering News, Stone, etc. Still we cannot thoroughly treat the raw materials without also considering the processes of manufacture to which they are adapted. We have also thought it would add considerably to the value of the report, to add a few statistics, for which we have to thank the Secretary of State and the Commissioner of Labor, to whose department such matters belong. A large amount of material is derived from the printed circulars and prospectuses of the various companies, or private correspondence with the same. It is, however, almost wholly from signed reports of reputable engineers, and is duly credited. Occasional comments which may be helpful by way of comparison are added.

Alpena Portland Cement Co.

Organized Aug. 9, 1899; capital, $500,000. The officers and directors of the company are: F. W. Gilchrist, president; William B. Comstock, vice-president; George J. Robinson, secretary; A. M. Fletcher, treasurer; W. H. Johnson, auditor; John Monaghan, C. H. Reynolds, Water S. Russell, J. H. Cobb, attorney; F. M. Haldeman, superintendent. Mill located just east of Alpena on the shores of Thunder Bay. A thousand foot pier gives water transportation, and the Detroit and Mackinac R. R. also runs to the mill. This was the first mill using limestone for the calcium instead of bog lime. It is the Alpena limestone close to the mill and belongs in the Traverse group, and corresponds somewhere nearly to the Encrinal limestone of the Hamilton of New York State. Not all of the bed is equally pure, however, and Dr. A. W. Grabau, who has made a particular study of the conditions for us, reports that the old coral reefs which occur in the bed furnish the purest calcium carbonate.* This is a very important result, for these coralline parts are easily recognized. The limestone is also used, especially the purer part, for the purification of sugar, and the report of the beet sugar chemists confirms the analyses of the local chemists, that at times the limestone is practically pure $CaCO_3$. This is one of the plants which have the advantage of using a local shale clay.

"The raw materials are very economically handled. The clay brought from the beds to the north is piled in great bins in the clay storage house. This house is 225 by 60 feet in dimensions and will hold clay sufficient for 60,000 barrels of cement. From the quarries to the plant, a distance of 800 feet, tracks on which are run cable cars are laid through the clay shed. Here, each car of rock, as it passes through, is weighed, analysis having been made, and the correct amount of clay is added to make a perfect cement mixture. The cars then run to the mill and their contents are dumped into the crushers.

"The materials then pass through the crushers, rolls, ball mills and tube mills automatically, being ground finer and more thoroughly mixed during each process. During the wet grinding process, water is added in the ball mills and the final and finishing mixing is done by the tube mills, which contain imported flint pebbles. The action of these against the wet mixture, produced by the revolutions of the mill, reduces it to a slurry. Then the mixture passes into correction tanks, from which samples are taken by the chemists and tests are made to guard against error. The contents of each tank are corrected before the slurry is allowed to leave it. There are 12 mixing tanks, each 14 by 16 feet high and with sufficient capacity to each hold enough slurry for 250 barrels of cement.

"This mixture carries about 33 per cent of water which makes the resultant process better. Marl and clay mixture must necessarily carry a higher degree of moisture than with the dry process. The kiln capacity is much greater where lime rock is used,

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*Annual report for 1901, pp. 174 to 191, especially page 178.

as there is less water to drive out of the material before it is calcined. At Alpena the rotaries each have a daily capacity of from 140 to 150 barrels of cement as against 100 by those using marl.

"From the storage tanks the slurry is fed into the rotary kilns. The fuel used in these kilns is powdered coal, prepared by drying and grinding, and is fed into the kilns by an air blast. The kilns are taken care of by experienced burners. From the kilns the cement clinker is discharged into conveyors and carried to the clinker room to cool. Six rotaries are in constant operation and the daily capacity reaches 1,000 barrels of cement. From the clinker room the material passes to the grinding machinery, consisting of rolls, ball mills and tube mills—the chemist takes the ground cement at this point and tests it for fineness, after which it is conveyed to the stock house, which has a capacity of 50,000 barrels, where it is allowed to season and then packed for shipment. Before shipment the chemical department makes a thorough test of the finished product for specific gravity, constancy of volume, soundness, tensile strength and setting time, and the cement is shipped only as certified by them to be in proper condition for immediate use.

"The dimensions of the various buildings are as follows: Stock house, 240 by 100 feet, making about 24,000 square feet of floor space; mixing and kiln building, 259 by 105; cement grinding room, 190 by 105. In addition to these there is a thoroughly equipped cooper shop, machine shop and round house."

Although they are not at present using the bog lime it may be of interest to give the analysis of it as well as of their shale. It comes from Middle Lake, on Sec. 18, T. 32 N., R. 9 E., about seven miles north of the mill, where the company own a thousand acres tract including also their shale clay beds.

BOGLIME.

Calcium carbonate	92.91
Magnesium carbonate	1.89
Silica	tr.
Ferric oxide	0.53
Alumina	0.21
Sulphuric anhydride	tr.
Organic matter	.80
Water, etc.	2.01
	99.87

CLAY SHALE.

CaO ($CaCO_3$ = 4.48)	2.51
MgO	.65
Silica	61.09
Ferric oxide	6.78
Alumina	19.19
Sulphuric anhydride	1.42
Water and CO_2	5.13
Potassium oxide	1.80
Sodium oxide	1.36
	99.93

Some of these shales and clays around Alpena will doubtless make good face and even paving brick.

The rocks around Alpena have been quite fully described by A. W. Grabau* in the Annual Report for 1901, and will before long be subject of a monograph by him.

Omega Portland Cement Co.,

Organized Feb. 18, 1899; capital, $300,000; Jonesville, Hillsdale Co. The officers were: Frank M. Stewart, president; Israel Wickes, vice-president; Chas. F. Wade, secretary-treasurer; George H. Sharp, superintendent; Homer C. Lash, chemist.

The following report was prepared for us by W. M. Gregory, and was printed in the Michigan Miner for May 8, 1901, Vol. 3, No. 6.

The Omega Portland Cement Company, of Jonesville, Hillsdale County, Michigan, with a plant at Mosherville, owns extensive land tracts in Section 15, Township 5 south, 3 west. The plant stands near Cobb's Lake, on the Fort Wayne branch of the L. S. & M. S. Railway. This lake is one of a series of small lakes at

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*See especially pages 175 to 190.

the headwater of the Kalamazoo River. In the near vicinity are Hastings, Johnson, and Mosher's Lakes, and many large areas of marsh. All by actual tests and explorations have been found rich in marl deposits of an excellent quality. The immediate topography of the land in this region is rolling and hilly, this being in the locality of parallel morainal ridges deposited by the ice fronts as it retreated to the north. The clay loam forms a storage basin for the lakes—three to four miles is the average distance from the crest to crest of the valley which holds this lake chain. The valley sides are gently sloping and in places covered with sand. This region of meandering creeks, sluggish rivers and plant choked lakes was formerly considered valueless and even hindered farming interests. The discovery of marl has been the means of making a busy little village in the midst of what was once worthless soil. This is only a type of what is occurring in many places in our State. Northeast of Jonesville there are many lakes of this same character. Already at Woodstock a 600 barrel plant has been erected, and a prospective plant is in consideration at Grass Lake. Near Hanover, Moscow, Duck Lake and Addison Lake are lands rich in marl deposits. At Coldwater, Quincy, Bronson, Union City and Sand Lake extensive deposits occur and four of these places have successful plants in operation. Spencer Lake, some miles east, has also a marl bed. This region within a radius of less than fifty miles is especially favorable for extensive cement manufacture because of the abundance of marl and clay. A few words concerning the lakes in this region: They are all elliptical in shape, and on the southern shore are low morainal ridges which extend northeast to north; in many cases partly enclosing the lake. A mile is the greatest length and one-half mile is the average width. The most valuable marl deposits occur in the deepest lakes, and in fact no extensive amount occurs in any of the shallow lakes, and in such cases the sand renders the marl valueless, as some of our manufacturers have found by experience. No large inlets are known to exist in lakes with an abundance of the deposit and as a rule the outlet is plant choked. The water is in the greatest part derived from the underlying Marshall sandstone.

The plant of the Omega Company has a daily capacity of 700 barrels. The buildings are of brick and steel, and the storage house of cement concrete. The power house is 80x160 feet, containing a 750 horse-power engine, air compressors, pumps, dynamo, etc. The largest building or wet end department is 80x200 feet, and here the handling of marl and clay takes place. The marl is taken from the lake, which is 400 feet east of the mill, by a large steam dredge, and the beds of marl run to an average depth of 50 feet. The lake is one-half mile in length and one-quarter mile wide, being filled along the shore with much plant material. At the center of this lake a depth of 40 to 60 feet is found. For convenience in handling the marl the lake has been slightly lowered by dredging the outlet.

The slimy marl taken from the lake bottom by the dredge is deposited in horse cars, skips or buckets, with a capacity of one cubic yard, and drawn to the conveyor shed, 30x130 feet, where the marl is elevated and conveyed by trolley and by automatic dump in skips dropped into the stone separator, which disintegrates the marl and relieves it of all sticks, grass and stones. In this building the clay, which is shipped in from Millbury, Ohio, is pulverized by passing through a dry pan, dried and weighed, and elevated to the mixing floor, where with the marl coming from the stone separator is mixed with the clay, forming a mud or slurry and passes to the pug mills.

The Omega Company also have a clay bed one and one-half miles northeast of the works, which matches the clay brought from Millbury, and which they use at times when weather and roads will permit of transportation economically.

ANALYSIS OF MILLBURY CLAY.*

SiO_2	64.85
Al_2O_3	17.98
Fe_2O_3	5.92
CaO	2.24
MgO	1.40
Volatile matter	4.98

It would seem quite possible that some of the shale outcrops near Reading, or south of Jackson, would furnish suitable clay. Clay taken from the surface, if free from sand, is more apt to

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*Compare other analyses of this clay elsewhere given, e. g., those made by J. G. Dean at the Peninsular plant at Cement City, and those given by Prof I. C. Russell in his report in the 21st Annual of the United States Geological Survey.

prove satisfactory for cement manufacture, as it is easier to mine and freer from lime than a lower strata. The manufacturer wishes a clay low in lime.

