# WATERS OF THE UPPER PENINSULA OF MICHIGAN.

BY A. C. LANE.

As I mentioned in my last annual report, my papers on the water supply being absolutely exhausted, an early duty should be to cover the ground again in a fuller way, either under State or United States auspices, but I have not got around to it. I have, however. prepared a brief abstract of the situation as to water supply in the Upper Peninsula for Mr. Alfred R. Schultz, who is working that region in connection with Wisconsin for the U. S. Geological Survey, and we have also compared notes on the Marinette, Menominee, and similar wells. I have also had some correspondence with S. Weidman of the Wisconsin Geological Survey in the matter, and with W. C. Alden, who is working on the stratigraphy for the U. S. Geological Survey. We have agreed quite fairly well in our correlation of things, and as it means a rather closer correlation of the Michigan and Wisconsin strata it may be well to give the records in connection with the hydrography, as that appears to be their greatest importance, though they also have economic interest in connection with oil, shale and limestone questions.

The Upper Peninsula is well supplied with water. Fig. 5 of Water Supply Paper No. 30 shows that the precipitation is mainly between 30 and 35 inches; a very large proportion is snow (page 49), which is often four or five feet deep on the level, and very markedly affects the mean annual soil and well temperatures.[1] The latter are 43° or over, the former 40°.

The long series of analyses of the Marquette City water supply, by Vaughan,[2] give a good idea of the Lake Superior waters and its variations practically, and should be compared with the analysis of Lake Superior water far from land, given fully in Water Supply Paper No. 31, which is in brief as follows:—

*Lake Superior Water, by W. F. Jackman.*[3]

At 27° C. Sp. Gr. 1.0004.

| | Grams per metric ton. |
|---|---|
| $SiO_2$ | 8.53 |
| Al | .48 |
| Fe | .69 |
| Ca | 12.80 |
| Sr | 1.34 |
| Mg | 2.78 |
| $CO_3$ | 22.23 |
| $SO_4$ | 3.73 |
| $B_2$ | trace |
| Na | 3.18 |
| K | very faint trace |
| Cl | 2.43 |
| $N_2O_6$ | .77 |
| Sum | 58.96 |

[1]Page 246 Annual for 1901.
[2]Numbers 254, 261, 281, 297, 298, 301, 302, 303, 289, 306, 308, 317, 325, 327, 330, 339, 340, 344, 346, 347, 350, 352, 355, 256, 258, 360, 362, 366, 368, 374, 378.
[3]Taken in the summer of 1886, about 50 miles from Keweenaw Point and 50 feet below the surface.

| | |
|---|---|
| Total residue | 69.97 |
| Inorganic residue | 57.61 |
| Loss on ignition | 12.36 |
| Free ammonia | .061 |
| Albumenoid ammonia | .12 |
| Oxygen consumed | 1.77 |
| | |
| Hardness temporary in grams per ton | 48.57 |
| Hardness permanent in grams per ton | 38.28 |

ANALYSES OF MARQUETTE CITY WATER SUPPLY (LAKE SUPERIOR).

BY VICTOR C. VAUGHAN.

| Number. | 254[4] | 261[5] | 281[6] | 297[7] | 298[8] | 301[9] |
|---|---|---|---|---|---|---|
| Date | 3/21/95 | 5/24/95 | 7/27/95 | 12/17/95 | 1/17/96 | 2/17/96 |
| Color[3] | ... | ... | ... | Dirty yellowish | ... | ... |
| Odor[3] | ... | ... | ... | Musty | Slightly musty | ... |
| Reaction | alkaline | alkaline | ... | ... | ... | ... |
| Hardness[1] | 3° | 3.4 | 2° | 3° | 2.9 | 3 |
| Total residue | 68 | 60 | 100 | 190 | 160 | 190 |
| Inorganic residue | 34 | 10 | 90 | 60 | 110 | 60 |
| Organic residue | 34 | 50 | 10 | 130 | 50 | 130 |
| Cl as NaCl | 8.25 | 5.775 | 2 | 4.1 | 4.125 | 4.1 |
| Potassium permanganate reduces | ... | ... | 2 | ... | ... | ... |
| Free ammonia | 0.01 | .0094 | 0.005 | 0.006 | .048 | 0.006 |
| Albumenoid ammonia | 0.076 | .05 | 0.001 | 0.120 | .132 | 0.120 |
| Nitrates | ... | faint tr. | ... | trace | ... | trace |
| Nitrites | ... | ... | ... | ... | ... | ... |
| No. of bacteria in 72 hours[2] | 500 | Liquefaction | 72 | 325 | Liquefaction | 325 |

[1]Degrees of hardness are number of grains of calcium carbonate per U. S. gallon that could produce an equivalent hardness, i. e., each degree of hardness is equivalent to about 17 grams per metric ton of calcium, magnesium and ferrous carbonates.

[2]The result of inoculation was in all cases negative; no pathogenic bacteria were discovered.

[3]Colorless and odorless unless otherwise stated.

[4]Vegetable debris (sawdust, etc.) bacteria, diatoms.

[5]Microscope shows small inorganic deposit. The hardness and amount of Cl show an error in the amount of inorganic residue.

[6]Trace of sulphates, vegetable fibres.

[7]Inorganic matter and vegetable debris.

[8]Microscope shows deposit of inorganic matter.

[9]Microscope shows deposit of inorganic matter and vegetable debris.



ANALYSES OF MARQUETTE CITY WATER SUPPLY.—CONTINUED.

| Number. | 302 | 303 | 289[1] | 306[2] | 308[3] | 317[4] | 325[5] |
|---|---|---|---|---|---|---|---|
| Date | 2/18/96 | 2/18/96 | 10/22/95 | 3/7/96 | 4/21/96 | 5/16/96 | 6/18/96 |
| Color | ... | ... | ... | ... | ... | ... | ... |
| Odor | ... | ... | ... | ... | ... | ... | ... |
| Reaction | ... | ... | alkaline | alkaline | ... | alkaline | alkaline |
| Hardness | ... | ... | 3° | 3°.8 | 4° | 6° | 5 |
| Total residue | ... | ... | 60 | 60 | 184 | 70 | 90 |
| Inorganic residue | ... | ... | 50 | 20 | 69 | 40 | 40 |
| Organic residue | ... | ... | 10 | 40 | 115 | 30 | 50 |
| Cl as NaCl | ... | ... | 3.30 | 8.25 | 6 | 3.30 | 4 |
| Potassium permanganate reduces | ... | ... | ... | ... | ... | ... | ... |
| Free ammonia | ... | ... | 0.02 | .048 | 0.03 | 0.040 | 0.05 |
| Albumenoid ammonia | ... | ... | 0.008 | .14 | 0.1 | 0.03 | 0.02 |
| Nitrates | ... | ... | traces | trace | ... | ... | ... |
| Nitrites | ... | ... | ... | ... | trace | ... | ... |
| No. of bacteria in 72 hours | ... | ... | Liquefaction | 150 | Liquefaction | Liquefaction | 120 |

[1]Trace of sulphates.

[2]Microscope shows little inorganic matter.

[3]Trace of sulphates, U. M. dead insect, vegetable debris, inorganic matter.

[4]Trace of sulphates, very small deposit.

[5]Trace of sulphates, small indeterminate granules.

