C. J. Blanchard.

DEPARTMENT OF THE INTERIOR

WATER-SUPPLY

AND

IRRIGATION PAPERS

OF THE

UNITED STATES GEOLOGICAL SURVEY

No. 31

LOWER MICHIGAN MINERAL WATERS.—LANE

WASHINGTON
GOVERNMENT PRINTING OFFICE
1899

IRRIGATION REPORTS.

The following list contains titles and brief descriptions of the principal reports relating to water supply and irrigation, prepared by the United States Geological Survey since 1890:

1890.

First Annual Report of the United States Irrigation Survey, 1890; octavo, 123 pp.

Printed as Part II, Irrigation, of the Tenth Annual Report of the United States Geological Survey, 1888-89. Contains a statement of the origin of the Irrigation Survey, a preliminary report on the organization and prosecution of the survey of the arid lands for purposes of irrigation, and report of work done during 1890.

1891.

Second Annual Report of the United States Irrigation Survey, 1891; octavo, 395 pp.

Published as Part II, Irrigation, of the Eleventh Annual Report of the United States Geological Survey, 1889-90. Contains a description of the hydrography of the arid region and of the engineering operations carried on by the Irrigation Survey during 1890; also the statement of the Director of the Survey to the House Committee on Irrigation, and other papers, including a bibliography of irrigation literature. Illustrated by 29 plates and 4 figures.

Third Annual Report of the United States Irrigation Survey, 1891; octavo, 576 pp.

Printed as Part II of the Twelfth Annual Report of the United States Geological Survey, 1890-91. Contains "Report upon the location and survey of reservoir sites during the fiscal year ended June 30, 1891," by A. H. Thompson; "Hydrography of the arid regions," by F. H. Newell; "Irrigation in India," by Herbert M. Wilson. Illustrated by 93 plates and 190 figures.

Bulletins of the Eleventh Census of the United States upon irrigation, prepared by F. H. Newell; quarto.

No. 35, Irrigation in Arizona; No. 60, Irrigation in New Mexico; No. 85, Irrigation in Utah; No. 107, Irrigation in Wyoming; No. 153, Irrigation in Montana; No. 157, Irrigation in Idaho; No. 163, Irrigation in Nevada; No. 178, Irrigation in Oregon; No. 193, Artesian wells for irrigation; No. 198, Irrigation in Washington.

1892.

Irrigation of western United States, by F. H. Newell; extra census bulletin No. 23, September 9, 1892; quarto, 22 pp.

Contains tabulation showing the total number, average size, etc., of irrigated holdings, the total area and average size of irrigated farms in the subhumid regions, the percentage of number of farms irrigated, character of crops, value of irrigated lands, the average cost of irrigation, the investment and profits, together with a résumé of the water supply and a description of irrigation by artesian wells. Illustrated by colored maps, showing the location and relative extent of the irrigated areas.

1893.

Thirteenth Annual Report of the United States Geological Survey, 1891-92, Part III, Irrigation, 1893; octavo, 486 pp.

Consists of three papers: "Water supply for irrigation," by F. H. Newell; "American irrigation engineering" and "Engineering results of the Irrigation Survey," by Herbert M. Wilson; "Construction of topographic maps and selection and survey of reservoir sites," by A. H. Thompson. Illustrated by 77 plates and 119 figures.

A geological reconnoissance in central Washington, by Israel Cook Russell, 1893; octavo, 108 pp., 15 plates. Bulletin No. 108 of the United States Geological Survey; price, 15 cents.

Contains a description of the examination of the geologic structure in and adjacent to the drainage basin of Yakima River and the great plains of the Columbia to the east of this area, with special reference to the occurrence of artesian waters.

1894.

Report on agriculture by irrigation in the western part of the United States at the Eleventh Census, 1890, by F. H. Newell, 1894; quarto, 283 pp.

Consists of a general description of the condition of irrigation in the United States, the area irrigated, cost of works their value and profits; also describes the water supply, the value of water, of artesian wells, reservoirs, and other details; then takes up each State and Territory in order, giving a general description of the condition of agriculture by irrigation, and discusses the physical conditions and local peculiarities in each county.

Fourteenth Annual Report of the United States Geological Survey, 1892-93, in two parts; Part II, Accompanying papers, 1894; octavo, 597 pp.

Contains papers on "Potable waters of the eastern United States," by W J McGee; "Natural mineral waters of the United States," by A. C. Peale; "Results of stream measurements," by F. H. Newell. Illustrated by maps and diagrams.

(Continued on third page of cover.)

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No. 31

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1899

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

LOWER MICHIGAN MINERAL WATERS

A STUDY INTO THE CONNECTION BETWEEN THEIR CHEMICAL COMPOSITION AND MODE OF OCCURRENCE

BY

ALFRED CHURCH LANE

WASHINGTON
GOVERNMENT PRINTING OFFICE
1899

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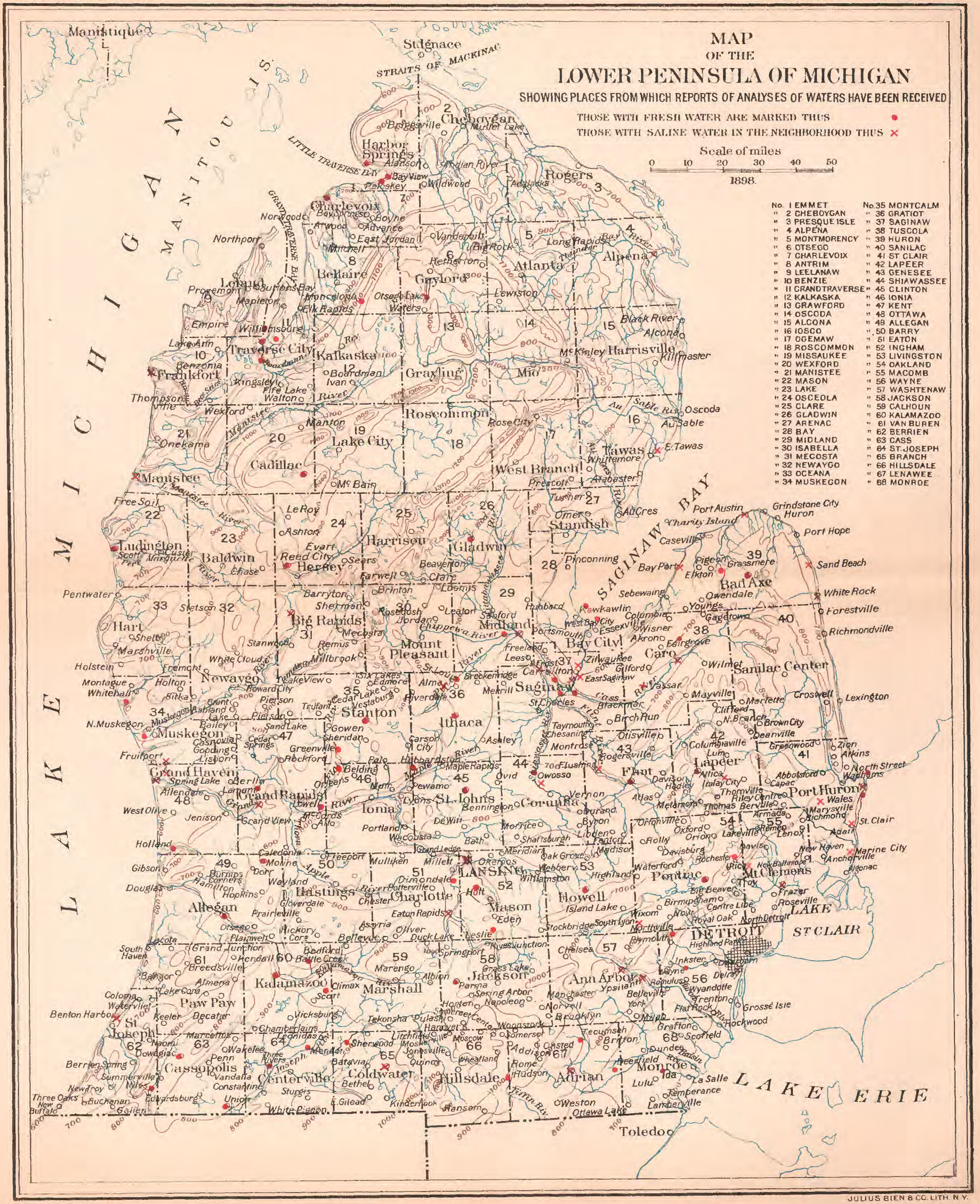
DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF HYDROGRAPHY,
Washington, May 15, 1899.

SIR: I have the honor to transmit herewith a manuscript on the mineral waters of the Lower Peninsula of Michigan, by Dr. Alfred Church Lane, now State geologist of Michigan, and to recommend that it be printed as one of the series of Water-Supply and Irrigation Papers. This is a continuation of Water-Supply Paper No. 30, entitled Water Resources of the Lower Peninsula of Michigan. The original plan was to have this and related information published as one report or monograph. It has been considered desirable, however, to issue the separate chapters or groups of chapters of the report as originally designed in pamphlet form, in order to insure an earlier publication and to facilitate the completion of portions for which an unexpected wealth of detail has been found. In this part of the report the water analyses have been brought together and discussed, particular attention having been paid to the relation which exists between the chemical composition and the geological horizons or mode of occurrence of the waters carrying mineral matter in solution.

Very respectfully,

F. H. NEWELL,
Hydrographer in Charge.

HON. CHARLES D. WALCOTT,
Director United States Geological Survey.



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LOWER MICHIGAN MINERAL WATERS: A STUDY INTO THE CONNECTION BETWEEN THEIR CHEMICAL COMPOSITION AND MODE OF OCCURRENCE.

By ALFRED CHURCH LANE.

INTRODUCTION.

This paper is the outcome of certain work in the Lower Peninsula of Michigan which I undertook for the State survey in 1895, and was originally planned as Chapter V of a paper of which the first four chapters have appeared as Water-Supply Paper No. 30.[1] The remainder of the material will be published in a later number of this series. To these two pamphlets frequent reference must be made, and they should be considered supplementary to the present paper.

In the region of the Saginaw Valley the country is exceedingly flat, and rock exposures are rare, so that for light on the detailed geology of the subsurface rocks of the region we are compelled to rely on well records—largely the untrustworthy data derived from pulverized drillings and the inferences that can be drawn therefrom concerning the rock topography—and on the characters of the waters. It was found, however, that the waters gave important objective clues, and our party carried a testing case of barium chloride, silver nitrate, ammonium oxalate, and tannic acid, a urinometer, and a thermometer, instead of the geologist's hammer. The work I had previously done in connection with the preparation of Volume V of the State reports led me to think that in general it was probably true that the various geological horizons yielded characteristic waters; therefore during the year 1897, with the guidance and support of Mr. F. H. Newell, I attempted, by means of circulars and personal visits, to extend my investigations of the waters of Michigan. I met with such hearty cooperation from the chemists connected with State institutions—Profs. R. C. Kedzie and F. S. Kedzie, of the State Agricultural College, Prof. A. B. Prescott, of the State University, and Prof. V. C. Vaughan—that the analytical material outgrew the limits of a chapter, and I began to gain a somewhat complete idea of the chemico-geological relations of the waters of the State.

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[1] Water resources of the Lower Peninsula of Michigan, by Alfred C. Lane: Water-Supply and Irrigation Paper No. 30, 1899.

Besides the gentlemen named, who have contributed many analyses, I owe acknowledgments to many other chemists who have also contributed or verified analyses for me—Messrs. Edgar and Mariner, of Chicago, Prof. S. P. Duffield, C. A. Tonnelé, and Geo. L. Heath—and to resort proprietors, secretaries of water boards, and others, too numerous to mention here, who have answered circulars of inquiry.

It is not the purpose of this report to treat the general subject of water resources or water supply, which has been discussed in a general and somewhat cursory way in Water-Supply Paper No. 30, and will be taken up for the different localities in a later paper, but to show that the chemical composition of water depends on the geological occurrence, so that from a given geological stratum at a given depth a certain kind of water may be expected; and that, vice versa, the geological horizon can be inferred to a certain extent from the character of the water.

To physicians and others who are interested in the famous mineral resources of the State in a practical way, I would recommend, in addition, the pamphlet issued by the State board of health, entitled Michigan, a Summer and Health Resort, compiled by Roberts P. Hudson, Lansing, 1898. That paper is fully illustrated and contains much practical information about railroad fares, etc. At the same time the present paper, since it contains the most complete collection of analyses to date, may be of service in pointing out waters of similar character, among which a choice can be based on climate or other considerations. It will also assist in a study of the drinking-water supply in connection with disease, by giving an idea of the normal percentages of chlorine, organic matter, etc., deviation from which must be regarded with suspicion.

ECONOMIC VALUE OF MINERAL WATERS.

MEDICINAL PROPERTIES.

The various inorganic impurities which unfit water for domestic and ordinary uses may be of value from a medicinal point of view. Thus the waters of many wells in the western part of Huron and the northwestern part of Tuscola County are laxative to men and cattle not accustomed to them, though regular users may not experience such effects. Sodium sulphate is a common laxative constituent in Saginaw waters.

The mineral table waters are derived from various sources, largely sandstones or the surface gravels. The Moorman well at Ypsilanti is concentrated to throw down the lime salts and then diluted and charged with CO_2. Other table waters also seem to be diluted salines. The main horizon for bathing purposes developed at Ypsilanti, Mount Clemens, Alma, Benton Harbor, etc., is that of limestones immediately underlying the Devonian black shales. In the Berea formation just above, and again upon entering the Traverse or Hamilton formation, a very salty mineral water, with gas or oil, is struck, and in the upper Helderberg (Dundee limestone) a water strongly mineralized with hydrogen sulphide. Unfortunately care is rarely taken to separate the constituents of the different flows. There are distinct indications that the first "bitter" water struck in the lower Helderberg contains in concentration rarer constituents, the earthy chlorides and H_2S, and that what is added below is mainly salt.

For the Mount Clemens wells it is customary to continue down until a satisfactory buoyancy, measured with the salinometer, is obtained, so that bathers can feel the strength of the water.

The waters from the upper Dundee (Corniferous, or upper Helderberg) or Mackinac limestone are usually strongly sulphated, and even where fresher at their margin, as at Petoskey, they are still characteristically sulphureted.

The Big Rapids well is apparently from a different horizon, the Marshall sandstone, as encountered in Midland, St. Johns, and Alma (upper water).

From these waters the salts can be extracted for medicinal purposes, as at Ypsilanti, Alma, and Big Rapids, or for their general value.

SALT AND SODA COMPOUNDS.

The production of common salt is a well-known industry of Michigan, fully treated in recent reports of the United States Geological Survey, so that only brief mention is necessary here. The State has produced altogether about 75,000,000 barrels (of 284 pounds), and in 1898 produced about 4,171,916 barrels. The production has been dying out in the Saginaw Valley, as the supply of lumber waste for fuel disappeared, and in Huron County, once lined with salt blocks, only one is left, the profit of which comes from local trade; but with the development of local coal fields the industry will be revived. On the other hand, the industry is increasing around Manistee, and also along the Detroit River, from Detroit to Trenton, where the production of salt is closely allied with that of soda ash, bleaching powder, etc. This latter district is exceptionally favored in possessing strong pure brines, strong and pure limestone, and excellent transportation facilities. Near Alpena the same favorable conditions exist, but that region is not yet developed. It has been proposed to mine the salt near Detroit, instead of pumping it, as has hitherto been the universal rule, and thus convert the deposit from a water resource to a mineral resource. While there is no law against pumping the salt out from under a man's property without compensation, it is illegal to mine it, so that pumping has the advantage of evading royalties. Newspapers report that the difficulty of sinking a shaft in face of heavy flows of water is the chief obstacle.

BROMINE.

Among the most important minor ingredients of the Michigan brines is bromine. The analyses from Midland (Nos. 281–284), Alma (Nos. 327–329), and Big Rapids (No. 278) are noteworthy for this constituent;

the Sand Beach (Nos. 324–326) and later analyses should also be compared.

The most active manufacture of bromine is at Midland, where the brine is treated for this product alone by the Dow process. The bromine seems to be concentrated in the deeper central parts of the basin, and to be more abundant in the Marshall than in any other formation.

The analyses also show other ingredients of value, but their exploitation has not gone far yet. The most promising field for further study and exploitation appears to be that of potash. Patents have been issued for the use of mother liquors of brines as an electric excitant, and the use of calcium chloride in preserving fruit, in drying, in refrigerating, and in the manufacture of artificial stone, is well known. The utilization of mother liquors has not gone far as yet.

DISCUSSION OF ANALYTICAL STATEMENTS.

DIFFICULTIES.

The analyses given in this paper are stated in various ways, according to the practice of the chemist who prepared them. I have tried to convert them all into the uniform system of grams per kilogram or parts per thousand. But it is at present practically impossible to reduce them to absolute uniformity.

In the first place, they are variously stated in grams per liter, grains per gallon, and parts per thousand, per hundred thousand, or per million. In regard to the former statements there are two uncertainties that arise. First, is the gallon imperial or United States? In most cases I have been able to remove this ambiguity. Second, was the specific gravity of the water taken into account, or was it neglected, as is customary in potable waters?[1] In other words, was the gallon or liter weighed or measured? Professor Prescott and T. Tonnelé state the results of their analyses both in parts per million and in grains per United States gallon, allowing for the specific weight of the gallon, although often only one statement is published. Professor Kedzie uses the imperial gallon of 10 pounds (70,000 grains), which is really a weight, not a measure. Professor Duffield also has used the imperial gallon, but of late uses the United States gallon of 231 cubic inches. Both weigh the waters and the specific gravity does not enter into the computation. Professor Vaughan reports in parts per million. The water is usually measured and the specific gravity neglected, as his sanitary analyses are potable waters with specific weight usually unity. Occasionally, as at Mount Pleasant, this introduces a sensible error. Messrs. Edgar and Mariner, of Dearborn Chemical Works, use the United States gallon of 231 cubic inches. In doubtful cases the imperial gallon can often be recognized by the fact that the figures of the analysis will be divisible by 7. In

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[1] Missouri Geological Survey, Vol. III., p. 22.

most other cases, but not in all, I have been able to ascertain definitely, by personal inquiry, concerning this matter. The United States gallon is commonly used by the mechanical profession (for instance, by the Railway Master Mechanics' Association), and therefore generally in analyses of boiler waters. It is much to be desired that all analyses should be stated explicitly in grams per kilogram—i. e., in parts per thousand by weight—for even statements in grams per liter are sometimes really in grams per kilogram. If this form of statement is not considered so intelligible as some other expression, a note might be added calling attention to the fact that, neglecting the specific gravity, one gram per kilogram, or one part per thousand, is practically 1 ounce per cubic foot, or 1 pound avoirdupois in 120 gallons. I have restated most of the analyses in parts per thousand by weight, but, as a check, in the case of newly published analyses, have also given the original figures in italics.

But if these difficulties are once surmounted there remains, in the second place, an even more serious obstacle in the fact that the partition of acids among bases is largely a matter of choice. For instance, the bromine is sometimes given as sodic and sometimes as magnesic bromide. This must necessarily be the case so far as real combinations are concerned, and there are no universally adopted conventions. Even the few laws more or less made out, such as that $CaCO_3$ is insoluble in a saturated brine, are not always followed (see analysis No. 312). When the acids and the bases have also been given separately I have given this form also, but such a statement seems less suggestive; perhaps were it more used it would not seem so.

Finally, there is the fact that a mineral water, especially when charged with gas, as most of them are, is exceedingly unstable, and when concentrated extremely corrosive, as is witnessed by the rapid destruction of casings and bathroom fixtures. This also makes analyses uncertain and hard to compare.

Among the constituents most puzzling in this respect are the carbonates and bicarbonates, especially of iron. It is practically impossible to get the same amount of CO_2 from a carbonated water, and it is probable that more than three grains to the gallon of $CaCO_3$ (0.04 per thousand) can not ordinarily exist in a noncarbonated water, the excess of lime shown in so many analyses being in the form of calcium bicarbonate. At the Agricultural College, from the average of the results of tests by a class of from seven to ten students, the hydrant water from a deep artesian well contains 4.75 degrees of temporary and 4.714 degrees of permanent hardness, the total hardness being 9.605. After aeration and heating in the purifier the hardness was reduced to 1.68 degrees temporary and 2.554 degrees permanent, or 4.237 degrees in all. A series of tests of samples of lake and well water collected by D. J. Hale and analyzed for free CO_2, $CaCO_3$, and $MgCO_3$ by A. N. Clark, showed free CO_2 ranging from 0.0 to 66 parts per million, using phenol phthalein as an indicator. The same thing is even more true of iron. According to Schweitzer,[1] in a chalybeate water with much gypsum one-fourth of the iron is present as carbonate and three-fourths as sulphate. Yet some analyses show more $CaCO_3$ than can be present except dissolved in H_2CO_3.

On the other hand, field observations about mineral wells have convinced me that in many cases the iron has been precipitated before the sample reached the chemist, and therefore escaped analysis. The effect of iron in solution is so marked on tea, and in precipitation as boiler or teakettle scale it is so conspicuous, that the field observer can hardly be mistaken in noticing it. But the question may often arise whether the iron is an original and essential constituent of the water or is derived from the casing of the well.

Other observations, such as exhalations and deposits, as well as the quantity and character of the boiler scale, etc., serve as checks on analyses. When, as Professor Sherzer has pointed out, native sulphur and celestite are crystallized together, as they are so characteristically at Scofield, it can hardly be amiss to assume that a trace of strontia was present in the sulphureted water, even though it is but rarely noted in the analyses. In this connection the amount of Sr shown in the analysis of Lake Superior water is noteworthy. Among the analyses those of waters from the Dundee limestone most frequently mention SrO.

Again, in Michigan, as elsewhere, certain algæ luxuriate and grow with remarkable rapidity in the deeper bicarbonated waters.

REDUCTION FACTORS.

Considering all the uncertainties mentioned as inherent in analyses, and the fact that by various methods of computation the number of grains to the United States gallon varies from 58,418.6092 to 58,372.3, the approximate reduction factors cited below are usually sufficiently accurate. Reduction of analyses from grains per United States gallon have been made by slide rule. For further details see report by Dr. A. C. Peale,[2] and references there given.

Table of equivalents.

1 United States liquid gallon = 231 cubic inches = 8.33888 pounds avoirdupois = 58,372.3 grains = 8 wine pints.

1 imperial gallon = 277.274 cubic inches = 10 pounds avoirdupois = 70,000 grains.

1 liter = 0.264179 United States liquid gallon = 0.22009 Imperial gallon.

1 gram = 15.432 grains.

Approximations.

1 part per thousand by weight = 1 gram per kilogram, or (neglecting specific gravity) = 1 gram per liter = 1 ounce per cubic foot.

To reduce grains per imperial gallon to grams per liter divide by 70.

To reduce grains per United States gallon to grams per liter multiply by 1.2 and divide by 70.

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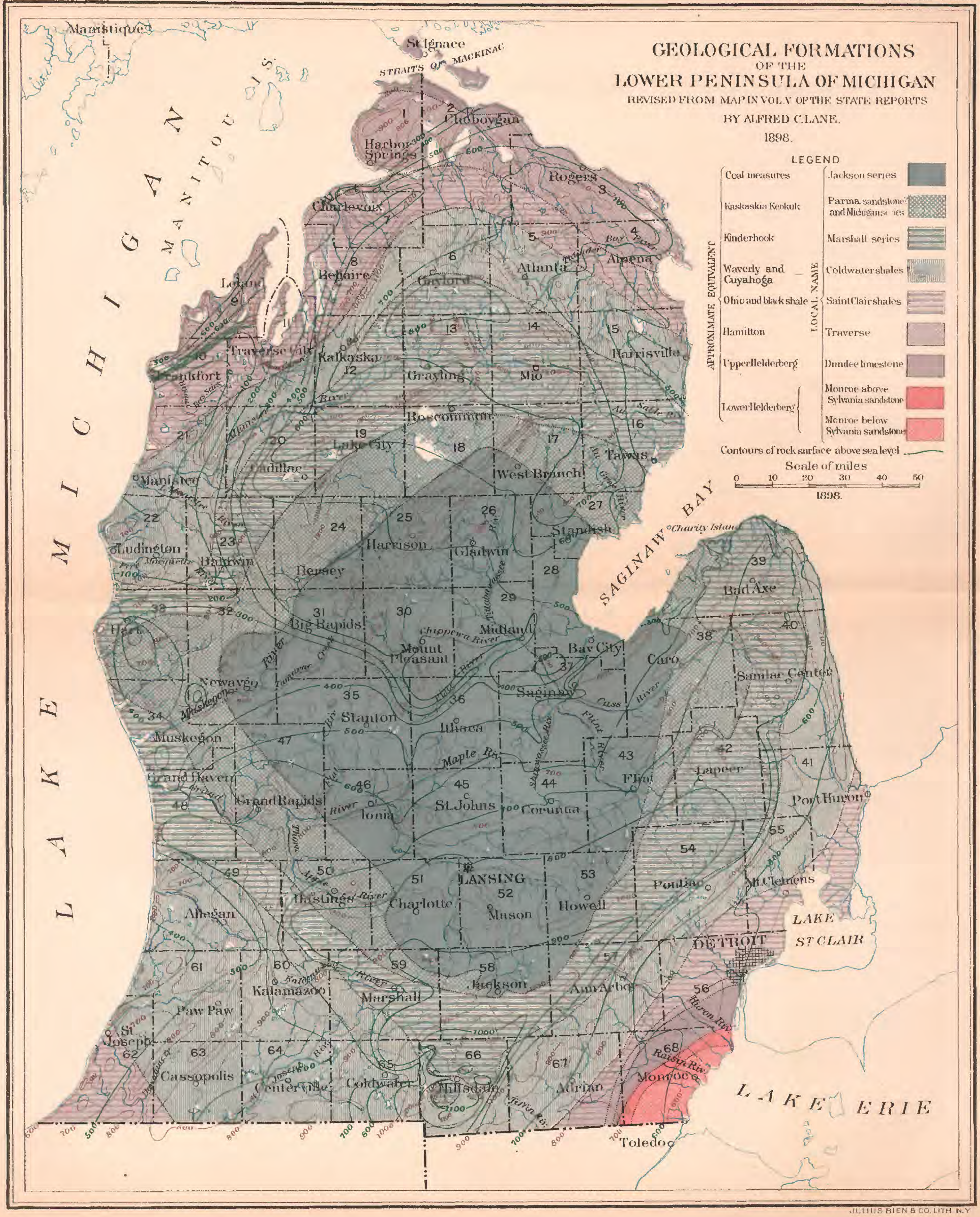
[1] Missouri Geological Survey, Vol. III, p. 19.

[2] Natural mineral waters of the United States, by A. C. Peale: Fourteenth Ann. Rept. U. S. Geol. Survey (1892-93), Part II, 1894, pp. 49-88.



GEOLOGICAL FORMATIONS
OF THE
LOWER PENINSULA OF MICHIGAN

REVISED FROM MAP IN VOL. V OF THE STATE REPORTS

BY ALFRED C. LANE.

1898.

JULIUS BIEN & CO. LITH. N.Y.

To reduce grains per imperial gallon to grains per United States gallon multiply by $\frac{5}{6}$.

Roughly, to reduce degrees salinometer or urinometer, etc.:

Urinometer reading = excess of specific gravity over 1 in thousandths = 2 × salinometer reading = 8 × per cent of salt or the Beaumé reading.

In estimating flows:

1 pail is usually 3 gallons.
1 barrel is usually 31½ gallons = 4 bushels = 128 quarts; sometimes 3 bushels.
1 cubic foot = 1,000 ounces fluid or avoirdupois = 30 quarts, roughly.
1 cubic foot per second = 30 quarts per second = about 150 3-gallon pails a minute = 20,000 4-bushel barrels a day = about 650,000 gallons a day.

In the Saginaw Valley the flow of the brine wells was estimated by noting the number of seconds required to fill a pail when pumping as hard as possible without pounding. Thus, a well might be known as an eight-, a ten-, or a twelve-second well, and when all were pumped a well of eleven seconds would fall off to twenty seconds.

CLASSIFICATION OF ANALYSES.

The geological occurrence and the chemical character of water are clearly interdependent, so that with some probability one may be inferred from the other. It has therefore seemed best to group together, for the purposes of comparison and study, analyses from geologically similar sources rather than to follow the alphabetical order. The analyses are generally arranged also in order of increasing concentration—i. e., of increase in the total amount of solids. To this rule there are, however, some exceptions, for I have grouped together analyses of waters from the same place and from substantially the same source, where the presumption is that the variation in concentration is accidental. The rather large groups of sanitary analyses of unknown geological environment, which I owe to Professor Vaughan and to Profs. R. C. and F. S. Kedzie, being fuller in some points and not so full in others, have been kept together, so that they may be more easily tabulated and compared. I have also grouped in a separate section those analyses the geological relations of which were somewhat uncertain, and which I did not therefore care to make use of in drawing deductions as to the character of the waters of the different strata.

The alphabetical index at the end of the paper will enable one to study the variation of chemical composition in waters from wells of varying depths at the same place. Among the places most instructive in this respect are Saginaw, Bay City, Midland, Alma, Detroit, and Ypsilanti.

The waters may be divided geologically into waters of the Great Lakes system, of rivers and smaller lakes, of wells and springs in the unconsolidated deposits, and of wells from beds above the Marshall (which are stronger in sulphates), in the Marshall, in the Berea grit (saline), and in beds below the Berea (sulphureted). To each group is given a section below.

In all analyses the results are in parts per thousand (grams per kilogram) unless otherwise stated. Where two sets of figures are given, the lower refer to parts per thousand. This is done in the case of analyses not, to my knowledge, elsewhere on record, and for which I have had to compute the lower figures from other forms of statement. As a check the original figures are given above them in italics.

In all the sanitary analyses by Professor Vaughan the color is clear, unless otherwise stated, the reaction neutral, and the water odorless, and this is the presumption in the case of other sanitary analyses. Profs. F. S. and R. C. Kedzie jointly furnished me with a list of analyses, the credit for which belongs sometimes to one and sometimes to the other.

Carbonates and bicarbonates are entered in the same place in the tables, the latter preceded by bi. It may be useful to say that the ratio of carbonate to bicarbonate for a given amount of the base found is: For lime, 100:162.02; for magnesia, 84.36:146.38; for iron (FeO), 116:178.02; for soda, 106.10:168.12. In a rough way, there is half as much again when the compound is given as bicarbonate as when it is given as carbonate.

WATERS OF THE GREAT LAKES SYSTEM.[1]

Constituent.	1. Manistee Lake.	2. Muskegon Lake.	3. Traverse Bay.	4. Detroit River.	5. Detroit River.
Al_2O_3	....	....	....	....	0.0105
$CaCO_3$	*5.898* .101	*4.882* .084	*3.412* .058	*3.144* .054	.033
CaP_2O_5	....	....	....	....	.0311
$CaSO_4$	Tr.	*1.660* .028	*1.793* .031	*.664* .011	....
$(FeAl)_2O_3$	Tr.	*.029* .001	Tr.	Tr.	....
$FeCO_3$	....	....	....	....	.00814
$MgCO_3$	*2.345* .040	*2.654* .046	*2.013* .034	*1.203* .021	....
K_2SO_4	....	....	....	....	.00283
SiO_2	*.292* .005	*.292* .005	*.215* .004	*.350* .006	.005
$(NaK)Cl$	*5.100* .087	*1.02* .017	*.680* .012	*.900* .015	....
$(NaK)_2CO_3$	*.147* .063	*.209* .004	*.764* .013	*.045* .001	....
Na_2SO_4	....	....	....	....	.0075
Organic matter	....	....	*.467* .008	....	....
Total	*13.782* .236	*10.746* .185	*9.344* .160	*6.306* .108	.09807

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[1] Analyses are given in grams per kilogram, or parts per thousand. Numbers in italic are quantities expressed in the units in which the analyses were originally published, usually, as in the first table, in grains per United States gallon.