Slurry is carefully watched and tested at the Omega plant, and no trouble has been encountered through presence of sand in the marl or clay. After leaving the disintegrating pug mills, the slurry passes into vats and is pumped up to an elevated tank, where it is again screened and runs by gravity to the mixing and grinding wet tube mills, these mills being lined with wood and one-half filled with Greenland flint pebbles. After the material has passed through these mills it will all pass a sieve of 10,000 meshes without residue. The object in very fine grinding is the attainment of the most intimate admixture possible of the clay and marl, so that the heat will quickly produce incipient vitrification. Slurry is then passed into large storage tanks and from these passes by gravity as needed into vats at rear of the five 60-ton rotary kilns; these are 60 feet long and six feet in diameter: the shell being made of extra heavy boiler iron, lined with aluminate brick. The slurry is pumped from vats and forced into the end of the rotary, the rotaries being set on an incline of one-half inch to the foot. The department containing the rotaries is 80′ x 100′. The rotaries are heated to about 2,900° F. by means of a gas flame generated by a continuous blast of powdered coal; the slurry while in the kilns is subjected to temperatures varying from 1,290° F., at which CaO, SiO_2 is formed, to 3,000° F., where CaO, Al_2O_3 is formed. The calcined product of the kilns is termed clinker and has the following analysis:

SiO_2	22.24
Al_2O_3	7.26
Fe_2O_3	2.54
CaO	64.96
MgO	2.26
SO_3	.41
H_2O and CO_2	.33

The clinkers, if good, have a lava-like texture, being somewhat porous and with a greenish black bronzed color. Too much clay is shown by a tendency to give a flaky powder on cooling. An excess of lime gives a clinker of great hardness with a glassy black luster, or a fractured surface may show white specks of free lime. The excess of lime is very injurious to cement, because caustic lime expands in slaking and will disintegrate the cement mortar and produce "blowing." Too much silica will cause the clinker to crumble. Iron imparts a bluish black color and tends to produce fusion in the presence of heat.

The building where the coal is prepared for use in the kilns is 52 ft. x 68 ft. in size, and contains a preliminary crusher, dryer, preliminary pulverizer and two German tube mills for finishing the product. The coal is pulverized to pass sieve of 10,000 meshes with not over two per cent residue. On an average three cars of coal are used per day and all is prepared in this special way for use and conveyed by blast from fans into the kilns. The composition of the coal is an important factor, as an abundance of sulphur or iron pyrites is a damage to the quality of the cement, and the percentage of ash in the coal is also an important factor, and coal must be analyzed each day.

PITTSBURG COAL.

Moisture	1.00
Vol. matter	39.37
Fixed car.	55.82
Ash	3.81
Sulphur	.92

The coal item in the expense of manufacture is a large one, and if Michigan coal could be used it might lessen the cost, but as yet its use has not been successful in this plant. After the clinkers are properly burned they pass from the rotaries to the cooling and grinding department.

The grinding mills are of the ball and tube mill patterns of German manufacture; the fine grinding of the clinker is one of the essential elements of cement manufacture. The following are some of the tests of the Omega brand:

THE OSBORN ENGINEERING CO. (INCORPORATED). CLEVELAND, OHIO. CEMENT TESTING DEPARTMENT.

Report No. 2. Records, p. 89. Reports of Tests of Omega Portland Cement. Samples received from John Laylin, City Engineer, Norwalk, Ohio. Reported to John Laylin, Sept. 6th, 1900.

Fineness, Activity, Constancy of Volume.

Brand or Mark.	Fineness.		Rate of Set.		Result of Pat Tests.		
	Per Cent Passing Sieve No. 80.	Per Cent Passing Sieve No. 100.	Initial. Hrs. Min.	Final. Hrs. Min.	Hot Test.	Cold Water.	Air.
Omega........	99.8	99.5	2-10	4-10	O K Boiling Test O K	O K	O K

Tensile Strength in Pounds per Square Inch. Results given for Tests of Sets 3 of Briquettes.

Brand or Mark.	Proport's by weight.		Per Cent of water.	Age, 24 Hours.			Age, 7 Days		
	Cement.	Sand.		Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.
Omega..................................	neat		22	384	322	361	683	550	601
"	1	3	11	....	....	....	339	263	298

We certify that the above tests were carefully made.

THE OSBORN ENGINEERING CO.,
By BERNARD L. GREEN.

It is said that 98% will pass a sieve of 10,000 meshes to the square inch, and that briquettes possess a tensile strength of 400 to 700 pounds when one week old and 500 to 800 pounds when one month old.

In the season of 1900 it produced 54,500 barrels, in 1902, 120,000 barrels.

The following are three analyses by Mr. W. H. Hess from the Cement and Engineering News for February, 1900:

	1	2	3
Silica	39.53	58.24	68.21
Alumina	11.46	20.56	18.64
Iron oxide	4.59	5.68	5.32
Calcium oxide	13.78	0.61	0.22
Magnesium oxide	5.19	9.24	9.16
Sulphur anhydride	1.62	9.91	9.12
Difference, carbon dioxide, organic matter, water, etc.	23.83	15.49	7.33
	100.00	100.74	100.00

In No. 1, which is of the surface clay type, the calcium oxide would mean 24.63 per cent of the carbonate, and similarly 19.84 magnesium carbonate, or 35.47 carbonates, which would leave from the "difference" about 7.33 for organic matter, basic water, alkalies, etc.

Peninsular Portland Cement Co.

Organized June 24, 1899; capital, $875,000. The office of the company is at Jackson, and Jackson capital is largely interested, but the plant is in the northwest corner of Lenawee County at Woodstock, on the L. S. & M. S. R. R., and Cement City on the Cincinnati Northern, the latter town site having been platted by the company. The officers were: W. R. Reynolds of Jackson, president; C. A. Newcomb of Detroit, vice-president; W. F. Cowham, secretary and manager; N. S. Potter of Jackson, treasurer.

The capitalization was half 7% preferred stock to be returned in 5 years. The net cost of manufacture was estimated at 80 cents.

The output when I visited it in the fall of 1901 was about 700 barrels a day. The following notes are from my visit and information kindly furnished by Mr. J. G. Dean, then chemist.:

The plant is located on the borders of Goose Lake not far from the northwest corner of Lenawee County.

The marl is dredged from the water of the lake, and forced through a pipe line into the marl tanks, where it is stirred and allowed to flow slowly into the mixers. While in transit the clay, which comes from Millbury, Ohio, is incorporated in the right proportions by an Archimedean screw. From the mixers it passes into the slurry tank, thence into the rotary roasters, in which a coal dust blast gives the heat. The coal is high in volatile matter and low in sulphur. At the lower end of the rotary it drops as a clinker and then passes into the grinder where it is reduced to powder, by being rattled with flint pebbles brought from abroad (France and Greenland). Experiments with Michigan pebbles have proven entirely unsatisfactory. The plant is producing about 700 bbls. a day with six kilns, and is beginning enlargement. The company owns a number of marl lakes in the region besides, but Goose Lake is the one which they are now using. It lies in an east and west deep trough, 60 feet or more, below the adjacent county. This trough to the east crosses the line of the Cincinnati Northern in a wide valley or open swamp, probably largely underlain by marl, and is said to extend up into Jackson County to the northeast. The outlet of the lake is to the west and the trough extends there also.

This trough appears to be not merely superficial, but to extend to the rock surface also, for in the village of Cement City half a mile north of the plant one has to put down a well but 8 to 11 feet to encounter sandstone and shale, while in the lake 60 feet below, soundings even 80 feet deep are said to be sometimes still in marl. Elk horns are said to have been found 30 feet down.

Not far north on Sec. 19, T. 4 N., R. 1 E., in a low swamp about the same distance below the high flat-topped hills as Goose Lake there is a drilled well (t. 50° F.) flowing. It is quite likely, therefore, that as seems often the case around marl lakes there is an upward artesian pressure of the ground water. It will be noticed that this lake conforms to Hale's rule that the marl lakes tend to lie in deep depressions.

The water is also hard, as is shown by the following analysis by Dr. Hodge:

	Grains per U. S. Gallon.	Parts per thousand.	
CaO	6.410	.110	$.101CaO + .079CO_2 = .180CaCO_3$
MgO	2.562	.044	$+ .048CO_2 = .092\ MgCO_3$
$Fe_2O_3Al_2O_3$	tr	tr	
SiO_2	.203	.003	
SO_3	.800	.014	$+ .009CaO = .025CaSO_4$
CO_2	6.275	.107	
Alkalies etc.	.220	.004	
Residue	16.470	.282	

Now in this analysis it is noteworthy that after supposing that all SO_3 is combined with CaO and that and the MgO is combined as carbonate, there is not enough CO_2 (.107—.048=.059 instead of .079) to satisfy the calcium oxide. This perhaps indicates some organic salt of lime, for instance the calcium succinate discovered by Davis.

Another point is that the water, as will be seen by reference to Treadwell & Reuter's paper, is almost or quite saturated with lime and magnesia. The sample was taken over the marl bed, directly at the mouth of the intake ditch.

A third point of interest is the higher ratio of MgO to CaO than in marl or clay. This indicates that the water is of a residual nature, left after the deposition of the marl. The company own a clay bank about two miles west of the plant, on the north side of the hollow in which the marl lies. They have not used it for cement manufacture, preferring to use Millbury Ohio clay of the composition of Analysis 1.

	(Average of 50)				
	1	2	3	4	5
SiO_2	61.06	67.06	55.26	58.85	45.27
Al_2O_3	18.10	20.50	23.34	18.36	8.33
Fe_2O_3	6.65	2.52	2.52	7.16	4.84
CaO	1.29	.94	4.15	1.18	15.99
MgO	.53	tr.	tr.	1.98	
SO_3	1.05	tr.	2.00	.38	
H_2O and organic matter	9.20	8.01	11.40	8.13	
Difference, alkalies, etc.	2.12	0.97	1.33	2.96	
	100.00			100.00	

Analyses 2 to 5 are of local clays,—No. 2 from under the marsh, No. 3 a surface yellow clay probably leached of much of its lime,—No. 4, also from the top of the bank, with a low per cent of lime, while No. 5 is a partial analysis of the clay 8 feet down in the bank. A similar relation of clay analyses is very widespread and will be noticed in many other sets given in this volume. From such analyses it is probable that the ground water leaches out the carbonates unequally, preferring the magnesia, and by comparison with the following marl analysis we see that the agent which throws down the marl decidedly prefers the lime, so that there must tend to be a concentration of the magnesia in the water:

ANALYSIS OF GOOSE LAKE MARL.

CaO	51.56
MgO	1.26
SiO_2	0.22
$Fe_2O_3Al_2O_3$	0.76
Volatile matter, etc.	46.20
	100.00

The marl abounds in shells which have been determined by Mr. Bryant Walker in his paper elsewhere given, but Chara is also found in the marl. As bearing on the origin of the marl it is worth noting that at times streaks of material which dredgers would call sand or gravel are struck. This proves, however, to be pure calcium carbonate and is probably largely composed of the Schizothrix aggregates which are elsewhere described. They tend, however, to settle in the slurry and cause trouble. The marl is said to range from 10 to 42 feet thick, and the lake is half a mile wide and a mile and a half long, the deposit of marl being over 300 acres. Besides this lake other lakes in the neighborhood are owned by the same company. It is said that the average of over 200 borings ran 96.12% $CaCO_3$ and less than 1% Mg.