ANALYSES OF MARQUETTE CITY WATER SUPPLY.—CONTINUED.

| Number. | 327[1] | 330[2] | 339[3] | 340[4] | 44[5] | 346[6] | 347[7] |
|---|---|---|---|---|---|---|---|
| Date | 8 1 96 | 8 22 96 | 9 26 96 | 10 29 96 | 12 3 96 | 12 21 96 | 11 24 96 |
| Color | ...... | ...... | ...... | ...... | ...... | ...... | Milky-Opalescent |
| Odor | ...... | ...... | ...... | ...... | ...... | ...... | Marked |
| Reaction | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| Hardness | 3 | 5 | 3.5 | 3.7 | 3.4 | 3.5 | 4.5 |
| Total residue | 90 | 120 | 100 | 75 | 57 | 66 | 77 |
| Inorganic residue | 81 | 105 | 80 | 46 | 32 | 44 | 18 |
| Organic residue | 9 | 15 | 20 | 29 | 25 | 22 | 59 |
| Cl as NaCl | 1.65 | 8.25 | 6.0 | 13.28 | 6.6 | 6.6 | 8.25 |
| Potassium permangana e reduces | 1 | 2 | 1+ | 2— | 2 | 2— | 4— |
| Free ammonia | 0.006 | 0.008 | 0.0066 | 0.012 | 0.0066+ | 0.0004+ | 0.104 |
| Albumenoid ammonia | 0.04 | 0.0106 | 0.0133 | 0.0266 | 0.0480 | 0.0024 | 0.094 |
| Nitrates | ...... | ...... | ...... | trace | ...... | ...... | ...... |
| Nitrites | ...... | trace | ...... | ...... | ...... | ...... | ...... |
| No. of bacteria in 72 hours | 78 | 310 | 80 | Liquefaction | Liquefied | 17 | Liquefaction |

[1] U. M. small amount of vegetable fibres.
[2] Trace of sulphates; small amount of vegetable debris.
[3] Very small amount of organic debris.
[4] Small amount of vegetable debris.
[5] U. M small deposit, desmids, diatoms and debris.
[6] U. M. very small amount of vegetable matter.
[7] Large amount of deposit; infusoria, Vorticellæ, paramœcium, Uvella glaucoma, diatoms, ova, algæ debris.



ANALYSES OF MARQUETTE CITY WATER SUPPLY.—CONTINUED.

| Number. | 350[1] | 352[1] | 355[1] | 356[1] | 358[2] | 360[1] |
|---|---|---|---|---|---|---|
| Date | 1/26/97 | 2/25/97 | 3/24/97 | 4/22/97 | 5/20/97 | 6/22/97 |
| Color | ...... | ...... | ...... | ...... | ...... | ...... |
| Odor | ...... | ...... | ...... | ...... | ...... | ...... |
| Reaction | ...... | ...... | ...... | ...... | ...... | ...... |
| Hardness | 3.5 | 3° | 4°.5 | 4°.2 | 3°.5 | 3°.5 |
| Total residue | 92 | 73 | 92 | 62 | 75 | 102 |
| Inorganic residue | 52 | 48 | 60 | 47 | 53 | 70 |
| Organic residue | 40 | 25 | 32 | 15 | 22 | 32 |
| Cl as NaCl | 8.25 | 8.25 | 8.25 | 6.6 | 6.6 | 6.6 |
| Potassium permanganate reduces | 2— | 2— | 2— | 2 | 2 | 2+ |
| Free ammonia | 0.0026+ | 0.0023 | 0.0106+ | 0.004 | 0.0053 | 0.003 |
| Albumenoid ammonia | 0.0133 | 0.0154 | 0.0186+ | 0.0213+ | 0.0176 | 0.0084 |
| Nitrates | ...... | ...... | trace | ...... | ...... | ...... |
| Nitrites | ...... | ...... | trace | ...... | ...... | ...... |
| No. of bacteria in 72 hours | Liquefaction | Liquefaction | Liquefaction | Liquefaction | Liquefaction | Liquefaction |

[1] Small amount of vegetable matter.
[2] Very small amount of organic debris.

ANALYSES OF MARQUETTE CITY WATER SUPPLY.—CONCLUDED.

| Number. | 362[1] | 366[1] | 368[1] | 374[2] | 378[3] |
|---|---|---|---|---|---|
| Date | 1/27/97 | 8/25/97 | 9/25/97 | 10/29/97 | 11/22/97 |
| Color | ........... | ........... | ........... | ........... | ........... |
| Odor | ........... | ........... | ........... | ........... | ........... |
| Reaction | ........... | ........... | ........... | ........... | ........... |
| Hardness | 3° | 3°.5 | 3°.7 | 3°.5 | 3°.2 |
| Total residue | 217 | 190 | 188 | 180 | 94 |
| Inorganic residue | 156 | 152 | 148 | 148 | 70 |
| Organic residue | 61 | 38 | 40 | 32 | 24 |
| Cl as NaCl | 3.3 | 6.6 | 6.6 | 5. | 4.95 |
| Potassium permanganate reduces | 2– | 2– | 2– | 1.57 | 2+ |
| Free ammonia | 0.003 | 0.012 | 0.016 | 0.015 | 0.0133 |
| Albumenoid ammonia | 0.015 | 0.06 | 0.072 | 0.056 | 0.0106 |
| Nitrates | trace | ........... | ........... | ........... | ........... |
| Nitrites | trace | ........... | ........... | ........... | ........... |
| No. of bacteria in 72 hours | 170 | 340 | 630 | 5 | 36 |

[1]Small amount of organic debris.
[2]Few vegetable fibres.
[3]Very small amount of organic matter.

We see that it is usually clear and odorless, but occasionally in the winter it becomes turbid and foul (analyses 297, 347), or musty.

The reaction is alkaline quite frequently.

The hardness of 3°, rarely over 4°, shows how soft Lake Superior water is relative to that of Lake Michigan.[1]

The total amount of solid residue *may* run up to 200 grams a metric ton in winter, when the organic matter accumulates under the ice, but usually is nearer 60 to 80, as in Jackman's analysis. The inorganic part of this is ordinarily 40 to 60 grams per metric ton, a minute quantity, which the hardness shows must be mainly calcium magnesium carbonates.

The chlorine estimated as sodium chloride varies from 3 to 6 grams per ton. These figures agree with that of the pure Lake Superior water, and show that on the whole the only difference is a varying amount of harmless organic matter, possibly due to sawdust.

To compare with the analyses of Lake Superior water in mid lake and at Marquette, we have the following of Lake Superior from the Calumet supply, Calumet and Hecla pumping plant, G. L. Heath analyst.

It agrees very fairly considering the minute quantities in most constituents, though as the quantities are so minute, relatively large errors may be due to impurity of chemical. The variation in the amount of strontium and potassium may be due to inadequacy of analytical methods. The total amount of "incrusting solids," that is the sulphates and carbonates of the earths is in Heath's and Jackman's analysis about the same—42.06 respectively 46.88 part per million.

[1]See analyses of Menominee Supply Nos. 250, 251, 309, 315, and those given in Water Supply paper No. 30, etc.



| | Lake Superior, Jan. 6, 1903. Per million. |
|---|---|
| Suspended sediment | 9.8 |
| Iron and aluminum oxide | 1.1 |
| Calcium sulphate | 2.0 |
| Calcium carbonate | 29.3 |
| Magnesium carbonate | 11.3 |
| Sodium chloride | 2.7 |
| Potassium chloride | 1.6 |
| Difference organic, etc. | 1.8 |
| | 63.9 |

The other Great Lake, the Green Bay Arm of Lake Michigan, is best illustrated by the Menominee Water Works analyses in the table below:—

GREEN BAY, LAKE MICHIGAN, MENOMINEE WATER WORKS,

ANALYZED BY V. C. VAUGHAN.

Color, odor, nitrites and reaction from inoculation none, unless so stated.

| Number. | 250[1] | 251[1] | 309 | 310[3] | 311[4] |
|---|---|---|---|---|---|
| Date | 2/2/95 | 2/2/95 | 4/27/96[2] | 4/27/96 | 4/27/96 |
| Reaction | alkaline | alkaline | alkaline | alkaline | alkaline |
| Hardness | 8° | 8° | 9°.6 | 9°.5 | 9°.6 |
| Total residue | 260 | 250 | 147 | 150 | 147 |
| Inorganic residue | 190 | 200 | 100 | 100 | 100 |
| Organic residue | 70 | 50 | 47 | 5 | 47 |
| Cl as NaCl | 1.65 | 1.65 | 6 | 6 | 6 |
| Free ammonia | .002 | .004 | 0.01 | 0.01 | 0.013 |
| Albumenoid ammonia | .06 | .059 | 0.052 | 0.052 | 0.060 |
| Nitrates | Faint trace | Faint trace | ........... | ........... | ........... |
| No. of bacteria in 72 hours | Liquefaction | Liquefaction | 90 | 750 | 100 |

[1]Trace of sulphates.
[2]U. M. shows some inorganic matter and vegetable debris.
[3]Large deposit of inorganic matter, unicellular animals and plants and vegetable debris.
[4]Small deposit.