Constituent.	6. Detroit River (A).	7. Detroit River (B).	8. Detroit River (C).	9. Bay City (A).	10. Bay City (B).	11. Bay City (C).	12. Saginaw Bay.
CaO	0.0355	0.0360	0.0348	0.079072	0.116928	0.105952	0.031136
P_2O_5	0	Tr.	0	....	....	....	....
SO_3	.0056	.0060	.0056	....	....	....	....
MgO	.0121	.0127	.0123	.030558	.049874	.053333	.016432
SiO_2	.0066	.0062	.0089	....	....	....	....
Cl	....	....	.0075	.058	.265	.284	.010
Total	.1188	.1184	.1140	....	....	....	....

Analyses 1 to 4 were made by commercial chemists of the Dearborn Drug and Chemical Works, of Chicago. Their primary purpose was to determine quality as boiler waters; they were stated in grains per United States gallon; they did not aim at completeness, and no summation was given in the original analysis.

No. 1, of water from Manistee Lake, was made for Filer & Sons, August 31, 1897. The water was probably contaminated by the large salt works there.

No. 2, of water from Muskegon Lake, was made for the Electric Light Company, November 23, 1897.

No. 3, of water from Traverse Bay, was made for the electric light works of H. D. Campbell & Sons, August 31, 1897. Further analyses will be found in the Appendix (2A, 2B, 2C). It will be noticed, on comparing them with the deep-well water supply, analyses Nos. 56 and 57, that the bay water is considerably less hard. Of course it is more liable to typhoid contamination.

No. 4, of water from Detroit River, was made January 22, 1897, for the Schiller Corset Company.

No. 5 is an old analysis, made by Prof. S. H. Douglass in 1854, and cited in the biennial report of the State geologist, A. Winchell, in 1861, page 204. The total solids agree with other analyses, but the phosphates and sulphates are quite different, though some phosphorus is probably often overlooked.

Nos. 6 to 12 were made by Prof. A. B. Prescott, Nos. 6 to 8, of water from Detroit River, in conjunction with T. J. Wrampelmier, for the Detroit board of health (First Annual Report, 1882, pp. 229–238). Further analyses will be found in the Appendix (Nos. 5A, 6A, 7A).

No. 6 is of water from a West Fort street hydrant at Detroit; No. 7 of water from the pumping well, and No. 8 of water from the river at the inlet pipe of the Detroit pumping station.

Nos. 9 to 12 were published in a special report to the board of waterworks of Bay City, October 24, 1885, the waters of Nos. 9 to 11 being taken from manholes Nos. 4, 2, and 1, respectively, in the pipe leading from the pumping station on the bay shore to Essexville. One object of the investigation was to see if the water was contaminated in the transit by any waste of salt manufacture.

Sample No. 12 was taken about 2 miles north from the mouth of Kawkawlin River, and 1½ miles from the west shore of the bay, in water 16 feet deep, September 27. This also contained 0.04 per million parts of free ammonia and 0.15 of albuminoid; it reduced permanganate very slightly, was colorless and odorless, as were all the samples, but the residue blackened slightly on ignition.

Analyses of water from Saginaw Bay near Bay City.

	13.	14.	15.	16.	17.	18.
Ammonia free	0.00007	0.00016	0.00005	0.00007	0.00004	0.00008
Ammonia albuminoid	.00011	.00012	.00008	.00017	.00022	.00016
Permanganate reduced	2	1	4	7	8	3
Color	Colorless.	Colorless.	Nearly colorless.	Slight.	Perceptible.	Distinct.
Chlorine	.012	.010	.029	.072	.072	.039

	19.	20.	21.	22.	23.	24.
Ammonia free	0.00007	0.00004	0.00002	0.00003	0.00005	0.00004
Ammonia albuminoid	.00016	.00022	.00007	.00024	.00024	.00012
Permanganate reduced	6	2	6	3	7	1
Color	Distinct.	Slight.	Very slight.	Slight.	Distinct.	Colorless.
Chlorine	.235	.226	.221	.200	.061	.010

Besides analyses Nos. 9 to 12 and the Saginaw River analysis (No. 45) below, Professor Prescott made a number of tests for ammonia, free and albuminoid, and chlorine (analyses Nos. 13 to 24). Prescott pronounced the waters of analyses Nos. 12, 13, 14, 24, which are all taken from Saginaw Bay, more than a mile from the shore and in water over 10 feet deep, to be suitable for city use. Analyses Nos. 19 to 22, of water taken from the waterworks system, are not satisfactory, the organic matter being on the limit of safety, and the chlorine, which is probably not, however, of organic origin, far too high. These should be compared with analyses Nos. 32 and 33, of water from the same system, made by Prof. V. C. Vaughan. Samples Nos. 15, 16, 17, 18, and 23, taken from the bay nearer the pumping station and the shore, are not quite satisfactory, and though they contain less chlorine the quantity is still abnormally large, while Saginaw River water No. 45, West Bay City waterworks, is entirely unfit for use. The exact locations from which the waters of these analyses were taken are as follows:

No. 13, about 1 mile NNW. from the mouth of the Kawkawlin River, in water 11 feet deep, July 23, 1885.

No. 14, about 4 miles NE. from the mouth of the Saginaw River, in water 21 feet deep, July 24, 1885.

No. 15, about 3¼ miles E. from the mouth of the Saginaw River and 1 mile N. from the present inlet works, in water 10 feet deep, July 23, 1885.

No. 16, inlet cut of the present works at the outer end of breakwater, July 23, 1885.

No. 17, the inlet basin at the bay, at the outer end of the pipe leading to the pumping station, July 23, 1885.

No. 18, same point as sample No. 17, August 11, 1885; turned very black on ignition.

No. 19, well at pumping station, inner end of pipe leading from the bay, August 11, 1885.

No. 20, hydrant near the corner of Fourth and Water streets, August 14, 1885.

No. 21, hydrant near the corner of McGraw avenue and Harrison street, August 14, 1885.

No. 22, same point as sample No. 20, but when there was a large quantity of sediment from flushing the pipes; sample taken August 22, 1885.

No. 23, a point 3,000 feet NNE. from the present inlet basin, in water 7½ feet deep, September 25, 1885.

No. 24, a point 5,500 feet NNE, from the present inlet basin, in water 10½ feet deep, September 25, 1885; blackened slightly on ignition.

	25. Detroit.	26. Marine City.	27. Port Huron.	28. Port Huron.	29. Port Huron.	30. Alpena.	31. Wyandotte.	32. Bay City.	33. Bay City.
Result of inoculation	—	+	+	+	—	+	+	—	+
Number of bacteria in 72 hours	2	(*a*)	(*a*)	(*a*)	(*a*)	22	1,890	420	450
Nitrites	....	Ft. tr.	....	....	....	....	0.0000082	....	....
Nitrates	....	Tr.	Tr.	Tr.	Tr.	....	.000653	....	....
Albuminoid ammonia	0.000102	0.00112	0.000120	0.000132	0.000126	0.00037	.00052	0.00048	0.00068
Free ammonia	.000016	.0001	.000009	.000007	.000006	.00048	.00008	.00034	.001
Permanganate reduced	....	....	....	....	....	.008104	.032548	.063832	.106176
Chlorine as NaCl.	.00115	.00990	.00830	.0099	.00825	.0066	.0495	.4257	.4653
Organic residue	.020	.110	.040	.070	.030	.025	.030	1.210	.980
Inorganic residue	.030	.043	.120	.150	.040	.162	.191	1.960	1.990
Total residue	.050	.153	.160	.220	.070	.187	.221	3.170	2.970
Hardness	.7°	4.°	2.°	2.1°	2.°	8.10°	7.°	15.°	15.5°
Sulphates	....	....	Tr.	Tr.	Ft. tr.	....	....	....	....

a Liquefaction.

Analyses 25 to 33 are sanitary analyses by Prof. V. C. Vaughan, made at Ann Arbor. The dates and the original numbers (in parentheses), the results of microscopic examination, etc., are as follows:

No. 25 (259), April 19, 1895, water said to be from the bay, i. e., the upper part of the Detroit River (?); reaction faintly alkaline; this is exceptionally low in solids, though it checks in chlorine fairly well with analysis No. 4.

No. 26 (230), August 21, 1894; water "musty alkaline, microscope shows nematoid worms, ova, vegetable débris, desmids, diatoms, infusoria, bacteria."

No. 27 (255). This and the two following analyses form a set of three, dated by Professor Vaughan March 3, 1895. At the waterworks I was told that Professor Kedzie made a set of three analyses, which had been lost—one of the river water above town, one of the river water below the town, and one of water 12 miles out on Lake Huron. I suspect that these are the analyses referred to, and that No. 27 is of water at the town, No. 28 of water from St. Clair River below the town, and No. 29, which is much more free from organic matter, is the one of water from out on Lake Huron. No. 27 (255) was milky colored (in 1897 when I visited the plant the water was slightly turbid from clay dredging), smelled musty, gave an alkaline reaction, and the microscope showed wood fiber, algæ, unicellular plants and animals, inorganic deposits, and much vegetable débris. On November 3, 1892, a test (165) showed granular sediment 7.3° hardness, 0.002 chlorides, 0.00007 free and 0.00012 albuminoid ammonia, 5,840 bacteria in seventy-two hours, and no inoculation effect.

No. 28 (256), also milky colored, musty, alkaline, with algæ, wood fiber, inorganic deposits, much vegetable débris, unicellular plants and animals.

No. 29 (257), also milky, musty, alkaline, with wood fiber, algæ, unicellular plants and animals, vegetable débris, inorganic deposits.

No. 30 (81), taken from the hydrant at Alpena (a town using Lake Huron water), June 10, 1890; microscope shows fresh-water algæ, white amorphous material, red spores of algæ, streptococci, oscillators, and bacilli; the extreme hardness reminds one that limestone crops out abundantly around Alpena.

No. 31 (93) Wyandotte waterworks, November 12, 1890. These works draw water from the Detroit River below Detroit, and there has been considerable complaint as to the prevalence of typhoid fever. At 100 diameters magnification crystals, algæ, and yellow and white amorphous matter are visible; at 500 diameters, crystals of NaCl, silica, fibers, algæ, Vorticellæ, yellow and white amorphous matter.

No. 32 (90) from Bay City hydrant, November 4, 1890; not clear, smells slightly fishy. Under 100 diameters the microscope shows diatoms, algæ, animalculæ, fibers; under 500 diameters, Navicula, Paramecia, Pinnula, Conferva.

No. 33 is a duplicate, same source and time and similar, but also shows desmids and Volvox. These two analyses are directly comparable with Prescott's analyses, Nos. 19 to 22, and show a similar large amount of chlorine.

It will be noticed that, while the water of the Great Lakes is not so hard as many of the waters described later, it is usually charged with more $CaCO_3$ than can be taken up without an excess of CO_2, viz, more than 0.034 ounce per cubic foot. The effect of the salt industry in charging the shallow Saginaw Bay with chlorides is well brought out, the normal amount of salt being probably 0.010 to 0.007. The effect of the salt industry of Manistee seems also to be traceable in the chlorides of Manistee Lake.

THE WATER OF LAKE SUPERIOR.

As none of the analyses given above were exhaustive and none were made with extreme care, it seems worth while, especially in connection with the question of the distribution of the rarer elements, to add the following analysis of Lake Superior water (No. 34) made in 1887 by W. F. Jackman, then a student in the University of Michigan, now professor of pharmaceutical chemistry in Maine State College, Orono, Me.[1]

The sample for analysis was obtained during the summer of 1886, by Captain Mooney, of the steamship *India*, about 50 miles from Keweenaw Point, at a depth of 50 feet, and was sent to the university laboratory in a large carboy. There was also secured at the same time with this sample a sample from Lake Huron, which it is regretted certain considerations compelled to be laid aside unexamined.

The analysis of the sample of Lake Superior water was not made until the latter part of December and first of January following its collection. Although the carboy contained over 18 liters of water, yet the small amount of inorganic solids (only 57.61 milligrams per liter) rendered this seemingly large amount of water really small for all the necessary estimations and duplicates, so that economizing of material had to be studied from the very first.

Among the precautionary methods employed was the frequent use of ammonium fluoride (in platinum crucible) after the usual final weight taken in gravimetric work—the whole thing being then reweighed, and this last weight taken as the true one—the first weight being simply a check.

With the fact of the slight solvent action on glass or porcelain of large quantities of boiling liquids—even of distilled water—all are familiar; but this is generally ignored as an insignificant amount. That it really becomes an important factor in work such as the present (involving large quantities of water with very small residues) Thorpe, Fresenius, and others have shown by definite experiments. In the present work the correction necessary from this cause was generally inconsiderable, but not always; e. g., in determinations of magnesium one sample, weighed as magnesium pyrophosphate, gave 48.3 milligrams before ignition with ammonium fluoride, while after such ignition it weighed only 41.6 milligrams, a loss of 6.7 milligrams. Another sample of magnesium pyrophosphate lost 5.2 milligrams, in both cases from 3 liters of water. Of course care was taken that loss did not occur from the crucible being uncovered or from spurting through sudden applications of heat, etc. In estimation of sulphuric acid (as barium sulphate) after ignition, to expel slight excess of ammonium fluoride and the silicon fluoride formed, the residue was treated with a drop of sulphuric acid and reignited. In the case of alumina and ferric oxide estimation there is generally present a small amount of silica which has escaped separation in its usual place; hence the silica found here was added to the total silica obtained in the regular estimation of that constituent. This silica found with alumina and ferric oxide may properly be thus regarded as wholly belonging to the total silica of the sample, as very little liquid is operated on after

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[1] Proc. Mich. Pharmaceutical Association, fifth year, p. 110.

the regular separation of silica before the separation of alumina and ferric oxide take place.

Evaporation was carried on in broad, shallow, ½-liter porcelain dishes, covered with a funnel of special design with an incurved rim, made to set snugly (but unfortunately not air tight) upon the rim of the evaporating dish.

I say unfortunately not air tight, for Mallet has shown that the flame of the Bunsen burner in time produces quite appreciable amounts (when fine work is considered) of $(NH_4)_2SO_4$ and that unless the evaporating dish is kept tightly covered, danger of error from this cause is likely to occur. (See Mallet's Report on Water Analysis in the Report of National Board of Health, 1882, p. 194, where he shows that nitrogen determinations by Frankland's combustion process, as ordinarily conducted, give too high results from this cause.) Mention of this is made here only to indicate that this might possibly somewhat affect the determination of sulphuric acid.

To the nozzle of the funnel was attached a rubber tube connected with a water section pipe. This served to create a rarefaction above the evaporating water, thereby increasing the rate of evaporation and permitting the use of the lower temperature. Any steam failing to pass off through the pump because of condensation on sides of the funnel could not run back into the dish, but was caught by the incurved rim of the funnel. Extraneous particles of dust, etc., were also thus excluded. When total solids were to be estimated evaporation was in no case continued to dryness; but the liquid concentrated to about 200 cubic centimeters was carefully transferred in portions to a large platinum evaporating dish, with subsequent thorough rinsing with distilled water, the whole evaporated to dryness, dried in the air bath at 100° C. for three hours, cooled in a desiccator over sulphuric acid, and weighed for total solids. Five such determinations were made. The residue was ignited at low red heat for about two hours to constant weight, cooled, and weighed as total inorganic solids. In a few cases this latter residue was treated with $(NH_4)_2 CO_3$ in solution, reheated, and weighed again; but the increase averaging only 0.6 milligrams per liter, this operation was subsequently neglected, although account was taken of it in final results.

One and one-half liters were concentrated by evaporation, transferred to platinum dish and evaporated to dryness, weighed, ignited, and weighed again, as described above, for total solids and inorganic solids. The residue was then examined qualitatively, by the usual methods, with good tests resulting for Al, Fe, Ca, Sr, and Mg (rather fainter test). The flame test showed Na but no K, which occasioned some surprise. Through the kindness of Prof. L. W. Langley, the aid of his spectroscope and his personal assistance were secured to identify any of the rarer metals that might be present—it being thought that Li at least might be present; but nothing was found that had not been already identified, except that faint, evanescent flashes of K were seen.

Thinking that previous estimation of total solids and consequent protracted ignition of this sample might possibly have affected the spectroscopic result somewhat, two or three fresh trials were made on concentrated solutions before full evaporation, but with no different results.

Pb was tested for in a large 8-inch test tube full of the sample (after acidulation with 1 to 2 drops of acetic acid) by addition of a drop of solution of $K_2Cr_2O_7$ with no result. Cu was tested for in a similar manner with 1 to 2 drops of solution of K_4FeCy_6 and allowed to stand over night, when a very faint green or greenish-blue tint was apparent, evidently due to Fe only. Mn was tested for by PbO_2 and HNO_3 (in concentrated solution), with no result.

Fair tests for HCl and H_2SO_4 were obtained. Cl water and CS_2 showed scarcely definable traces of Br, and $(NH_4)_2MO_4$ in HNO_3 solution gave no distinguishable trace of H_3PO_4, and no I nor TiO_2 was found, all, of course, worked for from concentrated solutions. Most, if not all, nitrates and nitrites would have been destroyed by ignition in presence of organic matter and were therefore not looked for at this point. (See under quantitative work.) In reference to the comparatively few elements found, it is to be remembered that different results might reasonably have been expected could larger quantities of the water have been spared for such work.

For quantitative work in each case 3 liters were taken and evaporated to dryness, after acidulation with HCl and SiO_2, separated in the usual way, with care against high heating and consequent danger of partial reunion of separated SiO_2 with the bases. Fe_2O_3 and Al_2O_3 were precipitated from the filtrate by boiling with fair excess of HH_4OH (in presence of NH_4Cl) and the united oxides weighed. The Fe was subsequently subtracted, after volumetric estimation by Oudemans' method (i. e., by $\frac{n}{10}$ $Na_2S_2O_3$ in presence of $CuSO_4$, with a drop of KCyS as indicator) and also by the excellent method described in Professor Cheever's Laboratory Notes (Part I, p. 27, and Part II, p. 6), by reducing Fe_2Cl_6 to $FeCl_2$ in boiling HCl solution, by means of $SnCl_2$ carefully added from burette, and any excess of $SnCl_2$ taken up with $HgCl_2$ and the $FeCl_2$ titrated with $\frac{n}{10}$ $K_2Cr_2O_7$. Al and Fe were also directly separated by pouring into boiling KOH in excess, after the method of Fresenius.

Ca and Sr were precipitated together from the filtrate from Fe and Al by addition of $(NH_4)_2C_2O_4$ and $(NH_4)_2CO_3$, the combined precipitates carefully heated in platinum crucible by playing back and forth underneath a small flame and carefully noting the change in color of the precipitates. After thus working to constant weight, the residue was tested with a bit of moistened turmeric paper to see that no reduction to oxides had occurred.

The Ca and Sr were then separated by the method of H. Rose (given by Fresenius) by precipitating with $(NH_4)_2SO_4$, filtering hot, and continued washing with concentrated solution of $(NH_4)_2SO_4$ until filtrate showed no test with $(NH_4)_2C_2O_4$. This filtrate after concentration was reworked for Ca by reprecipitation with $(NH_4)_2C_2O_4$. The Sr was treated similarly to $BaSO_4$ and weighed as $SrSO_4$. After weighing Ca as $CaCO_3$, in addition to the precautions mentioned above, the precipitate was in each case dissolved in excess of boiling $\frac{n}{10}$ H_2SO_4, to expel CO_2, and the excess of H_2SO_4 neutralized by $\frac{n}{r}$ KOH, with phenol phthalein as indicator, and Ca recalculated as a check.

Mg was precipitated from the filtrate from Ca and Sr in the usual way, as NH_4MgPO_4 and weighed as $Mg_2P_2O_7$. Double precipitation of the Ca and Sr was performed in each case to insure separation of Mg.

One liter was taken in each case, and the Na separated and weighed as NaCl, and then dissolved in water, and the Cl estimated with standard solution $AgNO_3$, and Na recalculated. The method for separation followed is the one used for separation of K, recommended by the Association of Official Agricultural Chemists, 1886 (Dept. Agriculture, Div. Chem., Bull. No. 12). The principle is familiar, i. e., the removal of bases and H_2SO_4 by boiling with $Ba(OH)_2$ and a little $BaCl_2$, filtering, and removing Ca by $(NH_4)_2C_2O_4$ and the excess of $BaCl_2$ by $(NH_4)_2CO_3$, the evaporated residue ignited, dissolved, filtered, acidulated with a drop of HCl, ignited, and weighed as NaCl, and treated as above. Great care and practice seem essential to obtain anything like closely concordant results. In the following table, because of considerable divergence in the gravimetric results, only the volumetric results are considered, the average of all being taken. That appreciable quantities of NaCl may be lost by several minutes' ignition at red heat is shown by Fresenius's experiments.

H_2SO_4. The precipitate in the preceding results for Na (thrown down by $Ba(OH)_2$ and $BaCl_2$) was treated with HCl in excess in hot solution, thoroughly washed and treated as usual for $BaSO_4$.

HCl. One-half to one-fourth liter was concentrated to about 100 cubic centimeters and the Cl estimated by $AgNO_3$, with K_2CrO_4 as indicator. Two strengths of the solution of $AgNO_3$ were tried; No. 1, 1 cubic centimeter of the solution = 1 milligram Cl; and No. 2, 1 cubic centimeter of the solution = 0.1 milligram Cl.

Combined CO_2. 250 cubic centimeters was concentrated to about 100 cubic centimeters, and moderate excesses of $\frac{n}{10}$ H_4SO_4 run in from burette, and the solution was boiled to free it from CO_2. Then excess of acid was neutralized with $\frac{n}{10}$ KOH with phenol phthalein as indicator. Fresenius recommends HNO_3 with tincture cochineal indicator; but probably through inexperience in its use the results were not thought to be so satisfactory as the method mentioned above. I am aware that the method adopted is open to very serious objections, not the least of which is the danger of loss of HCl and HNO_3 on boiling to expel CO_2. It was attempted to avoid this and the consequent higher results as much as possible by working to get the approximate point with the standard alkali with turmeric indicator before boiling, and then finishing in the usual way. It will be observed that if all the HCl and HNO_3 were lost it would increase the reading for CO_2 about 1.7 milligrams per liter. It would, on the whole, perhaps have been better to have used the theoretically much better method of liberating the CO_2 by acidulation in closed flasks and absorbing the CO_2 in KOH bulbs or standard $Ba(OH)_2$ solution by Pettenkofer's method. This was not tried, however, from fear of loss in transferring from evaporating dish to flask.

The specific gravity of the dish of water was taken by the spherical specific-gravity bottle used in this laboratory, and both distilled water and the sample were brought to 27° C. before filling the bottle.

In the following table all the results are the average of results obtained and in no case the result of a single estimation.

All results are given in parts per million; or, what is the same thing, milligrams per liter.

34. Lake Superior water.

Specific gravity (at 27° C)	1.0004
Total residue	69.97
Inorganic residue	57.61
Loss on ignition	12.36
Organic determinations:	
Free ammonia	.061
Albuminoid ammonia	.12
Oxygen consumed	1.77
Hardness:	
Temporary	[a]48.57
Permanent	[a]38.28

Inorganic constituents:

Al_2O_3 =	0.90	Al =	.48
Fe_2O_3 =	0.99	Fe =	.69
CaO =	17.98	Ca =	12.80
SrO =	1.60	Sr =	1.34
MgO =	4.63	Mg =	2.78
Na_2O =	4.29	Na =	3.18
K_2O	Very faint trace.	K	Very faint trace.
SO_3 =	3.11	SO_4 =	3.73
SiO_2 =	6.73	SiO_3 =	8.53
B_2	Trace.	B_2	Trace.
Cl =	2.43	Cl =	2.43
N_2O_4 =	0.00	....	
N_2O_5 =	0.67	N_2O_6 =	.77
CO_2 =	16.30	CO_3 =	22.23
			58.96

The purpose of this second set of figures, with bases reported as free elements and the acids as acid radicals, is that the total results thus obtained may be compared with the inorganic residue.

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[a] In parts per million, not in degrees.

WATERS OF RIVERS AND SMALL LAKES.

Constituent.	35. Battle Creek.	36. Owosso.	37. Jackson.	38. Ann Arbor.	39. Shiawassee.	40. Cass.	41. Chippewa.
$CaCO_3$	*3.679* .063	*6.041* .103	*8.652* .148	*7.495* .128	0.1090	0.1130	0.1314
$CaSO_4$	*1.494* .025	*1.394* .024	*2.490* .043	*5.810* .099	....	....	.0316
$(AlFe)_2O_3$	Tr.	*.058* .001	Tr.	Tr.	.0061	.0070	.0094
$MgCO_3$	*2.853* .049	*5.015* .086	*4.264* .073	*4.866* .083	.1789	.03322	....
$MgSO_4$	....	....	....	....	.0369	.0309	....
$(NaK)_2CO_3$	*1.770* .030	*1.228* .021	*.376* .006	*1.453* .025	....	....	....
(NaK)Cl	*1.020* .017	*1.360* .023	*1.200* .021	*.900* .015	.0231	.02405	.0504
SiO_2	*.380* .007	*.438* .007	*.537* .009	*1.343* .023	.0691	.0470	.0140
P_2O_5	....	....	....	....	Tr.	....	....
Ammonia, free	....	....	....	....	.00011	.00015	....
Ammonia albuminoid	....	....	....	....	.00054	.00054	....
Organic and volatile.	*.818* .014	*.818* .014	.... Tr.	*.818* .014	....	....	....
Total	*12.014* .205	*16.352* .279	*17.519* .300	*22.685* .387	*a* .423	*a* .2552	.2360
Hardness	....	....	....	....	16.6°	7.5°	....
Chlorine	....	....	....	....	.0140	.0146	....

a Inorganic.

Constituent.	42. Saginaw W.	43. Saginaw E.	44. Tittabawassee.	45. Bay City.	Constituent.	42. Saginaw W.	43. Saginaw E.	44. Tittabawassee.	45. Bay City.
$CaCO_3$	0.134	0.11057	0.138	....					
CaO	....	....	....	0.78624	Ammonia, free	0.00048	0.000104	0.000256	Tr.
$CaSO_4$	....	.01788	.04008	....					
$(FeAl)_2O_3$	.007	.0611	.0843	....	Ammonia albuminoid	.00043	.000350	.000440	0.00025
$MgCO_3$	.04678	....	....	....					
MgO	....	....	....	.36468					
$MgSO_4$	.02968	.01944	.0084	....	Total inorganic	.32686	.34509	.42438	....
SiO_2	.028	.078	.1092	....	Hardness	10.5°	6.4°	8.0°	....
NaCl	.0814	.0581	.0444	....	Chlorine	.0494	.0372	.027	.072
P_2O_5	Tr.	Tr.	Tr.	....					

Analyses 35A and 35B in the Appendix are of water from Boardman River near Traverse City, the former made by R. C. Kedzie and the latter by the Dearborn Drug and Chemical Works, and they agree in indicating a relatively soft water.

Analyses Nos. 35 to 38 are boiler-water analyses made by the Dearborn Drug and Chemical Works, of Chicago.

No. 35 is of the Battle Creek city water supply, which is usually obtained from Lake Goguac, and was made for the Advance Thresher Company on August 6, 1897.

No. 36 is of water from the Shiawassee River at Owosso, and was made for the Estey Manufacturing Company, factory A, on October 30, 1897; there is less matter in solution at Owosso than farther down the river, as shown by No. 39.

No. 37 is of water from the Grand River at Jackson, and was made for the Withington-Cooley Manufacturing Company on February 11, 1897.

No. 38 is of water from the creek at Ann Arbor (? the Huron River), and was made for the Ann Arbor Electric Company.

Analyses Nos. 39, 40, 42, 43, and 44 were made by G. A. Kirchmaier for the board of water commissioners of the city of Saginaw, and were published in the supplement to the annual report of that board for 1892, pages 31–33.

No. 39 is of water from the Shiawassee River.

No. 40 is of water from the Cass River.

No. 41 was made by J. E. Graves, of the Dow Chemical Company; the sample was taken from the Midland water supply (Chippewa River) on July 27, 1896. This analysis is very like analysis No. 44, of water from the Tittabawassee River.

No. 42 is of water from the west-side pumping station, Saginaw, and its thoroughly unsatisfactory condition will be treated in a later paper. The chlorine, 0.0494, is the highest of the set.

No. 43 is of water from the east-side pumping station, Saginaw.

Analyses 43A to 43D, made by H. and W. Heim for S. G. Higgins, show the composition of Saginaw River water at various places and the increase in NaCl and organic residue. The impurities in the water increase downstream. On the whole the magnesia and lime also increase, although quite irregularly.

No. 44 is of water from the Tittabawassee River.

No. 45 is of water from the Saginaw River at Bay City, and was made by Prof. A. B. Prescott at the same time as the analyses of the Bay City supply (Nos. 13 to 24), namely in July, 1885. The sudden increase in CaO and chlorides together is due to contamination by the waste bitterns of salt manufacture. The Marshall sandstone yields brines with considerable calcium chloride. The amount of lime carbonate does not increase with the general increase in mineral matter, but shows a strong tendency to stick at about one-tenth of an ounce per cubic foot, which is enough to indicate the presence of bicarbonates. Sulphates of lime are almost invariably present, though the sulphate is sometimes returned only as sulphate of magnesia. Throughout the coal basin and southwest of it this salt is very prevalent both in wells and streams.

Ten analyses, by college students, of water from a brook near the Agricultural College (analysis No. 36A in the Appendix) give, as an average result, a much softer water than most of the stream waters analyzed. The sample was probably taken after a rain.

A series of twenty-two analyses of waters from marl-depositing and other lakes, wells, and outlet streams, collected by D. J. Hale, near

Cloverdale, Barry County, were made by A. N. Clark. The $MgCO_3$ is usually between 0.065 and 0.085 parts per thousand, the extremes being 0.203 and trace. The amount of $CaCO_3$ is more variable, being as high as 0.217 and never less than 0.030. As much as 0.066 of free CO_2 was sometimes found, supposed to be in addition to that present as bicarbonate.

	46. Cadillac.	47. Battle Creek.	48. Mancelona.	49. St. Louis.	50. Wayne.	51. Wayne.
Result of inoculation	–	–	+		–	–
Number of bacteria in 24 hours	100	Countless.	76	1,088		
Nitrites						0.000026
Nitrates	Tr.		Tr.			.000016
Albuminoid ammonia	0.0000528	0.00022	0.0000533	0.00032		
Free ammonia	Tr.	.00015	.000013	.000046		
Permanganate reduced			26			
Chlorine as NaCl	.00066	.028	.0083			.033
Organic residue	.040	.080	.288			
Inorganic residue	.060	.100	.246			
Total residue	.100	.180	.534			
Hardness	4.0°	10.2°	14.3°	14.4°		

Analyses Nos. 46 to 51 are sanitary analyses by Prof. V. C. Vaughan, of Ann Arbor, and are in general subject to the same remarks and interpretation as the others (see p. 44).

No. 46 (193), water from Clam Lake near Cadillac, July 29, 1893; brownish, musty; microscope shows vegetable fibers and a few forms of animal life.

No 47 (294), water from a Battle Creek hydrant; reacts alkaline, and under the microscope shows diatoms and inorganic matter.