Peerless Portland Cement Co.

Organized Aug. 23, 1896; capital, $250,000. Oldest of the recent plants. First operated as a vertical kiln plant, as when visited by Hale and Ries, and when the view given in Plate III was taken; it has recently been remodelled to the rotary kiln.

The officers of the company are: A. W. Wright, of Alma, president; S. O. Bush, Battle Creek, vice president; J. R. Patterson, general manager; Wm. H. Hatch, secretary and treasurer; directors, the above officers, with W. T. Knowlton, Saginaw. It is a close corporation, and the stockholders are few.

The plant is located at Turtle Lake near Union City close to the line between Branch and Calhoun Counties.

Six hundred and seventy-five acres of marl land are owned by the company, and is reached by means of a little railroad. The marl is found upon the surface, and is so dry that water has to be added when it reaches the plant. The marl is almost entirely free from organic matter and is very readily worked. By means of a bucket dredge, operated on a track, the marl is dug and lifted into the dump cart.

To obtain the marl thus dry the level of Turtle Lake, "which had been twice lowered before, the last time in 1873," but still stood 22½ feet above the St. Joseph River, was lowered some 14 feet.

From the Detroit Journal of April 16, 1902, we cite the following account of the changes in the manufacturing plant:

"Intermittent vertical kilns were first installed by the company. These kilns were charged, then lighted and burned out like a limekiln. From a distance of three miles the marl was first hauled to the plant in wagons, then it was mixed with clay in a pug mill and made into bricks. These bricks were first dried in a drying kiln, then piled in the burning kilns with alternate layers of coke. After being burned the clinkers were drawn off and ground. The process was necessarily slow, as compared with that in use the present day. Two years ago another change was made in the mill and Dietch Continuous Vertical Kilns installed. In these kilns the mixture was charged at the top and the clinker drawn off at the bottom. Still progressing the company decided last fall to construct a modern cement mill and to that end hundreds of workmen have been engaged all winter in the erection of a model cement plant. Many entirely new features have been introduced into this mill, and right from the start an output of 1,200 barrels per day is confidently expected from the eight 70-foot rotaries. Two hundred thousand dollars is being expended upon this plant.

"Beds of both plastic and clay shale owned by the company are located within a mile of the mills. The shales belong to the Coldwater formation.

"The cars of marl are pulled up an elevated tramway on the track scales where the marl is weighed, and then the clay is added before being dumped into the stone separator. From there it goes to the pug mill and then into a large tank where through return pipes the mass is kept running continuously in order to obtain a uniform mixture. It is corrected at this point by the addition of the proper amount of clay or marl determined by the chemist. From these tanks the mixture is pumped into the wet grinding tube mills and then falls into great floor tanks of concrete. In the bottom of these tanks a continuous screw conveyor forces the slurry into mammoth concrete correction tanks. These tanks are the source of just pride to the engineering force of the company. They are constructed entirely of concrete and are 22 feet deep by 22 feet wide and 22 feet long. The slurry in these tanks will be agitated by compressed air. The clay is prepared by being first dumped into a dryer and then ground in a Williams mill.

"The great rotary room is undoubtedly the most interesting part of the plant. Some innovations are here introduced that will materially increase the output of each rotary. The inventions are the product of advanced thought and the broadest of experiments. The rotaries are seventy feet long, being ten feet longer than the largest rotaries in any Michigan mill. The pulverized coal, to feed the rotaries, is prepared in a separate building where the most improved coal grinding machinery has been erected. The Peerless company has placed devices on the rotaries from which the waste heat from the kilns is utilized in drying the slurry before it enters the kilns. This is automatic and is said to increase the capacity of each kiln to a marked degree. The rotary room was constructed on a side hill and this has proven especially advantageous, as it saves the handling of the clinker as it leaves the kilns. Under the clinker end of the kilns has been constructed a retaining wall and in this room, 21 feet below the kilns, are the foundations for the eight automatic Wentz clinker coolers, which are being erected so that the hot clinker falls directly into them. By this device the hot air is fanned off of the clinker and driven back to aid in reducing more slurry to a calcined state.

"As the clinker drops from the coolers it is conveyed along the floor to the rolls and from there into eight Griffin mills and then into two large tube mills for the finishing process. As the cement leaves these mills it is elevated by belt and tripper arrangement to the top of the three-story warehouse and there dumped into hopper bins. These bins are two stories in height and are constructed of the best Kentucky oak, the huge pillars not depending upon the walls of the building, the construction being entirely within itself. As the cement drops from the third to the second story bins it is turned over and from there goes to the packer. The old and the new warehouses, which extend along the Michigan Central tracks, have a capacity of 100,000 barrels. It will be seen that the company is amply provided for winter storage. At the track, coal can be unloaded and elevated to the boiler room of the plant.

"The power plant promises to be one of the finest in the state. Four Scotch Marine internally fired boilers will furnish steam for driving a 500 horse-power Hamilton Corliss engine, a Fitchburg Tandem Compound 450 horse-power, and a 300 horse-power simple engine. Rope drives will be used in part of the plant. Twenty electric motors are being installed and electrical transmission used to advantage in driving the gear of many of the machines."

Bronson Portland Cement Co.

Organized March 3, 1897; capital, $500,000. It is said that there is a mortgage of $100,000 on the plant which is said to have cost about $250,000. This is one of the well established plants of the State, and has been visited both by Dr. Ries* and Mr. Hale† and tests and a description of the process of manufacture are elsewhere given. In materials and location it is like and not far from those of the Wolverine Co.

The following are additional analyses of the Bronson clays, beside that given in Part I of this report.

REPORT OF ANALYSIS.

Date of receipt, Dec. 5th, 1900.

Composition	592 65	593 66	594 67	595 68
Silica	61.94	56.64	61.10	59.36
Alumina	11.58	12.18	13.91	12.38
Iron oxide (ferric)	3.49	3.59	3.62	3.62
Oxide of calcium	5.92	8.17	6.32	5.63
Oxide of magnesium	4.85	4.29	3.91	4.62
Sulphuric acid (anhydrid)	.18	.31	.31	.30
Organic matter				

Respectfully submitted,
(Signed) W. H. SIMMONS.

Bronson, Mich., Dec. 17th, 1900.

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*This volume (VIII), Part I, pp. 42 and 43.
†Chap. VI, p. 104.

Newaygo Portland Cement Co. (Gibraltar Brand.)

Capital, $2,000,000; organized May 24, 1899. Cornerstone laid June 29, started June 5, 1901.

The officers of the Newaygo Portland Cement Company are Daniel McCool, member of American Society of Civil Engineers, president; Wm. Wright, vice president; B. T. Becker, secretary and treasurer. Directors: F. G. Bigelow, Milwaukee; H. D. Higinbotham, Chicago; George Barrie, Philadelphia, and W. Northrup, St. Louis; Clay H. Hollister, Grand Rapids, Mich.

Description by Richard L. Humphrey.*

The Newaygo Portland Cement Company's plant is located at Newaygo, on the banks of the Muskegon river, thirty-six miles north of Grand Rapids, Michigan. It is one of the finest designed and equipped plants in the State of Michigan.

The plant is electrically operated, the power being furnished by two 500 H. P. 3-phase generators, driven by eight Lombard water wheels acting under a 15-foot head.

The water is furnished by the Muskegon river. The accompanying views, Plates XII and XVIII, show the dam, race way and interior of power house.

The slurry is agitated and handled entirely by compressed air. The efficiency of this system cannot be overestimated. The centrifugal pumps usually in use are very expensive to maintain as they wear out very rapidly.

The absence of line shafting is noticeable, each machine being equipped with an individual motor, in some cases two, which enables the mill to continue in service in case of break down of one of the motors. The automatic system for controlling the compressed air is admirable.

The marl is found in a series of lakes owned by the company in Newaygo county and about five miles from the plant, known as Little Marl, Great Marl, Pickerel, Kimball, Fremont and Hess lakes.

The following is an analysis of marl taken from the Great Marl lake:

Silica	1.24
Iron and Alumina	.80
Calcium carbonate	90.90
Magnesium carbonate	2.97
Organic matter by difference	4.09
	100.00

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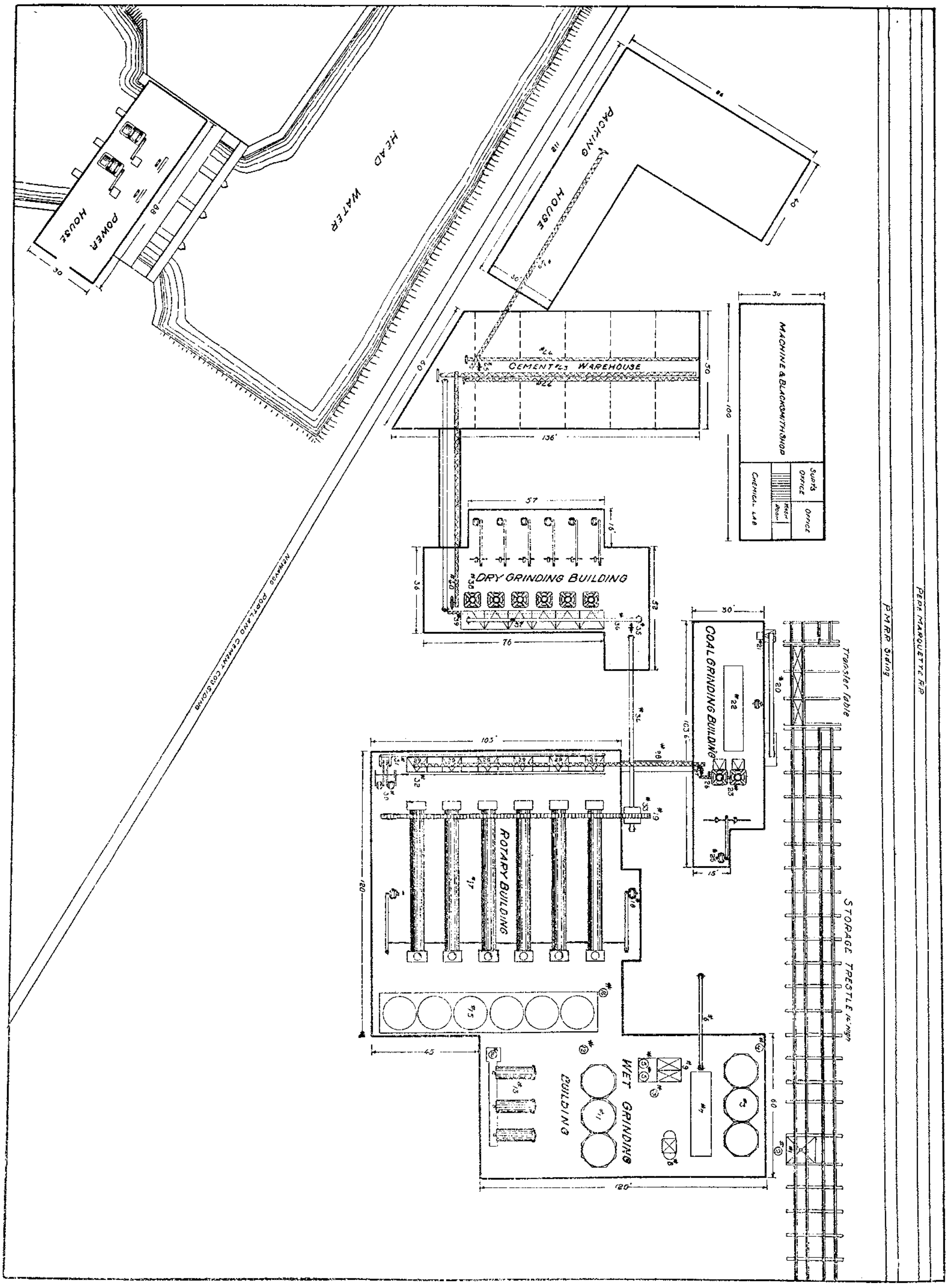
*Consulting Engineer, Philadelphia, Pa.