GREEN BAY, LAKE MICHIGAN, MENOMINEE WATER WORKS.—CONTINUED.

| Number. | 312[1] | 313[2], 314[2], 315[2]. |
|---|---|---|
| Date | 5 2 96 | 5 2 96 |
| Color | Brownish and cloudy | Slightly brown cloudy |
| Reaction | alkaline | alkaline |
| Hardness | 7 | 9+ |
| Total residue | 170 | 150 |
| Inorganic residue | 90 | 100 |
| Organic residue | 80 | 50 |
| Cl as NaCl | 6+ | 6 |
| Free ammonia | 0.03 | 0.009 |
| Albumenoid ammonia | 0.10 | 0.095 |
| Nitrates | ........... | ........... |
| No. of bacteria in 72 hours | Liquefied | Liquefied[3] |

[1]Considerable deposit of inorganic matter, vegetable debris, infusoria.
[2]Considerable deposit of inorganic matter and vegetable debris.
[3]Result of inoculation in 314 +, in 313 and 315 negative.

The hardness, it will be noticed, is twice that of Lake Superior, and not unlike the analyses of Lake Michigan, given in Water Supply Paper No. 31. It may be taken, then, as very nearly that of Lake Michigan.

It is interesting and important to notice that it is *not* as soft as many of the artesian wells of the same region, so that the frequent objection to artesian waters, that they are extra hard, does not apply here. The extra hardness of the Lake Michigan water shows even in the ice, the following two analyses being made from examples of ice sent from Ishpeming, one from Teal Lake, near by, and one from Lake Michigan. It is obvious that much of the hardness has been frozen out, but not all.



ICE ANALYSES.

BY V. C. VAUGHAN.

Samples from Ishpeming, No. 171, from Teal Lake, No. 172 from Lake Michigan.

| Number. | 171[1] | 172[2] |
|---|---|---|
| Date | 4 18 93 | 4 - 93 |
| Reaction | Slightly acid | Slightly acid |
| Hardness | 1.0 | 2.0 |
| Total residue | 10.0 | 29.0 |
| Inorganic residue | 6.0 | 0.00 |
| Organic residue | 4.0 | 29.0 |
| Cl as NaCl | 0.2 | 0.8 |
| Free ammonia | 0.10 | 0.10 |
| Albumenoid ammonia | 0 06 | 0.06 |
| Nitrates | .05 | 0.2 |
| Nitrites | trace | ........... |
| No of bacteria in 72 hours | 19,400 | 3888 |

U. M monads and bacteria. See p. 148.
[2]U. M. shows bacteria.

The conditions are favorable for artesian wells throughout nearly all the area of the Paleozoic rocks in the eastern half. The dips are southerly and the divide is generally close to Lake Superior, so that flowing wells from bed rock may be expected along the Lake Michigan shore and up all the river valleys for a width varying according to the surface and rock topography. Artesian wells of this sort occur at Menominee, Escanaba, Gladstone, Rapid River, Manistique, St. Ignace, Newberry, and numerous other points. Notes concerning some of these are as follows:

At Menominee, Hon. S. M. Stephenson has put down at least two deep wells. The character of the water is probably shown by Vaughan's analyses Nos. 328 and 331. Back of the S. M. Stephenson house there was one put down in 1895-6, from 500 to 1,000 feet deep. The well started in the Trenton limestone and is said to obtain its water from a sandstone, probably mainly Potsdam. Though the analyses could not be found for me at Menominee, and it is said to contain much magnesia, I suspect that analysis No. 328 may be of it. I also think it possible that in dealing with unusually large quantities of salt for potable waters, the decimal point has been misplaced, for the total solids are disproportionately large. The head is 15 feet and the temperature 55½° F., by Ther. No. 7536. Another well three miles west from No. 1, upon his farm, is 720 feet deep and 30 feet above the lake. The head is only one foot above the surface and the water is too hard for boilers. It starts in the Trenton, passes through some "slate and also white stuff and black slate." There was 60 feet of pipe, which may be to bed rock. Water was encountered at various levels, but a distinctly larger quantity at 620 feet. This may of

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course be a fissure in the Lower Magnesian or Calciferous, but is I think not far from the top of the Potsdam, and the base of the well may have reached the Archean. This may be represented by analysis 331.

MENOMINEE ARTESIAN WELL.

| Number. | 328[1] | 331[2] |
|---|---|---|
| Date | 8/1/96 | 8/24/96 |
| Reaction | Slightly acid | ........... |
| Hardness | 4° | 8° |
| Total residue | 2050 | 2054 |
| Inorganic residue | 1798 | 1783 |
| Organic residue | 352 | 271 |
| Cl as NaCl | 18.15 | 18.15 |
| Sulphates | 87 2 | 83.42 |
| Potassium permanganate reduced | 1 | 1 |
| Free ammonia | 0.0746 | 0.012 |
| Albumenoid ammonia | 0.0906 | 0.008 |
| Nitrates | Trace | ........... |
| Nitrites | Trace | ........... |
| No. of bacteria in 72 hours | 1260 | 8 |

[1]Result of inoculation positive, but it can hardly be due to bacterial contamination. It merely shows that this particular mineral water was not good medicine for the rabbit. The date renders it pretty certain that it is one of Mr. S. M. Stephenson's wells. L.
[2]Result of inoculation negative.

These analyses should be compared with that of the well of Hon. Isaac Stephenson, close by just over the Wisconsin line, which has, however, a much lower temperature, and hence probably a shallower source, though the surface piping may be in part responsible.

"Following the usual method of expressing the results of water analysis, the constituents have been grouped as follows":—[1]

| | Grams per metric ton. | Grains per gallon. |
|---|---|---|
| Sodium chloride | 119.50 | 7.649 |
| Potassium sulphate | 20.46 | 1.193 |
| Calcium sulphate | 727.60 | 42.432 |
| Magnesium sulphate | 182.34 | 10.634 |
| Aluminum sulphate | 47.27 | 2.757 |
| Magnesium chloride | 69.51 | 4.054 |
| Magnesium bicarbonate | 52.75 | 3.076 |
| Ferrous bicarbonate | 9.48 | 0.553 |
| Silica | 5.20 | 0.303 |
| Sulphuretted hydrogen, not determined. | | |
| | 1,184.11 | |

[1]University of Wisconsin Chemical Laboratory. Compare Geol. of Wis. II, p. 153.



There is one thing common to the Menominee and Marinette artesian well analyses. In both the sulphates seem to predominate over the chlorides. Yet they probably do not represent water from exactly the same horizon. The Marinette Stephenson well, drilled in August, 1895, at the house of Hon. Isaac Stephenson, passed through lime rock and dolomite, and a little light and reddish sandstone (St. Peters? not much) and narrow strata of slate for the first 200 feet. Water was first struck in a crevice in the Lower Magnesian at 405 feet, with quite a flow. Then, at 410 feet, there was a big crevice, with a drop of four feet, which broke the cable, and the water has a greater flow, and 21 feet head. Below this[1] there was no increase in water, though they went down to "granite" at 716 feet, passing largely through "limerock" (dolomite). No water, that is no additional water pressure, was encountered below 415 feet and a rubber plug was put in at 457 feet, and the pipes go down to 415 feet, so that in the I. Stephenson well we have a water purely from that level, the Lower Magnesian, or Calciferous dolomite. This is more than we can be sure of in other cases. Mr. Stephenson reported the temperature at 49°, I made it 50.°5. There are a number of other wells which flow or have flowed in Marinette.

A well at Oakwood, three and a half miles south of the town, is said to be 999[2] feet deep. A sample at 860 feet is a white sand, while one at 920 feet contains much feldspar, broken quartz fragments, etc., and is of a reddish color. Let run a few moments the temperature is 53°.