No. 48 (345), water from a lake in Mancelona, T. 29 N., R. 6 W., November 17, 1896. The water is reddish brown in color, has a marked odor and acid relation, and under the microscope shows the presence of considerable vegetable matter.

No. 49 (35), water from the Pine River at St. Louis; contained no pathogenic germs.

No. 50 (372), water described as "cloudy, stinking," and No. 51 (373), were tests of Huron River water and the overflow of the settling basins of the Wayne County poorhouse, October 25, 1897.

WATERS FROM WELLS IN THE UNCONSOLIDATED DEPOSITS (PLEISTOCENE) AND FROM SPRINGS.

This group includes those waters which have penetrated in their circulation but a little way under ground. All the common dug wells belong to this class, and probably a very large portion of the waters of the unclassified analyses given in a later section.

The Michigan board of health has issued a plate showing the relation that the depth of water in wells bears to the prevalence of typhoid fever during the different months of the year. From April to June the water in the wells is, on an average, within 200 inches of the surface of the ground, and typhoid fever is least common. By October the average water level has fallen over 30 inches, and typhoid fever is most prevalent.

I begin with analyses which show only a small proportion of mineral matter—considerably less than 1 ounce to the cubic foot—and which may be classed as pure drinking waters, soft or slightly hard. Some of these waters are reputed to have curative powers, but none have any mineral taste, and it is probable, as the proprietor of the Ponce de Leon spring remarks, that their virtue lies mainly in their purity.

As the percentage of mineral matter increases the waters, almost without exception, become hard, and are comparable to the river waters in lime (one-tenth to two-tenths of an ounce per cubic foot), but contain more iron and silica than the latter. In these more mineralized waters some of the apparent variety in the chemical combinations seems to be due to the fancy of the chemist—for instance, the presence of sulphate of potash in some and of carbonate of potash in others of the Benton Harbor Eastman springs. Analyses by Duffield are particularly unusual in the combinations assumed.

It will be noticed on comparing the deeper and shallower wells at Traverse City (Nos. 56 and 57), at Holland (Nos. 147 and 159), and at Ypsilanti (Nos. 70 and 71), that no tendency is seen toward a greater mineralization with depth—the rule which prevails among wells in the rock. It is probable that a careful study would show a zone close to the surface, a foot to a few feet down, from which the lime had been removed by leaching, for at Mecosta and other places I have found very shallow, easily exhausted wells used for laundry purposes. Then just below this would be a belt in which the lime and iron had been deposited as a cement in extra richness, while lower down would be found waters of the unaltered drift.

Finally, there is a group of waters (analyses Nos. 73 to 80) which are strongly sulphated, and, with the exception of the Detroit well, come from the same region, a region in which gypsum bowlders have been found scattered in the drift. The exception (No. 76) has more salt than the others, and is more like a weak brine. Near Marine City, on the farm of Mrs. E. Gardner, there is a well of which no complete analysis of the water is available, but which is said to contain, out of a thousand grains per gallon solids, more than half $MgSO_4$ (Epsom salts). Such sulphated waters may be due either to the solution of gypsum or to the production of sulphuric acid or sulphates by the decomposition of pyrite, which is abundant in the drift and in the rock, and their subsequent reaction upon carbonates or chlorides.

The wholesomeness of these sulphated waters depends largely on the individual constitution. Professor Kedzie condemned waters from Mount Pleasant as too high in sulphates (and I should agree with him) which Professor Vaughan passed as good because free from dangerous organic contamination. I find, however, that in such regions some doctors complain of the prevalence of indigestion, constipation, and calculi.

Belonging to the group of highly sulphated mineralized waters from the drift of the center of the State are probably some of the analyses by Kedzie of waters around Saginaw (Nos. 108 to 110), but as some of those wells penetrate a few feet into the top sandstone, and as others draw their water from a bed immediately overlying it, I have deemed it better to treat them in the next section, since it is not certain how far wells in the drift only are mineralized under that city. For example, the well at 905 Court street, East Saginaw, about 80 feet deep, gave in the analysis of Dr. Small only 6.5 grains to 1 liter, or 0.421 part to a thousand solids, with a faint Cl reaction. The two Midland waters (analyses Nos. 75 and 77) are in practically the same class.

Constituent.	52. Ponce de Leon spring.	53. Harbor Springs.	54. Greenville.	55. Ann Arbor (University).	56. Traverse City High School.	57. Traverse City (Asylum).	58. Pontiac.
Al_2O_3							*0.0806* .0014
$CaCO_3$	*7.2* .12312	*8.50* .121	*9.63* .136	0.178	0.128	*9.758* .167	*9.6807* .1660
$CaSO_4$	Tr.		0		.002	*1.328* .026	
Fe_2O_3		*.50* .007			.003	*.298* .005	*.5025* .0086
$FeCO_3$				.0029			
Li_2CO_3							*.0200* .0003
$MgCO_3$		*1.50* .021	*3.175* .045	.06058	.034	*4.004* .068	*3.9159* .0672
KCl							*.06990* .0012
K_2SO_4				.00678			
SiO_2		*1.00* .014		.0073	.006	*1.997* .034	*.4082* .0070
NaCl	Tr.	*.50* .007	0	.00448	.006	Tr.	*.3090* .0053
Na_2CO_3				.00152		*a .602* .010	*.2916* .0050
Na_2SO_4				.00507			*.2799* .0048
Nitric acid			*.207*				
Free CO_2			.003	.0015598			
Organic	*1.75* .030	*1.50* .021	0	.0023	.014		*c .9244* .0158
Total	*8.959* .153564	*13.00* .183	*13.25* .189	.28963	.193	*17.987* .307	*16.4827* .2826
Total hardness	7.2°	11.°			12.°		
Permanent hardness		5.°			6.°		
Free ammonia			.000052		.00015		
Albuminoid ammonia			.000003		.00008		

a CNa or K. *b* Oxygen reduced by permanganate. *c* Loss.

Constituent.	59. "King David," Benton Harbor.	60. "Silver Queen," Benton Harbor.	61. "Saul," Benton Harbor.	62. "Colonel's Own," Benton Harbor.	63. Springs, Petoskey.	64. "Park," Alma.	65. "Nochemo," Reed City.
Al_2O_3	*0.117* .0020						0.001
$CaCO_3$	bi. *8.124* .1390	bi. *6.800* .1165	bi. *7.797* .1336	bi. *8.835* .1520	*12.32* .176	0.188	bi. .203
Fe_2O_3				*.234* (*a*).00402	*.14* .002		0.03
Fe_2CO_3	bi. *1.298* .0223		bi. *1.049* .018			.106	.003
$MgCO_3$	bi. *3.532* .0605	bi. *3.225* .0553	bi. *6.144* .1052	bi. *6.296* .1078	*2.80* .040	.041	bi. .110
P_2O_5	Well-marked traces.						.0003
Mn	Do.						
K_2CO_3		bi. *1.074* .0184		bi. *1.559* .0267			
$MgSO_4$						.020	
K_2SO_4	*.145* .00244	Tr.	*.083* .00145	Tr.			Tr.
SiO_2	*.583* .0100	*.117* .0020	*.350* .006	*.117* .0020	*.70* .01	.017	.014
NaCl	*.119* .00205	*.096* .001645	*.095* .00163	*.119* .0020	*.49* .007	.007	.014
$NaCO_3$	bi. *.676* .01168	bi. *1.364* .0234	bi. *1.021* .0176	bi. *.835* .0188			bi. .033
Na_2SO_4			*.110* .00199				
Organic					*2.10* .03		
Total	*14.592* .2502	*12.676* .2004	*16.649* .2854	*18.035* .3096	*18.55* .265	.378	.378
CO_2 (*a*)	36.38	35.46	37.21	38.96		.027	

Constituent.	66. Ann Arbor (S. Mann).	67. Wayland (spring).	68. Otsego.	69. Albion (Warner's spring).	70. Ypsilanti (waterworks).	71. Ypsilanti (well).	72. Hubbardston (magnetic spring).
Al_2O_3				0.004		Tr.	
$CaCO_3$	0.228	*7.50* .107	bi. 0.244	bi. .290	0.289	*9.109* .156	bi. 0.400
$CaSO_4$		*3.20* .046	.011	.058	.039	*12.948* .223	
Fe_2O_3		0	.036		.021	Tr.	.005
$FeCO_3$	.00468			bi. .029			
LiCl					Tr.		
$MgCO_3$	.08936	*.520* .074	bi. .026	bi. .080	.100	*6.370* .109	bi. .187
K_2SO_4	.00531		.020	.006			

a + Al_2O_3.

Constituent.	66. Ann Arbor (S. Mann).	67. Wayland (spring).	68. Otsego.	69. Albion (Warner's spring).	70. Ypsilanti (waterworks).	71. Ypsilanti (well).	72. Hubbardston (magnetic spring).
SiO_2			0.048	0.003	0.014	*1.139* .018	0.004
H_2SiO_3	0.012						
NaCl	.00488	*0.65* .009	.028	.021	.035	*3.600* .062	
Na_2CO_3	.00042	*1.50* .021				*1.056.* .017	
Na_2SO_4	.00971			.036			
NaI	Tr.						
Nitrates					Tr.		
Volatile at red heat	.025	*8.00* .114		Loss. .017	.071	*.818* .014	
Total	.37936	*27.000* .386	.449	.546	.570	*35.04* .599	.596
Ammonia free					.00003		
CO_2	.285		8 cu. in.				
Ammonia albuminoid					.00002		

Constituent.	73. Mount Pleasant (waterworks).	74. Mount Pleasant (waterworks).	75. Midland (Reardon).	76. Detroit (Amos T. Hall).	77. Midland (magnetic spring).	78. St. Louis.
$Al_2O_3P_2O_5$					0.025	
$CaSiO_3$						0.096
$CaCO_3$	(?)	0.173	bi. 0.038	0.3919		bi. .991
$CaCl_2$					.089	
$CaSo_4$	0.620	1.044	.0443	.2826	.064	.950
$FeCO_3$				.0102		bi. .017
$MgCO_3$	.120	.067				bi. .250
MgCl				.3476	.031	
$MgSO_4$			.0560			
KCl				.1100		
K_2SO_4				.1045	1.174	
H_2SiO_3			.054			
SiO_2				.0237	.042	.041
NaCl		.086	1.155	.7252	.467	Tr.
$NaCO_3$						bi. 1.520
$NaSO_4$	.018				.315	
Loss at red heat	.100	.024			.046	.029
Organic					.035	
Total	1.130	1.580	1.416	1.9957	2.288	3.895
Nitrites	Strong.	Distinct.				
Nitrates		Strong.				
Temporary hardness	8.°					
Permanent hardness	30.°					
CO_2						.089
Ammonia free	.00008	.003				
Ammonia albuminoid	.00002	.00015				
H_2S						Tr.

	79. Mount Pleasant (test well).	80. Mount Pleasant (test well).
Result of inoculation	—	—
Number of bacteria in 72 hours	425	120
Nitrites	Large.	Very slight trace.
Nitrates	Tr.	Tr.
Albuminoid ammonia	0.0000213	0.000072
Free ammonia	.00012	.000043
Permanganate reduced	0.002	0.002

	79. Mount Pleasant (test well).	80. Mount Pleasant (test well).
Chlorine as NaCl	.1815	.198
Organic residue	.470	.440
Inorganic residue	1.676	1.852
Total residue	2.146	2.292
Hardness	2.4°(?)	2.6°(?)
Sulphates	Large.	Large.

No. 52 is of water from the Ponce de Leon spring, Grand Rapids, John DeBoe, analyst; bottled and used commercially since 1848; has no color, taste, odor, or sediment; specific weight at 59° F., 1.00465; found under 22 feet of clay; contains no nitrites; 0.000422 (0.0246) nitrates; 0.000015 (0.00087) free ammonia; and 0.000022 (0.00128) albuminoid ammonia. (For further notes and record of temperatures for different months in the year, see a later paper.)

No. 53, F. S. Kedzie, analyst for E. Shay & Son; water from 320-foot well at Harbor Springs. (See description in a later paper.)

No. 54 is of water from Greenville, February, 1888; furnished by city clerk. Oxygen reduced by permanganate 0.0003.

No. 55, Ann Arbor, water from well on north side of campus, 70 feet 8 inches deep; T. C. McNeill, analyst; temperature 50°; biennial report of State geologist (Michigan), 1861, page 203.

No. 56, F. S. Kedzie, analyst; nitrates, a slight trace; nitrites, none; water colorless, odorless, tasteless, of excellent quality; compare with analysis No. 3. This analysis is cited in Rafter's report to the city council of Traverse City as from Park Place Hotel. A full description of the numerous deep-flowing wells of Traverse City, of which this is an example, will be found in a later paper.

No. 57, Dearborn Drug and Chemical Works, analysts; primarily a boiler-water analysis; Na and K, Fe_2 and Al_2 included together. Well deepened since analysis was made. (See description in later paper.) The city is not supplied from these wells, the water being too hard, but from the bay (Nos. 2A, 2B, 2C, and 3).

No. 58, J. E. Clark, analyst; Welcome Island lithia water, 3 miles north of Pontiac, in the center of Lake Angelus.

No. 58A, an analysis of water from the Mount Clemens Pagoda springs; analysis of a much-used similar water will be found in the Appendix; C. G. Wheeler, analyst; temperature, 52°.

Nos. 59 to 62 are of waters from four out of the thirty or more springs of H. E. Eastman, 1 and 2 miles southeast of Benton Harbor; Professor Haines, analyst. The more mineralized waters, with the greater specific weight, seem to have a higher temperature and perhaps draw from a deeper layer, as follows:

No. 59, water from King David spring, Benton Harbor; temperature, 50° F.; specific weight, 1.000.

No. 60, water from Silver Queen spring, Benton Harbor; temperature, 50° F.; specific weight, 1.000125.

No. 61, water from Saul spring, Benton Harbor; temperature, 51° F.; specific weight, 1.00025.

No. 62, water from Colonel's Own spring, Benton Harbor; temperature, 51° F.; specific weight, 1.00025.

No. 63, water from Petoskey springs, F. S. Kedzie, analyst; 12° total hardness, 2° permanent hardness. Compare the analysis of water from the deep well (No. 294) in the Dundee limestone.

No. 64, water from Alma, C. A. Davis, analyst; originally stated in grains per United States gallon for the Alma Sanitarium. (See fig. 3, and compare descriptions and tests of waters from Alma wells in a later paper.) Temperature, 48.2° F.; reaction neutral or slightly alkaline.

No. 65, water from Nochemo spring; R. Fischer and A. B. Prescott, analysts; original statement in grains per United States gallon. Water bottled and sold is from flowing driven wells in a river bottom; the yellow of a chalybeate water is very apparent about them. The region is said to be an old deer-lick. (Compare analysis No. 83.)

No. 66, water from spring on land of Solomon Mann; T. C. McNeill, analyst; temperature, 50° F.; specific gravity, 1.001. Basis of sanitarium for several years. Biennial report of the State geologist (Michigan), 1861, page 204; Winchell, Geology of Washtenaw County (History of Washtenaw County), 1881, page 14. The CO_2 is partially free and partially combined acid. The water from Mount Clemens Pagoda springs (No. 58A) is similar.

No. 67, F. S. Kedzie, analyst; Wayland spring water. There are many flowing wells in Wayland, but only one is a rock well.

No. 68, cited by A. C. Peale, Bulletin U. S. Geological Survey No. 32; R. S. Kedzie, analyst. Water contains a trace of H_2S and 8 cubic inches CO_2 per gallon, and is from a rock well; the amount of potash is abnormal and reminds one of the Midland analyses.

No. 69, Warner's spring, Albion; D. Fall, analyst; cited by Peale, Bulletin U. S. Geological Survey No. 32, from Report State Board of Health, 1875, page 89; from flowing springs south of Lake Shore and Michigan Southern Railroad.

No. 70, F. S. Kedzie, analyst; water from Ypsilanti city waterworks; quality excellent. (See fig. 2.)

No. 71, 18-foot well; Dearborn Drug and Chemical Company, analysts for the Ypsilanti Electric Company; a boiler-water analysis, originally stated in grains per United States gallon.

No. 72, P. (? S.) H. Douglass, analyst; cited by Peale, Bulletin U. S. Geological Survey No. 32.

No. 73, July, 18, 1896; No. 74, Aug. 17, 1893. Nos. 73 and 74 are of water from the Mount Pleasant waterworks' 40-foot well; F. S. Kedzie, analyst. Note the apparent leaching out of sulphates in course of time. This water is not used for boilers, but river water is used instead. (See analysis No. 49.) It leaves a red coating in a porcelain dish.

No. 75, J. E. Graves (Dow Chemical Company), analyst. Water clear, neutral, odorless; tested by A. C. Lane November 2, 1897; SO_4 moderate, Ca low, Cl low; specific gravity, 1.001; 50° F.

No. 76, water from well of Amos T. Hall, Woodward avenue, Detroit; S. H. Douglass, analyst, 1854, for board of water commissioners; cited from Winchell's biennial report of the State geologist, 1861, page 203.

No. 77, water from Midland magnetic spring; cited by Peale, op. cit. (Compare Nos. 75, 248, and 249.) The amount of potash seems incredible, and suggests an error in transcription. It agrees in indicating a sulphated water. I believe that it and No. 248 are perverted versions of No. 249.

No. 78, water from St. Louis, S. P. Duffield, analyst; cited, slightly differently, by Peale, op. cit.; temperature, 50° F. This should be compared with the analysis of a water from St. Louis (No. 113), made by Kedzie December 1, 1893.

No. 79 (361), water from Mount Pleasant test well, V. C. Vaughan, analyst; July 13, 1897. Water yellowish opalescent. Microscope showed organic matter.

No. 80 (365), water from Mount Pleasant test well, V. C. Vaughan, analyst; Aug. 17, 1897. Water yellowish opalescent. Microscope showed a considerable amount of amorphous matter. The last two analyses are from the 205-foot test well. (See later paper.)

UNCLASSIFIED ANALYSES.

Among the analyses furnished me through the kindness of Professors Kedzie and Prescott there were a large number the records of which were not so exact as to make the geological source of the waters certain. It is true that, judging from the analyses, I can in each case give the probable source of the water, yet it would obviously be reasoning in a circle to thus doubtfully assign them to geological sections and then proceed to draw, from analyses so grouped, deductions as to the character of the water from a given formation. At the same time it seemed to involve too much burden on the time and kindness of the gentlemen mentioned, as well as delay in publication, to enter upon the search and correspondence necessary to ascertain with certainty the geological conditions in all cases. In a few instances the geological conditions have been determined with certainty, but too late to be available without a complete rearrangement of all the analyses.

As most of the waters sent in, especially those sent to Professor Vaughan, have been the subject of suspicion, and as most of the water sources in the State are wells in the drift, which are more open to suspicion than rock wells, it is obvious that most of these analyzed waters of uncertain origin belong to the group of the preceding section, waters more or less from the drift; this is the excuse for introducing these analyses here rather than later. Whenever one of these analyses seems to indicate a water not from the Pleistocene, attention is called to the fact.

Peale, in Bulletin U. S. Geological Survey No. 32, does not give the geological source of the waters analyzed. Most of them, however, I have been able to classify by determining their geological source in such ways as the following examples will indicate: The Alpena magnetic well is certainly one of the deep borings into the so-called Dundee limestone, as the temperature (52° F.) of the water, which is 10° higher than the mean annual temperature of Alpena (42°), and its sulphureted character indicate, and I have placed it accordingly. (Analysis No. 297.) The Berrien springs are uncertain, and no analysis is given. Butterworth's magnetic spring, or Grand Rapids magnetic, as I learn from Mr. Powers,[1] is a well into the Marshall, with mineral additions from the Michigan series; or, as Mr. Powers says, his own well (the Arcade) draws from the lower 18 feet of the Marshall sandstone, which is about 100 feet thick, and has less $CaCl_2$ than Butterworth's, which draws from the upper part. The waters of the Cascade springs are not analyzed. The chalybeate springs near Ann Arbor, although no analysis of the water is given, are in all probability wells in the drift (see analyses Nos. 55 and 66, from Winchell's biennial report, 1861, page 203, and Geology of Washtenaw County, 1881), and those of Wayne County may be from the drift, and are likely to be wells just above the rock. As Peale remarks, wells are often called springs, especially when the water rises markedly when struck. The Springville well is probably from the drift, but the water is not analyzed. The Eaton Rapids springs and well are flowing wells from the Coal Measures and the Parma. (Analyses Nos. 243 to 247.) The proportions of $CaCO_3$ and potash in these analyses are characteristically large.

The Erie sulphur springs are only examples of a great number of sulphur springs in the same region, flowing wells to or into the Dundee (upper Helderberg or Corniferous) limestone, of the same class as the Wyandotte or Riverside wells (analyses Nos. 296 and 300). Flint's magnetic springs at Three Rivers, in St. Joseph County, being saline are probably in the rock, as the drift well waters in that part of the State are not usually saline; while on the other hand the Berea or other saline beds of the Coldwater shales may readily be struck. The Fruitport artesian and magnetic well shows by its record and its temperature (48° F.) that it draws water from the Marshall. The water of the Grand Haven mineral spring is similar in analysis, and also comes from the Marshall (see analyses Nos. 264 to 266). The Grand Ledge water is probably from the Coal Measures. The Hubbardston magnetic spring

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[1] See also Winchell's biennial report, 1861, p. 168.

(well), if it is the one of which Mr. Lincoln has furnished a record, is in the Pleistocene, but if not, as the drift is thick over all the region and as I am informed that rock has not been struck, it is probably a drift water, although it should perhaps have been included here in the unclassified section, rather than as analysis No. 72. The Lansing magnetic (Michigan Congress) well shows by its depth that it goes through the Marshall. It is plugged part way down. The temperature (53.5° F.) being not more than 7° above the mean annual temperature of the place, indicates that the main flow is from the same horizon as the deep Agricultural College well, i. e., from the Marshall, and the analyses (Nos. 241 and 242) show, as I have likewise been informed, that the upper calcic waters are not cased out. The Leslie magnetic well is almost certainly from the Coal Measures, though we have placed the analysis near those furnished by Prof. F. S. Kedzie below (No. 228). The Midland magnetic well (analysis No. 77) has been placed for comparison beside No. 78. Its temperature indicates that its depth is no greater than that of No. 78, but the analysis needs verification, and it may be merely an erroneous form of analysis 249, which water is from the Coal Measures. We have no analysis of the water from the Arcade Building mineral well at Grand Rapids, unless some of the uncertain analyses of Vaughan or Kedzie refer to it. The Moorman well (analyses Nos. 304 and 305) is, as is obvious from the description below, from the temperature (57.5° F.) of the water, and from the section shown in fig. 2, chiefly from the Helderberg limestone. Owen's mineral well (56.6° F.) and the Ypsilanti mineral well (58.1° F.) are similar. The Mount Clemens springs are from the same horizons. The Ogemaw mineral springs are in all probability from the drift and similar to those around Rose City. The Otsego mineral springs (analysis No. 68) appear to be from the drift. The Owosso spring analysis is most likely of water from one of the wells into the upper Coal Measures. Its source is, however, so uncertain that it is given below in this section (analysis No. 227). The Riverside magnetic mineral springs (Springwell's Fort) in Detroit are from the Dundee and the upper Monroe, as the temperature (50° F.) shows, and are described in the appropriate place. The St. Clair spring belongs to the same family. (See pp. 77, 78.) The St. Louis magnetic spring analysis (No. 78) is of water from a deep drift well within the coal basin. The Springlake magnetic well analysis (No. 265) belongs with the analyses of water from the Fruitport and Grand Haven wells, as all draw from the Marshall (Nos. 264 to 266). The Shawnee mineral springs probably derive their supply from the Helderberg or the immediately overlying drift, but the waters are not analyzed. The temperature (47° to 49°) is practically the mean annual temperature of the place, which shows that the wells are not deep.

Sulphur springs are very abundant in that region and apparently derive their water from the Dundee limestones, in some cases, perhaps, from the Monroe. (Compare analyses Nos. 294 to 302.)

ANALYSES BY PROFS. R. C. AND F. S. KEDZIE.

Constituent.	81. Grand Haven (hydrant).	82. Grand Haven.	83. Reed City.	84. Coldwater.	85. Ludington.	86. Pontiac.
$CaCO_3$	*4.20* .06	*7.0* .100	*5.25* .075	*9.10* .130	*6.10* .087	*10.50* 1.50
$CaSO_4$	*.56* .008		*.14* .002	*.35* .005		*.14* .002
Fe_2O_3		0	*.07* .001	*.07* .001	*.20* .003	*.28* .004
$MgCO_3$	*.296* .042	*3.0* .042	*3.52* .050	*3.50* .050	*5.20* .074	*5.32* .076
K_2SO_4		0		*.56* .008		
SiO_2		0	*.84* .012	*.14* .002	*1.00* .014	*1.40* .02
NaCl	*.12* .002	*.87* .012	*1.38* .020	*.70* .010	*2.50* .036	*.63* .009
Volatile at red heat	*3.15* .045	*5.0* .071	*2.10* .030		*2.00* .029	0
Total	*10.99* .157	*16.6* .237	*13.30* .190	*14.42* .206	*17.00* .243	*18.27* .261
Total hardness		*6.* °			*14.* °	
Permanent hardness		3. °			7. °	
Nitrates		.000324			.0005	
Nitrites						
Free ammonia	.00007	.000105			.00007	
Albuminoid ammonia	.00010	.000008			.00001	

Constituent.	87. Soldiers' Home, Grand Rapids.	88. Grand Rapids No. 1.	89. Grand Rapids No. 2.	90. Dowagiac.	91. Niles.	92. Kalamazoo.	93. Kalamazoo No. 1.
$CaCO_3$	*8.50* .122	*8.80* .126	*8.70* .124	*10.00* .143	*8.86* .127	*10.50* .150	*12.60* .18
$CaSO_4$	*1.20* .017	*.28* .004	*.30* .004	*1.50* .021	Tr.	*1.51* .022	*1.50* .021
Fe_2O_3				*.50* .007	*.56* .008		$+SiO_2$ *3.67* .052
$MgCO_3$	*2.60* .037	*3.96* .057	*4.00* .057	*2.00* .029	*5.29* .076	*7.04* .101	*4.36* .062
K_2SO_4					*0.70* .01		
SiO_2				*1.00* .014	*.96* .014	*.61* .009	
NaCl	*.45* .006	*.50* .007	*.50* .007	*2.00* .029	*.20* .003	*.47* .007	*1.37* .020
Na_2SO_4					*1.02* .015		
Volatile at red heat	*3.00* .043	*6.46* .092	*7.00* .10	*4.20* .06	*3.50* 0.050	*2.27* .03	*2.50* .036
Total	*15.75* .225	*20.00* .286	*20.50* .293	*21.20* .303	*21.23* .303	*22.40* .320	*26.00* .371
Total hardness	*14.* °	*15.* °	*15.5*°	*12.* °			*16.* °
Permanent hardness	6. °	8. °	8.5°	2. °			5. °
Nitrates	.002				.00014		.001
Free ammonia	.00005	.00015	.00008		.0002		.00002
Albuminoid ammonia	.00008	.00025	.0001		.00003		.00002
O from permanganate							.000028

Constituent.	94. Kalamazoo No. 2.	95. Dimondale.	96. Adrian.	97. Stanton.	98. Rochester.	99. Battle Creek.	100. Owosso.
$CaCO_3$	9.80 .140	12.95 .185	8.75 .125	13.25 .189	14.50 .207	....	10.78 .154
$CaSO_4$	1.60 .023	.27 .004	Tr.	1.54 .022	2.00 .029	....	2.10 .03
Fe_2O_3	.30 a .004	.05 .001	....	....	1.00 .014	....	....
$MgCO_3$	4.66 .067	5.25 .075	6.62 .095	5.81 .083	2.25 .032	....	9.52 .136
KCl	....	.28 .004	....	....	....	....	....
SiO_2	....	.20 .003	....	1.00 .014	....	....	.07 .001
NaCl	1.64 .023	.70 .01	.33 .005	.40 .006	.75 .011	2.00 .029	2.10 .03
Volatile at red heat	3.00 .043	2.70 .039	7.00 .100	2.00 .029	3.00 .043	16.00 .229	1.68 .024
Total	21.00 .30	22.40 .32	22.70 .324	23.00 .329	24.50 .35	25.00 .357	26.25 .375
Total hardness	14.°	....	15.5°	21.°	19.°	10.°	....
Permanent hardness	6.°	....	10.°	10.°	8.°	9.°	....
Nitrates	.0005	....	....	....	Tr.	....	....
Free ammonia	.00005	.00002	.00015	....	.00005	.00003	....
Albuminoid ammonia	.00002	.00001	.00020	0.0	.00001	.00025	....
O from permanganate	.00025	....	....	....	....	....	....

Constituent.	101. Port Huron.	102. Howell.	103. Tecumseh.	104. Moline.	105. Belding.	106. Lapeer (Home of Feeble-Minded).	107. Lapeer.
$CaCO_3$	8.40 .12	14.10 .201	14.28 .204	11.20 .160	39. .557	....	....
$CaSO_4$	5.35 .077	2.00 .029	4.50 .064	1.35 .019	2.80 .04	9.90 .141	....
Fe_2O_3	Tr.	1.00 .014	.10 .001	.50 .007	.20 .003	.08 .001	....
$MgCO_3$	3.15 .045	5.00 .071	6.62 .095	12.25 .175	.50 .007	3.42 .049	....
SiO_2	....	1.40 .20	....	1.00 .014	....	.30 .004	....
NaCl	.53 .008	1.00 .014	.50 .007	.80 .011	5.00 .071	5.40 .077	b 16.33 b .233
Na_2SO_4	....	....	....	....	....	20.10 .287	....
Volatile at red heat	10.5 .15	3.60 .051	6.00 .086	5.8 .083	3.50 .05	4.20 .60	20. .286
Total	28.00 .40	28.10 .401	32.00 .457	32.9 .470	51. .729	43.40 .620	80. 1.143
Total hardness	17.°	20.°	17.°	....	....	11.°	14.°
Permanent hardness	9.°	10.°	6.°	....	....	7.°	10.°
Nitrates	....	.000	....	....	....	Tr.	.002
Nitrites	....	....	....	....	....	Tr.	0
Free ammonia	.00005	.00006	....	....	.000003	.00001	.00001
Albuminoid ammonia	.00009	.00005	....	....	.000001	.00003	.000004
Oxygen of permanganate reduced.	....	....	....	....	.0005	....	....

a + SiO_2.

b All chlorides.