GENERAL VIEW OF PLANT.



PLAN OF NEWAYGO PLANT.

The composition of the marl in calcium carbonate ranges from 65 to 95 per cent.

Clay is found on the company's property along the Muskegon river opposite the plant; the following is a representative analysis of this clay:*

Silica	55.84
Iron oxide	3.02
Alumina	8.90
Lime	9.98
Magnesia	5.16
Loss	13.68
	96.58

The cement produced by this plant is first-class in every particular, and the machinery is the best of its kind.

The following is a brief description of the plant:

The mill is on the line of the Pere Marquette railroad over which road for a mile and one-quarter the marl is hauled to the mill; the remaining three and one-half miles is over the cement company's siding.

The dredge and plant used in excavating the marl is shown on Plate XXII.

The marl is dumped into a bin [(1) on Plate XVII]. There is also storage provided, under the trestle (400 feet long), to supply the mill during the winter months.

From the bin the marl flows through a gate in the bottom, operated by a slide valve, into a machine called a separator, which drives the marl out through a perforated head in the machine, separating from the marl all foreign matter, such as sticks, stones, etc. Water is introduced at this point in quantity (about 55%) sufficient to reduce it to a slurry.

The pure marl flows through a pipe into pump (2) which pumps it by compressed air into three storage tanks (3) connected together by pipe. These tanks hold about 90 cubic yards each. From these tanks the chemist takes his samples for analysis, to determine the proportion of clay to be added. From the tanks the material, now in form of slurry, flows by gravity in a pump marked (4) which pumps it into two measuring tanks (5), these being used alternately. The

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*At present, however, the company is using a clay found in connection with the gypsum at Grand Rapids whose analysis is more like that given in Part I, pp. 40 and 41. L.

clay is brought from storage and fed into a pair of rolls, then into a pug mill where water is added and it is reduced to a thin slurry. From this mill it passes into two Gates' tube mills in which it is made impalpably fine. This in turn is forced or pumped by air into a measuring tank.

The marl and clay are fed separately from the bottom of the measuring bins into a measuring hopper.

From this hopper it is pumped into three 90 cubic yard tanks (11).

The number of hoppers of marl and clay pumped into each of these tanks will depend on the composition of the marl. When the tank is full it is thoroughly agitated by air. The chemist then takes another sample. These are called correction tanks. Should the composition not be correct clay or marl is added until the desired mixture is obtained.

From these tanks the slurry or syrupy mixture of clay and marl flows by gravity into a pump (12) which forces it into the automatic feeders into the three tube mills (13), in which the material is reduced to an impalpably fine state. The tube mills discharge it into a trough running to a pump (14), which forces it into the 90 cubic yard tanks (15) back of the kilns; there being a tank for each kiln. All tanks are continuously agitated by means of compressed air.

From the tanks it is pumped into automatic feeders from which it is fed into the rotary kilns marked (17), in which it is clinkered and is discharged into the McCasslin conveyor marked (19), which forms a continuous belt around all the rotary kilns passing in a trench underneath, then up a tower at the side of the building, overhead through the ventilator or louvre of the building and down the opposite side, where it is discharged into a cooling tower (33), and delivered by this tower onto a conveyor belt (34), which takes it to the dry grinding building and delivers it to elevator (35), by which it is elevated and deposited on conveyor belt (36) which in turn delivers it to clinker storage bins marked (37), there being one for each Griffin mill. From these bins it is fed by gravity into the Griffin mills marked (38) and pulverized to an impalpable powder; flowing from them by gravity again into a screw conveyor marked (39), by which it is delivered to elevator (40), and delivered by this elevator to either screw conveyor (41) or belt conveyor (42), either one being in reserve in case of a break down. These conveyors take the finished cement and deposit it again into a screw conveyor (43), which carries it overhead, through the cement warehouse, emptying it into any bin desired.

When the cement is shipped, it is drawn from the bottom of any one of these bins into screw conveyor (44) of which there are two, one on either side of the alleyway, conveyed by the screw conveyor to a second screw conveyor (46), which delivers it into the packing bins in the packing house, where it is either barreled or sacked by machinery, and if cars are not at hand to take it to market, it is piled in the warehouse adjoining the packing house.

The coal is either shoveled direct from a car standing on the trestle onto the conveyor belt (20), or is wheeled from storage under the trestle and dumped onto this same belt, which carries it to a coal cracker (21). From there it is elevated into a Cummer dryer (22), passes from the Cummer dryer into a second elevator, which carries it up and dumps into small bins over Griffin mills (23), where it is pulverized and then passed by a screw conveyor (26) into elevator (27), which elevates it into screw conveyor (28), by which it is carried and deposited in coal storage bins (29). From there it is fed into the rotaries by a blast of air from fan (31), driven by motor (30). These rotaries are all driven by motor (18) of which there is a duplicate kept in reserve.

In the coal grinding building the machinery is driven by motor (25), belted to a jack shaft (24), which drives both the Griffin mills. Each of the Griffin mills in the dry grinding building is driven by a separate motor, as in each of the tube mills in the wet grinding building. The agitators of each set of tanks, Nos. 3, 11 and 15, are also driven by separate motors.

The plant has been in continuous service for over one year during which time it has proved to be one of the most successful and economical in the State.

The story of the discovery of the deposits of marl is as follows:*

"A year ago Charles E. Greening, of the firm of Greening Bros., extensive nurserymen at Monroe, was on a business trip through the northern part of the lower peninsula. On May 23 he delivered an address at Newaygo, and the day following joined a fishing party at Pickerel Lake, near that village. While sitting on the trunk of a fallen tree, Mr. Greening observed that the roots of the tree were covered with a white substance resembling snow. His curiosity prompted him to taste it and he detected in it a strong flavor of lime. He sent a sample to the Agricultural College for analysis, but never heard from it.

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*Grand Rapids Herald, May 9, 1899.

"A few months later Mr. Greening met Prof. Fred H. Borradaile, State analyst, and gave him a sample for analysis. When the latter reported he startled Mr. Greening by urging him to go to Newaygo at once and buy up all the land containing the deposit that he could get his hands on, explaining that the substance was a most valuable specimen of marl.

"Mr. Greening hastened to Newaygo and immediately purchased about 1,000 acres of land surrounding four little lakes, the shores and bottoms of which contain unlimited deposits of marl which is said to be of a finer quality than any heretofore discovered in this country, the analysis showing 96 per cent of carbonate of lime, with little or no trace of iron. Within a short distance of the marl beds there is to be had an abundance of clay, which is an essential in the manufacture of cement.

Numerous other deposits of marl at Pine Lake, Fremont Lake, etc., exist not far off, elsewhere referred to. That of Fremont Lake is described by Mr. Hale on p. 135.

Elk Rapids Portland Cement Co.

Organized March 3, 1900; capital, $400,000. Bonds issued in 1902 to improve machinery, etc., $100,000. Original actual cost of plant about $225,000, the balance of stock being issued for land or unsold and issued as bonus with bonds, which were floated at par.

Officers: Schuyler S. Olds, president and general manager; Fitch R. Williams, vice president; Frank B. Moore, secretary and treasurer. Directors: Fitch R. Williams, attorney, Elk Rapids; M. B. Lang, merchant, Elk Rapids; Frank B. Moore, president Elk Rapids Savings Bank; Schuyler S. Olds, railroad counsel, Lansing, Mich.; Thomas A Wilson, attorney, Jackson, Mich.; C. A. Whyland, Chicago, Ill.; H. B. Lewis, manager Elk Rapids Iron Co.

Within the limits of the village of Elk Rapids the plant of the Elk Rapids Portland Cement Co. has been erected. The company own a frontage of 80 rods on the shores of Grand Traverse bay, Sec. 20, T. 9 N., R. 9 W., and the plant was built at the water's edge. The surroundings are far more picturesque than usually found accompanying a large industrial institution. In a grove of pine trees the various buildings were erected, and thrusting its arm out into the waters of the bay, a distance of 1,200 feet, is a substantial pier. At the end 16 feet of water is found, which allows the largest boats on the lakes to discharge and load. This dock is equipped with clam shell, hoisting engine, boiler, etc., and the cable dock car system for loading and conveying cargoes to and from the plant. As lake transportation is generally cheaper than rail, the company possess a decided advantage in this particular. Tracks of the Pere Marquette also run to the mills and the company uses both methods of transportation.

Thirteen and one-half acres comprise the land owned by the company, upon which the plant has been erected. Two and one-half miles south of the plant site, in the extreme northern end of Grand Traverse county, is situated the marl lands of the company. This tract comprises 350 acres of solid marl. It was formerly a shallow lake (Petobago Lake, sometimes called Tobacco Lake, Sections 5 and 8, T. 28 N., R. 9 W.), about 20 feet above Grand Traverse Bay, but the company drained off the water and the marl is now very easy to raise and put into the dump cars of the company. This great body of marl averages, in depth, throughout its extent about 18 feet. Very little muck or organic matter lies on top of this marl bed and it goes to the mill in a very pure state. They have also recently bought some limestone lands. Within a stone's throw of the plant, clay of fine quality has been discovered. Besides this clay the company own a fine bed of shale clay (Antrim shale) on the east half of Sec. 3, T. 33 N., R. 7 W., on Pine Lake in Charlevoix County, also I am told in Lake Susan, Charlevoix County, and if needed the Watervale lands, No. 23, could be acquired.