A well for oil and gas, two miles south of Stephenson's, put down in 1902-3, by a company of which Mr. H. B. Simcox was manager, may have reached the Precambrian at 850, where there was a change from white sand to red, the record being:—

| | | |
|---|---|---|
| Drift to bed rock | 70 | 70 |
| 70 ft. 10-inch casing. | | |
| (Trenton?). Very hard rock | 300 | 370 |

150 ft. 8-inch casing, 450 ft. 6-inch casing; water at about 400, 500 and 600 feet.

(Calciferous?). Various layers, including "hurry up sands," which occur in beds a few feet thick, soft, but cutting the drill and themselves light, mixed with hard layers.

(Potsdam?). At end, white sandstone; bottom, red sand (granite?).

The temperature of a mixture of all the flows was 51.°8. Probably the plug in the Stephenson well cuts off a little warmer water from below.

Mr. A. C. Merriman also has two or three wells, the one at his house being 719 feet deep.

From a well at the water works, samples have been preserved, and the following are my notes of inspection, with the interpretation put on them, after consultation with S. Weidman, Alfred R. Schultz and Wm. C. Alden. Mr. Schultz writes that the records obtained at Marinette this summer all indicated that the St. Peters is not represented, although no first-class record and samples were available. Mr. Alden wrote to Dr. Weidman a letter given below, and various letters to me afterwards, the substance of which is that in a number of wells like the above the

[1]A still more recent record with samples kept by the kindness of Mr. H. B. Simcox, shows the St. Peters sandstone well marked from 325 to 400 feet, so that the I. Stephenson well probably draws from that horizon.
[2]An error of an even hundred feet the depth of the well and the sample is to be suspected.

question is whether the St. Peters is absent and the limestone dolomite series to be divided between the Trenton and Lower Magnesian, or whether the erosion which he supposes to have taken place at the end of the deposition of the Lower Magnesian may not have cut it away entirely, so that the whole limestone series should be referred to the Galena-Trenton. In order to understand the question, the following abstract of the different strata of Eastern Wisconsin, compiled from Volume II of the Wisconsin reports, is given.

EASTERN WISCONSIN SECTION.[1]

HAMILTON, argillaceous limestone, page 395. Cement rock, fossiliferous.

Unconformity.

LOWER HELDERBERG (Monroe), p. 390, hard, brittle, angular, acicular or dark dolomite, laminated with alternating light and dark bands.

Unconformity.

| | Feet. |
|---|---|
| NIAGARA, p. 335 .................................... | 719-450 |
| White dolomites, generally very little impurity, divided into: | |
| 1. Guelph, like Racine but different in fossils. | |
| 2. Racine, buff, gray or blue granular, fossiliferous—9 ft. thick below, rough. | |
| 3. Upper Coral; thin bedded buff or bluish, fine, with chert and druses, splitting, very fossiliferous .................... | 45-70 |
| 4. Lower Coral beds (p. 348). | |
| Massive, rough, with layers cherty or argillaceous or like the Byron, full of *Favosites* and brachiopods. | |
| 5. Byron, white, smooth, fine, pure, mudcracks and ripple marks, tinged with gray or pink, conchoidal fracture ........... | 110 |
| 6. Mayville, rough, coarse grained, fossils ill preserved. | |
| 1. Brecciated, vertical fissured ......................... | 60-100 |
| 2. Even bedded white, pure, often porous, granular. | |
| 3. Brecciated, cherty, gray ........................... | 5-35 |
| 4. Hard heavy bedded, vertical fissures .................. | 6-12 |
| 5. Shaly impure, yellow to greenish ..................... | 4-10 |
| CLINTON. Irregular lens like masses of iron ore............... | 0- |
| Unconformity beneath. Lorraine and Utica often in contact. | |
| CINCINNATI (Lorraine & Utica), clayey shales and limestones, p. 315 ............................................ | 240 |
| Blue green, fine or impure, with fossiliferous grits, grading to limestone, sometimes sandy. | |
| GALENA, lime and dolomite, impure, crystalline granular dolomite; greenish blue and often non-fossiliferous, impure earthy —*Murchisonia major*, more shaly to the N. | 160 |
| TRENTON subdivided into ................................. | 53 |
| 1. Upper blue 1. Upper blue bed; *Lept. sericea*, Brachiopods *Bryozoa*, & *Chætetes* ............................ | 15 |
| 2. Upper buff bed (p. 296); *Cyathophyllum*, lamellibranchs ................................ | 55 |

[1] Chamberlin Geol. Wis. II. Van Hise, Ore Deposits, p. 397.



| | Feet. |
|---|---|
| 2. Lower buff dolomite. 3. Low blue beds dolomite, cherty, blue green, thin impure, carbon, corals .................... | 25 |
| 4. Low buff beds, earthy yellow crystalline ......... | 25 |
| ST. PETER'S sandstone (p. 286-289) ......................... | 0-212 |
| Well rounded incoherent quartz grains light colored, laminated, cross bedded, iron ore nodules at top. | |
| Probable erosion interval possibly the line between Cambrian and Silurian. | |
| LOWER MAGNESIAN (CALCIFEROUS), p. 268, granular dolomite, with 2-10% disseminated silica, chert nodules, quartz geodes and a little sand, sometimes oolitic, with some sand centers, irregular, at times brecciated. ............................. | 62-141 |
| Top eroded and very uneven, bottom even. Fossils very rare. | |
| POTSDAM (p. 260). | |
| 1. Madison sandstone .................................. | 35 |
| Typically coarse grained, thick bedded, but soft, slightly calcareous, light colored ................................ | 60 |
| 2. Mendota limestone, | |
| Alternating sandy dolomites, sandy calcareous shales, and shaly calcareous sandstones. The dolomites are soft, granular, porous, thin bedded, buff colored with frequent sand seams. The shales are variegated yellow and red and characteristically purple, mottled, soft brittle, readily weathered. The sand stones are either white, buff yellow or orange calcareous, or a glauconitic green sand. Upper and lower limits ill defined. | |
| Dr. Owen's fifth trilobite bed and *Dicellocephalus minnesotensis, D. pepinensis, Lingula aurora, L. mosia, Lingulepis pinniformis, Illænus quadratus.* | |
| 3. Light colored sand stone, mainly quartz, slightly calcareous, a little chert, limestone and granite. | |
| 4. Blue green shale, micaceous, calcareous. | |
| 5. Light colored quartz and sandstone. | |
| 6. Coarse non-calcareous sandstone with large grains of transparent light colored quartz. | |

Mr. Alden is inclined to accept the possibility of a suggestion which had independently occurred to me that the base of the deep Sheboygan well might be in the Potsdam, in which case the same may be true at Oshkosh and Marinette, and the Lower Magnesian also absent. On the whole, however, I am inclined to accept the older interpretation of Chamberlin as more likely to be right, as I think that the Potsdam water is not so hard and is not so much sulphated as the waters above.

MARINETTE WATER WORKS WELL.

The record of the manager, W. S. Kulm, through Mr. Schultz, is:—

| Drift. | Thickness. | Total. | Comparison. |
|---|---|---|---|
| Surface sand gravel | 70 | 70 | S. 70 |
| *Galena and Trenton—* | | | |
| Gray limestone | 10 | 80 | S. 80, S. 85. |
| Soapstone and limestone | 64 | 144 | |
| Soapstone | 52 | 196 | S. 144 |
| Soft limestone | 44 | 240 | S. 196 |
| Hard gray limestone | 10 | 250 | S. 240 |
| Slate and limestone | 70 | 320 | S. 250 ("slate". Gladstone 327 to 404 |
| Soft flaky limestone | 134 | 450 | S. 320 |
| Very hard limestone | 100 | 550 | S. 450 |
| *Potsdam—* | | | |
| Hard yellow sandstone | 10 | 560 | Gladstone 642 |
| Gray limestone | 20 | 580 | |
| *S. 550, 560 and 580 possibly mixed—* Gray sandstone (small flow) | 90 | 670 | |
| White sandstone | 46 | 716 | S. 670 Gladstone 743 |
| Reddish granite | ........ | ........ | S. 712, S. 716 |

S. Stand for sample.

My notes on the samples are:—

*Pleistocene—*

70—red sand and gravel.

*Galena?*

80, 85—chipping limestone.

*Trenton?*

144—blue shales (compare 481 at Wagner's well).
196—coarse chipping limestone.
240—chipping limestone.
250—"slate" light blue and white.