Constituent.	108. Saginaw (Brand & Hardin).	109. Saginaw (Washington ave.).	110. Saginaw (Tower Block).	111. St. Charles.	112. Bay City.	113. St. Louis.	114. Saginaw (William Hicks).
$CaCO_3$	*3.00* .043	*6.40* .091	*11.55* .165	*8.40* .120	*14.70* .210		
$CaSO_4$	*5.40* .077	*9.20* .131		*9.80* .140	*31.99* .457	*39.90* .570	*28.* .400
RSO_4			*23.10* .330				
Fe_2O_3	*.35* .005	*.50* .007				*.35* .005	Tr.
$MgCO_3$	*3.92* .056	*5.50* .079		*8.50* .121	*8.47* .121	*26.81* .383	
$MgSO_4$							*15.3* .219
KCl						*13.65* .195	
SiO_2	*1.00* .014	*1.00* .014			*a .14* .002	*.28* .004	*.5* .007
NaCl	*28.83* .412	*30.28* .433	*2.00* .029	*32.90* .470	*53.20* .760	*100.31* 1.433	*118.7* 1.696
Na_2SO_4	*19.00* .271	*20.12* .287					
SO_3							*2.1* .003
Total mineral						*200.30* 2.861	
Volatile at red heat	*5.50* .079	*6.00* .086	*3.00* .043	*8.40* .120	*10.50* .150		*17.5* .25
Total	*67.0* .957	*79.* 1.129	*50.10* .716	*68.00* .971	*119.* 1.700		*210.* 3.000
Total hardness	*14.*°	*18.*°			*18.*°		*19.*°
Permanent hardness	10.°	13.°			14.°		18.°
Nitrates		.021					
Nitrites		0.0					
Free ammonia		.00050			.00013	.00003	
Albuminoid ammonia		.00025			.00003	.00002	

Constituent.	115. Flushing No. 1.	116. Flushing No. 2.	117. Flushing No. 3.	118. Flushing No. 4.	119. Frost.	120. Vassar.	121. Caro.
$CaCO_3$	*9.00* .129			*2.80* .04	*20.60* .294		*21.00* .30
$CaSO_4$					*20.00* .286	*105.7* 1.51	*185.50* 2.65
Fe_2O_3	*2.00* .029				*.25* .003	*1.0* .014	*.70* .01
$MgCO_3$	*1.13* .016	*1.00* .014	*2.00* .029	*1.00* .14	*13.30* .19	*17.5* .25	*19.60* .28
KCl							*3.50* .05
K_2SO_4						*10.5* .15	

a + Fe_2O_3.

Constituent.	115. Flushing No. 1.	116. Flushing No. 2.	117. Flushing No. 3.	118. Flushing No. 4.	119. Frost.	120. Vassar.	121. Caro.
SiO_2	*5.00* .071				*1.15* .016	*1.5* .021	
NaCl	*158.69* 2.267	*141.27* 2.018	Not determined.	*122.* 1.743	*168.70* 2.41	*277.2* 3.96	*466.90* 6.67
Na_2CO_3	*17.08* .244	*22.00* .314	*42.50* .671	*41.00* .586			
Na_2SO_4	*89.00* 1.271	*3.50* .05	*7.80* .111	*5.40* .077			
Total mineral	*289.90* 4.156						
Volatile at red heat		*4.90* .07	*9.80* .140	*7.00* .10	*14.* .2		
Total		*181.10* 2.573	*233.80* 3.340	*179.20* 2.56	*238.* 3.400	*413.4* 5.906	*697.20* 9.96
Total hardness		*2.*°	*4.*°				
Permanent hardness		1.°	1.5°				
Free ammonia		.00012	.00015		.00015		
Albuminoid ammonia		.00002	.00002		.00005		

Constituent.	122. Wales.	Constituent.	122. Wales.
$CaCl_2$	*59.64* .852	KCl	*5.00* .071
$CaSO_4$	*1.00* .014	NaCl	*1152.88* 16.47
Fe_2O_3	*.74* .011	Total mineral residue	*1255.8* 17.94
MgCl	*36.54* .522		

Of the foregoing analyses No. 110, and doubtless others, should be credited to Prof. R. C. Kedzie alone. It should not be forgotten that these are not all the analyses furnished me by the Professors Kedzie, but only those which I preferred not to class geologically.

The first analysis of this list, being doubtless of water from the Grand Haven waterworks, which obtain their supply from driven wells, might perhaps have been included among those in the Pleistocene if the very low percentage of mineral matter did not suggest that the source is practically Lake Michigan, filtered through sand. The analysis is suggestively similar to that of Muskegon Lake (No. 2).

There is next a series of analyses, Nos. 82 to 105, in every respect comparable to the series Nos. 55 to 89. As arranged, the solids increase from one-fifth to one-half of an ounce per cubic foot of water, which is the normal range. The carbonates invariably form by far the largest proportion of the solid matter. The amount of gypsum is usually barely a tenth as great, and there is a small but variable amount of salt, which does not increase regularly with the amount of mineral matter, and when high may be assigned in part to sewage contamination. The wells furnishing these waters occur all over the State except in the central region around Midland. It is noteworthy that the percentage of solids is most commonly near 0.30 per thousand, and the hardness correspondingly near 15°. There is no reason why any of these analyses may not be of waters from common wells in surficial deposits, and most of them are undoubtedly such. No. 83, from Reed City, is of water from a region where I could find no wells which had reached bed rock, even when 100 feet deep. The same statement holds true at Ludington. On the other hand, in cases like Owosso the well may pierce bed rock a little, though near Owosso plenty of water and even flows are found in the drift. Taken as a whole, the analyses belong to a fairly well-defined type of water from the drift.

With only two transitional analyses, those at Lapeer (Nos. 106 and 107), we pass, with an increasing proportion of solid matter, to an entirely different type of analysis. The total solids quickly double in amount, reaching about an ounce per cubic foot. But the lime and magnesia, or at any rate the carbonates, fall off, and instead there are sulphates and salt. Frequently there is more chlorine and sulphuric acid than can be satisfied by their usual bases, sodium and calcium, and we have sodic sulphate, potassic chloride, and other salts.

All the places from which analyses of this type come are well within the basin of the Marshall sandstone, except Wales and Vassar, and may be supposed to derive their percentage of sulphates from the gypsum of the Michigan series and the decomposing sulphide of iron that occurs with the coal.

Some of these analyses—e. g., those from Saginaw (Nos. 108 to 110), from St. Charles (No. 111), from Bay City (No. 112), and from St. Louis (No. 113, compare No. 78)—show a considerable amount of lime and no more mineral matter than often occurs in waters from drift wells of this region, and may either be from such wells or from wells that go a short distance into the rock. On the other hand, wells like the Flushing wells, with water containing so low a percentage of lime, yield waters so extremely soft that one can hardly believe them to be derived from the drift, when he considers how much limestone and gypsum are disseminated through them. From the evidence of the analyses alone, therefore, one could say that the water must come from some of the Coal-Measure sandstones below the drift, like the water of the Bancroft House, Saginaw (the prominent hotels in Saginaw have their own artesian wells down into the sandstone), tests of which indicate water of this character with Na_2SO_4. The Saginaw analyses are intermediate in character, as would be natural in waters from wells just from the base of the drift, but the generally sulphated type is confirmed by the analyses of Heim Brothers. The water of analysis No. 108 is reported by Kedzie as "colorless, odorless, nearly tasteless, and good for domestic use." The water of No. 109 is only "fair, having too much sulphates." Both blacken very slightly on ignition. The water of No.

110 is "clear, bright, tasteless, and odorless; would be excellent but for the large amount of sulphates." The Brand & Hardin well (analysis No. 108) gave Heim Brothers 0.879 solids (61.5 grains per gallon), and the Washington avenue well (analysis No. 109) 1.043 solids (73 grains per gallon). Our inference that the waters of the Flushing analyses come from wells in the Coal Measures is confirmed by the fact that there are many such rock-drilled wells there. The well of W. Wartzel (analysis No. 119) was said to have been bored in 1896 to a depth of only 40 feet. The water flows naturally, with several feet head; temperature about 45°; specific weight in 1899, 1.007. Analyzed March 5, 1896. The last three analyses show more mineral matter than the water from any drift well known. The Vassar and Caro wells would naturally tap the gypsiferous Michigan series, and the Wales well the Berea grit. In confirmation of this supposition the Vassar and Caro analyses are strong in sulphates, while the Wales analysis is strong in salt and the earthy chlorides and low in sulphates—a thoroughly characteristic Berea grit analysis. Accordingly, analyses Nos. 82 to 104 are most probably of water from wells in the drift; analyses Nos. 108 to 121 of water from the Carboniferous above the Marshall, while No. 122, from Wales, is of water from the Berea, and may be compared with analyses at Birmingham (No. 285) and Utica (No. 225), towns which are similarly situated.

SANITARY ANALYSES BY PROF. V. C. VAUGHAN.

In the large and interesting list of sanitary analyses which have been furnished by Prof. V. C. Vaughan some are not complete, and frequently the total solids are not given. It seemed impracticable, therefore, to arrange them in the usual way, and hence they have been given a special tabulation of their own. The gaps in his numbering (given in parentheses) are in general due to the omission of analyses from other States or from the northern peninsula of Michigan.

There is a general parallelism between this series of analyses and those of Professor Kedzie, and many cross references have been inserted. It will be found that many of the analyses showing especially small amounts of solids belong in one of three classes. (1) Like the Petoskey (analyses Nos. 130 to 132), they are probably surface waters, or from lakes; or (2) there is good independent evidence that they are strictly surficial, largely from rain-water wells; or (3) they come from the sands of the modified drift or glacial drainage, like that at Lowell (analyses Nos. 123 and 124). It is noteworthy that inoculation is nearly as likely to produce bad results in these as in more highly mineralized waters. In other words, exceptionally low mineralization often means dilution with rain water, and that implies exposure to surface contamination. As in the Kedzie analyses, the vast bulk of these samples contain from one-fifth to one-half of an ounce of solid matter per cubic foot. The analyses are rather widely distributed, though of course the more populated part of the Lower Peninsula has the greater number. Most of these analyses are doubtless of water from wells in the drift (i. e., Pleistocene), although some, e. g., Eastlake and Manistee (analyses Nos. 146 and 153), may be of water from the lakes, and others, like some of the Lansing analyses, may be of waters from rock wells and belong to the following section.

There is a somewhat larger number of transition analyses than in the case of the Kedzie analyses, having from 0.500 to 0.650 parts per thousand (ounces per cubic foot) of solids. Some of these evidently belong to the previous group, however, and merely have more organic matter than usual. (See analyses Nos. 205 to 211.) Other analyses are of waters from wells which in all probability draw their supplies from bed rock, e. g., the Saginaw well (analysis No. 214), with its comparatively soft water, is probably of the sodic-sulphate type. It is worth noting that all such wells, except No. 209 at Kalamazoo, are within the area covered by rocks above the Marshall, and should probably be included among the analyses of the next section. The remaining analyses, with the exception of one or two (No. 217—water presumably contaminated with the waste bittern of salt manufacture—and No. 218), are most probably of waters from rock, and usually there is corroboratory evidence which renders it possible to fix also the stratum from which the water comes.

The Holt well (analysis No. 221) probably draws water from the Grand Rapids limestone or from a horizon near.

The Holland (analysis No. 219), low in sulphates and strong in chlorides, is an analysis characteristic of water from the Marshall. A similar analysis of water within the coal basin would suggest strong contamination. The Wyandotte water (analysis No. 220) would seem to be from the Dundee limestones. The Adrian waters (analyses No. 222, etc.) are peculiar. It may be that they are contaminated with sulphate of iron from the sulphides in the Ohio black shale.

The two Imlay City wells (analyses Nos. 223 and 224) almost certainly draw water from the Coldwater shales or the lower Marshall. Under Imlay City water from the Berea would be much salter, as the Wales and other analyses show, and that from the Napoleon sandstone would contain less salt.

The Utica well (analysis No. 225) is shown to be in the Berea, by the same line of argument which applies to the Wales well (analysis No. 122), which is similarly situated and connects the Utica well with the Birmingham wells. The latter are certainly in the Berea.

No. 299, water from Alpena, is classed solely on the basis of its analysis, which resembles the tests of waters from the rock wells of Alpena in the Traverse or deeper limestones.

The analyses of waters from around Bay City are very puzzling, owing to the leakage from deep salt wells, and Prescott's paper tends to warn against rashness in diagnoses.

In the analyses reported by Vaughan the number, according to Vaughan's list, follows in parentheses after the serial number (the numbers omitted representing analyses outside our purview). Next follows the identification—the name of the place, the date of the analysis, and, when stated, the origin of the water. The water is understood to be colorless, odorless, and neutral, if nothing to the contrary is stated. The hardness is given on the usual (Clark's) scale—i. e., the number of grains of $CaCO_3$ per gallon which would be required to make a water equally hard. The total residue (obtained by evaporation at 110° C.) and total inorganic residue are self-explanatory. As remarked, the specific gravity of the water is neglected, which makes a perceptible error only in the analyses from No. 217 on. The quantities are in parts per thousand. The row of figures after "organic" (i. e., loss on ignition) obviously represents the differences between the two residues. The chlorine is computed as salt (NaCl). The next row of figures above gives the parts of potassium permanganate reduced by organic matter, and, in the rows above, the free and albuminoid ammonia, and the nitrates (N_2O_5) and nitrites (N_2O_3) in parts per thousand. The sulphates when given are computed as SO_3. It will be noticed that the ammonia is quite prominent even in the waters from such wells as the Mount Pleasant of the previous section, which is deep and free from possible surface contamination (analyses Nos. 79 and 80). The first two rows of figures give the biological examination, viz, the result of inoculation of cultures on the health of animals (no effect on the health being indicated by a —) and the number of bacteria per cubic centimeter after standing 72 hours.

Professor Vaughan gives the following explanatory notes:

While no absolute standard for the chemical purity of drinking water can be given, the following conclusions may be regarded as approximately correct:

(1) The total residue should not exceed 500 parts per million.

(2) The inorganic residue may constitute the total residue.

(3) The smaller the amount of organic residue the better the water.

(4) The amount of earthy bases should not exceed 200 parts per million.

(5) The amount of sodium chloride should not exceed 10 parts per million. A larger amount may be expected, however, in certain salt-producing districts.

(6) The amount of sulphates should not exceed 100 parts per million.

(7) The organic matter in 1,000,000 parts of the water should not reduce more than 8 parts of potassium permanganate.

(8) The amount of free ammonia should not exceed 0.05 parts per million.

(9) The amount of albuminoid ammonia should not exceed 0.15 parts per million.

(10) The amount of nitric acid should not exceed 0.5 parts per million.

(11) The best waters contain no nitrous acid, and any water which contains it in quantity sufficient to be estimated should not be regarded as a safe drinking water.

The word trace ("tr.") whenever used indicates the existence of the substance in quantity sufficient to be recognized by the test, but too small to be determined quantitatively.

Explanation of microscopical examination, i. e., description of deposit, if any, magnified 100 diameters and 500 diameters:

Six ounces of water are placed in a conical glass, and the deposit, if any, is examined after from 12 to 24 hours. The presence of any appreciable deposit, especially if it be of animal or vegetable nature, would detract from the suitability of the water.

The bacteriological examination consists in counting the number of germs developed on a gelatine plate inoculated with one drop of water:

(1) After 24 hours, (2) after 48 hours, (3) after 72 hours. Then follow remarks on the kinds of germs observed.

Inoculation experiments are conducted as follows:

The animals inoculated with germs are white rats, guinea pigs, or rabbits; the method of inoculation, into abdominal cavity. The kind, amount, and age of culture used is noted, the effect on the animal's health, and eventually its post-mortem appearance. One drop of the water is added to 1 dram of some culture medium, such as beef tea, and this, after it has been kept at the temperature of the body for 24 hours or longer, is used for inoculating the animals.

	123 (190). Lowell, T. 6 N., R. 9 W.	124 (192). Lowoll, T. 6 N., R. 9 W.	125 (169). Pontiac.	126 (168). Sand Beach.	127 (369). Lansing.	128 (257). Port Huron.	129 (320). Pontiac.
Result of inoculation	—	+	—	—	—	—	+
Number of bacteria in 72 hours	25	Liquefied.	4874	812	230	Liquefaction.	400
Nitrites	....	Tr.	....	....	....	....	Tr.
Nitrates	....	Tr.	....	....	....	Tr.	Tr.
Albuminoid ammonia	0.0004	0.0005	0.00006	0.00008	0.000021	0.000126	0.000174
Free ammonia	Tr.	Tr.	.00002	.00002	.000013	.000006	.000044
K Permanganate reduced	.0015	.002	.002	.003	.002	....	....
Chlorine as NaCl	.0003	.0005	.002	.002	.00825	.00825	.00148
Organic residue	.005	.007	.011	.020	.017	.030	.012
Inorganic residue	.023	.023	.024	.035	.041	.040	.0584
Total residue	.028	.030	.035	.055	.058	.070	.0704
Hardness	8.°	8.°	2.5°	5.5°	4.°	2.°	6.°
Sulphates	....	....	....	Tr.	....	Ft. tr.	....

No. 123 (190). Lowell, T. 6 N., R. 9 W. July 17, 1893. Microscope shows molds. The hardness assigned to this and the following analysis is not consistent with the low amount of total solids.

No. 124 (192). Lowell, T. 6 N., R. 9 W. July 7, 1893. Microscope shows a few vegetable fibers.

No. 125 (169). Pontiac. December 16, 1892. Microscope shows indeterminate granules. This is so much softer than any of the other Pontiac analyses (Nos. 129, 133, 139, 150, 175, 190–192, 211, and 218) that, as is in the previous analysis, rain-water contamination is indicated.

No. 126 (168). Sand Beach. December 6, 1892. From a well which must be shallow, as deeper wells soon pass into the Coldwater series and are saline. Microscope shows indeterminate granules.

No. 127 (369). Lansing. September 6, 1897. From the waterworks, which draw their supply chiefly from wells in gravel beneath clay; but deep rock wells have also been bored. Very small amount of organic matter.

No. 128 (257). Port Huron. March 9, 1895. Microscope shows wood fiber, algæ, unicellular plants and animals, vegetable débris, inorganic deposits. Color, milky; odor, musty; reaction, alkaline.

No. 129 (320). Pontiac. July 10, 1896. From a well which is almost certainly a shallow one in the drift. Microscope shows a small amount of vegetable and inorganic débris.

	130 (205). Petoskey.	131 (206). Petoskey.	132 (207). Petoskey.	133 (95). Pontiac.	134 (245). Grand Rapids.	135 (157). Bay City.	136 (136). Ithaca.
Result of inoculation.	—	—	—	—	—	....	—
Number of bacteria in 72 hours	0	0	0	190	2,600	570	0
Nitrites	....	....	Tr.	....	....	Tr.	....
Nitrates	....	....	....	Very slight tr.	Strong tr.	Tr.	....
Albuminoid ammonia	0.000008	0.000006	0.000006	0.000574	0.000113	0.000125	0.00024
Free ammonia	.000002	.000002	.000002	.000422	.000014	.000344	.000302
Permanganate reduced	....	....	....	.02212	....	.0158	.05114
Chlorine as NaCl	.00082	.00082	.00082	.0099	.0165	.0145	.028
Organic residue	.040	.050	.040	.054	.040	.015	.060
Inorganic residue	.050	.050	.070	.070	.100	.133	.089
Total residue	.090	.100	.110	.124	.140	.148	149
Hardness	7.°	7.°	7.°	12.°	4.5°	11.3°	10.2°
Sulphates	....	....	....	....	Tr.	Strong tr.	Tr.

No. 130 (205). Petoskey. February 9, 1894. Microscope showed small amount of algæ and plant detritus, reaction alkaline.

No. 131 (206). Petoskey. February 9, 1894. Microscope showed small deposit of unicellular plants and plant detritus, reaction alkaline.

No. 132 (207). Petoskey. February 9, 1894. Microscope showed inorganic matter, algæ, and plant detritus, reaction alkaline.

No. 133 (95). Pontiac. August 21, 1890. Town water supply; slightly turbid. Microscope (100 diameters) showed organic material, yellow, red, and black, animalculæ; (500 diameters) several species of diatoms, green algæ, blue algæ, amœbæ, violet spores, yellow reticulated organic material, fibers, Entomostraceæ.

No. 134 (245). Grand Rapids. December 20, 1894. Slightly milky, alkaline. Microscope showed inorganic matter, vegetable débris, a few unicellular plants.

No. 135 (157). Bay City. October 1, 1892. Microscope showed carbonate of lime, pigment granules, bits of woody fiber, floculent matter. It is a well, and judging by analysis is shallow.

No. 136 (136). Ithaca. February 12, 1892. Microscope showed crystals of calcium carbonate; cloudy.

	137 (305). East Tawas.	138 (79). East-lake.	139 (97). Pontiac water supply.	140 (133). Hastings.	141 (178). North-ville.	142 (239). Petoskey.	143 (132). Ithaca.
Result of inoculation.	—	—	—	—	+	—	+
Number of bacteria in 72 hours	27	....	18	850	4,300	400	500
Nitrites	Tr.	....	Very slight tr.	Tr.	Tr.	Tr.	....
Nitrates	Tr.	0.000202	Very slight tr.	Tr.	Tr.	....	....
Albuminoid ammonia	0.000062	.000058	0.00035	0.00011	0.00005	0.00012	0.00016
Free ammonia	.0000053	.000067	.00013	.0002	.00001	.00002	.00041
Permanganate reduced	....	.0004662	.02307	.1311	.0075	....	.04318
Chlorine as NaCl	.0099	.04474	.0099	.018	.0035	.00165	.025
Organic residue	.090	.0630	.064	.065	.047	.040	.072
Inorganic residue	.060	.101	.101	.105	.140	.150	.118
Total residue	.150	.164	.165	.170	.187	.190	.190
Hardness	7.9°	4.70°	11.5°	11.6°	15.°	9.°	9.5°
Sulphates	....	.0485	....	Tr.	Tr.	....	Tr.

No. 137 (305). East Tawas. March 7, 1896. Alkaline. Microscope shows inorganic matter and vegetable débris.

No. 138 (79). Eastlake. May 13, 1890. From a well. Microscope (100 diameters) shows slight traces of fresh-water algæ; (500 diameters) a few threadlike Vibrios.

No. 139 (97). Pontiac. August 21, 1890. Town water supply. Microscope (100 diameters) shows yellow organic material, fibers; (500 diameters) many short, rod-shaped germs, several species of diatoms, fibers, Palmellaceæ, Entomostraceæ.

No. 140 (133). Hastings. February 3, 1892. From a well and smells musty. Microscope shows vegetable fibers, molds, Paramecia.

No. 141 (178). Northville. September 30, 1893. From a well. Microscope shows some vegetable débris.

No. 142 (239). Petoskey. September 20, 1894. Alkaline. Microscope shows algæ, infusoria, bacteria, plant detritus, inorganic matter.

No. 143 (132). Ithaca. February 3, 1892. Microscope shows dust and dirt, cloudy in color, with a slight odor.

	144 (363). Battle Creek.	145 (246). Grand Rapids.	146 (364). Eastlake.	147 (138). Holland.	148 (341). Traverse City.	149 (256). Port Huron.	150 (96). Pontiac.
Result of inoculation.	—	—	—	—	—	+	—
Number of bacteria in 72 hours	14,020	1,300	263	340	Liquefied.	Liquefaction.	48
Nitrites	Tr.	....	Tr.	Tr.	....	....	.0109
Nitrates	....	Tr.	0.00005	Tr.	Tr.	Tr.	Very slight tr.
Albuminoid ammonia	0.0000293	0.000136	.00014	0.000166	0.0000346	0.000132	0.000302
Free ammonia	.000005	.000009	.000065	.000514	.0000026	.000007	.000266
Permanganate reduced	.002	....	.002	.02212	.002	....	.018644
Chlorine as NaCl	.0132	.0099	.002	.015675	.00825	.0099	.009075
Organic residue	.062	.09	.091	.090	.096	.07	.124
Inorganic residue	.137	.110	.111	.120	.123	.150	.096
Total residue	.199	.20	.202	.210	.219	.220	.220
Hardness	7.6°	8.°	11.°	9.°	13.2°	2.1°	11.5°
Sulphates	....	0	....	Tr.	....	Tr.	....

No. 144 (363). Battle Creek. August 10, 1897. Microscope shows small amount of organic débris.

No. 145 (246). Grand Rapids. December 20, 1894. Colorless and odorless; alkaline. Microscope shows small deposit of no significance. This is one of a long series. (See index.)

No. 146 (364). Eastlake. August 11, 1897. Microscope shows a small amount of amorphous matter.

No. 147 (138). Holland. March 2, 1892. From a deep well. Cloudy. Microscope (100 diameters) shows indeterminate granules; (500 diameters) vegetable detritus. This is probably from the Marshall sandstone, as rock is not far from surface at Holland, but the expression "deep" may mean only beneath the clay.

No. 148 (341). Traverse City. November 4, 1896, at the same time as No. 163. Microscope shows very small amount of vegetable débris. (See index for other analyses.)

No. 149 (256). Port Huron. March 29, 1895. Milky, musty, alkaline. Microscope shows algæ, wood fiber, inorganic deposits, much vegetable débris, unicellular plants and animals.

No. 150 (96). Pontiac. August 2, 1890. Town water supply. Microscope (100 diameters) shows yellow organic material, colorless fibers; (500 diameters) many short, rod-shaped germs, several species of diatoms, yellow algæ, orange algæ, Cymbella ehrenbergii, fibers, Entomostraceæ.

	151 (167). East-lake.	152 (279). Caro.	153 (270). Manistee.	154 (241). Grand Rapids.	155 (176). Kalama-zoo.	156 (237). Grand Rapids.	157 (235). Grand Rapids.
Result of inoculation.	+	—	—	—	—	—	+
Number of bacteria in 72 hours	180	25	Liquefaction.	2,500	350	160	200
Nitrites	Tr.	Tr.	....	Tr.	0.0003	Tr.	Tr.
Nitrates	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.
Albuminoid ammonia	0.00071	0.00002	0.000075	0.00004	.00012	0.00008	0.000056
Free ammonia	.0003	.00019	.000003	Tr.	.00004	.000006	.000008
Permanganate reduced..............	.10902	.005	....	....	.0012	....	....
Chlorine as NaCl....	.01419	.006	.00165	.0165	.00247	.00713	.00713
Organic residue......	.110	.029	.050	.090	.090	.070	.080
Inorganic residue....	.114	.201	.180	.140	.160	.180	.170
Total residue	.224	.230	.230	.230	.250	.250	.250
Hardness............	16.5°	5.6°	8.5°	9.°	10.°	8.°	8.°
Sulphates...........	....	Tr.	Tr.	Tr.	Tr.	....	....

No. 151 (167). Eastlake. November 21, 1892. From town supply pipes. Clear after filtering; putrid odor on standing. Microscope shows vegetable débris. (Compare with No. 138; the deep-rock well character of this water is plain.)

No. 152 (279) Caro. July 27, 1895. Microscope shown vegetable débris. Cloudy, alkaline.

No. 153 (270). Manistee. June 29, 1895. Probably from lake. Slight milkiness, alkaline. Microscope shows vegetable débris and inorganic matter, algæ, infusoria. Agrees quite closely with Nos. 1 and 146.

No. 154 (241). Grand Rapids. November 5, 1894. Alkaline. Microscope shows algæ, desmids, diatoms, bacteria, infusoria, vegetable débris, inorganic matter.

No. 155 (176). Kalamazoo. October 31, 1893. Odor stale; alkaline. Microscope shows vegetable débris, with vegetable and animal microorganisms.

No. 156 (237). Grand Rapids. September 4, 1894. Alkaline. Microscope shows algæ, infusoria, inorganic matter, vegetable débris.

No. 157 (235). Grand Rapids. September 4, 1894. Alkaline. Microscope shows inorganic matter, vegetable débris, infusoria, algæ.

	158 (227). Grand Rapids.	159 (139). Holland.	160 (224). Grand Rapids.	161 (271). Manistee.	162 (225). Grand Rapids.	163 (342). Traverse City.	164 (367). Traverse City.
Result of inoculation.	+	—	+	—	+	+	—
Number of bacteria in 72 hours.........	Liquefaction.	120	Liquefaction.	Liquefaction.	Liquefaction.	Liquefied.	12
Nitrites..............	....	Tr.	....	....	....	....	....
Nitrates	Tr.	Tr.	....	Tr.	....	Tr.	....
Albuminoid ammonia	0.00003	0.000134	0.0002	0.000082	0.000215	0.0000346	0.00006
Free ammonia........	.000016	.000088	.00098	.000006	.000055	.0000026	.000005
Permanganate reduced..............	....	.00948	....	....	....	.002	.002
Chlorine as NaCl.....	.0165	.00693	.01485	.00247	.01485	.00825	.0033
Organic residue......	.090	.070	.057	.07	.167	.120	.100
Inorganic residue....	.160	.180	.202	.190	.113	.160	.185
Total residue	.250	.250	.259	.260	.280	.280	.285
Hardness	11.°	10.°	12.°	9.1°	12.°	13.2°	11.°
Sulphates............	....	Tr.	....	Tr.	....	....	Slight tr.

No. 158 (227). Grand Rapids. August 9, 1894. Alkaline. Microscope shows vegetable débris, diatoms, infusoria, bacteria.

No. 159 (139). Holland. March 3, 1892. From shallow well. Microscope (100 diameters) shows indeterminate granules; (500 diameters) vegetable cells, a few green algæ. (Compare with No. 147 and note that the water from the shallow well is more highly mineralized.)

No. 160 (224). Grand Rapids. August 3, 1894. Alkaline. Microscope shows vegetable débris, algæ, diatoms, infusoria. (See index for other analyses.)

No. 161 (271). Manistee. June 29, 1895. Alkaline. Microscope shows a few unicellular plants and animals.

No. 162 (225). Grand Rapids. August 3, 1894. Alkaline. Microscope shows vegetable débris, algæ, diatoms, infusoria.

No. 163 (342). Traverse City. November 9, 1896. Microscope shows small amount of vegetable débris. (See No. 148.)

No. 164 (367). Traverse City. August 27, 1897. From lake or well. Slight opalescence. Microscope shows small amount of vegetable débris.

	165 (226). Grand Rapids.	166 (268). Grand Rapids.	167 (242). Grand Rapids.	168 (292). Dowagiac.	169 (329). Grand Rapids.	170 (78). Three Rivers.	171 (104). Three Rivers.
Result of inoculation	+	—	—	+	—	—	—
Number of bacteria in 72 hours	Liquefaction.	50	2,000	50	40	8	248
Nitrites	....	....	Tr.	....	....	0.000043	Very ft. tr.
Nitrates	Tr.	Very ft. tr.	Tr.	Tr.	....	....	....
Albuminoid ammonia	0.000052	0.000208	0.000043	0.000013	0.0000133	.000019	0.000212
Free ammonia	.000026	.0000132	Tr.	.000015	.0001286	.000015	.000198
Permanganate reduced	....	....	....	....	.001	.0005	.005372
Chlorine as NaCl	.01465	.0198	.0165	.00181	.002475	.006288	.0099
Organic residue	.110	.070	.0750	.050	.160	.130	.0760
Inorganic residue	.190	.220	.215	.240	.132	.163	.220
Total residue	.300	.290	.290	.290	.292	.293	.296
Hardness	11.°	8.3°	9.°	13.°	17.°	14.2°	14.°
Sulphates	....	Ft. tr.	Tr.	Tr.	....	....	....

No. 165 (226). Grand Rapids. August 9, 1894. Alkaline. Microscope shows vegetable débris, algæ, diatoms, bacteria, infusoria.

No. 166 (268). Grand Rapids. June 19, 1895. Yellowish, alkaline. Microscope shows algæ, diatoms, inorganic deposits, unicellular plants and animals.

No. 167 (242). Grand Rapids. November 5, 1894. Alkaline. Microscope shows algæ, desmids, diatoms, bacteria, infusoria, vegetable débris, inorganic matter.

No. 168 (292). Dowagiac. November 19, 1895. Alkaline. Microscope shows inorganic matter.

No. 169 (329). Grand Rapids. August 22, 1896. From Grand River; filtered. Opalescent. Microscope shows small amount of amorphous sediment.

No. 170 (78). Three Rivers. May 5, 1890. From a well. Microscope (100 diameters) shows inorganic salts; (500 diameters) hexagonal crystals, a few algæ, yellowish amorphous organic matter in small amount.