"The buildings of the company are quite extensive and are arranged with the view of economically handling the materials as they pass from one process to another. The buildings comprise, frame coal storage building with cement floors, 50x175 feet, equipped with coal crushers, two elevators, two screw conveyors, rope drives. Concrete storage and packing buildings, 98x118 feet, concrete floors and conveyors for handling the cement. The capacity of this building is about 30,000 barrels of cement. Machine and blacksmith shop of brick, 30x50 feet; this room is very essential in a cement plant as all necessary repairs can be made in a short space of time. This shop is equipped with all of the tools and machines necessary to perform a high class of work.

"The engine and grinding rooms are in one building. This is of brick, 80x160 feet, with steel trusses, iron roof and cement floors. Steam for power is generated in two Sterling water tube boilers of 500 horse power and the motive power consists of a 500 horsepower Russel engine, with rope drives, also a Westinghouse dynamo and engine for the lighting plant. These are separated from the clinker room by thick walls. Four Griffin mills are required to grind the clinker and in this room are clinker car conveyors, cement conveyors and elevators.

The rotary building is of brick set in cement and is 80x200 feet, with steel trusses, iron roofs, and cement floors. Here are found two pug mills, four tube mills, clay grinder, six large cement vats, ten steel slurry storage tanks, 12x16 feet each, and five Bonnet steel rotary kilns, 6x60 feet, lined with fire brick for burning cement clinker. The foundations of all machinery and all ground vats are constructed of solid concrete, resting on clay strata about eight feet below the surface of the ground. Besides these buildings there are laboratory, office, barns, boarding house and residences on the ground and owned by the company.

"To reach the marl beds the company have built a standard gauge railroad and the cars are propelled by a 35-ton locomotive. Economy in getting the raw materials to the mills has been sought and the operation expenses are very low. The road extends over the marl bed about half a mile and improved dredging apparatus is in use there.

"All of the machinery was installed with a view of increasing the plant to 10 rotaries as soon as the occasion demands. As the marl is carried to the separating machine it is weighed and then goes into the separator where all foreign matter is extracted; then the clay which has been finely pulverized is added in the quantity desired by the chemist and it goes into the pug mills and the mixing machines. After the most thorough grinding and mixing the correction tanks are reached and here the mixture is again analyzed and corrected to the proper mixture desired to make a fine grade of cement. Through the rotaries the slurry rolls and as it leaves the far end it has been transformed into a small clinker. These clinkers are of irregular size. By means of an automatic conveyor this clinker goes to the mill to be ground into a fine powder. Test sheets are sent out with each shipment and the party receiving them knows just what he has purchased. The corps of cement makers and chemists have been carefully selected and every process of manufacture is carefully watched. A splendid system of tests has been inaugurated and any hour of the day test sheets will show just what results are being accomplished."

Wolverine Portland Cement Co.

Coldwater Portland Cement Co., organized May 25, 1898; capital, $300,000. American Construction Company, Michigan Portland Cement Company, capital $2,500,000; organized June 30, 1898.

This group of companies has had a somewhat varied financial history, but this has not prevented the steady production of cement under the "Wolverine" brand. The first company planned, the Coldwater, was a relatively modest affair with a capital stock of $300,000, $150,000 paid in with 640 acres of marsh land, a building to cost $100,000 and to have but 500 barrels capacity. Soon the plants and the capital were enlarged and the original company under the name of the American Construction Company took the contract of preparing the plant, turning in what it had done to the larger company, the Michigan P. C. Co., which issued $1,000,000 of bonds, covering the plant and lands, mainly in Coldwater and Bettrel Townships.

In recapitalizing $100 in 6% bonds were offered with every $100 of stock for $100 cash. When, therefore, in the fall of 1901 the interest failed to be paid on these bonds foreclosure proceedings began, and as a result of a compromise between the bondholders, which may be taken to represent the subscribing public, and the other creditors, prominent among which was the Construction Company, representing the promoters, the present company was formed.

The officers of the Coldwater Company were: John T. Holmes of Detroit, president; L. W. Hoch of Adrian, vice president; George M. Conner of Detroit, secretary and treasurer. In the Michigan Portland Cement Co. W. L. Holmes became president, H. H. Hatch vice president, and John T. Holmes secretary, while Mr. Hoch remained manager for a while. The officers were later changed.

This company, perhaps more than any other, brought the cement industry of Michigan into prominence by the thorough advertising they gave it in placing the large amount of stock.

They have two plants which were visited by Mr. Hale (page 105). One is at Coldwater, on the margin of Coldwater Lake,—a fourteen rotary plant, said to have cost $500,000, with a capacity of 1,500 barrels a day. The other is at Quincy, and the total capacity is said to be some 3,000 barrels. Some of the marl is said to run as high as 99% $CaCO_3$.

The following are typical analyses of the raw materials furnished by the chemist, Mr. H. E. Brown:

	Light marl (dried).	Blue marl (dried).
Calcium carbonate	93.75	91.34
Magnesium "	2.42	.77
Soluble silica	.18	.42
Insoluble "	1.01	.78
Aluminum oxide	.55	.55
Ferric "	.25	.40
Sulphur trioxide	tr.	.26
Alkalies and rest (by difference)	1.84	*5.79

	Clay, light brown upper layer.	Blue, 12ft. from surface.
Silica	60.59	57.26
Titanium oxide	.40	.82
Aluminum oxide	17.70	20.77
Ferric oxide	7.54	6.53
Magnesium oxide	1.46	2.31
Sulphur trioxide	.41	1.34
Calcium oxide	....	1.50
Loss on ignition	8.74	6.19
Alkalies	3.16	3.28

*Determined.

It is to be noted that all these samples are dried, the loss on ignition being to a slight extent CO_2, but mainly combined water. It will be noticed that while neither specimen of clay contains much carbonate of lime, being derived from the Coldwater shales, which are practically free from it, the superficial clay has the least, and much less sulphur, showing that the calcium carbonate and pyrite have been leached out.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Hecla Cement and Coal Co.

Organized April 6, 1901. Capital $5,000,000, in shares of $100. A West Virginia corporation, but with offices in Detroit and business centering around Bay City, consisting of marl lands in Ogemaw county, and coal and clay shale lands in Bay county.

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

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

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

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

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*Edwards Lake has been lowered.

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

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

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

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

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

George Lake.

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

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

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

This lake presents probably the deepest deposit of marl of any owned by you, many borings showing a depth of from 27 to 34 feet, but the dry marl is thickly covered with a growth of small trees and brushwood, and a large portion of the deepest marl is

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

under water of considerable depth. The water in this lake could, however, be reduced by deepening the channel at the outlet, but it is a question whether a sufficient change of water level could be made without an expenditure of a considerable sum of money.

Edwards Lake.

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

The analyses of these two clays are as follows:

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

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

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

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

Chapman Lake.

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

An average analysis of Chapman Lake is as follows:

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

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

An average analysis of this clay is as follows:

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

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

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

Plummer Lake.

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

An average sample of the marl shows the following analysis:

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

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

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

Crapo Lake.

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

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

Lab. No. 891. Crapo Lake marl, No. 1 (see p. 260).
Lab. No. 896. Crapo Lake marl, No. 2 (see p. 260).

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

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

Analyses of samples of these clays give the following results:
Lab. No. 822. Section 9 (see p. 265).
Lab. No. 823. Average of section 10.

Mills Lake.

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

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

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

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

Lab. No. 904. Clay marked No. —04 (see p. 263).
Lab. No. 905. Clay marked No. 2 —05.

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

Lab. No. 727. Light shale (see p. 265).
Lab. No. 728. Dark shale (see p. 265).
Lab. No. 863. Goetz shale, No. 1 (see p. 265).
Lab. No. 906. Clay marked 06 (see p. 263).

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

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

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

Lab. No. 921.

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

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

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

CEMENT TEST.

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

Cold Water Test Good.

Hot Water Test Good.

Tensile Tests.

Neat 48 Hours.

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

CEMENT TEST.—*Continued.*

7 Days.

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

28 Days.

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

Respectfully submitted,
(Signed) LATHBURY & SPACKMAN.

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

BOGLIME ANALYSES BY R. E. DOOLITTLE.

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

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

Sample No.

1 is from Edwards Lake, T. 21 N., R. 1 E., 11 feet thick.
2 is from Edwards Lake, "a little high in clay."
3 is from Edwards Lake, "very high in clay with some sand, not a good sample."
4 is from Plummer Lake, "a very good sample."
5 is from Plummer Lake, "fair; rather high in sulphuric acid."
8 is from Plummer Lake, "fair; rather high in sulphuric acid."
X is from Plummer Lake, " a good, fair sample."
8 feet, Chapman Lake, "a very good sample."
9 Chapman Lake, "fairly good marl though a little high in sulphuric acid."
E. Chapman Lake, "good, fair sample, a little high in sulphuric acid."

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

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

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

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

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

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

Calcium as carbonate....	80.89	80.78	85.46	97.09
Magnesium as carbonate.	0.43	3.20	3.74	1.44
Silica	7.96	7.96	3.74	0
Alumina	3.74	1.76	1.88	
Iron oxide...............	0.62	1.16	0.40	trace
Sulphur anhydride	1.94	2.51	1.28	0
Organic matter by difference	4.42	2.63	3.50	1.47
Totals, 100.00.				

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

BOGLIME ANALYSES BY LATHBURY AND SPACKMAN.

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

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

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

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

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

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

Lab. No. 896 is from the same lake.

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

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

ANALYSES BY R. C. KEDZIE.

Clays, Sample No.	7B	36
Sand	1.10	0.95
Silicate of alumina	46.70	45.66
Carbonate of calcium	15.30	18.40
Carbonate of magnesium	2.63	1.50
Oxide of iron	8.15	6.90
Water	25.00	24.00
Difference	1.12	2.69
Totals, 100.00.		

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

Marls sample.	Mills.	Crapo.
Calcium as carbonate	84.50	88.57
Magnesium as carbonate	2.20	1.50
Insoluble (as sand, etc.)	1.00	2.00
Oxide of iron, etc.	.50	1.00
Difference (water and organic matter)	11.80	6.93
Totals, 100.00.		

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

CLAY ANALYSES BY F. S. KEDZIE.

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

† Difference. * CO_2. ‡ Manganese tr.

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

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

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

CLAY ANALYSES BY R. E. DOOLITTLE.