*St. Peter's sandstone absent or ignored, according to Alden.*

*Lower Magnesian=Calciferous.*

320—chipping limestone, coarse.
450—coarse chipping, light colored limestone and dolomite.

*Potsdam?*

550—very white looking marly calciferous sandstone.
560—unwashed white calciferous sandstone.
560—white and greenish calcareous sandstone.
670—white sand.
685, 700—rounded white sand.

*Archean.*

712—"granite" broken and loose.
716—dark red quartzite (also quartz).



Mt. Vernon, Ia., Nov. 5, 1903.

Dr. Samuel Weidman,
Wisconsin Geological Survey, Madison, Wis.:

My Dear Dr. Weidman—Your favor of the 3d inst. enclosing letters and well records from Mr. Alfred C. Lane is received.

In regard to the treatment of the Calciferous formation in Wisconsin, my observations in the southeastern part of the state have been entirely confirmatory of those of Dr. Chamberlin and his associates as presented in Volumes I and II of the Geology of Wisconsin, where the subject is fully discussed. As you know, the Lower Magnesian limestone, which has been regarded as the equivalent of the Calciferous of the east, is not a sandstone at all here, but a hard, gray, rough-textured dolomite carrying much chert and crystallized quartz. On the other hand, the St. Peter sandstone, which has been regarded by some as the equivalent of the Chazy limestone of the east, is here a loosely coherent, quartz sandstone, with rarely more than a slight calcareous cement, and that not always present. The lower part of this formation in many places is reddish and not infrequently is somewhat shaly. This has been noted at several places to the south and east of Madison. In the shaft of the Waterloo "iron mine," east of Madison, I found this summer above the typical Lower Magnesian limestone, the following beds, which I am inclined to regard as belonging to the lower part of the St. Peter group, though it is possible that they really belong with the underlying Lower Magnesian limestone:—

| | | |
|---|---|---|
| Interstratified buff and purplish rock, varying from a calcareous sandstone to a sandy limestone | 3 | feet |
| Fine grained, buff, arenaceous limestone | 2 | " |
| Similar bluish, fine grained rock, with fine grains of green color (green sand?) disseminated throughout, said to be shaly | 4 | " |
| Fine grained buff dolomite and shale, somewhat variable in character | 18 | " |
| Red and purplish arenaceous shale | 6 | " |
| Interbedded, thin layers of buff limestone and purplish limestone, shaly in part | 4 | " |
| | — | " |
| These thicknesses are only approximte, the total being | 33 | " |

| | | |
|---|---|---|
| Below this is the typical, rough textured, cherty, brownish-gray Lower Magnesian limestone, decidedly different in character from the above | 28½ | feet |

I have not found any limestone layers in the lower part of the St. Peter group except in this locality. It may be that these correspond to the "Lime and sandstone in mixed layers," which Mr. Lane reports between the depths of 325 and 404 feet in the St. P. & Ste. Marie R'y [Gladstone] well record which you sent.

I think it not strange that we should find in Michigan that the St. Peter sandstone is not developed so well as in Wisconsin. We would expect to find a gradual change in both this and the Lower Magnesian to the types developed farther east. Some such change occurs in the later formation on going southwestward into northeastern Iowa, though the St.

Peter sandstone continues above it. In the Geology of Allamakee county (Iowa Geological Survey, Vol. IV., pp. 61-71), Prof. Calvin discusses these formations under the name of Oneota limestone and St. Peter sandstone. He says (p. 63-64):—

"The last fifty or sixty feet in ascending towards the St. Peter sandstone are characterized by the presence of beds of sand and shale interstratified with the Magnesian limestone. The sandstone layers, as already noted, differ as to number and position in different localities, and it is not possible to recognize any one as sufficiently constant to mark a definite horizon. It is in the last 50 or 60 feet that the Iowa equivalents of the New Richmond sandstone and the Willow River limestone of Wisconsin, or the New Richmond sandstone and the Shakopee limestone of Minnesota, are found."

On page 68, Prof. Calvin states that there can be little doubt as to the essential equivalence of the Lower Magnesian (Oneota) limestone and the Calciferous sandrock of New York and Vermont, both on stratigraphical and paleontological grounds. He says:—

"The relations of the Calciferous sandrock of the Champlain valley are paleontologically more intimate with the overlying Trenton than with the underlying Potsdam. The formation belongs to the Ordovician or Lower Silurian, and not to the Cambrian, and the same statement may be made with respect to its equivalent, the Oneota limestone in northeastern Iowa."

Concerning the taxonomic relations of the St. Peter sandstone, he states that Sardeson gives a list of fossils from the St. Peter sandstone near Minneapolis, in the Bull. of Minn. Sci., Vol. III, No. 3, p. 318. He says:—

"The collection embraces casts of Gasteropods and Lamellibranchs belonging to the genera Maclurea, Murchisonia, Cypricardites and Modiolopsis. The fauna of the St. Peter, as indicated by Sardeson's collection, is closely related to the Trenton, if not identical with it, and lends support of the views of those geologists who would correlate the St. Peter of the Upper Mississippi with the Chazy of New York."

In Wisconsin but few fossils have been found in either formation. I have never seen any except a fragment or so in the Lower Magnesian limestone.

From the stratigraphic relations, it has seemed to me that the Lower Magnesian limestone was more closely connected with the Potsdam than with the overlying formations. There is no real break between the formations, the Potsdam sandstone grading into the bottom of the limestone above. Between the limestone and the St. Peters there is, however, evidence of an erosion interval in the well marked unconformity in the region where I have worked in the S. E. Dr. Chamberlain and his associates of the earlier survey noted the unevenness of the Lower Magnesian surface, but, in part, at least, this unevenness was referred to an intraformational break, i. e., they supposed that condition occurred by which the newly deposited beds of limestone were somewhat broken up and heaped up into mounds by the waves, and over these more continuous beds were deposited, covering the ridges and hollows. On the uneven surface thus produced, the St. Peter sandstone was deposited with consequent varying thickness.

It appears to me, however, that this unevenness of the surface of the Lower Magnesian limestone is, in large part, at least in the area where I have been working, due to the erosion of the rock beds during an interval



of emergence as land. At Albany, southwest of Madison, a street cut shows eight feet or more of loose fragmental chert overlying a weathered surface of the Lower Magnesian limestone, and upon this loose material are the basal beds of the St. Peter sandstone. There is a little conglomerate here composed of sandstone enclosing somewhat worn fragments of the chert. I have found this bed of chert developed at intervals over quite a widespread area, as shown by exposures and well records. This seems to me clearly to indicate an erosion interval. The emergence of the Wisconsin land at this time does not, however, seem to have extended so far as northeastern Iowa, for there deposition seems to have been continuous. It is noted, however, as indicated above, that in northeastern Iowa there was sufficient shallowing of the water to cause the deposition of considerable sand in the upper part of the Oneota (Lower Magnesian group), such as would be expected if the land in Wisconsin emerged.

At the top of the St. Peter sandstone, again there are transition beds indicating a gradual change to the limestone-depositing conditions of the Trenton. This gradation usually takes place within a thickness of 10 feet or less.

There is no indication of a later interval of erosion during which the St. Peter sandstone could have been eroded so that we must conclude that its absence at certain places, as shown by exposures and well records, is due to the fact that its deposition did not overtop all the Lower Magnesian hills. The drill may thus pass from the Trenton right down into the Lower Magnesian limestone with no intervening sandstone, as Dr. Chamberlin explained for the well at Oshkosh.

On the other hand, there are places where the pre-St. Peters erosion entirely cut away the Lower Magnesian limestone and the St. Peter sandstone was there laid down upon the Potsdam sandstone with no intervening limestone. Mr. F. M. Gray, a driller of Milwaukee of wide experience, informs me that this was the case in many of the wells at that place, and at Wauwatosa. The log of the well at Lake Park, Milwaukee, as I interpret the data furnished by Mr. Gray, is as follows:

*Lake Park Well, Milwaukee.*

| | |
|---|---|
| Hamilton group— | |
| Soapstone | 80 feet |
| Cement rock | 12 " |
| Soapstone | 30 " |
| Waterlime? Brown limestone | 30 " |
| Niagara limestone | 320 " |
| Cincinnati shale | 180 " |
| Galena and Trenton limestone | 330 " |
| St. Peters sandstone | 958 " |
| Potsdam sandstone | |

The well at the E. P. Allis works in Milwaukee showed a like condition as far as the absence of the Lower Magnesian is concerned, but a bed of "red marl" occurs lower down, probably at the Mendota horizon. This latter condition occurs in other wells in the city. The Lower Magnesian is also absent at Wauwatosa.