No. 171 (104). Three Rivers. December 23, 1890. Microscope shows algæ, crystals, amorphous material, diatoms, Draparnaldia, crystals of NaCl, yellowish amorphous matter.

	172 (376). Lansing.	173 (276). Flint.	174 (265). Grand Rapids.	175 (291). Pontiac.	176 (269). Grand Rapids.	177 (127). Adrian.	178 (248). Grand Rapids.
Result of inoculation.	—	+	+	—	—	+	—
Number of bacteria in 72 hours	97	Liquefied.	Liquefaction.	31	75	44	50
Nitrites	....	Tr.	....	....	....	Tr.	....
Nitrates	....	Tr.	....	Tr.	....	Tr.	Tr.
Albuminoid ammonia	0.0000133	0.00004	0.000047	0.0001	0.000044	0.0002	0.00008
Free ammonia	.0000053	.00001	.000016	.00009	.00002	.00003	.00001
Permanganate reduced	.002	.006	....	....	....	.008	....
Chlorine as NaCl	.0033	.005	.01897	.0066	.007425	.010	.0132
Organic residue	.110	.020	.030	.060	.07	.0474	.120
Inorganic residue	.189	.280	.270	.240	.230	.257	.190
Total residue	.299	.300	.300	.300	.300	.3044	.310
Hardness	9.8°	10.°	7.7°	12.°	7.5°	12.1°	10.°
Sulphates	....	....	Ft. tr.	Ft. tr.	Ft. tr.	Tr.	Ft. tr.

No. 172 (376). Lansing. November 19, 1897. From wells in drift. Microscope shows considerable amount of amorphous débris, probably iron rust. (See index for other analyses.)

No. 173 (276). Flint. July 20, 1895. Microscope shows only indeterminate granules.

No. 174 (265). Grand Rapids. June 19, 1895. Yellowish, alkaline. Microscope shows algæ, diatoms, unicellular plants and animals, inorganic deposit. (See index.)

No. 175 (291). Pontiac. October 25, 1895. Slight milkiness, alkaline. Microscope shows inorganic matter, unicellular plants and animals. (Compare No. 218.)

No. 176 (239). Grand Rapids. June 29, 1895. Yellowish, alkaline. Microscope shows diatoms, algæ, inorganic matter, unicellular plants and animals.

No. 177 (127). Adrian. November 23, 1891. Slightly turbid.

No. 178 (248). Grand Rapids. December 20, 1894. Alkaline. (See index.)

	179 (266). Grand Rapids.	180 (349). Union City.	181 (273). Ann Arbor.	182 (370). Lansing.	183 (175). Ann Arbor.	184 (105). St. Johns.	185 (197). Merrill.
Result of inoculation.	—	—	—	—	—	+	—
Number of bacteria in 72 hours	Liquefaction.	Liquefaction.	Liquefied.	235	30	Liquefied.	10
Nitrites	....	Tr.	....	....	....	0.00000416	....
Nitrates	....	Tr.	Tr.	....	....	....	Tr.
Albuminoid ammonia	0.000046	0.0000266	0.00004	0.000018	0.000018	.00013	Tr.
Free ammonia	.00002132	.000008	.00002	.00002133	.00002	.000472	0.0000532
Permanganate reduced	....	.002+	.006	.004	.007	.02464	....
Chlorine as NaCl	.013875	.0099	.012	.01485	.00075	.01815	.0043
Organic residue	.120	.120	.130	.100	.030	.148	.055
Inorganic residue	.200	.200	.200	.232	.310	.201	.295
Total residue	.320	.320	.330	.332	.340	.349	.350
Hardness	7.7°	11.°	8.5°	4.8°	16.°	16.5°	8.1°
Sulphates	Tr.	Tr.	Tr.	....	Tr.	....	....

No. 179 (266). Grand Rapids. June 19, 1895. Yellowish, alkaline. Microscope shows algæ, inorganic deposits, diatoms, large number of unicellular organisms. (See index.)

No. 180 (349). Union City. January 22, 1897. City water supply, probably from driven wells, and is notably weaker than the well water (No. 200). Microscope shows small amount of organic matter.

No. 181 (273). Ann Arbor. July 15, 1895. Probably from wells. Microscope shows inorganic deposit. (See index for other analyses.)

No. 182 (370). Lansing. September 30, 1897. City water supply. Probably principally from wells to the base of the drift. Kedzie gives .271 total solids, of which .157 is organic, .0008 free, and .0001 albuminoid ammonia, with a hardness of 13°. There is probably an error in the hardness given. Opalescent. Microscope shows small amount of organic matter.

No. 183 (175). Ann Arbor. December 1, 1893. From well. Slight milkiness, alkaline. Microscope shows vegetable débris, inorganic matter. (Compare No. 38.)

No. 184 (105). St. Johns. January 17, 1897. Microscope shows crystals of NaCl, bacilli, Draparnaldia, Conferva, Paramecia, diatoms.

No. 185 (197). Merrill. June 22, 1893. Microscope shows a few vegetable fibers. The low degree of hardness of the water from this well for the degree of mineralization is noteworthy and points to the presence of sodic sulphate.

	186 (293). Dowagiac.	187 (247). Grand Rapids.	188 (236). Grand Rapids.	189 (106). St. Johns.	190 (129). Pontiac.	191 (272). Pontiac.	192 (359). Pontiac.
Result of inoculation	—	—	—	—	—	+	—
Number of bacteria in 72 hours	45	700	150	3,464	30	Liquefaction.	63
Nitrites	....	....	Tr.	Very f. tr.	Tr.	....	....
Nitrates	....	Tr.	Tr.	....	Tr.	....	....
Albuminoid ammonia	0.00001	0.0001	0.000052	0.000122	0.0001	0.000036	0.000018
Free ammonia	.000021	.000012	.00001	.000094	.00018	.000024	.000028
Permanganate reduced	....	....	.00001	.11534	.003	....	.004
Chlorine as NaCl	.00181	.0165	.00713	.01815	.012	.05775	.05675
Organic residue	.130	.070	.080	.132	.130	.050	.140
Inorganic residue	.220	.280	.280	.242	.250	.330	.240
Total residue	.350	.350	.360	.374	.380	.380	.380
Hardness	13.°	11.°	8.°	20.1°	15.5°	9.5°	6.7°
Sulphates	Tr.	....	....	.1455	....	....	....

No. 186 (293). Dowagiac. November 19, 1895. Alkaline. Microscope shows deposit of inorganic matter. This differs from No. 168 mainly in organic matter.

No. 187 (247). Grand Rapids. December 20, 1894. Microscope shows inorganic matter, a few unicellular plants. Alkaline. (See index.)

No. 188. Grand Rapids. September 4, 1894. Microscope shows algæ, infusoria, vegetable fibers, and inorganic matter. Alkaline. (See index.)

No. 189 (106). St. Johns. November 7, 1891. Microscope shows crystals, colorless amorphous matter, diatoms, desmids, germs, navicula, NaCl crystals, fibers.

No. 190 (129). Pontiac. January 16, 1892. From a well, slightly turbid. Microscope shows freshwater algæ. This and the following analyses have a relatively large amount of organic matter.

No. 191 (272). Pontiac. July 1, 1895. Slightly milky, strongly alkaline. Microscope shows unicellular plants and animals, inorganic matter.

No. 192 (359). Pontiac. May 28, 1897. Microscope shows small amount of amorphous matter.

	193 (274). Sherwood.	194 (208). Petoskey.	195 (334). Union City.	196 (137). Holland.	197 (264). Adrian.	198 (371). Battle Creek.	199 (240). Ann Arbor.
Result of inoculation.	+	—	+	—	—	—	—
Number of bacteria in 72 hours	Liquefied	0	Liquefied	20	Liquefaction.	85	....
Nitrites	0. 00004	....	Tr.	Tr.	....	Tr.	Tr.
Nitrates	Large amount.	....	Tr.	Tr.	Ft. tr.	Tr.	....
Albuminoid ammonia	0. 00005	0. 000012	0. 000024	0. 00009	0. 000022	0. 000014	0. 00003
Free ammonia	.00006	.000006	.0000026	.000068	.00001066	.00001	Tr.
Permanganate reduced	.008	....	.0035	.005672	....	.002+	....
Cl. as NaCl	.011	.00246	.01485	.01385	.012375	.330	.00098
Organic residue	.170	.140	.276	.217	.080	.056	.100
Inorganic residue	.210	.240	.112	.173	.320	.402	.320
Total residue	.380	.380	.388	.390	.400	.458	.420
Hardness	12. 9°	11. °	13. °	10. 5°	10. 4°	5. 9°	14. °
Sulphates	....	.00540	Tr.	Tr.	.460	Tr.	Tr.

No. 193 (274). Sherwood. July 15, 1895. On June 20, 1893, a test (198) gave no inoculation effect and but 464 bacteria in 72 hours. This water has an undue amount of organic matter.

No. 194 (208). Petoskey. February 9, 1894. Slight yellowish brown color; reaction alkaline. Microscope shows small deposit of inorganic matter and plant detritus.

No. 195 (334). Union City. September 8, 1896. Opalescent. Microscope shows small amount of organic débris.

No. 196 (137). Holland waterworks, i. e., possibly from driven wells. March 2, 1892. Microscope (100 diameters) shows indeterminate granules; (500 diameters) vegetable fibers, molds.

No. 197 (264). Adrian. June 3, 1895. Yellowish, musty, alkaline. Microscope shows small inorganic deposit. Weakest of Adrian analyses.

No. 198 (371). Battle Creek, city pump. October 5, 1897. Microscope shows very small amount of organic matter.

No. 199 (240). Ann Arbor. November 3, 1894. Alkaline.

	200 (348). Union City.	201 (195). Howell.	202 (343). Mancelona, T. 29 N., R. 6 W.	203 (263). Adrian.	204 (288). Adrian.	205 (267). Grand Rapids.	206 (213). Saginaw.
Result of inoculation.	—	—	—	+	+	—	—
Number of bacteria in 72 hours	Liquefaction.	Countless.	Liquefaction.	Liquefaction.	150	Liquefaction.	Liquefaction.
Nitrites	Tr.	....	Tr.	....	Ft. tr.	....	Tr.
Nitrates	Tr.	Tr.	Tr.	Ft. tr.	Tr.	Very distinct tr.	....
Albuminoid ammonia	0. 0000346	0. 00016	0. 0000453+	0. 000036	0. 00012	0. 000058	....
Free ammonia	.0000018	Very ft. Tr.	.0000093+	.000016	.00008	.00001066	....
Permanganate reduced	.004+	....	.018—	....	....	....	....
Chlorine as NaCl	.0299	.000891	.00825	.01815	.0165	.0312	0. 00196
Organic residue	.177	.200	.231	.150	.196	.180	.030
Inorganic residue	.253	.250	.231	.330	.284	.340	.500
Total residue	.430	.450	.462	.480	.480	.520	.530
Hardness	14. °	6. °	15. °	10. 5°	12. °	7. 8°	7. °
Sulphates	Tr.	....	....	.68978	Tr.	Ft. tr.	....

No. 200 (348). Union City. January 22, 1897. From well. Microscope shows small amount of organic matter. (Compare Nos. 180 and 195.)

No. 201 (195). Howell. June 26, 1893. From proposed water supply. Microscope shows a few vegetable fibers, diatoms, etc. Agrees well with Kedzie's analysis.

No. 202 (343). Mancelona. November 14, 1896. From a well. Water similar to the lake water (analysis No. 48). Inorganic, but with less organic matter. Light yellow, opalescent; odor marked. Microscope shows considerable amount of vegetable matter.

No. 203 (263). Adrian. June 3, 1895. Yellowish, musty, alkaline; diatoms, a few unicellular organisms, inorganic matter. There is some error in the amount of sulphates in these Adrian analyses (Nos. 203, 204, 219); charged with decomposing sulphides.

No. 204 (288). Adrian. September 23, 1895. Dirty, yellow, stale, alkaline. Microscope shows large amount of inorganic matter, unicellular plants and animals.

No. 205 (267). Grand Rapids. June 19, 1895. Alkaline. Microscope shows small deposit of inorganic matter.

No. 206 (213). Saginaw. May 26, 1894. Alkaline. Microscope shows small deposit. (Compare No. 213; rather stronger than Saginaw River and yet much less mineralized than Nos. 108–110 and 214.)

	207 (166). Okemos.	208 (85). Gladwin.	209 (177). Kalamazoo.	210 (275). Sherwood.	211 (103). Pontiac (well).	212 (87). Gladwin.	213 (80). Gladwin.
Result of inoculation	—	+	—	+	—	—	—
Number of bacteria in 72 hours	Liquefied	Liquefied	200	Liquefied	265	12	315
Nitrites	0.00055	0.000271	....	0.00003	....	....	Faint tr.
Nitrates	Heavy tr.	....	Tr.	Large amount.	....	....	0.0000192
Albuminoid ammonia	0.00036	0.000102	0.000004	0.00004	0.000368	0.000116	0.000044
Free ammonia	.000158	.00026	.000002	.00003	.000366	.000526	.000374
Permanganate reduced	.1106	.0003614	.00316	.006	.04834	.04424	.0008
Chlorine as NaCl	.0049	.00132	.000825	.035	.04455	.02145	.0118
Organic residue	.270	.211	.030	.350	.280	.125	.153
Inorganic residue	.270	.334	.52	.220	.310	.473	.489
Total residue	.540	.545	.550	.570	.590	.598	.642
Hardness	14.5°	16.5°	11.°	12.°	7.5°	17.°	7.2°
Sulphates	.00582	.002425	....	....	.03497	....	.0388

No. 207 (166). Okemos. November 18, 1892. From well. Microscope shows pigment granules vegetable débris, woody fiber.

No. 208 (85). Gladwin. June 10, 1890. From well with much organic matter. Microscope shows three varieties of crystals, yellow and green amorphous matter, a few germs. (See Nos. 212, 213.)

No. 209 (177). Kalamazoo. October 21, 1893. Alkaline. Microscope shows vegetable débris. (See index.)

No. 210 (275). Sherwood. July 15, 1895.

No. 211 (103). Pontiac. November 15, 1890. Microscope shows organic débris, brownish yellow amorphous matter, algæ; colorless, odorless amorphous matter and yellow amorphous matter; spherical germs, Oscillatoriæ, Draparnaldia, crystals of NaCl. The large amount of organic matter points to a surface water.

No. 212 (87). Gladwin. July 28, 1890. Microscope (100 diameters) shows vegetable fiber, yellow amorphous matter, crystals; (500 diameters) red amorphous material, yellow amorphous material, many bacilli, crystals, probably NaCl.

No. 213 (80). Gladwin. May 17, 1890. Turbid. Microscope (100 diameters) shows vegetable fiber and reddish amorphous matter; (500 diameters) 4 species of bacteria, a few diatoms, colorless crystals. (See No. 208.)

	214 (228). Saginaw.	215 (99). Parma.	216 (17)0. Bay City.	217 (102). Bay City.	218 (290). Pontiac.	219 (316). Holland.	220 (92). Wyandotte.
Result of inoculation.	+	—	—	—	—	+	+
Number of bacteria in 72 hours	100	1,340	480	780	73	900	2,580
Nitrites	....	0.000234	0.0023	....	Tr.	Tr.	0.000247
Nitrates	Tr.	.01143	.005	0.000617	Tr.	Tr.	.01306
Albuminoid ammonia	.00026	.000124	.0000288	.00038	0.0002	0.00006	.00056
Free ammonia	.00004	.000224	.0008	.000176	.000016	.000007	.00046
Permanganate reduced	....	.01896	....	.05523	.037	....	.04108
Chlorine as NaCl	.0099	.10065	.120	.33995	.014025	.08250	.2664
Organic residue	.040	.247	.340	.312	.42	.100	.240
Inorganic residue	.600	.452	.510	.578	.53	.970	.850
Total residue	.640	.699	.830	.890	.95	1.070	1.090
Hardness	2.°	10.5°	7.5°	16.°	6.°	13.°	13.°
Sulphates	Tr.	.3753	0	.01848	Tr.	Tr.	Strong tr.

No. 214 (228). Saginaw. August 11, 1894. From deep well. Note the relatively low hardness and compare with No. 116; probably a rock well. Alkaline. Microscope shows vegetable débris, algæ.

No. 215 (99). Parma. November 28, 1890. The amount of sulphates would be appropriate for a rock well. Microscope (100 diameters) shows fibers, yellow amorphous matter, white amorphous matter, algæ, animalculæ; (500 diameters) fibers, yellow amorphous matter, white amorphous matter, blue spores, short thick bacilli, paramecia, oscillatoriæ.

No. 216 (170). Bay City. March 7, 1893. Granular sediment, alkaline. Microscope shows fungus, spores, and monads.

No. 217 (102). Bay City. November 20, 1890. Microscope (100 diameters) shows fibers, yellow amorphous matter, colorless amorphous matter, germs; (500 diameters) algæ, diatoms, bacilli. Slightly cloudy, slightly musty. The organic matter and sulphates suggest contamination by salt wastes.

No. 218 (290). Pontiac. October 25, 1895. From well. Alkaline; slightly milky. Microscope shows vegetable débris.

No. 219 (316). Holland. May 15, 1896. Milky, alkaline. Microscope shows large amount of inorganic matter. (See index.) This well is probably in the Marshall sandstone, improperly cased.

No. 220 (92). Wyandotte. November 12, 1890. From well. Color, dirty. Microscope (100 diameters) shows crystals, yellow amorphous matter, white amorphous matter; (500 diameters) NaCl crystals, algæ. Yellow and white amorphous matter, precipitated sulphur.

No. 221 (209). Holt. February 9, 1894. Microscope shows deposit of inorganic matter, algæ, and plant detritus in small amount. (Compare Lansing analyses.) This is probably a rock well.

	221 (209). Holt.	222 (262). Adrian.	223 (88). Imlay City.	224 (86). Imlay City.	225 (357). Utica.
Result of inoculation	—	+	—	+	....
Number of bacteria in 72 hours	2000	Liquefaction.	0	120	....
Nitrites	Distinct tr.	....	Ft. tr.	....	....
Nitrates	Distinct tr.	Ft. tr.	....	....	....
Albuminoid ammonia	0.00005	0.00011	0.000102	0.000052	0.0000133+
Free ammonia	.00003	.0002932	.000462	.00052	.000016
Potassium permanganate reduced	.008	....	.0082	.000234	.006+
Chlorine as NaCl	.02475	.0528	1.32825	1.321	1.815
Organic residue	.430	.510	.240	.037	.280
Inorganic residue	.740	1.070	1.436	1.648	1.946
Total residue	1.170	1.580	1.676	1.685	2.226
Hardness	2.5°	8.8°	12.°	12.°	10.°
Sulphates	Tr.	1.01784	....	.21828	....

No. 221 (262). Adrian. June 3, 1895. Very yellow, foul, alkaline. Microscope shows small inorganic deposit. (See Nos. 203, 204.)

No. 223 (88). Imlay City. July 28, 1890. Microscope (100 diameters) shows red amorphous material, crystals; (500 diameters) cubic crystals, feathery algæ.

No. 224 (86). Imlay City. June 24, 1890. Microscope (100 diameters) shows considerable sediment, yellow amorphous matter; (500 diameters) colorless triangular prisms. A few red spots in the yellow organic matter. Note the large amount of salt in these two analyses; almost certainly from a rock well, perhaps 708 feet deep. (See Geol. Survey Mich., Vol. V, Pt. II, Pl. XXII.)

No. 225 (357). Utica. May 3, 1897. From well. Slightly opalescent. Microscope shows very small amorphous deposit. (Compare with Birmingham analyses.)

MISCELLANEOUS ANALYSES.

Constituent.	226. Owosso.	227. Owosso.	228. Leslie.	229. Chesterfield.	230. Sanford.	231. Hudson.
Al_2O_3	Tr.	(*a*)	....	....	....	0.00043
$CaCO_3$	*0.160* 9.395	bi. 0.440	bi. 0.525	0.14	0.15	CaO .09747
$CaCl_2$	....	....	....	.13	.93	....
$CaSO_4$	*2.988* .051	....	.121	.15	.76	....
Fe_2O_3	Tr.	....	....	.01	....	.00382
$FeCO_3$	....	bi. .273	bi. .039	....	....	....
Li_2O	....	....	....	....	....	Tr.
$MgCO_3$	*7.123* .121	bi. .327	bi. .180	....	....	MgO .0592
$MgCl_2$	....	....	....	.37	1.25	....
K_2CO_3	....	....	bi. .077	....	....	K_2O .00421
SiO_2	*.584* .010	(*b*) .011	.036	....	....	.01972
NaCl	(*c*) *.680* .016	(*c*) .036	....	5.49	16.16	....
$NaCO_3$	(*c*) *.838* .014	....	bi. .090	....	....	Na_2O .02784
SO_3	....	....	....	....	....	.02077
Cl	....	....	....	....	....	.024
P_2O_5	....	....	....	....	....	.00073
Organic	....	....	.011	....	....	....
Total solids	*21.608* .372	1.087	1.079	6.29	19.26	.4081
CO_2	....	....	13.5 cu.in.	....	....	.36635

a Included with SiO_2. *b* Including Al_2O_3. *c* Including the corresponding potash salt.

No. 226. Owosso, city supply wells. Dearborn Drug and Chemical Works, analyst, for E. F. Dudley. This analysis checks quite closely with No. 100 by Kedzie; No. 227 is somewhat stronger, more like the Eaton Rapids waters, and very like the Leslie magnetic, No. 228, and is, therefore, probably from a well in the Coal Measures.

No. 227. Owosso, chalybeate. Given by A. C. Peale, Bull. U. S. Geol. Survey No. 32, p. 149.

No. 228. Leslie magnetic wells. Given by Peale, op. cit., R. C. Kedzie, analyst. There are a number of flowing wells in the Coal Measures, both at Owosso and Leslie, from which the two analyses just mentioned probably come.

No. 229. Section line between sections 2 and 11, Chesterfield Township (T. 3 N., R. 14 E.). From report of Douglas Houghton, State geologist, 1838, p. 29, and Winchell, 1861, p. 186. Sp. gr. 1.0057. (Compare the Salutaris (No. 310), Wales (No. 122), Utica (No. 225), and Birmingham (No. 285) analyses, waters of the Berea grit.)

No. 230. Sanford. Sec. 25, T. 15 N., R. 1 W. This very old analysis is probably of water from the State salt well, and the amount of earthy chlorides seems likely to be erroneous. Sp. gr. 1.0132. (Same references as No. 229.)

No. 231. Hudson "Zauberwasser." Analyzed for Dr. George Chapman by A. B. Prescott in 1881.

The total of the bases and acids amounts to 0.62454; this excess over the total solids as given, which is the residue found constant at 220° F., is mainly accounted for by the free CO_2 (0.20795 parts per thousand).

WATERS FROM BEDS ABOVE THE MARSHALL FORMATION.

Constituent.	232. Bayport.	233. Bayport.	234. Agricultural College.	235. Agricultural College.	236. Agricultural College hydrant.	237. Agricultural College purifier.
$CaCO_3$	*10.36* .148	bi. 0.344	*10.60* .151	0.206		
$CaSO_4$	0	.019		Tr.		
Fe_2O_3			*.40* .006			
$FeCO_3$		.009		.022		
$MgCO_3$	*2.14* .031		*4.97* .071	.078		
MgCl		.016				
KCl				Tr.		
Silicic acid		.010				
NaCl	*.50* .007	.022		Tr.		
$NaCO_3$		bi. .078				
Organic	*1.00* .014				*7.09* .101	*2.727* .390
Total	*14.00* .200	.499	*15.970* .228	.325	*22.756* .321	*7.729* .110
Temporary hardness	12. °				3.32°	1.17°
Permanent hardness	6.5°				3.30°	1.78°

Constituent.	238. Lansing.	239. Lansing (artesian well).	240. Lansing (condensed milk factory).	241. Lansing (Americanus spring.)	242. Lansing (magnetic spring).
$CaCO_3$	*10.80* .154	*11.00* .157	*22.00* .314	*103.086*	bi. 1.537
$CaSO_4$	0		0		
Fe_2O_3	*.25* .004	*.50* .007	*.50* .007		
$FeCO_3$				*3.681*	bi. .027
LiCl				*.101*	
$MgCO_3$	*5.95* .085	*2.70* .039	*4.00* .057	*bi. 80.560*	bi. .329
Nitrites	0				
Nitrates	Tr.				
K_2SO_4				*14.94*	.213
SiO_2	*1.00* .014	*.50* .007	*.50* .007	*3.96*	.057
NaCl	*1.00* .014	*.300* .004		*220.224*	4.575
$NaCO_3$			*a* *3.00* .043	*bi. 112.08*	bi. 1.601
Na_2SO_4					.429
NaBr				*30.065*	
Organic	*4.00* .057	*2.920* .042	*25.00* .357		
Total solids	*23.00*	*17.92* .256	*55.00* .786		8.768
Temporary hardness	13. °		1. °		
Permanent hardness	7. °		4. °		
Free ammonia	.00008				
Albuminoid ammonia	.0001				
O from permanganate	*.50* .007				

a Plus KCl.

Analyses Nos. 232 to 240 were all prepared by R. C. and F. S. Kedzie, except Nos. 236 and 237, the averages of partial analyses by a class of ten of their students, and No. 233, which was made by A. B. Prescott. No. 232 was given incorrectly in Geological Survey Michigan, Vol. V, Part II, 1895, page 32. The sample is from a well near the Bayport Hotel, and the analysis is given inaccurately on its circulars. The well goes down 15 feet into a bed said to be sandstone, which must be one of the sandstones associated with the Bayport limestone of the upper Grand Rapids series, since the outcrops on the bluff near by are limestone.

No. 233 is of water from the Bayport station, September 19, 1891. Analyst, A. B. Prescott, for W. L. Webber. Reaction faintly alkaline. The residue of half a liter was tested for K, Li, and Br. Saline solids determined directly were 0.5006 per thousand.

These two analyses resemble each other in the small amount of magnesia. The Bayport limestones are usually quite low in magnesia.

No. 234 is of water from the Agricultural College well, October 9, 1891. Furnished by Professor F. S. Kedzie.

No. 235 is an analysis of water from the same well, cited in an article on boiler water purification by Prof. R. C. Carpenter (Transactions Am. Soc. Mech. Engineers, Vol. XI, p. 939), in which the well is said to be 260 feet deep. As a matter of fact, Professor Weil assures me that but one well, 470 feet deep, has been used. Another well, just sunk (1899) to 325 feet, found flowing water at a less depth. Professor Carpenter probably refers to depth of chief stream. L. J. Lincoln's record of the well and a full history of it are left to a later paper. It probably draws water both from the Marshall and beds above.

No. 236 is of the same water drawn from the hydrant, and is the average of analyses by ten students.

No. 237 is of water taken from the purifier, and shows the effect of aeration and heating nearly to boiling in precipitating the lime and reducing the hardness.

Nos. 235 and 236 agree well in total solids, and the variation in No. 234 is probably due partly to different conditions of pumping and partly to different points of sampling. Analyses 172A and 172B in the Appendix show that such variations make appreciable differences.

No. 238 is of the Lansing city supply, which is obtained from wells of various depths, 40 to 150 and more feet deep. It is one of a series of analyses made every year by Professor R. C. Kedzie. The analyses are all similar, though the total solids may be as low as 19 grains per gallon. This analysis was made July 3, 1893, and indicates very good water. It is hard, however, and was so heavily bicarbonated that toward the end of the system dead ends of the pipes became highly charged with iron.

No. 239 is of water from an artesian (i. e., flowing) well in Lansing, which is not specified. There are a number of wells, generally about 200 feet deep, which have flowed. (See records in a later paper.)

No. 240 is of water from the deep well of the condensed-milk factory at Lansing, the record of which is known, so that it is certain that none of the Marshall water is included (as may be the case in other wells). The water is probably almost entirely from the Parma sandstone—Bayport limestone horizons—as the relatively high percentage of lime shows.

No. 241 is an analysis made in Chicago in 1893, of water from the old mineral well of Lansing. It is still advertised as 1,402 feet deep, which was the original depth of the well; I am informed, however, that the water was originally quite salt; that the well is plugged about 500 feet down, and cased probably only 57 feet—just to bed rock. Before I had learned these facts, however, this analysis and No. 242 were sufficient to show such a state of affairs, for waters so strong in lime, relatively to salt, point to the limestones as partially their source. The CO_2 (235.55) is added artificially.

No. 242 is an older analysis by Dr. Jennings, taken from Peale, Bulletin U. S. Geological Survey No. 32, page 148. It is from the same well as the water of analysis No. 241, which has been variously known as Lansing magnetic, Michigan Congress, and Americanus. The casing and plugging may, however, have varied.

EATON RAPIDS, MIDLAND, PORTSMOUTH, BAY CITY, AND SAGINAW SPRINGS AND WELLS.

Constituent.	243. Frost well.	244. Mosher spring.	245. Sterling spring.	246. Shaw spring.	247. Bodine spring.	248. Midland magnetic spring.	249. Midland mineral spring.
$Al_2(P_2O_5)_3$						0.025	*1.73* .0247
$CaCO_3$	0.661	0.333		0.356	bi. 0.692		
$CaCl_2$						.089	*6.22* .089
$CaSO_4$	.066	.775	0.945	.827	.983	.064	*4.46* .0637
$FeCO_3$	.034	bi. .017	.048	bi. .038	bi. .039		
$MgCO_3$	.130	.077		.066	bi. .144		
MgCl						.031	*2.19* .031
$MgSO_4$			.161				
K_2SO_4						1.174	*32.190* .460
KCl						Tr.	
K_2CO_3		.020		.022	bi. .052		
SiO_2	.225	.044		.024	.034	.042	*2.96* .042
NaCl	.132	.015	.089	.015	.026		*32.70* .467
Na_2CO_3		.092		.198	bi. .087	.467	
Na_2SO_4			.216			.315	*27.07* .315
Loss						.046	*3.21* .046
Organic	.013	.015		.015		.035	*2.47* .035
Total solids	1.260	1.388	1.460	1.559	2.057	2.288	*110.20* 1.574
CO_2	22.22	15.38		15.97	17.35		

Constituent.	250. Midland.	251. Portsmouth (664-foot well).	252. Bay City (Gillmore 505-foot well).	253. East Saginaw (575-foot well).	254. East Saginaw (617-foot well).	255. East Saginaw (617-foot well).
$CaCO_3$	0.8924					
$CaCl_2$		3.472	5.302			5.37
$CaSO_4$	.5832	4.884	3.961			2.25(?)
$Fe_2O_3 + Al_2O_3$	.320					
$MgCO_3$	.005					
MgCl		4.333	4.115		4.41	12.41
MgBr					Erroneous.	
KCl	Tr.					
SiO_2	.19					
NaCl	7.373	125.315	152.674	139.0	194.4	190.88
Total solids	9.0778	138.004	166.052	158.2		210.91

Analyses Nos. 243 to 247 are of waters from a group of wells in Eaton Rapids. A record of the strata met in one is on file and will be given in a later paper, but the chemical variation in the waters indicates that there must have been some differences in casing or depth at the time the analyses were made. These are taken from Peale (op. cit., page 147).

No. 243 is of water from the Frost well; S. P. Duffield, analyst.

No. 244 is of water from the Mosher spring (i. e., flowing well?); R. C. Kedzie, analyst.

No. 245 is of water from the Sterling spring or flowing well; C. T. Jackson, analyst.

No. 246 is of water from the Shaw spring or flowing well; R. C. Kedzie, analyst.

No. 247 is of water from the Bodine spring or flowing well; R. C. Kedzie, analyst.