Sample No.	5	11	C	"lift"
Coarse sand	2.00	11.60	1.00	14.70
Silica	42.56	40.76	44.02	44.29
Alumina	9.47	10.05	13.36	9.00
Iron oxide	3.56	2.70	1.82	2.60
Calcium oxide ...	15.15	14.80	17.28	14.45
Magnesium oxide.	5.95	7.45	2.60	6.26
Sulphur anhydride	1.06	1.73	2.36	1.50
Difference	20.25	10.76	17.56	7.20
Totals, 100.00.				

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

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

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

CLAY ANALYSES BY LATHBURY AND SPACKMAN.

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

*Including .79 sulphur.

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

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

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

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

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

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

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

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

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

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

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

CLAY ANALYSES BY L. AND S.—CONTINUED.

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

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

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

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

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

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

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

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

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

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

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

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

CLAY ANALYSES BY L. AND S.—CONTINUED.

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

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

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

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

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

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

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

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

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

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

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

12. The Great Northern Portland Cement Co.

Organized 1899, capital, $5,000,000, in 50,000 shares; there was $2,000,000 preferred stock bearing 7% interest, the balance common. In selling the preferred, a bonus of one-half share of common was given. Located at the company's village of Marlborough, two miles south of Baldwin, on the Pere Marquette R. R., Secs. 14 and 15, T. 17 N., R. 13 W., Lake County. They also own or control about 6,200 acres in the neighborhood, about 3,500 of them with bog lime, to wit: Sec. 13, T. 16 N., R. 13 W., lakes and lime; Sec. 15, and most of 21 and 10, T. 17 N., R. 12 W., also the N. 1/2 of the N. E. 1/4, Sec. 18, surface clay, especially on 10, and marl; N. 1/2 of N. W. 1/4 of Sec. 36; N. 1/4 of Sec. 34; Sec. 27; Sec. 14; E. 1/2 of Sec. 15 and part of Sec. 10 all in T. 17 N., R. 13 W. Also parts of sections 23, 26, 27, 34, 35, T. 18 N., R. 13 W.; Sec. 27 and parts of 26, 34, 35, T. 19 N., R. 13 W., all marl lands. There are in all some 17 lakes, generally with low shores, surrounded with a rim of marsh or tamarack growth underlain with marl. One of these lakes is said to have water from one to six feet deep with marl from 20 to 58 feet deep. In general the deposits are 18 to 20 feet deep.

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

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

Great Northern Portland Cement Co.,
82 and 84 Griswold street, Detroit, Michigan.

Gentlemen:—

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

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

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

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

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

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

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

ANALYSIS.

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

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

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

Very truly yours,
BOOTH, GARRETT & BLAIR.

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

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

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

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

13. Detroit Portland Cement Co.

Organized March 7, 1900. Capital, $1,000,000.

From the Fenton Independent of March 31, 1900, comes the following item (see Plate XXI and Fig. 23):

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

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

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

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

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

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

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

ANALYSIS OF THE CLAY AND THE MARL.

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

14. Egyptian Portland Cement Co.

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

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

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

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

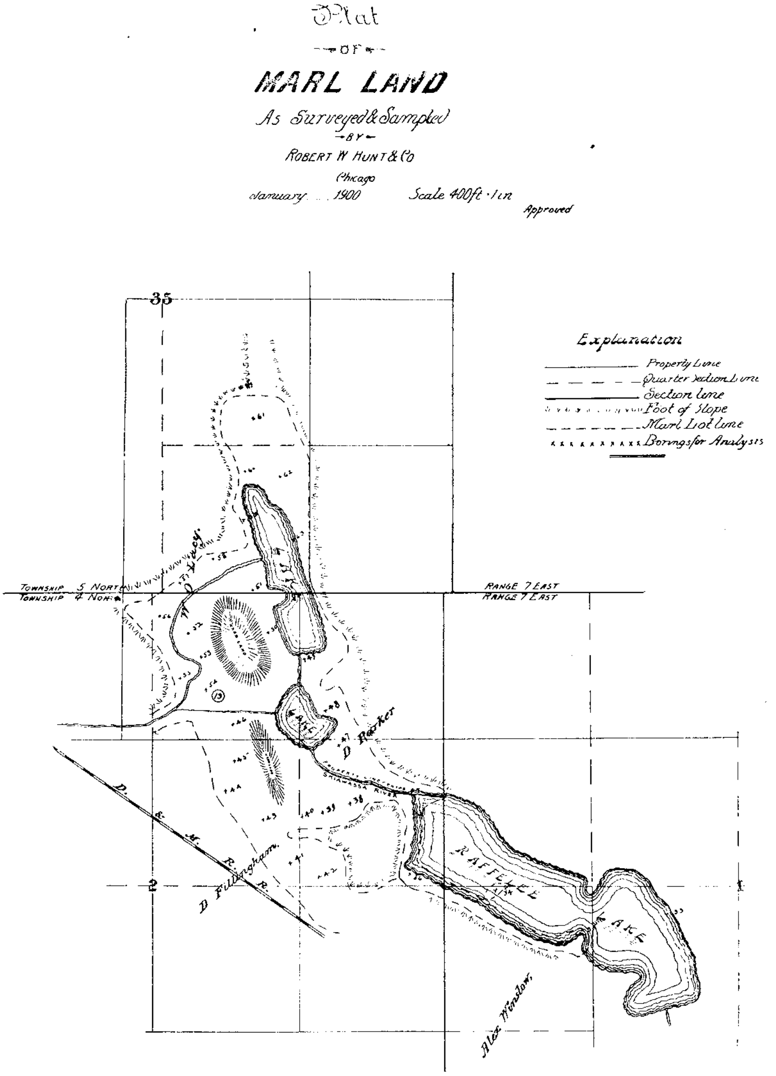

Fig. 21. Plat of Raffelee Lake, Holly Township, Oakland Co.

tions of careful surveys of Runyan Lake, Sections 9 and 10, T. 4 N., R. 6 E. (Fig. 22), and of Mud Lake, just north of Silver (Fig. 23).

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

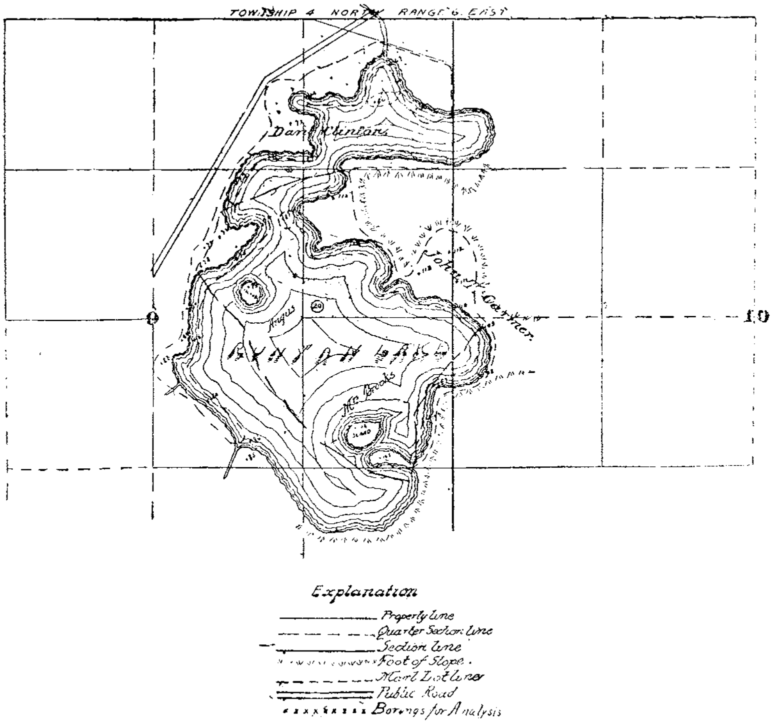

Fig. 22. Runyan Lake. T. 4 N., R. 6 E., near Fenton.

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

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

Report dated Jan. 30, 1900.

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

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

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

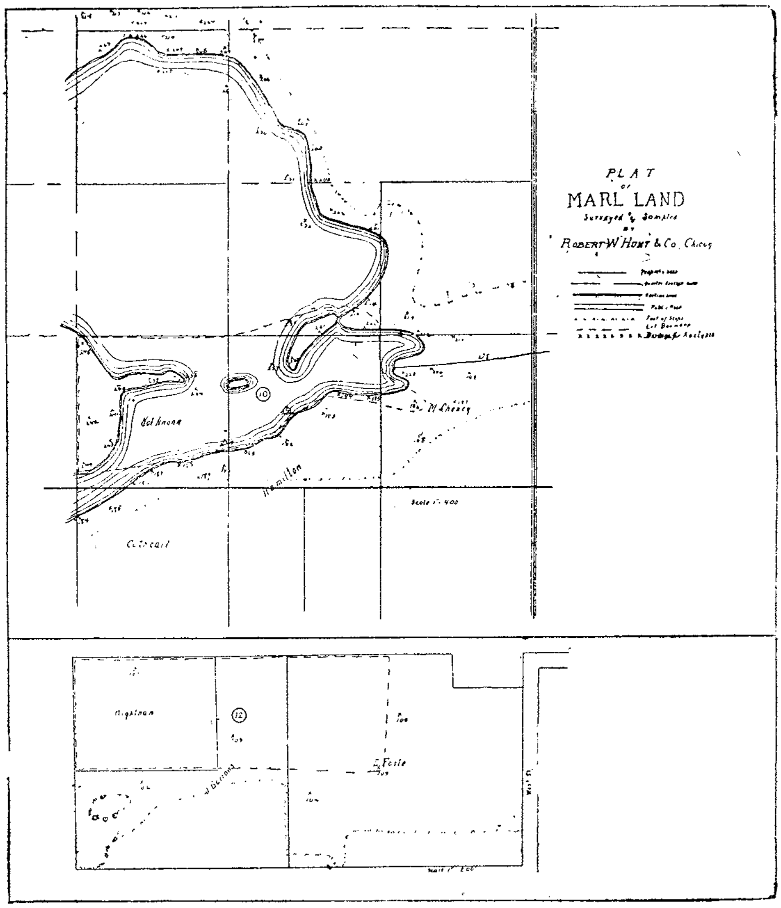

Fig. 23. Mud Lake. Sec. 22, T. 5 N., R. 6 E.