The Lower Magnesian limestone is absent here and not included in the

17

330 feet referred to the Galena and Trenton, with the St. Peter absent, is shown by the fact that on going still farther west to Elm Grove and Waukesha, the Trenton (including the Galena) shows thickness of 320 and 300 at the two places, with both the St. Peter and Lower Magnesian present below.

This will explain things at the Sheboygan well referred to by Mr. Lane. (See Plate XIII, Vol. II, Geol. Wis., p. 335.) The thickness of limestone referred to the Trenton and Galena is less at Sheboygan than at the old city well at Milwaukee, and this latter thickness is less than that shown by the Lake Park well just referred to. In neither this old Milwaukee well or the Sheboygan well is the thickness of the sandstone penetrated below great enough to indicate surely that the Lower Magnesian limestone may not be present below, though it may be absent. Where the Lower Magnesian is absent, there is no means of drawing a line in the log of a well between the base of the St. Peter and the top of the Potsdam. It is reported to me that the well at Union Grove in Racine county penetrated more than 1,400 feet of sandstone below the base of the Trenton with no limestone beds at all. I do not know whether later and deeper wells at Sheboygan found any Lower Magnesian present at a greater depth than in this old well cited by Chamberlin or not.

It may really be, in the Oshkosh well, that it is the Lower Magnesian that is absent, with nothing to cut off the St. Peters sandstone from the Potsdam below, instead of the sandstone being absent and the Lower Magnesian and Trenton both being included in the 208 and 240 feet of limestone, as interpreted by Dr. Chamberlin. The local conditions, however, may warrant his interpretation.

As a general thing, however, in southeastern Wisconsin, the St. Peter sandstone is present, though varying greatly in thickness, so that the Trenton and Lower Magnesian is usually distinguishable.

The following is my interpretation of the well records sent by Mr. Lane, on the basis of the formations in eastern Wisconsin. There may, of course, be local conditions which, if known, might change this somewhat.

### LOG OF WATER WORKS WELL AT MARINETTE.

Interpretation of Wm. C. Alden, Asst. Geol. U. S. G. S.

*Pleistocene.*

| | | Thickness. |
|---|---|---|
| 1-70 feet. | Red sand and gravel | |
| 70-85 | ? ? | 85 feet |

*Galena limestone.*

| | | |
|---|---|---|
| 85-144 feet. | Round chipped limestone | 59 feet |

*Trenton limestone.*

| | | |
|---|---|---|
| 144-196 feet. | Blue shales. | |
| 196-240 | Chipping limestone coarse. | |
| 240-250 | Chipping limestone. | |
| 250-320 | "Slate" light blue and white | 176 feet |

(Base of Trenton uncertain.) (St. Peter sandstone absent.)



*Lower Magnesian limestone.*

| | | |
|---|---|---|
| 320-450 feet. | Chipping limestone coarse. | |
| 450-550 | Coarse chipping limestone light colored, and dolomite. | 230 feet |

*Potsdam group.*

| | |
|---|---|
| 550-560 feet. | White sandstone, very white, mealy-looking. |
| 560-560 | ?White sandstone. |
| 560-670 | White and greenish, calcareous sandstone. |
| 670-685 | White sand. |
| 685-712 | Rounded white sand. |

*Huronian or Archean.*

| | |
|---|---|
| 712-716 feet. | "Granite" (broken and lost). |
| 716 | Dark red quartzite. |

### LOG OF ST. P. & STE. MARIE WELL, GLADSTONE.

Location ?
Interpreted by Wm. C. Alden, Asst. Geol. U. S. G. S.

| | | |
|---|---|---|
| 0- 87 feet. | Pleistocene | 87 feet |
| 87-326 | Galena and Trenton limestone | 234 |
| 325-404 | St. Peters (probably), lime and sandstone in mixed layers | 89 |
| 404-642 | Lower Magnesian limestone | 228 |
| 642-743 | Potsdam, shell sandstone | 101 |
| 743- | Hard rock, possibly Archean | ... |
| | Total depth | 743 feet. |

Altitude about 605 feet.

NOTE.—Comparing this with the log of the well at Marinette, the elevation of whose curb is, I suppose, somewhere about 600 ft., it is seen that the two wells are very much alike except for the St. Peters, which is absent in one and 89 ft. thick in the other. The elevation of the base of the Trenton not far from 280 ft. in each and the thickness of the Lower Magnesian is about the same in each. If these beds are really St. Peters their absence at Marinette may be due to the higher elevation of the Lower Magnesian surface at that place, which the St. Peter deposition did not overtop. It is not possible for me to say, however, that this mixed sandstone and limestone is not a part of the Lower Magnesian group as in northeastern Iowa.

### LOG OF THE WAGNER WELL.

The data below the Utica shale cannot be very satisfactorily correlated with the typical Wisconsin formations because of the discordance in the character of the beds. The following grouping is suggested, but the dividing lines might be moved up or down in each case:

*Pleistocene.*

| | | |
|---|---|---|
| 0- 9 feet. | Gravel and clay | 9 feet |

*Hudson River* (Lorraine).

| | | |
|---|---|---|
| 9- 54 feet. | Blue shale | 45 feet |
| 54- 67 | Fossiliferous shale | 13 |
| 76- 95 | Brown shale | 28 |
| 95-115 | Blue shale | 20 |
| 115-123 | Brown shale | 8 |
| 123-193 | Gray shale | 70 |
| 193-201 | Light gray shale | 8 |
| | Total | 242 feet |
| | Utica shale | 251 feet |
| 201-251 feet. | Bituminous shale | 50 |

*Galena Limestone.*

| | | |
|---|---|---|
| 251-334 feet. | Limestone | 83 feet |
| 334-389 | Fossiliferous limestone | 55 |
| 389-397 | White limestone | 8 |
| 397-406 | Dark limestone | 9 |
| 407-412 | Quartzite (?) | 6 |
| 412-456 | Limestone | 44 |
| 456-457 | Quartz | 1 |
| 457-481 | Limestone | 24 |
| | Total Galena (possibly some Trenton) | 230 feet |

*Trenton shale and limestone.*

| | | |
|---|---|---|
| 481-485 feet. | Blue shale | 4 feet |
| 485-499 | Black limestone | 14 |
| 499-518 | Limestone | 19 |
| 518-522 | Blue shale | 14 |
| | Total | 51 feet |

*St. Peters group, possibly including some of Trenton and Lower Magnesian groups.*

| | | |
|---|---|---|
| 522-560 feet. | Sandstone, soapstone, limestone | 38 feet |
| 560-561 | Red clay shale | 1 |
| 561-562 | Sandy shale | 1 |
| 562-628 | Limestone, soapstone, sandstone | 66 |
| | Total | 106 feet |
| 628-640 feet. | Lower Magnesian, very crystalline limestone | 12 feet |
| | Total depth | 640 |

I have gone into this considerably at length, possibly more so than is necessary. I shall be glad, however, if this is any assistance in understanding the relations of these formations.



You might send this letter to Mr. Lane, with any suggestions you wish to add. I shall be glad to be of any further assistance to him or to hear from him directly. I should like, myself, to have a better understanding of the real relations of these formations.

Respectfully,
(Signed) WM. G. ALDEN,
Asst. Geol. U. S. G. S.