The large amounts of carbonate of lime and iron are characteristic of the waters of these wells. Nos. 227 and 228, waters from Owosso and Leslie, will be recognized as belonging to the same group, although objective evidence of the fact is weak. The Lansing and Midland analyses (Nos. 241, 242, 248, and 249) all have the same character. The presence of potash is less uniformly noted, but this may be due to defective analyses. The fire clays of the Coal Measures are, however, very low in potash, so that one could not expect to find this element prevalent in the mineral waters. Perhaps it has been leached out into the mineral waters, and the concentration previous to the formation of the Coal Measures which deposited the gypsum of the Grand Rapids series may have left the potash more than usually abundant afterwards.

No. 248 is an analysis of the Midland magnetic water, cited by Peale (op. cit.), and is probably from the same well, possibly differently cased, as the water of the following analysis, but most likely is merely a different version of the same analysis, as only the K_2SO_4 differs materially in the two analyses.

No. 249 is an analysis by Dr. S. P. Duffield of water from the Midland mineral springs. Well said to be 400 feet deep and probably cased 200 feet deep, i. e., to bed rock. These should be compared with other analyses of wells of various depths at Midland. The discussion of the rock records and varying salinity of the waters at Midland must be left to a later paper.

No. 250 is of the overflow water of the casing of the Midland Chemical Company's well No. 3, January 20, 1895. Analyst, J. E. Graves. The stream of water which has forced itself up outside the casing and, overflowing, yielded the sample analyzed, is supposed to come mainly from between 300 and 600 feet in depth, i. e., from the upper Coal Measures at about the level from which samples Nos. 248 and 249 were taken. The temperature as given, 55° F., agrees with this. On November 2, 1897, qualitative tests of this water showed a specific gravity of 1.030. Tests of water flowing from abandoned salt wells gave—from Foster's Block—specific gravity 1.012; and from 1¾ miles west of town 1.014, all overflowing with a strong current, and strong in salt and sulphates. Presumably, therefore, No. 250 is very largely but variably from lower levels than Nos. 248 and 249.

No. 251 is of water from a Portsmouth (part of Bay City) 664-foot well, with a 54° salinometer brine. Analyst, C. A. Goessmann. This and the following analysis are commercial analyses taken from Geological Survey Michigan, Vol. III, Pt. I, page 182. They serve to show that the tendency to a high percentage of sulphates continues to be characteristic of the waters above the Marshall, even in the deeper brines which have been used for salt manufacture.

This fact, so far as I know, was first remarked by Garrigues, from whose report the analyses are cited, and is entirely natural in view of the prevalence of gypsum in the Grand Rapids series, and of pyrite in the coal.

No. 252 is of water from the Gillmore well, 505 feet deep, at Bay City. Analyst and authority, same as for No. 251. Strength, 65° salinometer.

Nos. 253 to 255 are cited from A. Winchell's report of the State geologist, 1861, and are of water from the first salt well sunk by the East Saginaw Salt Company.

No. 253 is of the water when the well was 575 feet deep. Specific gravity, 1.110; 64° salinometer. Analyst, Dr. Chilton. 1,155 grains of solids and 1,014.57 grains of NaCl in a wine pint. (Op. cit., p. 170.)

No. 254 is of the water when the well was 617 feet deep. Specific gravity, 1.172 grains; 86° salinometer. Analyst, Dr. I. G. Webb. 1,416 grains of NaCl and 32 grains of other chlorides in a wine pint.

No. 255 is of the same water as No. 254, and by the same analyst.

It is hardly worth while to reproduce all Dr. Houghton's analyses of brine spring waters in his report of 1838, because of their early date. In Huron County the boundary of the sulphated waters above the Marshall is very sharp, the change from waters giving a strong reaction for sulphates to those giving no reaction coming within a mile. In the southern part of the coal basin gypsum deposits are not struck in the wells and the waters are less sulphated, being chalybeate carbonated waters low in magnesia, not unlike those from the drift.

WATERS FROM THE MARSHALL FORMATION.

Constituent.	256. Badaxe No. 1.	257. Badaxe No. 2.	258. Grasmere.	259. Oak Grove.	260. Bayport. 328-foot well.	261. Old Bayport well.
Al_2O_3						
$CaCO_3$			.171	bi. *14.053* .241	bi. *2.2141* .038	*26.5262* .454
$CaCl_2$			Cl.0025			
$CaSO_4$		0.0		*13.703* .234	*25.6405* .440	*20.9813* .360
Fe_2O_3				Al_2O_3 *.583* .01		
$FeCO_3$					*.2570* .044	
LiCl				Tr.		
$MgCO_3$				bi. *12.145* .208	bi. *5.8245* .100	
MgCl				*1.253* .021		*11.5630* .198
$MgSO_4$						
KCl				*2.973* .051		
SiO_2				Tr.	*.8412* (*a*).144	*.8598* (*a*).015
NaCl				*98.363* 1.685	*53.9742* .925	*138.7109* 2.379
$NaCO_3$					*11.7249* bi. .201	
Inorganic	*16.45* .235	*14.30* .204				
Organic	*7.000* .100	*6.300* .090				
Total solids	*23.45* .335	*20.650* .295		*143.075* 2.506	*110.4764* 1.892	*198.6412* 3.403
Hardness	5°.9	5.2°	10.°			
Free ammonia	.0000024	Slight tr.				
Albuminoid ammonia	.000072	.000048				
Loss						

a Silicic acid.

It is not at all certain that water above the Marshall is not admitted to many of the wells represented in these analyses. Even where the upper water is supposed to be cased off there may be leaks in the casing. As a whole, however, the analyses show very well the characteristics of the formation. One feature which deserves special attention is the freshness of these waters—i. e., low amount of mineral matter for a given depth—compared with those of other horizons.

No. 256 is of the Badaxe water supply, which comes from artesian wells, whose record is known, over 200 feet deep in the Marshall. Partial analysis by F. S. Kedzie in 1897. This and the following analysis were made because of complaint regarding the excessive growth of algæ. This sample was taken at the pump, while sample No. 257 was taken from the dead end of a pipe. In this respect they correspond to 172A and 172B. In both cases, the sample taken farthest from the pump contains the greater amount of matter, both organic and inorganic. Suggested remedies are frequent—flushing and covering the standpipe so as to exclude light. F. S. Kedzie also suggested that the reaction of $CaSO_4$ with organic matter might produce H_2S and add to the disagreeable character of the water, but it is doubtful if $CaSO_4$ exists appreciably in the Badaxe water. Qualitative tests failed to reveal it.

No. 258, Grasmere, is of water "from a coarse-grained gray sand rock reached at 40 feet and extending 138 feet, rising to 8 feet above the surface." Analyst, A. B. Prescott, for W. L. Webber. Qualitative tests showed Ca, Mg, Na, Al, SO_3, CO_2, Fe not more than a trace.

No. 259 is of water from the Oak Grove mineral well at Flint, 265 feet deep, flowing about 9 gallons per minute. Analyst, J. E. Clark. Original statement in grains per United States gallon. There are only 39 feet of casing, and water comes in above the Marshall, as the amount of $CaSO_4$ shows.

No. 260 is of water from a well 328 feet deep near the Bayport House, Bayport. A. B. Prescott, analyst for W. L. Webber. The water said to be found in a coarse gray sand rock (upper Marshall) at the bottom (below 250 feet), but the analysis indicates that the upper waters are not altogether excluded. This is the flowing well just north of, but quite a little below, the hotel. The temperature of 47° F. is said to be the same throughout the year. Specific gravity, 1.0017. Reaction faintly alkaline. Analysis, as given in table, as combined from CaO 0.1933, MgO 0.0421, NaO 0.5583, FeO 0.0027, SO_3 0.2582, Cl 0.6389, CO_2 0.1264, SiO_2 0.0111, total 1.8310. A similar well lies close to the bay and just west of the railroad track.

No. 261 is of water from the Old Bayport well. This was a well for salt, 1,900 or more feet deep; when plugged at 750 feet the water was still salt, but when plugged at 550 feet it was a potable water, presumably the one analyzed. Analyst, A. B. Prescott, for W. L. Webber. Reaction faintly alkaline. Specific gravity, 1.0029. The constituents are combined from CaO 0.2978, MgO 0.0835, NaO 1.2900, SO_3 0.2110, Cl 1.5850, CO_2 0.2358, SiO_2 0.0113, total 3.7144.

No. 262 is of water from Butterworth's magnetic spring, Grand Rapids. S. P. Duffield, analyst. Mr. Powers says that this well draws mainly from the upper 18 feet of the Marshall sandstone—i. e., 261–274 feet of the record given by Winchell—and that the water contains more $CaCl_2$ than the water of his well—the Arcade—which draws from the lower 18 feet of the Marshall—i. e., 295 to 300 feet from the surface. This would apply better if we took No. 262 to be the analysis of the Arcade well water, low in $CaCl_2$, and No. 263 to be the analysis of water from the top of the Marshall, from which, indeed, it is derived. The constituents other than the NaCl and the $CaCl_2$ are remarkably similar.

No. 263 is of water from the original test well, Scribner's, at Grand Rapids, October 14, 1859. Analyst, Prof. L. R. Fisk. Specific gravity, 1.01752. Biennial report of State geologist, 1861, pages 146, 167, 186, and Geological Survey Michigan, Vol. III, Part I, page 180. The water at 248 feet depth is reported as fresh, but there are saline streaks at 82 feet and at 140 feet, so that probably most of the salt, etc., comes from that section.

Nos. 264 to 266 are of waters from wells within a few miles of each other, analyzed by the same chemist, and, as the record of one and the date concerning the others show, drawing chiefly on the Marshall sandstone at 179 to 250 feet depth.

No. 264 is from Peale, Bulletin U. S. Geological Survey No. 32, page 148.

No. 265 is from Peale, loc. cit. I also have an independent version of the analysis, giving 0.1808 bicarbonate of lime; trade name, "Attapah;" specific gravity, 1.0064. Temperature, 52° (Peale), or 50° F.

No. 266 is also taken from Peale, or from Geological Survey Michigan, Vol. V, Part II, 1895, page 60. Temperature, 48°.

I would not lay too much stress upon the presence of Br, Li, etc., in the foregoing group of analyses, for much depends on whether the chemist looked for them. Yet the presence of bromine is interesting in connection with its undoubted presence in abundance in the Marshall brines of the center of the basin. The absence of $CaSO_4$ is noteworthy, also the prevalence of chlorides and bromides of calcium and magnesium over other salts.

Constituent.	262. Grand Rapids (Butterworth).	263. Grand Rapids (original).	264. Grand Haven.	265. Springlake (Attapah).	266. Fruitport (iron magnetic).
Al_2O_3	0.007		0.009	Tr.	Tr.
NH_4Cl				0.0003	
$CaCO_3$	.143	0.0473	.035	bi. .002	bi. 0.087
$CaCl_2$	.010	2.764	2.557	1.944	1.903
$CaSO_4$	1.288	1.312			
CaF_2			.001 (?)		
$FeCO_3$	.017	.0145	.001	bi. .017	bi. .129
Li_2CO_3				Tr.	

Constituent.	262. Grand Rapids (Butterworth).	263. Grand Rapids (original).	264. Grand Haven.	265. Springlake (Attapah).	266. Fruitport (iron magnetic).
$MgCO_3$	0.100	0.0084	0.027	Tr. 0.001	Tr. 0.071
MgCl	.718	.7196	1.065	.619	.803
MgBr			.005	.037	.013
MgI			.001		
$MnH_2(CO_3)_2$				Tr. .001	Tr. .002
KCl	.168	.1561	.033	.073	.007
K_2CO_3			.049		
SiO_2	.009	.0025	.018	.009	.182
NaCl	.218	17.3696	5.311	6.950	7.950
$NaCO_3$	.086		.038	bi. .003	bi. .113
$NaSO_4$			1.190	.799	.789
Organic		*a* .8841		.314	
Total solids	2.871	23.3385	10.431	10.766	12.048
CO_2		*b* .0603			7 cu. in.
Loss	.011				

a . oss. *b* Free.

SAGINAW RIVER SALINE WELLS.

Constituent.	267. East Saginaw Salt Mfg. Co., (Oct., 1862).	268. Swift & Lockwood.	269. East Saginaw (Apr. 10, 11, 1860).	270. T. N. Whittier.	271. East Saginaw.	272. Oneida Salt Co., Zilwaukee.	273. Bangor Salt Mfg. Co.
$CaCO_3$					0.500	Tr.	
$CaCl_2$	22.665	26.430	21 42		32.873	26.23	29.611
$CaSO_4$	1.516	.983	1.16		.982	.80	.722
$FeCO_3$			1.05		.116	.054	
$FeCl_2$						.032	
$MgCO_3$						Tr.	
MgCl	9.629	10.685	15.22		17.743	13.43	12.612
MgBr						Tr.	
KCl			2.20				
$Al_2O_3+SiO_2$					.245		
NaCl	168.636	175.103	179.12		168.710	193.04	198.595
NaBr					.401	Tr.	
Organic					.65	3.724	
Total solids	*a* 202.446	*a* 213.201	*a* 220.17		*b* 221.570	*b* 237.31	*a* 241.54
Specific gravity	80.°	86.°	90°=1.179	92°	90°=1.177	1.1864	1.1771
CO_2						Tr.	

a By addition. *b* Direct determination.

Analyses No. 267 et seq. show much stronger waters. Such a sharp line does not exist in nature, but is due merely to the fact that man wants waters either weak enough to be drinkable or as strong as possible.

No. 267 is of water from the East Saginaw Salt Manufacturing Company's well when 806 feet deep. Analyst, C. A. Goessmann. October, 1862. Geological Survey of Michigan, Vol. III, 1876, Part I, page 183. Total obtained by addition.

No. 268 is of water from Swift & Lockwood's well, 860 feet deep, at Saginaw. Same analyst and date as No. 267. Total obtained by addition.

No. 269 is of water from the East Saginaw Salt Manufacturing Company's well when 636 feet deep. Prof. S. H. Douglass, analyst. April 11, 1860. Same reference as No. 267, and also biennial report of the State geologist, 1861, pages 171 and 186. Total obtained by addition. April 16, specific gravity, 1.170. As No. 269 is stronger than No. 267, which is of a water with deeper source, an admixture of the upper waters—that is, leaky casing when the water for No. 267 was drawn—is suggested, especially since the weaker water is stronger in sulphates.

Sample No. 270, from Saginaw River, specific gravity 92°, was left for an analysis, not yet reported, by T. N. Whittier.

No. 271 is an analysis of the same water as Nos. 267 and 269, the well being 649 feet deep. Analyst, Dr. Chilton. May, 1860. Reported by W. L. Webber in the biennial report of the State geologist, 1861, pages 171 and 186. It agrees quite well with previous analyses and reports, the bromides probably overlooked by the others. Total directly observed.

No. 272 is of water from the well of the Oneida Salt Company, Crow Island, Zilwaukee. Analyst, H. C. Hahn. Geological Survey of Michigan, Vol. III, Part I, page 185. Total directly observed.

No. 273 is of water from the Bangor Salt Manufacturing Company's well at Banks, Bay City. Well 774 feet deep. Analyst and references the same as No. 267.

BRINES OF THE MARSHALL SANDSTONE.

Constituent.	274. Michigan Solar Salt Co., Zilwaukee.	275. Buffalo Salt Mfg. Co., East Saginaw No. 1.	276. Buffalo Salt Mfg. Co., East Saginaw No. 2.	277. New York Solar Salt Co., Zilwaukee.	278. A. L. Clark's well, Big Rapids.	279. Bay City No. 1.	280. Bay City No. 2.
$CaCO_3$	0.010	....	....	0.010	....	....	....
CaCl	29.16	24.106	24.321	30.40	46.40938	33.878	32.556
$CaSO_4$	.82	1.028	1.038	.73	.47316	.689	.691
$FeCO_3$	.123	.119	.123	.058	.06354	.856	1.292
$FeCl_2$	....	....	....	.038	....	....	....
$MgCO_3$	.015	....	....	.006	....	....	....
MgCl	13.81	10.803	8.744	14.19	19.79204	13.783	13.779
NaBr	....	Tr.	Tr.	1.2374	1.2374	....	....
H_2SiO_3	....	....	....	....	.00108	....	....
NaCl	196.71	187.764	189.472	199.14	185.69219	202.945	204.204
Organic or loss	loss 2.20	21.104	21.226	5.02	....	14.518	14.147
Total solids	242.85	*a* 244.924	(*b*)	*c* 249.58	*d* 253.66878	*a* 266.669	(*b*)
Degrees salinometer, or specific gravity	1.1900	1.1771	....	1.1930	1.205	1.1989	....
CO_2	....	....	....	....	....	....	....

a Average of No. 1 and No. 2. *b* See No. 1. *c* Direct determination. *d* By addition.

No. 274. Michigan Solar Salt Company, Zilwaukee. Analyst and references the same as No. 272.

No. 275 and No. 276 are duplicate analyses, cited from the unpublished thesis "Saginaw Salines: a short sketch of their history and source; of the methods of obtaining them; of the processes used in the manufacture of salt from them; together with analyses of representative specimens," by John Ayres, Ann Arbor, June, 1880, of which an abstract from the copy in the general library of the University of Michigan was made for me through the kindness of Professor Prescott. For this analysis and probably the others by Mr. Ayres the specific gravity was taken at 20° C., the total residue by drying at 110° to 115° C. In No. 275 the total Cl in 25 cubic centimeters brine was 4.043.

No. 277 is of water from the well of the New York Solar Salt Company at Zilwaukee. Analyst and reference the same as No. 272.

No. 278 is of water from the Red Cross well at Big Rapids, A. L. Clark original owner. Depth, 1,400 feet. Analyst, A. B. Prescott. The published statement is in grains per United States gallon at 62° F.—i. e., United States gallon=70,277.19 grains. The following is the statement of bases and acids: NaO 98.95923, MgO 8.35636, CaO 3.66594, FeO 0.03944, SiO_2 0.00073, Cl 156.97050, Br_2 0.96057, SO_3 0.27833, CO_2 0.02415=289.23289, which, less oxygen not in the salts and plus the water of silicic acid 35.56590, gives the tabulated footing.

A sample from a drug-store gave specific gravity 1.156 with 0.75 Br. When I tested it, December, 1895, the specific gravity was 1.202. The water is said to have been struck at 1,300 feet and to have had at first the specific gravity 1.229. The mineral strength is thus lasting very well.

Nos. 279 and 280 are duplicate analyses of representative Bay City brine, obtained through S. S. Garrigues. Analyst and reference the same as No. 275. In 25 cubic centimeters brine was 4.6496 Cl.

BRINES AT MIDLAND.

Constituent.	281. Midland No. 1.	282. Midland No. 2.	283. Midland bittern No. 1.	284. Midland bittern No. 2.
$CaCl_2$	86.666	88.760	143.574	145.859
$CaSO_4$	.199	.220	.160	.160
$FeCO_3$	1.144	.954	....	....
MgCl	24.665	24.109	39.263	34.019
$MgBr_2$	8.771	8.771	48.356	48.356
NaCl	148.984	147.599	56.754	60.801
Total solids	304.750	366.059	....	....
Loss	34.321	34.337	77.952	76.864

Nos. 281 and 282 are duplicate analyses of Midland brine, Harris Brothers' well, 1,300 feet deep, flowing 30 gallons a minute. Analyst and reference the same as No. 275. In 25 cubic centimeters brine was 0.2340 Br and 5.0414 Cl. See also Geological Survey Michigan, Vol. V, Part II, page 69. The specific gravity and total solids do not seem accordant, since the total solids would imply a higher specific gravity. The Larkin & Patrick well at the same depth is said to have had strength of 115° salinometer (1.239 specific gravity), and the Dow (Midland Chemical Company) well has 1.235 specific gravity.

Nos. 283 and 284 are of bittern left after the crystallization of salt from the same well as Nos. 281 and 282. Same analyst and reference. Published also by Rowland, Tenth Census of the United States, Vol. II, p. 22. See also Geological Survey Michigan, Vol. V, Part II, page 35, and note corrected NaCl. In 25 cubic centimeters was 1.32 Br and 4.8869 Cl. "In the estimation of Br by Mr. Ayers, this element was expelled by treatment with excess of chlorine during evaporation to dryness, then obtaining the total of silver chloride in ratio of the weight of mixed silver chloride and bromide from the brine"—not a very accurate method. Note the large amount of loss when total solids are independently and directly determined. This shows that ammonium and potassium chlorides and other constituents have not been determined. Potassic chloride is made from the Marshall brines by the North American Chemical Company at Bay City. Mr. Ayres's chemical work was done under Prof. H. W. Cheever about three years before the writing of "Select methods of qualitative analysis."

An analysis of the water from the Alma Sanitarium Company's well was made by Prof. C. A. Davis, May 5, 1889. Said to be almost a pure Marshall sandstone water. The published form was inaccurate, and I am not able to give corrected figures. The analyses given in a later section (Nos. 325 to 327) show the lower water and the two waters mixed.

In the above group of analyses the characteristics of the Marshall waters are well defined—i. e., the excess of Cl so as to be far more than to satisfy the soda; or, as Garrigues says, a "decrease in percentage of gypsum, an increased percentage of the earth chlorides, and an increased quantity of salt."

Numerous qualitative tests have convinced me that the sulphates are often from higher beds, and for a given depth the Marshall is less mineralized than the beds above or below. It is not charged with gases to any marked extent.

As soon as we leave the porous upper Marshall and get down to the boundary between it and the Coldwater—that is, the lower Marshall—the beds are likely to become saline again. For instance, S. O. Hickok, of Allen, Hillsdale County, Michigan, has a well 221 feet deep, which yields 277.04 grains NaCl and 33 of $CaSO_4$ per gallon. I have numerous other qualitative tests that show the same thing. But on the whole, between the Marshall and the Berea grit the strata are dry and the waters do not merit a separate section.

WATERS FROM THE BEREA GRIT.

Constituent.	285. Birmingham.	286. Ann Arbor.	287. White Rock.	288. East Tawas.	289. Port Austin.	290. Sand Beach.	291. Oscoda.
$CaCO_3$	0.10205						Tr.
$CaCl_2$		24.53	5.373	34.843	31.274	3.000	42.100
$CaSO_4$			2.623	.350	.129	2.539	Tr.
$FeCO_3$	.0049	*a* 4.381	*b* .0032				
$MgCO_3$	.0645						
MgCl		6.95	4.106	12.433	15.675	1.591	19.3
KCl	.03156						
SiO_2	.0206						
NaCl	2.27256	138.96	189.102	156.141	176.161	225.673	179.300
Na_2CO_3	.15558						
$NaNO_3$	.00122						
Organic	.03546						
Total solids	2.70453	174.8	201.236	203.767	223.239	232.803	241.9
Salinometer		68.°	78.5°	85.°	88.°	284.°	90.°

a As oxide? *b* FeO.

The well at Utica, with 2.226 ounces per cubic foot solids, probably obtains water from the Berea; the only sample of potable water, however, of whose geological horizon we are certain, independent of the analyses, is No. 285. Kedzie's analysis of the Wales water comes next. Some idea of the composition of the Berea brine at Ypsilanti may be obtained by comparing the analyses of the Ypsilanti wells (Nos. 304 and 305), in the first of which the higher water is cased out and in the second admitted. We see that the water from the Berea is extra strong in NaCl and is a very pure brine.

No. 285 is of water from the new well on the farm of J. R. Cooper, Birmingham. No. 2, about 1,500 feet southwest of the first well, which was about 20 feet above the swamp, the water rising to about 16 feet from the top; No. 1 also contained more chlorides and less carbonates. There is an excess of CO_2, probably in the form of bicarbonates, present in the water, and the organic matter and loss does not include this, but does include the CO_2 with the iron. Analyst and informant, George L. Heath.

No. 286 is of water from the Ann Arbor deep well, of which there are two accounts. According to Rominger (Geol. Survey Michigan, Vol. III, 1876, Part I, p. 92), the brine from the sandstone 333 feet down—i. e., from the Berea grit—has a specific gravity of 1.142, and 19 per cent residue by evaporation, "almost pure chloride of sodium." Winchell, in his Geology of Washtenaw County (Chicago, 1881, p. 26), gives the strength as 68° salinometer, corresponding to a specific gravity of 1.131 and 17.48 per cent salt; he also gives an analysis of the residue, and putting the two together we obtain the figures of the tabulated analysis. Illuminating gas also escapes, and is also reported from a well at Blackmar which reaches this horizon.

No. 286A of the Appendix is a recent analysis, by J. E. Clark, of water from the Ypsilanti Sanitarium, and is so pure a solution of sodic chloride that the lower water must now be almost entirely eliminated.

No. 287 is of brine from Thompson Bros.' 566-foot well at White Rock, Huron County, and is cited from Vols. III and V of the Geological Survey Michigan, as are also the remaining analyses of the section. The analysis, however, is corrected and the iron added from a statement in the report of the Commissioners to the Centennial Exposition of 1876 at Philadelphia. The specific gravity is there given as 1.155.

No. 288 is of brine from Grant & Co.'s 908-foot well, East Tawas. References as for No. 287.

No. 289 is of brine from Ayres & Co.'s 1,198-foot well at Port Austin, Huron County. References as for No. 287, and also Hunt in Geological Survey of Canada, 1866–1869, p. 220.

No. 290 is of the brine from Jenks & Co.'s well, Sand Beach. S. P. Duffield, analyst. G. W. Jenks reports that 98.7 per cent of the solids was NaCl.

No. 291 is of brine from Smith, Kelley & Dwight's 1,070-foot well at Oscoda. Same references as No. 287.

No. 291A of the Appendix is an analysis of the Berea brine where it is struck, at a depth of 2,200 feet, at Bay City, near the center of the basin, and even at this depth it has no more $CaCl_2$ than the much less deep-seated brines of Midland and Mount Clemens.

That this Berea brine is a purer solution of NaCl than the brines immediately above or below is shown not merely by comparing the Ypsilanti analyses and the analyses in general, but by such facts as when Frank Crawford's well at Caseville, which had been drawing from the Berea at 1,760 feet, was deepened to 2,270 feet it became necessary to clean the pans twice as often.

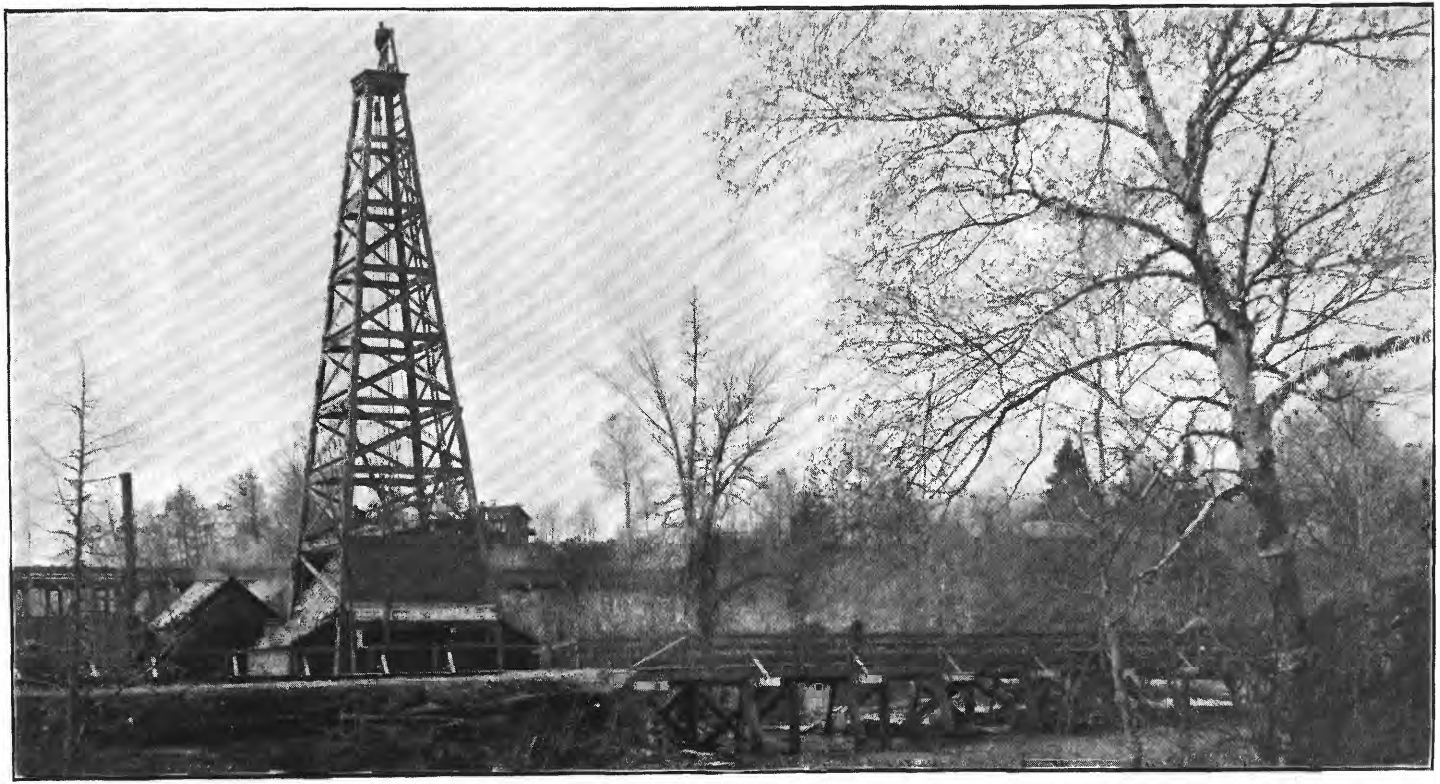
WATERS FROM BEDS BELOW THE BEREA GRIT.

When wells pass through the Berea and go through the Devonian black shales they usually encounter no water until near the bottom of the Devonian. It would be interesting, if possible, to sort out those wells which draw merely from the limestone of the Traverse (Hamilton), those which tap the upper Helderberg or Corniferous, a very well-marked horizon, and those which go deeper into the lower Helderberg and Salina; but this does not seem practicable at present, for in the southern part of the State the Traverse formation is less than 100 feet thick, and there has been little attempt, so far as I have record, to isolate the various brines. I suspect, however, that such determination might lead to important economic results, as in some of them rare elements, like K, Br, and Sr, may be richly contained. At the outcrop of the lower Devonian limestones are the various sulphur springs mentioned by Peale and widely distributed in Monroe and Wayne counties (Erie, Shawnee, Wyandotte). For the northern part of the State the Harbor Springs' analysis (No. 53) may show what kind of water is taken into the rock. We have analyses showing very lightly mineralized waters from Charlevoix, Bay View, and Petoskey (Nos. 292, 293, 294). The Charlevoix waterworks well has probably not pierced through the (Marcellus?) shale at the bottom of the Traverse series, according to the record of the strata. On the other hand, the Petoskey well probably draws from the Dundee limestones. This well is located near the Chicago and West Michigan Railway station, and the surroundings are now somewhat changed. The view shows how they looked at the time of well drilling (Pl. III).

WATERS FROM DEVONIAN OR SILURIAN LIMESTONES.