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

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

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

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

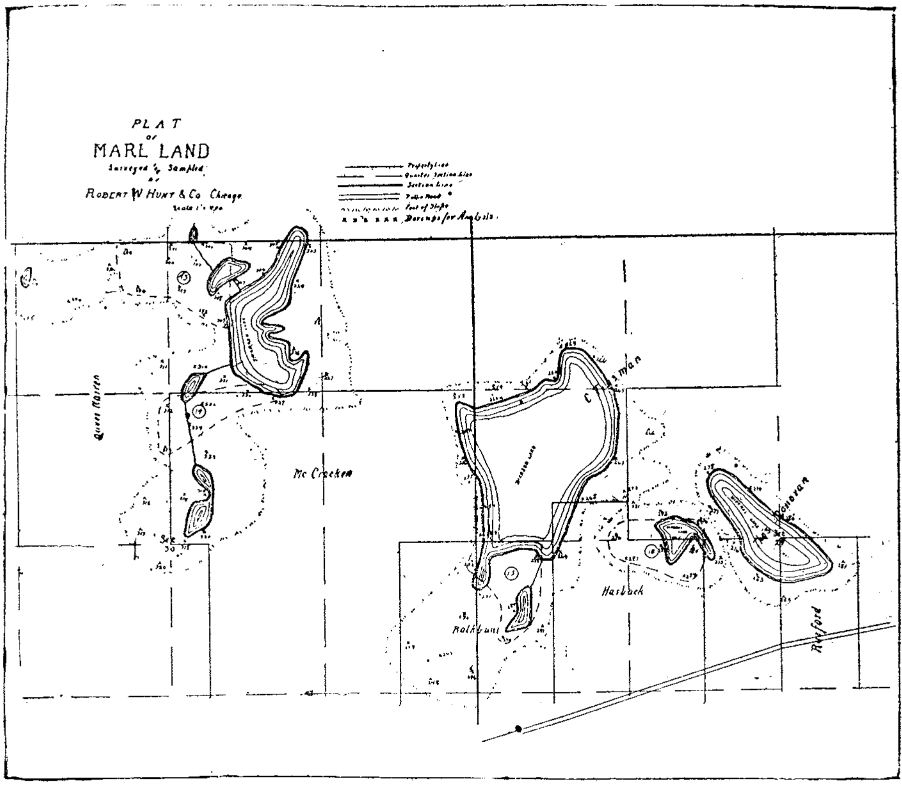

Fig. 24. Warren, Dickson, Mineral and adjacent lakes and marl beds. Sections 29 and 30, T. 5 N., R. 7 E.

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

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

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

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

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

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

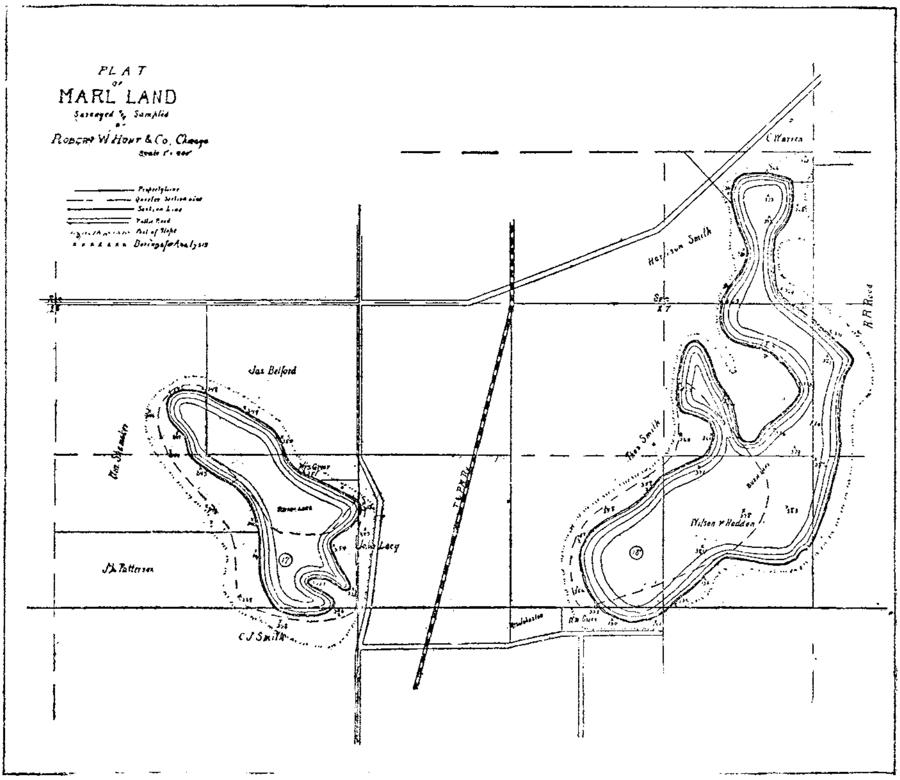

Fig. 25. Bush Lake, Sec. 27, T. 5 N., R. 7 E, and adjacent marl beds nea Holly.

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

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

The following statement shows total acreage:

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

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

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

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

	Lot 1.	Lot 3.	Lot 5.	Lot 6.	Lot 7.	Lot 8.	Lot 9.	Lot 10.	Lot 11.
Calcium carbonate.									
Average	89.717	89.03	90.31	87.92	89.633	87.57	88.57	91.045	84.51
Range	92.19 85.19	95.00 85.71	94.64 85.89	92.86 83.75	92.1 86.61	90.71 80.89	92.86 83 57	93.39 87.14	92.86 78.21
Magnesium carbonate.									
Average	3.408	34.303	3.072	3.16	3.902	3.84	3.276	3.213	3.60
Range	4.76 1.97	3.74 2.82	3.65 2.62	3.48 2.66	4.35 2.70	4.27 3.57	3.69 2.82	4.16 2.57	4.54 3.18
Iron and Alumina.									
Average	.895	1.008	.765	.828	1 049	.92	1.22	....	1.035
Range	3.66 2.24	1.24 .82	1.46 .30	1.18 .58	2.72 .56	2.00 .54	1.44 1.04	3.34 .70	1.54 .70
Silica.									
Average	.708	.994	.959	1.415	.966	1.411	2.926	1.269	2.014
Range	1.20 .24	1.62 .40	2.82 .48	1.96 .72	1.92 .64	2.54 .84	5.44 1.28	1.76 .76	3.02 .70
Average depth feet	22 6 ft.	13.6 ft.	16.9 ft.	23.4	13.	11.8	16.4	21.3	20.
Stripping cu. yds.	153, 920	70, 340	77, 280	4, 000	7, 600	61, 380	None.	43, 300	54, 710
Lime cu. yds.	1, 879, 260	183, 780	849, 600	880, 420	1, 280, 340	533, 300	511, 200	639, 620	812, 300

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

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

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

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

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

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

(Signed) ROBT. W. HUNT & CO.

Lansing, October 1, 1900.

Egyptian Portland Cement Company,
Detroit, Michigan.

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

FINENESS.

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

SETTING TIME OF NEAT CEMENT.

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

CONSTANCY OF VOLUME TESTS.

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

TENSILE TESTS OF STANDARD NEAT BRIQUETTES.

(1 square inch section.)

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

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

Lansing, Michigan, Oct. 1, 1900.

Egyptian Portland Cement Company,
Detroit, Michigan.

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

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

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

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

Twentieth Century Portland Cement Company.

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

Zenith Portland Cement Company.

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

The following are extracts from reports of engineers:

Extract from prospectus of the Zenith Portland Cement Co.:

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

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

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

T. C. BEEBE, C. E.

Cleveland, Ohio, July 23, 1900.

The Zenith Portland Cement Co.,
Detroit, Michigan.

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

Yours very truly,
C. B. STOWE.

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

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

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

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

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

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

Grass Lake is prevailingly shallow. The deeper holes do not appear to be over five to ten feet deep, and large areas are less than three feet deep. Over most of the lake bulrushes (*Scirpus lacustris*) are growing more or less scattered. In a general way they are most thinly scattered over the deeper holes, and these are points where the marl is covered by most water and appears to have most organic matter. On the figure their distribution, i. e., that of the marl which comes close to the surface and appears to be better is indicated. When the marl surface comes within a foot or so of the surface, Sagittaria and other plants join and soon the marl becomes

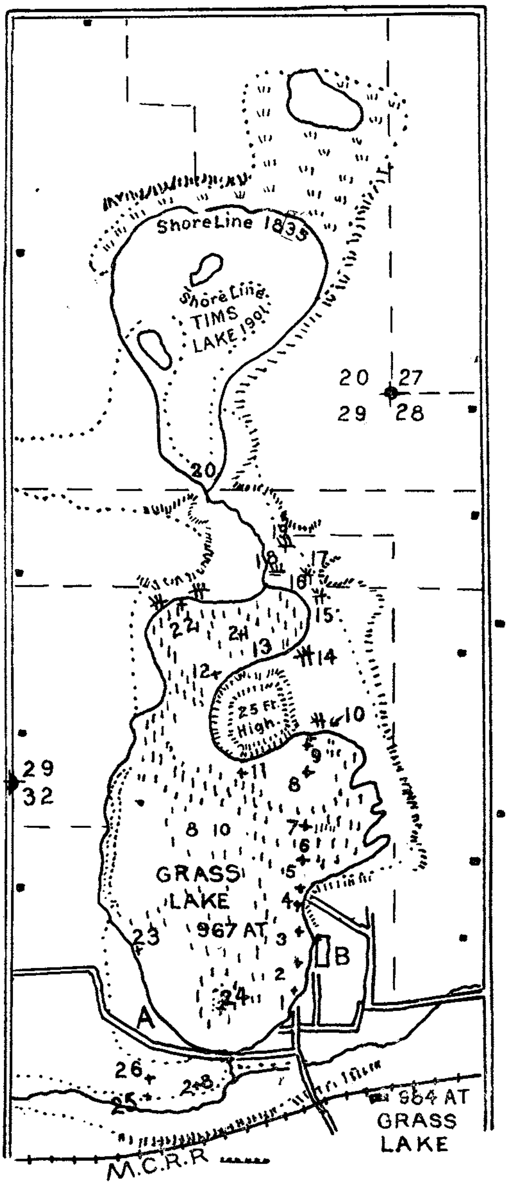

Fig. 26. Sketch of Grass Lake, T. 2 S., R. 2 E. Property of Zenith Portland Cement Company. The numbers are references to tables of soundings, not of depths.

covered with a peaty layer extending over the marl, ending abruptly in a vertical wall a foot or two high. Between localities 10 and 14 extends a tamarack swamp. At 14 good yellow marl is found beneath four feet of muck and sand, and at 10, which was at the inside edge of the belt of rushes and pond lilies, and at the beginning of that of tussocks, ferns, and ordinary swamp vegetation, there was marl close to the surface and over eight feet deep, so that the point 25 feet high with steep gravel banks, and shores terraced on the west side, which cuts off the northernmost bay of Grass Lake was once an island but is now joined to the shore on the east by this marl bottomed tamarack swamp.