We have at this point introduced a compilation of the Eastern Wisconsin section, from Chamberlin's report in the second volume of the Wisconsin Geological Survey reports. We find, coming up the Lake Michigan shore, a series of wells,—at Kenosha 1805 feet deep, at Racine 1600 feet deep, at Milwaukee 1700 or more, at Sheboygan 1475 feet deep, and at Manitowoc 1263 feet deep, all flowing and all ending in a sandstone of which the question arises whether it is the St. Peters, the Potsdam, or both combined. In this matter the letter of W. C. Alden is of interest, which is given above. But the practically important matter is, without question,—that along the Lake Michigan shore at from 1500-2000 feet plenty of water can be obtained in the sandstone, and that this water is distinctly mineral, but not very hard. Flows are likely to occur up to about 100 feet above the lake.

Back of the other side of the ridge made by the Niagara is another belt of flowing wells illustrated by Oshkosh, where there is standstone from 714 or 680 to 961; Appleton, where wells are 600 to 790 feet deep, and Marinette, where, as we have just seen, the sandstone still comes in at from 600 to 700 feet depth, and the depth of the Archean is still from 700 to 900 feet, which is continued up into Michigan.

Both these belts undoubtedly may be extended into Michigan, though I do not know as yet of any wells on this outer lake shore belt. The Manistique flows are not so deep.

Continuing the Oshkosh-Appleton-Marinette-Menominee line of wells we find others of various depths along the lake shore, as at Ford River, Escanaba, Gladstone, and Rapid River. All these wells start in the Trenton. The only one that begins above it is opposite Escanaba at the place of H. Wagner, of which I insert a record below, which differs somewhat from that given in the 1901 report (p. 228):

H. Wagner, Delta County, S. W. 1/4 of N. W. 1/4 of Sec. 8, T. 39 N., R. 21 W.

*Drift.*

| | | |
|---|---|---|
| Gravel and clay | 9 | |

*Lorraine* (Hudson R.)

| | | |
|---|---|---|
| Blue shale | 45 | 54 |
| Fossiliferous shale | 13 | 67 |
| Brown shale | 28 | 95 |
| Blue shale | 20 | 115 |
| Brown shale | 8 | 123 |
| Gray shale | 70 | 193 |
| Light gray shale | 8 | 201 |

*Utica.*

| | | |
|---|---|---|
| Bituminous | 50 | 251 |

*Trenton.*

| | | |
|---|---|---|
| Galena— | | |
| Limestone | 83 | 334 |
| Fossiliferous limestone | 55 | 389 |
| White limestone | 8 | 397 |
| "Upper blue" of Wisconsin, Trenton? | | |
| Dark limestone | 9 | 406 |
| "Upper buff"? | | |
| Quartzite (? geodes) | 6 | 412 |
| Limestone | 44 | 456 |
| Quartz (? geodes) | 1 | 457 |
| Limestone | 24 | 481 |
| "Lower blue." | | |
| Blue shale | 4 | 485 |
| Black limestone | 14 | 499 |
| Limestone | 19 | 518 |
| Blue shale | 4 | 522 |
| "Lower buff." | | |
| Sandstone, soapstone and limestone (perhaps in part St. Peters) | 38 | 560 |

*St. Peters.*

| | | |
|---|---|---|
| Red clay shale (weathered surface of Lower Magnesian?) | 1 | 561 |
| Sandy shale | 1 | 562 |

*Calciferous.*

| | | |
|---|---|---|
| Limestone, soapstone and sandstone | 66 | 628 |
| Crystalline limestone | 12 | 640 |
| Depth of hole | | 640 |

As complete samples have not been seen it is not certain that the record is correct, but the probabilities are that the lower part of the well extends into the Calciferous or beds below the Trenton. I was, however, informed that upon re-measurement, the well proved not as deep as was supposed. In a recent well near by at 860 to 900 feet a broken formation, either the conglomerate of the Archean quartzite, was apparently struck, with a good body of sandrock above. We can see in the beds from 481 feet to 562 feet down about where the shale comes in, which appears in the records at Menominee and other points. Around Maple Ridge there was a well which went through 30 feet of limestone and then, as reported, 150 feet of soft blue shale, which may correspond to and represent some of the blue beds of the Trenton. At Flat Rock, near Escanaba, a flowing well is said to be 800 to 900 feet deep. But not all flowing wells need to be this deep. At the charcoal furnace north of and near Gladstone, there are a group of flowing wells that belong to the Cleveland Cliffs Co., described below.



At Rapid River, Section 19, T. 41 N., R. 21 W., or nearby, there are eight or nine flowing wells which are supposed to go through 270 feet of the Trenton rock and strike sandstone below. One is 270 feet deep, rises three or four feet above ground and the temperature of the flow is constantly 45.8° F. by measurements July 12, 1902, and Aug. 26, 1903. Another opposite Dillabaugh's is 275 feet deep and has a 10-foot head. Seven miles north and two miles east of Rapid River there was a well put down for oil on Sec. 34, T. 42 N., R. 21 W. A set of samples were to have been kept for me, but were said by Mr. M. D. Kelley to have been stolen from him. As near as I can judge, there was about 300 feet of more or less oily Trenton and below that, down to within 20 or 30 feet of the bottom, was very largely white sandstone. The extreme bottom was apparently decomposed schist of the iron bearing series. At 170 feet or more above was sandstone, some of it a very clear white sand. The flow outside the casing, which is 800 feet deep, was very strong; the temperature being 47.3° F., and the amount over a quart a second. It probably works around the casing from about the same level as the Rapid River wells or somewhat deeper. Assuming, however, that certain samples which I found left in the boxes were arranged inversely from the bottom up each 10 feet, which seemed to be the system they were working on, we have the following record which harmonizes with what might be expected. The papers have recently[1] had many accounts of flows of oil from this well, or one near it, but while there is little doubt but what there is a strong flow and some oil the relative proportions of oil and water are quite possibly reversed.

RAPID RIVER OIL WELL, HYPOTHETICAL RECORD.

200 paces W., 505 S. of N. E. corner Sec. 34, T. 42 N., R. 21 W.

*Surface.*

| | | |
|---|---|---|
| Swamp peat and muck | 3 to 6 | 6 |
| Marl | 10 | 16 |
| 16 feet 10 inches casing. | | |

*Trenton.*

| | | |
|---|---|---|
| Dolomite with geodes lined with fine dog-tooth spar calcite and filled with oil "gum" | 264 | ?280 |

*St. Peters horizon?*

| | | |
|---|---|---|
| Signs of oil. Strong flow of water, over 1 quart a second. Temperature 47°3 F. | | |
| An old well 300 feet west was 202 feet deep | 350 | 630 |

*Calciferous?*

S. at 620 box 380 a dolomite.

[1] Saginaw Evening News, 10/25/1903; Marquette Mining Journal, 12/2/1903; Gladstone Delta, 12/5/1903, and 10/31/1903; Detroit Tribune, 11/13/1903; Iron Mountain Press, 11/5/1903; Crystal Falls Drill, 11/28/1903; Chicago Record-Herald, 11/1/1903.

*Potsdam.*

| | | |
|---|---|---|
| "White sandstone comes in 600-700 feet down." Clear white glass sand (Upper Potsdam of Rominger). | | |
| Samples, boxes 300 to 370 | 80 | 710 |
| Reddish sandstone coarse. | | |
| Sample, box 290 | 10 | 720 |
| Coarse red sandstone. | | |
| Sample, boxes 250 to 280 | 40 | 760 |
| Feldspathic sandstone. | | |
| Box 290 | 10 | 770 |
| Coarse mixed very micaceous red sandstone. | | |
| Box 210-230 | 30 | 800 |

Last samples, large fragments of decomposed chloritic schist, like Archean rocks.

This should be compared with a record of a well put down for water at the station of the Minneapolis, St. Paul & Sault Ste. Marie R. R. at Gladstone, elevation 605 A. T., which according to letters of Mr. P. Swenson of the company, and J. F. McCarthy, the contractor, must be about as follows:—

| | Thickness. | Total. | Dates and Remarks. |
|---|---|---|---|
| *Pleistocene.* | | | |
| Old dug well (in sand) | 13 | 13 | Began May 9. |
| Quicksand | 38 | 51 | |
| Till (clay and hard pan) | 10½ | 61½ | |
| Sand and gravel | 15 | 76½ | |
| Clay and limestone | 10½ | 87 | |
| Boulders | 4 | 91 | |
| *Trenton.* | | | |
| Limestone | 234 | 325 | |
| Lime and sandstone in mixed layers | 89 | 404 | |
| St. Peter's horizon? Some water at 400 feet. | | | |
| *Calciferous.* | | | |
| Limestone | 228 | 642 | At 580 Sept. 15. Compare Rapid River 630. |

Sample 632 is crystalline magnesian limestone.