Constituent.	292. Charlevoix.	293. Bay View.	294. Petoskey.	295. Frankfort.	296. Wyandotte.	297. Alpena No. 1.	298. Alpena No. 2.
$CaCO_3$	*3.27* .056	*11.00* .157			0.633	0.788	
$CaSO_4$		*4.00* .057	*11.200* .160	1.220	1.274	.429	*a* .109125
Fe_2O_3	*4.331* *b* .074	*.50* .007	*.20* .003	.018	.004		
$FeCO_3$						.026	
$MgCO_3$	*.85* .015	*4.70* .067		.090		.899	
$MgSO_4$			*8.50* .121	1.100	.691		
KCl				Tr.			
K_2SO_4			*.57* .008		Tr.		
SiO_2	*.54* .008	*.60* .009	*.97* .014	.017		(*c*)	
NaCl	*1.30* .023	*4.20* .060	*7.70* .110	.409	.327	.975	.00464
Na_2CO_3					.434	.225	
Na_2SO_4	*2.02* .035	*6.00* .086		.580	.369		
N						*c* .240	
CO_2					.436	*c* 8.4	
H_2S			Tr.	*c* 44.5	*c* 20.00	*c* 35.36	19.02
Volatile at red heat		*6.00* .086	*6.16* .088				
Organic						.013	.791
Total solids	*12.31* .212	*31.00* .442	*43.88* .629	3.433	4.191	3.399	3.060
Total hardness		15.°					
Permanent hardness		8.°					
Free ammonia		.00002	.00006				.00072
Albuminoid ammonia		.00001	.00005				.00174
Permanganate			.00020				.004102

a All sulphates together. *b* $+Al_2O_3$. *c* In cubic inches per gallon.



DRILLING OF PETOSKEY WELL.

Constituent.	299. Alpena No. 3.	300. Detroit (Riverside No. 1).	301. Detroit (Riverside No. 2).	302. Detroit (Riverside No. 3).	303. Ypsilanti No. 1.	304. Ypsilanti No. 2.	305. Ypsilanti No. 3.
Al_2O_3				0.230			
$CaCO_3$		0.281	0.191	2.556	0.6322	0.98181	0.99712
$CaCl_2$			.728	14.743		2.45765	2.87328
$CaSO_4$	3.1314	1.968	2.756	30.702	3.0802	3.01121	2.98794
$FeCO_3$			.002		Sl. tr.	Tr.	.02856
$MgCO_3$			.004	.193			
$MgCl_2$	1.3417	.445	1.882		.9911	2.19596	2.63344
$MgBr_2$					.0610	.188	
$MgSO_4$		.759		18.549	1.1659	1.774	1.94260
KCl				.003			
KBr							.26764
K_2SO_4					.2330	.6058	
NaCl	4.1835	.554	5.320	58.460	14.241	26.97644	36.94436
Na_2CO_3	.0283		.048				
NaS	.4812				.2087	.1445	
SiO_2		Tr.	.003	.060	.0240	.3398	.43910
Total	9.1677	3.997	10.941	[a]132.442	20.6362	38.6788	49.11404
H_2S	.1267	[b]19.02	[b]14.77	6.946	[b]21.0786	[b]32.216	[b]35.84

[a] Sum including H_2S.

[b] In cubic inches per gallon.

No. 292 is of water from the Charlevoix waterworks well No. 2. Analysis obtained through H. P. Parmelee. Depth, 400 feet.

No. 293 is of water from the Bay View well. Depth, 498½ feet. Flow, 200 barrels an hour. Water likely to be roily. F. S. Kedzie, analyst. August 20, 1895. Well completed in July, 1895.

No. 294 is of water from the Petoskey well, 555 feet deep. Analyst, R. C. Kedzie. The two wells (analyses Nos. 293 and 294) are close together, but, as will be noticed on comparing their records, No. 294 has passed through and is drawing its water beneath a bed of shale, probably the base of the Traverse or the Hamilton, in which the Bay View well stopped. The Petoskey is apparently, therefore, a water from the Dundee (upper Helderberg), with the characteristic presence of H_2S, while the Bay View water is in the Hamilton.

No. 295 is of water from Butler's well at Frankfort. R. C. Kedzie, analyst. See Geological Survey Michigan, Vol. V, Part II, page 59, also plate. The temperature of 58° F., compared with the well record and statement that the main flow is at 1,400 feet, indicates that this water also is from the top of the Dundee limestone, with which its sulphated and sulphureted character is in entire accord.

No. 296, Wyandotte white sulphur springs, is of a similar water from the other end of the State. Analyst, Courtis. Cf. Peale, Bulletin U. S. Geological Survey No. 32, page 150. Generally the CO_2 is computed as bicarbonate.

No. 297, Alpena No. 1 (?), 1,164 feet deep, with chief flow at 600+ feet (?). Analyst, S. P. Duffield. Given by Peale as in grains per

United States gallon, but really per imperial gallon. The records of the first and second wells put down at Alpena seem to have been confused somewhat. See later paper; also Peale, Bulletin U. S. Geological Survey No. 32, pages 145, 147, Geological Survey of Michigan, Vol. III, Part I, page 39, and Vol. V, Part II, page 46. The temperature given by Peale, 52° F., nearly agreeing with my own observations, indicates a water about 500 feet nearer the surface than at Frankfort (900 feet), and Rominger says it is an "upper sulphur water," contaminated with a little salt from lower down. With this description both Nos. 297 and and 298 agree, and I found, by qualitative test at the well in 1897, markedly sulphated and sulphureted waters, with extremely little chlorine. The waters were then flowing naturally and not pumped, and this might give the upper water greater purity.

No. 298 is Vaughan's partial sanitary analysis of water from Alpena spring, so called because it is customary to speak of flowing wells as springs. The analysis doubtless refers to one of these wells. At any rate, in its strength in sulphates and extremely low Cl, it agrees with my qualitative tests of the wells. Brownish in color, with amoebæ, diatoms, algae, zoöglœa, several varieties of germs, and amorphous matter.

No. 299 is of water from Alpena well No. 3. Analyst, W. F. Edwards, of the Michigan University School of Pharmacy. Analysis probably made in 1892.

J. J. Mason & Co. report drilling wells 625 feet deep for the Northern Extract Company—water struck at 400 feet—which flow 450 gallons a minute and eat out the casing in about six years. These waters are merely "alkaline," whereas rock salt was struck at 1,200 feet in the Sanitarium well in 1893.

We next introduce a series of analyses of waters from wells bored in or near the Riverside bath house, corner West Fort street and South Clarke avenue, Detroit. There are said to be two wells, one more salt than the other. No. 302 is said to be of water from the two wells mixed; this can not refer to Nos. 300 and 301, but probably to No. 301 and another well put down later and still deeper. The temperature of 50° F. indicates no great depth for the wells from which samples Nos. 300 and 301 were taken, and they are not strong. No. 300 is like No. 297.

No. 300, Riverside magnetic mineral springs, Springwell's Fort, No. 1, is taken from Peale, Bulletin U. S. Geological Survey No. 32, pages 146–7, and is much like No. 296.

No. 301 is taken from Peale, Bulletin U. S. Geological Survey No. 32, pages 146–7, and is much like No. 296.

No. 302, Clark's Riverside bath house, Detroit. Depth of wells unknown. Analyst, S. P. Duffield. November 3, 1889. Cited from a pamphlet, where the analysis is given both in grains per imperial gallon and in parts per liter, the former figures being 700 times the latter. I give the latter figures multiplied by 10.

No. 303, Ypsilanti mineral springs. Depth 550 feet. Analyst, A. B. Prescott. Water drawn by his assistant March 31, 1883. Temperature, 58° F. (14.5° C.). Specific gravity at 15° C., 1.0163. Reaction alkaline. Total H_2S in volume at 58° F., 91.233 cubic centimeters. The analysis, dated May 5, 1883, is given in grains per United States gallon, not imperial gallon, as the same figures are given by Peale (p. 150), and grams per liter, the former figures being 58.37 times the latter. I give the latter figures, but, taking the specific gravity into account, the figures should be diminished by dividing by 1.063 in order to reduce to grams per kilogram, or parts per thousand. As has been noticed in connection with the Big Rapids analysis, Professor Prescott allowed for the specific gravity in stating the result in grains per gallon from parts per thousand, and has apparently done so here. But it is sometimes neglected, and I do not know how Shepherd, the analyst of No. 304, worked. I have preferred, therefore, to leave the Ypsilanti analyses as stated rather than to introduce a small and dubious correction.

This analysis (No. 303) is probably from the Cornwall mineral well or the original well (see fig. 1).

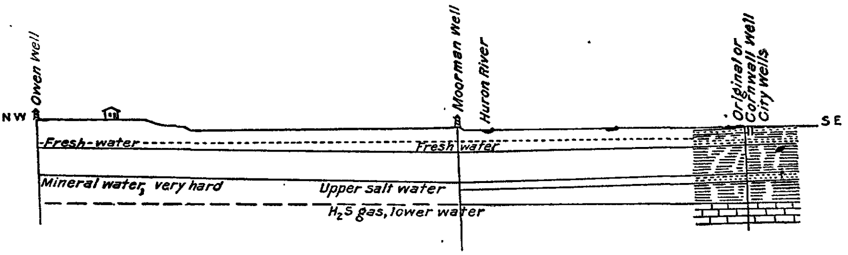


FIG. 1.—Section showing the relations of the deep wells at Ypsilanti to each other, to the wells of the city water supply, and to the several water-bearing strata.

The following is Prescott's statement of constituent acids and bases:

Total solids determined in grains	1205.6905
Hydrosulphuric acid, total in volume at 58.1° F. (14.5° C.)	91.2330
Total solids by evaporation	20.5800
Constituent bases and acids:	Grams per liter.
1. Potassa	0.1260
2. Soda	7.7120
3. Lithia	Tr.
4. Magnesia	0.8190
5. Lime	1.4865
6. Strontia	Tr.
7. Baryta	Slight tr.
8. Iron (ferrous oxide)	Slight tr.
9. Carbonic anhydride	0.3435
10. Sulphuric anhydride	2.6950
11. Hydrosulphuric acid	0.1321
12. Chlorine	9.3828
13. Bromine	0.0530
14. Fluorine	Slight tr.
15. Boric anhydride	Tr.
16. Phosphoric anhydride	Slight tr.
17. Silicic anhydride	0.0240
	22.7739
Deduction of hydrosulphuric acid and of oxygen displaced in the bromide, chlorides, and sulphide in excess over addition of sulphur in the sulphide and of water in the bicarbonate	2.1377
Total salts determined	20.6362
Total bases and acids determined	22.7739

No. 304, Ypsilanti Mineral Bath Company, Moorman mineral well. (See fig. 1.) Analyst, James H. Shepherd. Water drawn September 5, 1884. Temperature of water, 14.2° C. (57.5° F.); of air, 26.3° C. (79.3° F.). Specific gravity, 1.0280. Reaction, alkaline. The results cited are said to be in grams per liter, and are also stated in grains per imperial gallon, the latter figures being 70 times greater than those given (by which I have detected one or two misprints in the analysis as published in the pamphlet of the company; in Peale's paper also, op. cit., it should read 124.42 $MgSO_4$), and accordingly, though grams per liter are stated, parts per thousand may be meant, the imperial gallon being taken as 10 pounds. At the time this sample was taken the well was cased to 550 feet, to shut off all higher waters, and practically this is pure Dundee limestone water.

No. 305, water from same well as No. 304. Analyst, De Forest Ross, September 13, 1897. Temperature of water, 16.5° C. (?). Reaction, alkaline. Specific gravity, 1.0358. The pamphlet statement is in grains per imperial gallon. Before this analysis was made the casing was pulled back to 185 feet, so as to admit the upper stronger water of the Berea grit which is more predominant in No. 286A.

No. 306, T. C. Owen's well Atlantis, on the hill near the normal school at Ypsilanti. (See fig. 1.) Analysts, J. H. Shepherd and W. F. Pett, 1884. Peale, op. cit., page 150.

It will be noticed that No. 305 is the strongest water of the four, and that the addition of the Berea water has increased mainly the NaCl, while the sulphates have not increased in the same proportion. The relations of the three wells are shown in fig. 1.

The remaining analyses are for many reasons difficult to group. In the first place, the specific gravity is so great that parts per thousand—i. e., grams per kilogram—and grams per liter are by no means equivalent expressions. Yet chemists accustomed to analyzing waters whose specific gravity is practically unity, speak of grains per imperial gallon, when grains per unit of 70,000 grains or 10 pounds is meant. Others, like A. B. Prescott, are careful to apply the volume correction. Then, again, the specific gravity of a brine varies, at different temperatures, to a measurable, though trifling, extent (cf. analysis No. 323). Thus the reduction of the analyses to strictly comparable units is not easy. Again, one can not be sure in such analyses as are issued in advertising pamphlets whether care has been taken in proof reading, or even whether they have not been altered. A number of minor errors seem thus to have crept into Peale's list. Often the kind of gallon is not specified, and Peale's rule—to assume the United States gallon unless otherwise stated—is not safe. In fact, when most figures for different constituents are multiples of 7 the imperial gallon is probably used. Finally, as will be easily seen, the analyses vary considerably, and imperfections of analysis, though they may be considerable, are unimportant beside the larger ones due to variation, from time to time, in the quality of the water itself. A most important factor in this connection is the character and depth of the casing, as is seen in the Ypsilanti wells just described (analyses Nos. 304 and 305). The same thing is seen in the Alma analyses (Nos. 327 to 329), in all of which cases the withdrawal of the casing admitted a different water. We do not know the condition of the casing in many instances, and, moreover, casing supposed to shut off an upper water does not always succeed in effectually doing so. How far the great variations, for example at Mount Clemens, are due to the casings remains to be proved. Then, again, variations have been found which seem to be connected with the rate of pumping. There are very few waters on the list below that are not composite—made up of waters from various levels, and, as they come from beds of varying porosity as well as varying head, a well pumped nearly to its capacity will draw more largely from the more porous beds than when it is more gently pumped. In fact, a very porous bed with low head might, under heavy pumping, yield a large proportion of the water, which would yield none in the normal flow. Such are some of the considerations which we must especially keep in mind in studying the analyses from No. 232 on. There is still another consideration which is forced upon us by the first analysis to be described.

No. 307 is supposed to be of water from the well of the Port Huron Mineral Bath Company. I am informed by Mr. W. L. Jenks, who is now interested in the well, that illuminating gas comes at 400 feet and this mineral water at about 800 feet. Compare, in Geological Survey of Michigan, Vol. V, the water at 772 feet in the Junction well, Pl. LIV. I have included this analysis rather against the wishes of Prof. A. B. Prescott, the analyist, for he does not consider it a natural water. The element which has evidently been tampered with is the bromine, which is so out of harmony with the proportions of other constituents that the discrepancy is apparent at once. Professor Prescott had the Ypsilanti mineral water drawn by his own assistant, and in that water the Br was barely a twentieth part of what it is in this analysis. The potash and iodine may also have been altered in No. 307. But I have thought it best to include the analysis—first, to show how recognizable an altered analysis is likely to be to a student of natural ones. The analysis was recognized as not natural by Professor Prescott and myself quite independently. Again, I think the real mineral water was used as a base, and in some respects the analysis is quite comparable with and an interesting link to the other Dundee limestone water analyses. The sample gave Professor Prescott a specific gravity, at 15.05° C, of 1.070, and the oxides and acids were K_2O 3.537, Na_2O 37.502, MgO 3.116, CaO 4.203, SO_3 2.312, Cl 49.408, Br 5.380, I 0.319, CO_2 0.035, SiO_2 0.010, H_2S 0.649.

It must be recognized that we are dealing with a group of waters which are unquestionably of high healing value and economically of great importance, in which there is lively competition, and where there is a temptation for an owner to add to his well, before analysis, elements considered desirable, just as the famous Apollinaris water is said to have a little salt continually added to it. It is legitimate if there is no deception about it and if the water is kept true to its quality. The above statement may apply also to No. 310, though reported to me as coming from a well 340 feet deep. The CO_2 is certainly added, and the analysis could be nearly reproduced by diluting No. 311 with pure water one-hundred fold. I do not say that this is not an excellent table water. Strong brines must also be diluted to be drinkable, and so the St. Clair mineral water, analyzed by Professor Prescott in December, 1894, and the analysis published by the owner, was a dilution of a very strongly saline water, artificially charged with carbon dioxide, and did not represent a natural water. Most waters are artifically charged for the market.

No. 308 is of water from a well 1,400 feet deep at Benton Harbor (see Geological Survey of Michigan, Vol. V, Part II, Pl. VII). The water is known as Benton Harbor Excelsior mineral water. Prof. John H. Long, of Northwestern University, analyst. The H_2S is cubic inches per gallon at 70° F. Specific gravity of water at 70° F., 1.1058; allowed for in the reduction.

No. 309 is of water from Coldwater, sent by C. B. Randall. Professor Prescott, analyst, 1893. Compare also Geological Survey of Michigan, Vol. V, Part II, Pl. X. The bases and acids determined were as follows:

Specific gravity, at 20° C., 1.159.

	Parts per thousand.
Aluminum oxide	0.1910
Ferrous oxide	0.0249
Ferric oxide	0.0649
Manganese	Tr.
Magnesium oxide	5.2517
Calcium oxide	11.5650
Sodium oxide	82.9500
Chlorine	121.1360
Bromine	1.3040
Sulphur of sulphides	0.0012
Sulphuric anhydride	0.5650
Silicon dioxide	0.0109
Estimation of Br as described in an article by Prescott and Dunn, Jour. Anal. Chem., *3*.375 (1889)	223.0646

No. 310 is of Salutaris water, bottled and put on the market. Analyst, C. F. Chandler. Reduced from grains per United States gallon to grains per liter or kilogram. Chandler's No. 2779, June 10, 1890. This water is said to be from a well 340 feet deep, and cased down to rock. Compare above under No. 276; see also Geological Survey of Michigan, Vol. V, Part II, Pl. LXII. It is barely possible that by an unexpected fold or fault the Berea grit comes in here, for the water resembles very much that of Wales (No. 122) and Birmingham (No. 285).

No. 311 is of water from the St. Clair mineral springs. Cited by Peale, op. cit., page 149; no analyst is given. The analysis is not complete, and I have doubts as to whether it is in grains per United States or imperial gallon, and also as to the specific weight.

No. 312 is of water from the St. Clair spring, Oakland House well. Depth, 1,250 feet, cased 1,000 feet. Statement published in pamphlet is in grains per United States imperial gallon (really imperial gallon). Analyst, S. P. Duffield. "I think you would find more salt if you went deeper." "Your water shows a large proportion of calcic chloride." This analysis is remarkable for the largest proportional amount of earth chlorides, and yet only traces of bromides, etc. It would be interesting to know how much potash the water contains. (Compare No. 313.)

No. 313 is of Somerville spring mineral water, St. Clair, Michigan. Statement in published pamphlet in grains per imperial gallon (as the figures are multiples of 7). Analyst, S. P. Duffield. This well is very close to that from which sample No. 312 was taken, and yet the waters are markedly different; the analyses were made by the same chemist. Do the potash and bromide belong to an upper flow which is cased out of No. 312? In other cases also the KCl and the $CaCl_2$ are inversely proportional.

No. 314 is of water from the Mount Clemens original well, which has also at times been known as the Avery and the Soolbad. Analyst, H. F. Meier; cited in grains per gallon without specific weight, by Peale, op. cit., page 148. This water is the least mineralized of all the Mount Clemens waters analyzed, having as much or more NaCl, but being deficient in earthy chlorides, elsewhere so marked a feature of the waters. As the Mount Clemens resort, like most Michigan resorts of this class, started in an abandoned salt industry, this may represent more nearly the original brine, the casing being afterwards withdrawn to let in brine stronger in other constituents.

No. 315 is of water from the same well as No. 314—the Avery. Analyst, S. P. Duffield. As given by Peale this is in grains per United States gallon, and the $CaSO_4$ is stated as 100.56. In pamphlets I find the $CaSO_4$ 100.335 and the gallon stated as the imperial, the same figures, which are mostly multiples of 7, being used. This is the analysis of Mount Clemens water most often cited in other reports for comparison. The presence of nitrogen is interesting. Perhaps some of the rare gases recently discovered which have masqueraded behind N are also present.

No. 316 is of water from the same well as Nos. 314 and 315—the Soolbad. Analyst, S. P. Duffield, 1884. Only a partial analysis. Cited by Peale, Bulletin U. S. Geological Survey No. 32, page 148.

No. 317 is of water from the Clementine well, 1,060 feet deep, at Mount Clemens, B. B. Coursin, proprietor. Cf. Geological Survey of Michigan, Vol. V, Part II, Pl. XLII. Fenton Hotel. Analyst, Theo.

Tonnelé, McKeesport, Pennsylvania, June 14, 1893. Specific gravity 1.1313. Given on advertising card as in grains per United States gallon; specific gravity allowed for, the units for gas not given. Total solids by evaporation, at 20.5° C., 10,786.3 grains per gallon. By sum, mation, including S 10,874.526 hydrosulphate and hydrosulphite of sodium lumped together, but not the clay and sulphide of iron, as insoluble matter. The sulphide of iron and free S indicate decomposition of the H_2S and precipitation on the long journey to Pennsylvania.

No. 318 is of water from the Mount Clemens Medea well. Depth 1,244 feet. Second well put down. See Geological Survey of Michigan, Vol. V, Part II, page 71. Analyst, S. P. Duffield, 1884. Cited by Peale, Bulletin U. S. Geological Survey No. 32, page 148, as in grains per United States gallon. This analysis is so similar to No. 319 as to appear like an incomplete version of the same; but the latter is given in grains per imperial gallon.

No. 319 is of water from the same well as No. 318. Analyst, S. P. Duffield, cited from pamphlet in grains per imperial gallon. In NaCl, $MgCl_2$, and in total solids this checks well with the Clementine analysis, No. 317; but No. 319 has $CaCl_2$ where No. 317 has the same amount approximately divided between potassic and calcic chloride.

No. 320 is of the water of the Mount Clemens Sanitarium Company, Limited. This is from the most recent well, 1,000 feet deep, with, it is believed, only 70 feet casing. Analyst, John E. Clark. Water taken July, 1896. Analysis dated August 5, 1896. Gas in cubic inches; other constituents in grains per imperial gallon. I have not been able to find by inquiry whether or not the specific gravity was taken into account, but I have assumed for the reduction that the imperial gallon was taken as 10 pounds. In this sample and in No. 319 CO_2 was present, but was not estimated, and the iron sulphide precipitate is included in the summation.

No. 321 is of water from the well of the Windsor Salt Works, Windsor, Ontario (directly opposite Detroit). Analyst, F. E. Englehart. Specific gravity 1.1817. I have taken this analysis, in default of any analysis of water on the Michigan side of the river, to show the nature of the lower salt brine.

The foregoing analyses show clearly the nature of the waters from a geological point of view. Passing through the impervious cap of black shale, at first comparatively weak water strongly charged with gas, especially H_2S, is struck (analyses Nos. 296, 300, 301, and 303 to 307). Penetrating deeper we come to a set of strata saturated with bitterns or mother liquors (cf. Nos. 283 and 284 with Nos. 318 and 319) deposited from the sea which was left after the great beds of rock salt, which have been and are now actively exploited through still deeper wells (analyses Nos. 320 and 321), had been laid down. Organic matter, as already mentioned, may have decomposed $CaSO_4$ and produced the H_2S.

The records of various wells, as given by Mr. Wright in Vol. V of the reports of the geological survey of Michigan, contain a mass of data as to the specific gravity of the brines at the various depths, illustrative of these points.

No. 322 is of water from the Canfield & Wheeler well at Manistee; Geological Survey of Michigan, Vol. V, Part II, Pl. XXXI. A. B. Prescott, analyst. Analyzed between 1883 and 1890. Specific gravity at 60° F., 1.20054.

No. 323 is of water from the same well as No. 322, and by the same analyst; 1893. Evidently the brine had deteriorated in purity. Specific gravity at 16° C., 1.26; at 25° C., 1.255. The analysis was only partial, as follows:

Cl	184.477
Br	9.730
CaO	65.352
MgO	24.280
Fe	Tr.
SO_3	Sl. tr.
K	Tr.
Li	Tr.

A provisional estimate of the potassium was obtained (weighing potassic platinic chloride) giving 0.0169 per cent of K_2O. An estimate of the lithium weighed as sulphate gave duplicates for 0.0111 LiO_2, which "is surely far too high."

The estimate of the bromine was made by the indirect method described in Journal of Analytical Chemistry, Vol. III, page 375, 1889, but with a solution of silver nitrate of known strength for precipitation and estimating the excess of this solution used, so that the consumption of silver nitrate in precipitating can be held as a control for the weight of metallic silver obtained through reduction of a known amount of silver chloride bromide.

No. 324 is of brine from Sand Beach mineral well. Depth, 1,920 feet. See Geological Survey of Michigan, Vol. V, Part II, pages 80–83. R. C. Kedzie, analyst, August, 1890. Original figures are in grains per imperial gallon of 10 pounds. This and the two following analyses have an interesting history. The well whose record is given, loc. cit., was originally a salt well. When Dr. Kedzie's analysis showed the astounding and unsuspected proportions of K and Br given, Mr. George W. Jenks had the sample sent to S. P. Duffield for verification. The analysis returned, No. 325, shows an even stronger water, and, curiously enough, all the constituents increased in exactly the same proportion. Finally, a sample sent in 1896 to Hetherington & Rasher, an English firm of commercial chemists, with a view to testing before exploiting such remarkable richness, gave analysis No. 325, in which the Br and K have dropped to more usual proportions. Some comments may be made later on this whole subject. Suffice it to say now, that a considerable sample of the original water still exists at the Agricultural College, and there is every reason to believe that the original analysis is a correct one of the original water at 1,860 feet. The sample analyzed in 1896 was mixed with a deeper water, for the well was then deeper.

No. 325 is of brine from Sand Beach. S. P. Duffield, analyst. Reference as above. Specific gravity at 60° F., 1.180. Statement given in grams per liter (really per kilogram). H_2S is 0.2271 gram or 10.745 cubic inches. Total solids directly estimated per liter, 311.6 grams.

No. 326 is of brine from Sand Beach, taken in 1896. Analysts, Hetherington & Rasher, England. Specific gravity, 1.187. Probably in this analysis the imperial gallon is really a volume, and not as in the two previous analyses 10 pounds; in such a case the total solids would agree closely. The reduction is, however, made by dividing by 70.

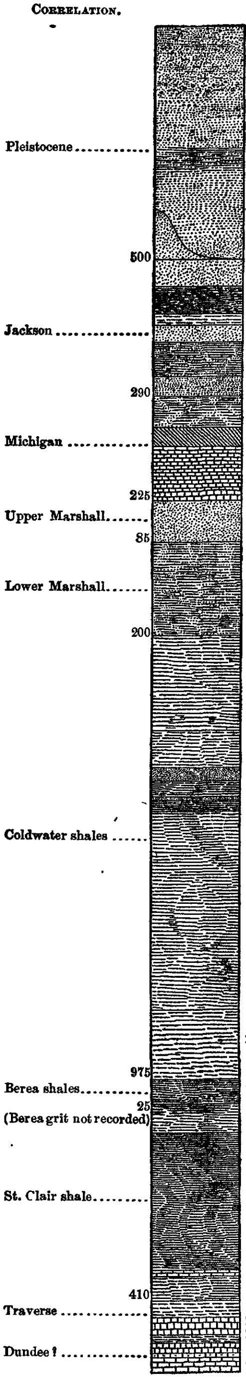
The next group of analyses are all from the same well—that of the Alma Sanitarium, Dr. J. H. Lancashire, president. The well record is illustrated in fig. 2, which, being of a deep well in the center of the basin, illustrates also the general relations of the strata for most of the other wells mentioned. The Berea grit, however, was not reported in this well; this is quite strange, as the formation is well developed at Bay City. These wells do not give off H_2S perceptibly, but a small amount of illuminating gas is discharged which the analysis does not mention. The effect of pulling back the casing so as to let in the Marshall waters seems to increase the bromine and decrease the total solid constituents. The relative increase of salt and diminution of chlorides of lime and magnesia agree in indicating that thereby a more purely salty brine like No. 281 is admitted. A similar experience was had at Ypsilanti. In other words, the Alma water is a mixture of the upper bitterns of Mount Clemens with a brominiferous Marshall water. The analyses are stated in grains per United States gallon, and I have not been able to obtain the original figures nor the specific gravity, but they should be reduced to parts per thousand, for comparison, by dividing by about 70; this implies a specific gravity of about 1.2, which must be nearly correct.

No. 327 is dated August 17, 1894. Analysts, C. F. Chandler and C. E. Pellew, of Columbia University. See Geological Survey of Michigan, Vol. V, Part II, page 46.

No. 328 is dated May 24, 1894. Same analysts and references as No. 327. The casing had been pulled back for the above analyses, I am informed.

No. 329 is dated January 15, 1890. The well struck this water in March, 1889. This I understand to be purely the bottom water. Another account of the casing is as follows:

> This well was cased with 8-inch casing 500 feet, then a 5⅝-inch casing 615 feet. At 1,053 feet the hole was reduced to admit a 4½-inch casing, which was eventually carried down to the 1,500-foot level. From this point there is no casing and we are using a pump that extends down 1,500 feet.



DESCRIPTION.

60 feet to quicksand and water; less Ca and more Fe than surface wells; Al, Mg, Na, trace K, H_2S sometimes.

157 feet to bottom of second sand and water, through 3 feet gravel; analysis, C. A. Davis, Dec. 7, 1891, T. 48.2° F.

226 feet; analysis, S. P. Duffield, May 5, 1889.

Clay and gravel to 475 feet.

At St. Louis bed rock was struck at 335 feet; the rock thence to 590 feet being at first red sand rock, then mainly white sand rock.

475 to 500, sand and gravel.

500, 8-inch drive pipe.

500–550, white feldspathic sandstone.

550–615, black shale with $FeCO_3$. At 615 feet, 5⅝ inch casing cuts off fresh water.

Light shale.

637–675, white conglomerate sandstone; salt water.

675–750, blue and black shale, sandstone, and coal.

750–790, ferruginous sandstone; salt water with FeCO4.

790–850, sandy shales.

850–900, shale and gypsum.

900–1,015, dark bituminous dolomites.

1,015–1,100, yellow to white sandstone; brine; analysis, C. A. Davis, May 5, 1889.

1,100–1,300, red sandy shales.

1,300–1,500, red or blue shales.

(Cased at first to this point.)

1,500–1,575, blue shale.

1,575–1,605, brownish, very fine-grained grit.

1,605–1,640, dark calcareous shale.

Fine light-yellow sand.

1,645–1,675, dark shale.

1,675–2,000, dark-blue shale, with some sand and $FeCO_3$; drilling 25 feet a day.

2,000–2,275, blue shale.

2,275–2,300, black shale.

2,300–2,360, blue shale (Bedford shale).

2,360–2,640, black shale.

Gray limestone.

2,660–2,710, black shale.

2,710–2,760, dark-blue shale.

2,760–2,780, buff dolomite.

2,780–2,800, blue shale.

2,800–2,825, hard brown dolomite; drilling 3 feet a day.

At 2,825, white sandy limestone with water, T. 98° F.; analyses: C. F. Chandler, Jan. 15, 1890, May 22, 1894, Aug. 17, 1894.

Well begun July, 1888; reached 2,500 feet Feb., 1889; finished June, 1889.

FIG. 2.—Geological column at the Alma Sanitarium.