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

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

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

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

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

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

The auger reached only 8 feet.

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

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

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

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

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

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

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

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

Analyst.	Prospectus av.?	W. M. Courtis.	F. S. Kedzie.
Silica SiO_2	1.22	See diff.	9.64
Alumina and iron	.61		1.92
Calcium oxide CaO			43.15
as carbonate	95.13	83.045	(77.2)
Magnesia			1.50
as carbonate	2 04	1.201	(3.72)
Sulphuric acid SO_3		0.485	
Carbon dioxide CO_2			32.80
Organic matter and water	.74	11.700	
Difference		3.569	10.99
		100.000	100.00

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

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

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

The prospectus figures selling price at $1.40 a barrel, which was probably right then, but later, September, 1901, cement was delivered in Lansing at from $1.40 to $1.50 per barrel, and even at times perhaps $1.25 for new brands, and I am told that it has been sold in

Michigan f. o. b. at factory at 90 cents to $1.00. Cement advanced, however, during the printing of this report, to over $2.00.

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

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

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

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

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

Standard Portland Cement Co.

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

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

Referring to the map, Fig. 27, we see a group of lakes, which evidently were once much more continuous, and have been separated by marsh growth, while the 15 to 20-foot bluffs which mark the original borders of the lakes are plain. Zukey Lake was the one which I studied myself more carefully. The west side is lined with a thick and pure bed of bog lime which is capped by a growth of marsh plants and peat, a foot or two thick and coming up to the lake in a perpendicular wall. The marl bed projects out white beneath, and upon it there is Chara, and occasionally dead shells of

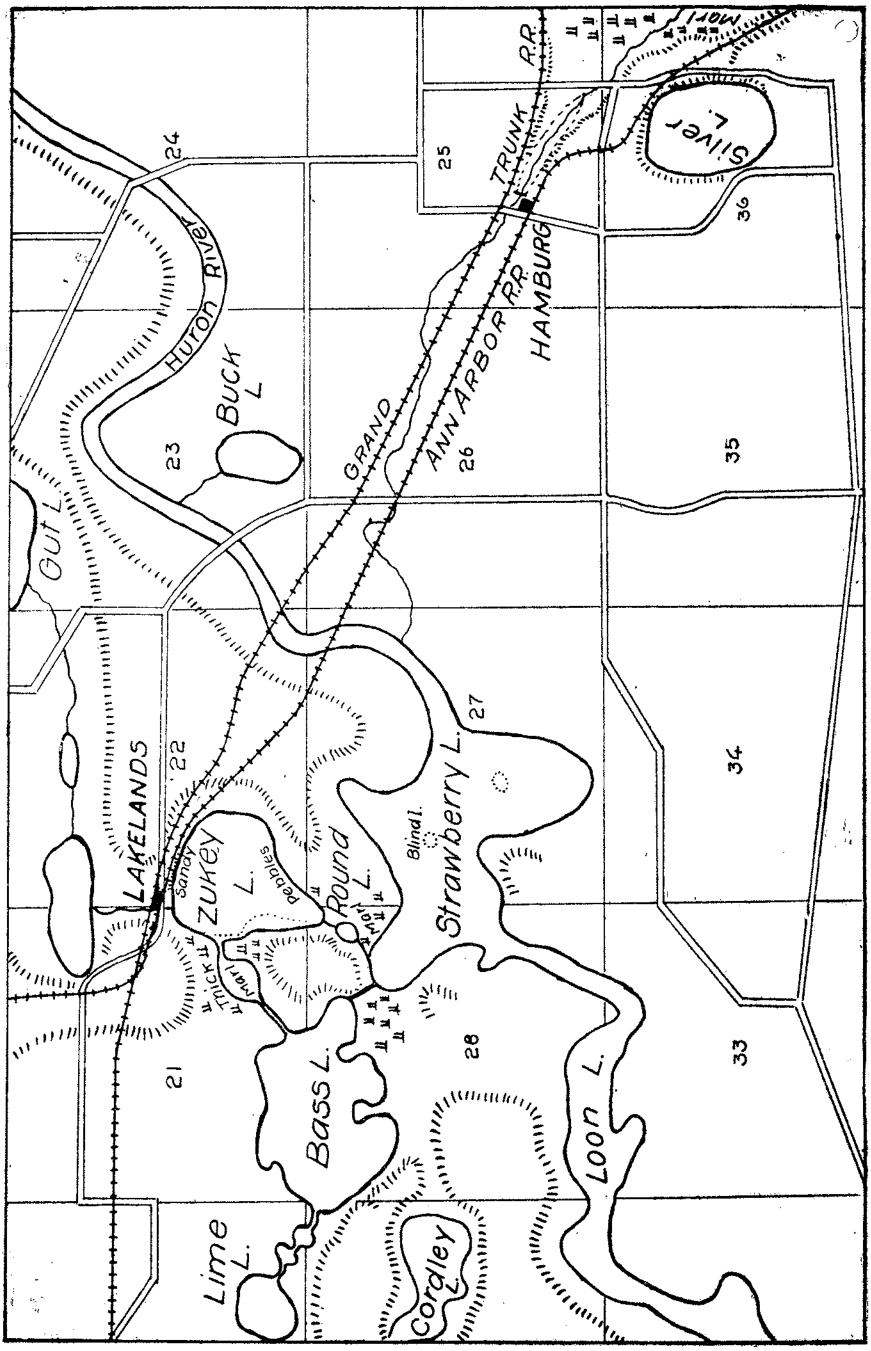

Fig. 27. Lakes near Lakelands, T. 1 N., R. 5 E. Location of Standard Portland Cement Co.

Unio, etc., and twigs are heavily coated with lime. The north part of the lake has a sandy shore and the bluffs are of gravel, and the shells are not so coated. On the southeast side of the lake the marl seems to be covered with pebbles, brown above and green below, which prove, however, to be Schizothrix concretions.

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

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

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

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

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* Detroit Today, 12: 6: 1902.

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

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

Wayne Portland Cement Co.

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

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

Pyramid Portland Cement Co.

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

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

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

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

German Portland Cement Co.

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

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

They expect to use water power for grinding and electricity.

The lime comes from Marl Lake, two miles southeast of the town, which has been described by Mr. Hale on p. 103.

Three Rivers Cement Co.

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

Farwell Portland Cement Co.

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

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

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

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

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

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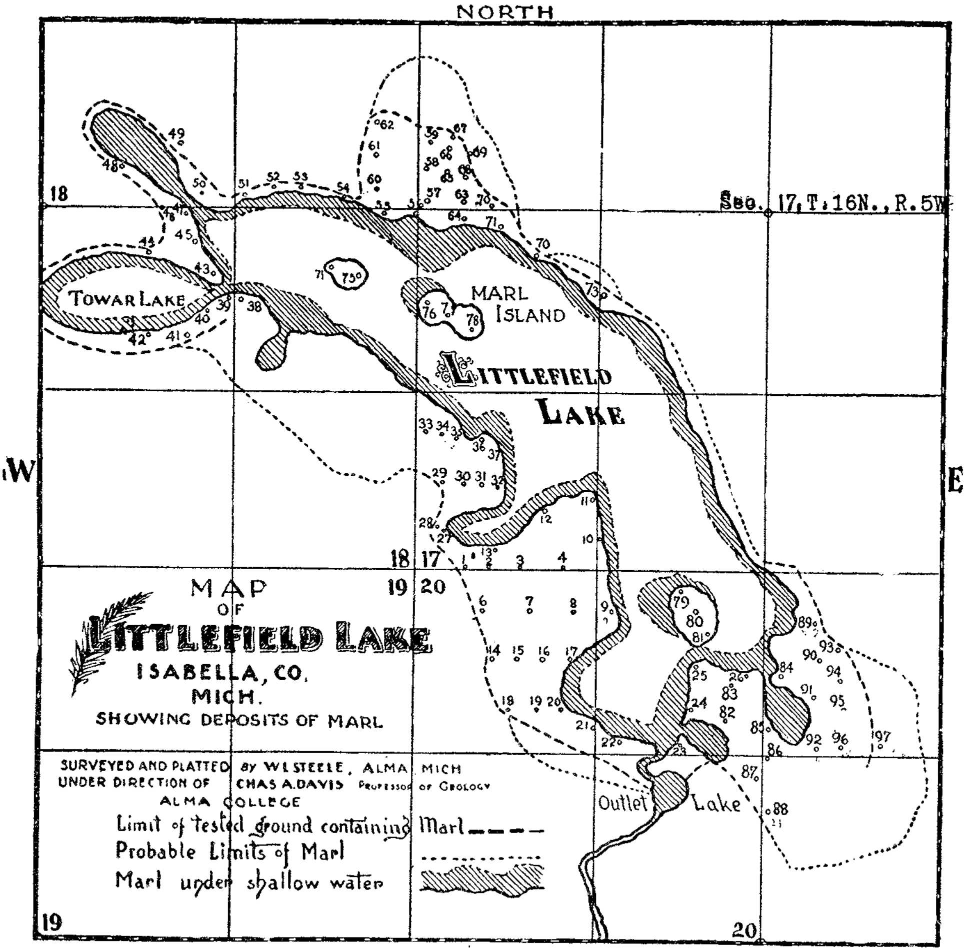
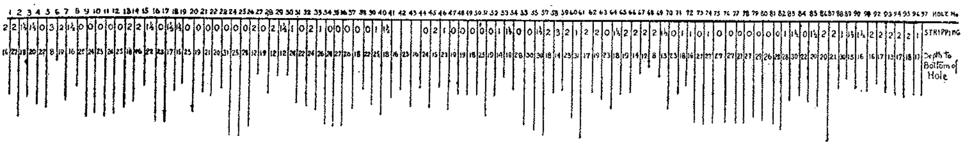
*Page 92.



PROPERTY OF FARWELL PORTLAND CEMENT COMPANY.



RECORD OF BORINGS.

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

No. 2 is from hole 24, unmixed.

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

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

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

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

Clare Portland Cement Co.

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

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

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

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

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

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

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

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

Location.

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

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

Amount of Cement Material.

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

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

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

The marl as found at the bottom of the lakes usually contains 70 per cent of water, and that from swamps usually contains 50 per cent of water. This would indicate that for each cubic foot taken from the bottom of the lake would contain 48 pounds and that from the marsh would contain 80 pounds of carbonate of lime.

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

Consequently, it would require for each barrel of cement made, 12.5 cubic feet of lake marl, or 7.5 cubic feet of marsh marl. It is seen from this that the marsh marl is preferable, for the reason that it contains less water, which must be evaporated during the process of manufacture.

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

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

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

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

Character of Cement Material.

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

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

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