Constituent.	306. Ypsilanti (Atlantis well).	307. Port Huron.	308. Benton Harbor (Excelsior well).	309. Coldwater.	310. St. Clair (Salutaris water).	311. St. Clair mineral spring.	312. St. Clair spring.
Al_2O_3			*0.035* .005	*a* 0.643			*840.00* 12.00
$CaCO_3$	0.827		Tr.			*0.15*	Tr.
$CaCl_2$	3.000	5.118	*1,378.24* 21.350	*1,535.786* 22.717	*b 5.1337* bi. .0879	*2,437.49*	*7,382.2* 105.46
$CaSO_4$	.666	3.930	*85.449* 1.324	*13.901* .205		*140.19*	*144.2* 2.06
$FeCl_2OH$				*11.279* .167			
$FeCl_2$				*3.672* .054			
LiCl	*d* Tr.		Tr.				
Barium	Tr.						
$MgCO_3$					*c 3.8814* bi. .0665	*1.10*	Tr.
$MgCl_1$	1.911	1.012	*605.90* 9.386	*791.42* 11.70		*398.38*	*1,012.2* 144.6
$MgBr_2$	.193	12.374	*46.72* .725	*101.193* 1.497		Tr.	
$MgSO_4$	1.320						
Fluorides	Tr.						
Phosphates	Tr.						
KCl		5.511	Tr.		*1.6979* .0293		
K_2SO_4	.527	.080			Tr.		
Silicates	.015						
SiO_2		.010	*.233* .004	*d* .0109	*.5717* .0098	*29.41*	*406.00* 5.800
NaCl	34.457	70.871	*6,821.12* 105.680	*10,911.25* 161.39	*81.3344* 1.388	*e 9.56501*	*8,120* 116.00
NaI		.377				MgI tr.	MgI tr.
NaS				*.1346* *.002*			
$NaHCO_3$					*4.8754* bi. .08135		
Organic matter	Tr.				Tr. NH_3		
Total by addition	42.916	99.283	8,938.002			*12.57173*	17,904.6
Total by evaporation			138.474	*13,412.831* 198.3601	*97.4943* 1.671		255.78
H_2S	*f*15.527	.649	*f* 27.8	Tr.		*f* 16.43	*f* 25.597
CO_2					*465.325*		
Sp. wt			1.1058				

a Aluminum sulphates.
b $CaH_2(CO_3)_2$.

c $MgH_2(CO_3)_2$.
d And borates.

e +KCl.
f Cubic inches.

Constituent.	313. St. Clair (Somerville spring).	314. Mount Clemens (original well).	315. Mount Clemens (Avery).	316. Mount Clemens (Soolbad).	317. Mount Clemens (Clementine).	318. Mount Clemens (Media).	319. Mount Clemens (Media).
Al_2O_3			*29.47* .421	*11.21*	*2.920* .044	*29.00*	*42.07* .601
NH_4Cl		Tr.		Tr.		Tr.	
$CaCO_3$		*3.98*	*0.98* .014	Tr.		*91.00*	*0.91* .013
$CaCl_2$	*2,803.78* 40.054	*172.41*	*934.5* 13.35		*2,827.606* 42.820		*4,128.53* 58.979
$CaSO_4$	*87.78* 1.254	*35.20*	*100.335* 1.433	*44.00*	*69.970* 11.060	*14.30*	*143.43* 2.049
Fe_2O_3	*30.100* .430			Tr.		*8.500*	
$FeCO_3$			*.560* .080				*8.54* .122
$FeH_2 (CO_3)_2$					*1.924* .029		
$FeCl_2$							
FeS		Tr.			*a433.536* 6.5626		
LiCl				Tr.			
$MgCO_3$		Tr.	*0.70* .01	Tr.		*0.70*	*0.07* .001
$MgCl_2$	*242.90* 3.470	*129.60*	*648.48* 9.264		*1,228.002* 18.596		*1,656.2* 23.66
$MgBr_2$	*68.60* .980		*6.37* .091	Tr.		Br. *8.50*	*8.54* .122
MgI_2		*b 0.32*	*0.07* .001	*b 0.05*		*b .07*	*.07* .001
KCl	*1,680.00* 24.00	Tr.		Tr.	*1,057.889* 116.020		
SiO_2	*119.00* 1.700	*c 8.97*	*27.60* .394			*28.00*	*28.09* .401
NaCl	*8,983.94* 128.342	*8,637.44*	*11,900.00* 170.00	*d 11,181.00*	*5,684.255* 86.080	*11,741.00* *(e)*	*5,957.35* 85.105
Na_2SO_4	*f 11.9* .170	*77.25*			*g 1.960* .0		
Sr					Tr.		
S					Tr.		
Organic		Tr.					
Total solids	*14,028.00* 200.4	*9,065.17* 155.00	*13,654.105* 195.062	*11,236.26* 192.00	*10,874.526* 164.678	*11,921.07* 170.301	*11,973.80* 171.054
H_2S		*h* 27.52	*h* 40.00	*h* 33.00	*h* 9.910	*h* 40.00	*h* 38.00
CO_2		Tr.	*h* 5.85		*h* 3.457		

a Insoluble and not included in summation.
b Iodine.
c $+Al_2O_3$.
d +Ca+Mg.
e Na+Ca+Mg.
f Hydrous.
g Hydrosulphate and hydrosulphite of sodium.
h Cubic inches.

Constituent.	320. Monnt Clemens Sanitarium.	321. Windsor, Ontario.	322. Manistee No. 1.	323. Manistee No. 2.	324. Sand Beach No. 1.	325. Sand Beach No. 2.	326. Sand Beach No. 3.
$CaCl_2$	*10,166.356* 145.234	.3643	CaMg Cl_2 3.449	129.54	56.89	62.6636	*2,875.00* 41.07
$CaSO_4$	*75.909* 1.0844	5.443	4.395	....	.90	.9936	*40.6* .58
$FeH_2(CO_3)_2$	*2.149* .031	....	....	....	....	....	....
$FeCO_3$	*122.998* *a* 1.757	....	....	....	Tr.	....	....
LiCl	....	....	....	Li_2O .111?	....	....	....
$MgCl_2$	*843.493* 12.050	1.6652	....	46.11	4.85	5.3542	*1,571.00* 22.44
$MgBr_2$	Tr.	....	....	11.19	22.500	24.84	*58.5* .836
MgI_2	Tr.	....	....	....	....	....	....
KCl	*2.943* .042	....	....	....	34.22	37.7788	*215.00* 3.07
K_2O	....	....	....	.169?	....	....	....
SiO_2	*2.112* .030	....	....	....	....	.7303	....
NaCl	*8,709.306* 124.4187	227.0157	(*b*)	111.14	162.64	179.2391	*14,230.00* 203.29
Loss	....	....	....	....	....	....	*1,079.00* 15.414
Total solids	*19,947.277*	....	....	....	*19.740*	*21.812*	*20.0691*
Grams per liter	284.9611	234.4872	262.00	297.98	282.00	311.60	288.13
H_2S	*c* 38.00	....	....	....	*c* 10.5	*c* 10.745	....

a FeS. *b* Rest of solids are mainly NaCl. *c* In cubic inches.

Constituent.	327. Alma No. 1.	328. Alma No. 2.	329. Alma No. 3.	Constituent.	327. Alma No. 1.	328. Alma No. 2.	329. Alma No. 3.
Al_2O_3	*5.0325*	*3.905*	*4.0823*	SiO_2	*1.4883*	*.8324*	*4.6654*
NH_4Cl	*41.9133*	*43.0859*	....	NaCl	*8,963.7825*	*9,581.3242*	*9,539.5974*
$CaCl_2$	*6,514.2006*	*6,304.2741*	*7,324.0548*	NaBr	*84.9091*	*80.8238*	*154,026.00*
$FeCl_2$	*22.4089*	*15.4101*	*23.0911*	NaI	Tr.	Tr.	Tr.
LiCl	Tr.	Tr.	Tr.	Sodium phosphate	Tr.	Tr.	Tr.
$MgCl_2$	*2,465.4775*	*2.256.9909*	*2,215.8903*				
KCl	*125.5798*	*63.7845*	*100.6261*	Total	*18,240.7291*	*18,408.6213*	*19,241.0949*
K_2SO_4	*15.8466*	*58.1949*	*13.6849*				

RÉSUMÉ.

In spite of the difficulties, upon which I have enlarged perhaps too much, I am able to make some generalizations of interest and I trust of practical value.

If we take any one stratum yielding water, we find that the deeper it is the more strongly mineralized it is. At the margin the salts are more often carbonates and sulphates, and are replaced below by chlorides, and the earthy chlorides and bromides, etc., appear to be richer in the deeper or central parts. But the rate of mineralization is far from the same in different beds. The freshest horizons for a given depth appear to be the Dundee and the Marshall. The former appears to be characteristically sulphureted, far more so than any other horizon. The latter is the chief horizon for potable water, and is capable of supplying a large part of the State, but must be shielded in many cases from overlying waters. Above the Marshall the waters are likely to be mineralized even if quite shallow, and generally strong in sulphates, with or without salt. Below the Marshall is the Berea grit, which is somewhat saline even in shallow wells, yields excellent brine in the deeper wells, illuminating gas and oil rather than H_2S, and is marked by the predominance of sodium and the relative freedom from earthy chlorides. Has this any connection with its isolation in a shale series away from any limestone? Below the Dundee the predominance of these earthy chlorides is characteristic, and also probably the concentration of K and some of the rarer elements from the great salt depositing process, the results of which we find still farther down.

So far as the rarer elements and less sought for compounds are concerned, it must be said, however, that analytical methods are not yet satisfactory for brines. The Midland Chemical Company is a large manufacturer of bromine, practically dominating the industry, and is said to have improved methods of analysis. But these are commercial considerations. I have had complaints that efforts had been made in vain to get from the East Tawas brines the bromine that was said to be there. Again, the presence of celestite associated with sulphur at Scofield and other points in the Helderberg series, suggest that Sr must be a constant constituent of the sulphureted waters. But its presence, even in traces, is rarely noted in the analyses. Doubtless, if especially looked for, it would be found more widely diffused. On the other hand, I have been assured by a competent chemist that the Michigan brines differ from those of Ohio and Pennsylvania in the absence of iodine and lithium. Ammonic chloride, reported from Alma, is probably widespread and generally overlooked.

From the Dundee and the limestone series below are a number of interesting brines which we are not yet able to differentiate. The first analysis of the Sand Beach brine was, I believe, correct, and the brominiferous pocket was either exhausted or diluted with a lower water, for even the English analysis shows a notable amount of K and Br. The general criticism may be made, on the exploitation of the undoubtedly valuable medicinal bitterns of Michigan, that too little attention and study has been given to the precise effects of the various components in particular classes of diseases. Although both a sulphureted water and a saline water have medicinal values, they are not exactly the same. Yet the usual custom is to let them flow together and to continue boring until the salinometer shows considerable strength, so that "the bathers may feel the buoyancy and feel that they are getting their money's worth," and it is desired that the analysis may show as strong a water as a neighboring establishment, or a similarity to some famous water. No attempt to separate the various waters and use them according to the circumstances of the case seems to have been made, further than to have one well for drinking and another for bathing. And yet anywhere along the Detroit and St. Clair rivers it would be easy enough to have, even from one well, a sulphureted water, a calcium chloride water, and a strong salt water, and perhaps other varieties, to be used as each case required.

I have been told that hygienic living and drinking plenty of water are essentially the most important curative agents, and next to them is salt. So far, however, as particular mineral and gaseous ingredients are really of importance, the plan above suggested would certainly be a step in advance. Again, in view of the evidence of gradual changes in analysis, perhaps from deterioriation of casing, it would be well to keep weekly records of salinometer strength and temperature and also of the quantity of water pumped, which would quickly indicate any leak in the casing, and if any notable difference was thus detected it might be well to analyze the water again.

In studying the sanitary analyses of potable waters I am brought to the conclusion that, so far as typhoid and kindred diseases are concerned, direct microscopic investigation and bacteriological study are more important than consideration of chemical constituents as indicators of sewage contamination. It is easy to see that chlorine in particular is no guide, unless one knows accurately the normal percentage for uncontaminated water under the same geological conditions. Prof. Delos Fall, of the State board of health, is pursuing researches along this line. In many cases even an abnormally low percentage of mineral matter or salt is suspicious, as indicating dilution with rain and other surface water. This is especially true of abnormally soft waters.

I have given the dates of the analyses, because the State board of health has shown that the prevalence of typhoid fever increases with the lowering of the water in the wells, the curves of their diagram showing the prevalence of typhoid from month to month and the parallel lines the height of water in the wells. The lowest water (231 inches below ground on the average) and the greatest number of cases of typhoid occur in October, the highest water (197 inches below ground) and the fewest cases of typhoid in the spring.

MAP SHOWING AREAS OF HEAVILY MINERALIZED SHALLOW WATERS.

Not only does ammonia occur in peaty waters, which are not necessarily dangerous, though likely to be malarial, but in the Alma well, at a depth of 2,860 feet we find it playing the same rôle as magnesium or calcium. Hence it is not a reliable indication of contamination. It does not, however, by any means follow that a chemical examination of ordinary waters is valueless. With due regard to all conditions, such analyses may furnish valuable indication as to sewage contamination, and it is one of the objects of this paper to enable the chemist to study and judge what the normal analysis should be. But germ diseases are not the only ailments of man, and extremely hard waters, like those around Mount Pleasant, are by no means wholesome simply because there is no possible surface contamination. The relation between the percentage of various mineral constituents and certain chronic diseases, and the uric acid diathesis has not, to my knowledge, been carefully studied. The map (Pl. IV) shows by shaded areas those parts of the State where the waters commonly drunk are most likely to be highly charged with mineral matter, and it would be interesting to see if these areas correspond in any significant way to disease distribution. Of course in these shaded areas there are many surface wells of nonmineral waters. Yet the waters of many wells are strongly cathartic or otherwise unpleasant to those unused to them, as strangers coming temporarily to help in harvest and threshing soon discover. It seems natural to suppose that a water which will favorably affect some sick people will unfavorably affect others, and that some waters may be permanently too strong for some constitutions, while other systems which may be at first decidedly unsettled by them in time become perfectly accustomed to them. Throughout the central or shaded area, in chronic diseases like rheumatism and constipation it might be worth while to experiment with pure filtered rain water (flavored if necessary with a little salt or lithium carbonate) as a beverage.

In regard to brine for salt making, rock salt and very pure brines occur in the Salina, north of a line from Trenton to Muskegon. Next ranks the brine of the Berea, and then that of the Marshall.

Just above the Salina the rocks seem to be saturated with bitterns. That would seem to be a most hopeful field to develop for potash salts. September 29, 1899, newspapers report that explorations, particularly for potash, will begin in October. Some of the Coal-Measure waters seem also to run relatively high in potash. At considerable depths both this horizon and the Marshall seem to possess bromides in valuable quantities.

APPENDIX.

The Appendix contains some analyses which were received too late for insertion in their proper places without entirely renumbering the analyses. References to these later analyses have, however, been inserted in the proper place in the body of the text, and the place in which each should come is indicated by the number given it.

The first fourteen are cited from the Report of the Special Water Supply Committee of the City Council of Traverse City—the report of Engineers H. F. Northrop and George W. Rafter.

No. 2A, of water from the west arm of Grand Traverse Bay, was made November 24, 1884. Analyst, R. C. Kedzie. (Op. cit., p. 10.)

No. 2B was of water from the same arm, collected April 18, 1897, from the surface at a point a little north of Carter's dock and about 1,200 to 1,500 feet out from the west shore. Analyst, R. C. Kedzie. (Op. cit., table No. 2.) Some blackening on heating; nitrites none, nitrates a trace.

No. 2C, of water from the east arm of Grand Traverse Bay, was made in April, 1897. Analyst, R. C. Kedzie. (Op. cit., table No. 2.)

No. 2D is of Lake Michigan water at Chicago. (Op. cit., p. 20.)

No. 5A is of Detroit city water. April, 1896. (Op. cit., p. 14.) Microscope shows fine sand, mud, diatoms, and algæ. Oxygen absorbed in fifteen minutes, 0.0003; in four hours, 0.0006. Turbid; reaction neutral.

No. 6A is of Detroit city water. July, 1896. (Op. cit., p. 14.) Oxygen absorbed, 0.00034 and 0.00062, respectively.

No. 7A is of Detroit city water. February 15 to 22, 1897. (Op. cit., pp. 14, 15.) No nitrites. Oxygen absorbed in fifteen minutes, 0.00036; in four hours, 0.00070.

No. 7B is of Lake Michigan water, 5 miles off shore at Milwaukee and 44 feet beneath the surface, where the lake is 118 feet deep. (Op. cit., pp. 18 and 19, where a number of other analyses are also given.) Nitrites none.

No. 7C is of Lake Michigan water, near Chicago, 12 miles out. October 23, 1896, on which date the city water contained 0.0091 NaCl. (Op. cit., p. 19, where other analyses are also given.) No nitrites or nitrates.

No. 35A is of water from Boardman River, which empties into Grand Traverse Bay at Traverse City. April 19, 1897. Analyst, R. C. Kedzie. (Op. cit., table No. 2.)

No. 35B is a boiler-water analysis of Boardman River water. March, 1896. Analyst, the Dearborn Drug and Chemical Works, of Chicago. (Op. cit., p. 29.)

No. 35C is of water from a brook on the insane asylum grounds, Traverse City. November, 1881. Analyst, R. C. Kedzie. (Op. cit., p. 48.)

No. 35D is of water from a large spring on the land of Hannah, Lay & Co., to the south of the asylum at Traverse City. Analyst, R. C. Kedzie. (Op. cit., p. 49; also report of commissioners appointed to select a location and site for the Northern Michigan Asylum for the Insane, September 30, 1882.) In analyses Nos. 35C and 35D some misprints have been corrected. Both samples were free from odor, faintly alkaline, and contained a small amount of suspended sand and humus.

No. 36A is of water from a brook near the Agricultural College; average of the results of ten students.

Nos. 43A, 43B, 43C, and 43D are all analyses, made by Messrs. H. and W. Heim for S. G. Higgins, of Saginaw River water. Sample No. 43A was taken opposite the mouth of the Tittabawassee; No. 43B, in front of the East Side waterworks, i. e., about a quarter of a mile downstream; No. 43C, at the Mackinaw street bridge, about a mile and a half farther north and a little below the West Side waterworks; No. 43D, at the Genesee avenue bridge, about 2 miles farther northwest. The organic residue was determined as the difference between the total and the inorganic residues. Neither was determined by summation of constituents.

No. 58A is of the water of the Pagoda Springs, Mount Clemens. Analyst, C. Gilbert Wheeler. Temperature, 52° F.

No. 172A. September 30, 1897. From Lansing waterworks pumping station. Light straw color. No sulphates. Can not produce disease. Chemically somewhat better than 172B. Analyst, Prof. V. C. Vaughan.

No. 172B. September 30, 1897. From the Lansing waterworks, remote from pumping station (No. 216 West Main street). Opalescent. Microscope magnifying 100 and 500 diameters shows a small amount of organic matter; bacteria developed are nontoxicogenic. Analyst, Prof. V. C. Vaughan.

These two analyses were made on account of a typhoid-fever scare, but it was discovered that although city water had been introduced into the house where the disease existed, it had been cut off and well water had been used.

Constituent.	2A. Grand Traverse Bay.	2B. Grand Traverse Bay.	2C. Grand, Traverse Bay.	2D. Lake Michigan, Chicago.
Al_2O_3				Tr.
$CaCO_3$	0.0930	CaO. 0.0392	CaO. 0.0393	0.0601
$CaSO_4$		0.		.0273
Fe_2O_3		Tr.	Tr.	Tr.
$FeCO_3$	.003			
$MgCO_3$	.0086	MgO. .0146	MgO. .0145	.0200
SiO_2	.007			.006
NaCl		.0064	.0071	(NaK).0177
Na_2CO_3				(NaK).0027
Organic	.0170	Loss. .0600	.0470	
Total residue	.1286	.1500	.1100	Mineral, .1338
Total hardness		8.°	8.°	
Permanent hardness		5.°	5.°	
Free ammonia		.00001	.00002	1.00002
Albuminoid ammonia		.00001	.00002	1.00008
Oxygen from permanganate		.0005	.0005	1.00167

	5A. Detroit.	6A. Detroit.	7A. Detroit.	7B. Lake Michigan, Milwaukee.	7C. Lake Michigan, Chicago.
Number of bacteria per cu. cm	140	9 95 15 110 18 80	80 to 800	....	520.
Loss on ignition, organic matter	0.0420	0.0412	0.0320	0.080	.0024
Nitrates	....	....	.00013	0.	....
Albuminoid ammonia	.00008	.00007	.00008	.0000005	.00008
Free ammonia	.00007	.00006	.00006	.0000075	1.00000
NaCl	.0042	.0043	.0045	.0092	....
Organic suspended matter	.0007	....	....	....	.0180
Inorganic suspended matter	.0137				
Total solids	.1240	.1100	.1144	.2000	.13

Constituent.	35A. Boardman River.	35B. Boardman River.	35C. Asylum brook.	35D. Spring near Asylum.	36A. Brook near Agricultural College.
$CaCO_3$	CaO 0.0588	$CaCO_3$ 0.0744	0.122	0.135	....
$CaSO_4$	0.0	.0455	.007	.003	....
Fe_2O_3	Much.	....	....	....	....
$FeCO_3$	....	.0001	.003	.002	....
$MgCO_3$	MgO .0147	.0400	.015	.060	....
SiO_2	....	.0078	.005	.003	....
NaCl	.0077	.0167	.002	.001	....
Loss on ignition	.060	....	.09	.064	.1083
Total solids at 212° F	.190	.1964	.2440	.268	.2695
Albuminoid ammonia	.00002	....	.0005	.002	....
Free ammonia	.00007	....	.001	.0015	....
Temporary hardness	9.°	....	....	....	2.5°
Permanent hardness	6.°	....	....	....	6.°
O from permanganate by boiling	.02	....	....	....	....

Constituent.	43A. Saginaw River.	43B. Saginaw River.	43C. Saginaw River.	43D. Saginaw River.
CaO	*5.95* .085	*4.83* .069	*6.80* .077	*5.60* .080
$Fe_2O_3 + Al_2O_3$	*3.15* .045	*3.43* .049	*4.72* .067	*4.20* .060
MgO	*.63* .009	*2.02* .029	*.50* .007	*1.50* .021
SiO_2	*.315* .0045	*.35* .005	*1.19* .017	*.35* .005
NaCl	*2.76* .039	*2.76* .039	*4.84* .069	*5.07* .072
SO_3	*2.60* .037	*2.39* .034	*1.04* .015	*2.48* .036
Organic residue	*5.25* .075	*4.20* .060	*7.35* .105	*9.10* .130
Total residue	*22.75* .325	*24.15* .345	*23.80* .340	*28.35* .405

Constituent.	58A. "Pagoda," Mount Clemens.
Al_2O_3	Tr.
$CaCO_3$	*10.273* .1468
$CaSO_4$	*.359* .0051
$FeCO_3$	*.067* .0009
$MgCO_3$	*5.473* .0782
K_2SO_4	*.306* .0044
SiO_2	*.524* .0075

Constituent.	58A. "Pagoda," Mount Clemens.
NaCl	*1.959* .0280
Na_2SO_4	*1.234* .0176
P_2O_5	Sl. tr.
Organic	Sl. tr.
Sum	*20.195* .2885
CO_2	19.2 cu.in.

	172A. Lansing.	172B. Lansing.
Result of inoculation		
Number of bacteria in 72 hours		235
Nitrites	0	0
Nitrates	0	0
Albuminoid ammonia	0.000021	0.000019
Free ammonia	.000013	.000021

	172A. Lansing.	172B. Lansing.
Potassium permanganate reduced	0.002	0.004
Cl as NaCl	.00825	.01485
Organic residue	.017	.100
Inorganic residue	.041	.232
Total residue	.058	.332
Hardness	4.°	4.8°

Constituent.	No. 286A. Ypsilanti.	No. 291A. Bay City.
Al_2O_3	*10.5* .15	.18
$CaCO_3$	*194.71* 2.78	
$CaCl_2$		87.85
$CaSO_4$	*161.84* 2.312	.04
Fe_2O_3	*a 17.50* .25	.31
$MgCl_2$	*255.76* 3.65	10.67
KCl	*42.70* .61	
SiO_2		

Constituent.	No. 286A. Ypsilanti.	No. 291A. Bay City.
NaCl	*9,632.99* 137.61	162.86
NaBr	*12.60* .18	*b* .17
NaI	*5.60* .08	
H_2S	*144.10* 2.06	
P_2O_5	Tr.	
Total solids by evaporation	*10,476.60* 149.67	262.1
Total solids by calculation	*10,478.30* 149.69	262.08

a Carbonate. *b* MgBr.

No. 286A is a recent analysis of water from the Ypsilanti Sanitarium. Analyst, Prof. John E. Clark, of Detroit. Specific gravity, 1.038; reaction slightly alkaline; analysis in grains per imperial gallon. Note that the H_2S appears to be included in the total solids by calculation.

No. 291A is of the brine encountered in the Bay City deep well at 2,200 feet, which rose to the surface, notwithstanding a specific gravity of 1.2223. Analyst, Prof. F. S. Kedzie.

INDEX.

1895.

Sixteenth Annual Report of the United States Geological Survey, 1894-95, Part II, Papers of an economic character, 1895; octavo, 598 pp.

Contains a paper on the public lands and their water supply, by F. H. Newell, illustrated by a large map showing the relative extent and location of the vacant public lands; also a report on the water resources of a portion of the Great Plains, by Robert Hay.

A geological reconnoissance of northwestern Wyoming, by George H. Eldridge, 1894; octavo, 72 pp. Bulletin No. 119 of the United States Geological Survey; price, 10 cents.

Contains a description of the geologic structure of portions of the Big Horn Range and Big Horn Basin, especially with reference to the coal fields, and remarks upon the water supply and agricultural possibilities.

Report of progress of the division of hydrography for the calendar years 1893 and 1894, by F. H. Newell, 1895; octavo, 176 pp. Bulletin No. 131 of the United States Geological Survey; price, 15 cents.

Contains results of stream measurements at various points, mainly within the arid region, and records of wells in a number of counties in western Nebraska, western Kansas, and eastern Colorado.

1896.

Seventeenth Annual Report of the United States Geological Survey, 1895-96, Part II, Economic geology and hydrography, 1896; octavo, 864 pp.

Contains papers on "The underground water of the Arkansas Valley in eastern Colorado," by G. K. Gilbert; "The water resources of Illinois," by Frank Leverett, and "Preliminary report on the artesian waters of a portion of the Dakotas," by N. H. Darton.

Artesian-well prospects in the Atlantic Coastal Plain region, by N. H. Darton, 1896; octavo, 230 pp., 19 plates. Bulletin No. 138 of the United States Geological Survey; price, 20 cents.

Gives a description of the geologic conditions of the coastal region from Long Island, N. Y., to Georgia, and contains data relating to many of the deep wells.

Report of progress of the division of hydrography for the calendar year 1895, by F. H. Newell, hydrographer in charge, 1896; octavo, 356 pp. Bulletin No. 140 of the United States Geological Survey; price, 25 cents.

Contains a description of the instruments and methods employed in measuring streams and the results of hydrographic investigations in various parts of the United States.

1897.

Eighteenth Annual Report of the United States Geological Survey, 1896-97, Part IV, Hydrography, 1897; octavo, 756 pp.

Contains a "Report of progress of stream measurements for the calendar year 1896," by Arthur P. Davis; "The water resources of Indiana and Ohio," by Frank Leverett; "New developments in well boring and irrigation in South Dakota," by N. H. Darton, and "Reservoirs for irrigation," by J. D. Schuyler.

1898.

Nineteenth Annual Report of the United States Geological Survey, 1897-98, Part IV, Hydrography, 1899; octavo, 814 pp.

Contains a "Report of progress of stream measurements for the calendar year 1898," by F. H. Newell and others; "The rock waters of Ohio," by Edward Orton, and "A preliminary report on the geology and water resources of Nebraska west of the one hundred and third meridian," by N. H. Darton.

WATER-SUPPLY AND IRRIGATION PAPERS, 1896-1899.

This series of papers is designed to present in pamphlet form the results of stream measurements and of special investigations. A list of these, with other information, is given on the outside (or fourth) page of this cover.

Survey bulletins can be obtained only by prepayment of cost, as noted above. Postage stamps, checks, and drafts can not be accepted. Money should be transmitted by postal money order or express order, made payable to the Director of the United States Geological Survey. Correspondence relating to the publications of the Survey should be addressed to **The Director, United States Geological Survey, Washington, D. C.**

WATER-SUPPLY AND IRRIGATION PAPERS.

1. Pumping water for irrigation, by Herbert M. Wilson, 1896.
2. Irrigation near Phœnix, Arizona, by Arthur P. Davis, 1897.
3. Sewage irrigation, by George W. Rafter, 1897.
4. A reconnoissance in southeastern Washington, by Israel C. Russell, 1897.
5. Irrigation practice on the Great Plains, by E. B. Cowgill, 1897.
6. Underground waters of southwestern Kansas, by Erasmus Haworth, 1897.
7. Seepage waters of northern Utah, by Samuel Fortier, 1897.
8. Windmills for irrigation, by E. C. Murphy, 1897.
9. Irrigation near Greeley, Colorado, by David Boyd, 1897.
10. Irrigation in Mesilla Valley, New Mexico, by F. C. Barker, 1898.
11. River heights for 1896, by Arthur P. Davis, 1897.
12. Water resources of southeastern Nebraska, by Nelson Horatio Darton, 1898.
13. Irrigation systems in Texas, by William Ferguson Hutson, 1898.
14. New tests of pumps and water lifts used in irrigation, by O. P. Hood, 1898.
15. Operations at river stations, 1897, Part I, 1898.
16. Operations at river stations, 1897, Part II, 1898.
17. Irrigation near Bakersfield, California, by C. E. Grunsky, 1898.
18. Irrigation near Fresno, California, by C. E. Grunsky, 1898.
19. Irrigation near Merced, California, by C. E. Grunsky, 1899.
20. Experiments with windmills, by Thomas O. Perry, 1899.
21. Wells of northern Indiana, by Frank Leverett, 1899.
22. Sewage irrigation, Part II, by George W. Rafter, 1899.
23. Water-right problems in the Bighorn Mountains, by Elwood Mead, 1899.
24. Water resources of the State of New York, Part I, by George W. Rafter, 1899.
25. Water resources of the State of New York, Part II, by George W. Rafter, 1899.
26. Wells of southern Indiana (continuation of No. 21), by Frank Leverett, 1899.
27. Operations at river stations, 1898, Part I, 1899.
28. Operations at river stations, 1898, Part II, 1899.
29. Wells and windmills in Nebraska, by Erwin Hinckley Barbour, 1899.
30. Water resources of the Lower Peninsula of Michigan, by Alfred C. Lane, 1899.
31. Lower Michigan mineral waters, by Alfred C. Lane, 1899.

In addition to the above, there are in various stages of preparation other papers relating to the measurement of streams, the storage of water, the amount available from underground sources, the efficiency of windmills, the cost of pumping, and other details relating to the methods of utilizing the water resources of the country. Provision has been made for printing these by the following clause in the sundry civil act making appropriations for the year 1896–97:

> *Provided*, That hereafter the reports of the Geological Survey in relation to the gauging of streams and to the methods of utilizing the water resources may be printed in octavo form, not to exceed 100 pages in length and 5,000 copies in number; 1,000 copies of which shall be for the official use of the Geological Survey, 1,500 copies shall be delivered to the Senate, and 2,500 copies shall be delivered to the House of Representatives, for distribution. [Approved, June 11, 1896; Stat. L., vol. 29, p. 453.]

The maximum number of copies available for the use of the Geological Survey is 1,000. This number falls far short of the demand, so that it is impossible to supply all requests. Attempts are made to send these pamphlets to persons who have rendered assistance in their preparation through replies to schedules or who have furnished data. Requests specifying a certain paper and stating a reason for asking for it are granted whenever practicable, but it is impossible to comply with general requests, such as to have all of the series sent indiscriminately.

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