*Potsdam.*

Shell sandstone.

Sample at 742 feet, white, round sand, like Rapid River, 630 to 710. At 690 feet Oct. 1. Main water flow, 150 gallons a minute. Hardness only 5.°86. Finished Oct. 9.

Hard rock, not Archean granite at the end.

Average progress 5 feet a day, but from Sept. 15 to Oct. 1, and Oct 1 to Oct. 9, 7 feet a day.



It is a pity that we cannot have analyses of each water separately, yet the low hardness is significant. Though drawing from a deeper source, it is less hard than the Marinette, and one of the Menominee wells, and the Escanaba waters, including one of the shallower artesian wells given below.

ESCANABA WATERS.

ANALYZED BY VICTOR C. VAUGHAN.

| Number | 243.[3] | 244. | 296.[1] |
|---|---|---|---|
| Date | 12/8/94 | 12/8/94 | 11/30/95 |
| Reaction | alkaline | alkaline | alkaline |
| Hardness | 8° | 8° | 11° |
| Total residue | 240 | 140 | 290 |
| Inorganic residue | 180 | 80 | 270 |
| Organic residue | 50 | 60 | 20 |
| Cl as NaCl | 11.55 | 11.55 | 3.30 |
| Sulphates | trace | trace | trace |
| Free ammonia | 0.069 | 0.075 | 0.028 |
| Albumenoid ammonia | 0.33 | 0.29 | 0.165 |
| Nitrates | trace | trace | ........... |
| Nitrites | trace | trace | ........... |
| Bacteria in 72 hours | 250 | quefaction. | 120 |

[1] Artesian well, microscope shows small deposits.

[2] Slightly milky, stale odor, no reaction; unicellular plants and animal water fleas, vegetable debris and organic matter.

[3] Dirty yellow color, stale odor, no reaction; Algae, desmids, unicellular, plants and animals, vegetable debris inorganic matter. This and No. 244 are probably from the bay.

*An important practical deduction, therefore, is that by going to the deeper waters in the Potsdam and casing off the waters from the limestone a softer water can be obtained.* In explanation of this it must be remembered that there is an upward pressure and circulation which will prevent the limestone waters from working down into the sandstone to any great degree, while the Potsdam and Archean normally contain soft waters. The wells at the furnace, two miles north of Gladstone, deserve a moment's attention here, for there appears to be an exception, but it is not. There are at least five flowing wells here.

1. The one on the mainland, at the south end of the row of tenements flows a quart or more a second with a temperature of 45.5° to 46°. It is housed; there are two casings, the 8-in. comes one foot above ground, and the 4-in. two feet more, and there is a curved neck of inch pipe 2½ feet long.

2. At the north end of the tenements has a similar but fluctuating flow as though affected by the pumping of the wells at the plant. Temperature, 44.9°.

3. Is the most southwestern of the plant wells, put down in the winter of 1900-1901, said to be 174 feet deep in sand and gravel. Temperature, 47.7° to 47.8°.

4. The northern of the three wells at the plant was put down deeper, i. e., to 500 feet for more water, and did not get it, but got more lime. Temperature, 49° to 49.3° F. This, however, evidently did not go deep enough. It should be put down 200 feet more.

5. Inaccessible; capped.

Before passing to the waters of the Archean area, we will include a few more notes on those of the sedimentary or eastern end of the Upper Peninsula. Over at Brampton, west of Rapid River, the wells go through 20 feet of hard pan and then find water in the limestone. A little north of the station on section 21, T. 41 N., R. 22 W., is a spring with a strong flow of over a quart a second and a temperature, July 12, 1902, of 48° F. Three miles north, at Perkins, there are wells from 150 to 250 feet deep through rock all the way, and wells of the same general type occur at Maple Ridge and Lathrop. Similar wells have been put down near the Wisconsin line at Ingalls by James Lucas.

At Talbot there is a drilled well close to the station. At Daggett there is a well, put down by W. H. Dolan, which at 40 feet was in a hard, white non-effervescent clay shale that might be valuable. At 45 feet it passed into a dolomitic sandstone. At 60 feet the sandstone was still calcareous, but at 80 feet it was almost pure quartz sand. This well must be in the Calciferous, possibly finishing in the Potsdam.

A short record of a well at Neebish Island down into the Potsdam sandstone, is given in the annual report for 1901. Mr. Alden suggests as a possible correlation for it:—

| | | |
|---|---|---|
| "?No samples | 111 | |
| Trenton limestone | 112 | 223 |
| St. Peter's sandstone | 161 | 384 |
| Potsdam | 33 | 417 |
| ?Pre-Cambrian shale and quartzite | 110 | 527" |

I think that the bottom is conglomeritic Potsdam, and the limestone in part, at least, Trenton, yet I am not sure but that the Lower Magnesian is wholly gone and the white, sugary sandstone is St. Peter's. At any rate the top of the true Potsdam seems to be similar at times.

The drillers' full record is as follows:—

*Drillers' "Log."* [1]*Neebish Well.*

| | Thickness. | Total. |
|---|---|---|
| Clay, boulders, and sand | 33 | 33 |
| Limestone, hard | 1 | 34 |
| Limestone, vein water, soft | 1 | 35 |
| Limestone, hard | 14 | 49 |
| Limestone, gritty, softer | 40 | 89 |
| Limestone, darker in color, not so gritty but harder [111-138 light colored] | 17 | 106 |
| Limestone, softer | 13 | 119 |
| Limestone, shale | 2 | 121 |
| Limestone, hard | 3 | 124 |

[1]Matter in brackets are notes on samples, the rate of effervescence with acid varies, being greatest at 123 and 190 to 200 feet, least at 138 and 211-223 feet.



| | Thickness. | Total. |
|---|---|---|
| Limestone, softer | 3 | 127 |
| Limestone, hard | 7 | 134 |
| Limestone, softer | 6 | 140 |
| Limestone, shale | 2 | 142 |
| Limestone | 7 | 149 |
| Limestone, hard [148-158 light colored] | 4 | 153 |
| Limestone, softer | 5 | 158 |
| Limestone, shale [bluish, thin chips] | 5 | 163 |
| Limestone, brittle [bluish, chipping, 163-200] | 22 | 185 |
| Clay | 1 | 186 |
| Limestone, brittle | 4 | 190 |
| Shale; cased here for first time | 8 | 198 |
| Limestone | 2 | 200 |
| Shale, [large chips, thin bedded] | 5 | 205 |
| Limestone, darker in color [sandy dolomite] | 9 | 214 |
| Limestone, shelly, full of little seams | 9 | 223 |
| White sand rock | 10 | 233 |
| Shale | 2 | 235 |
| White sand rock,[1] got first flow water at 250 feet, and more in several places in going through the sand | 176 | 411 |
| Sand; harder, looks like granite boulders pounded up | 8 | 419 |
| Sandy shale;[2] sand pumpings look red but when washed out are black | 87 | 506 |
| Sand rock | 21 | 527 |

Average, about 10 feet per day drilling. Worked just day time.

Reported by A. W. Palmer, Jan. 16, 1900.

Location, across the west channel on the mainland opposite Trombleys and about 1,000 feet south of north line of Trombleys; about 100 feet from water in the Sault Ste. Marie river and 6 or 7 feet above level of river about 1½ miles below the rapids in the river.

The St. Ignace flowing wells have been reported in the annual report for 1901. The temperature is about 51°.

At Manistique flowing wells are from 200 to 800 feet deep. At 800 feet in the Hiawatha House well a flow was struck, which lifted the drill and had 30 to 40 feet of head, occurring in a "not hard shell rock" (Trenton?). John Luce is in charge of 30 wells which furnish city water and are also used for fire protection. They are cased from 30 to 40 feet down and range in depth from 250 to 500 feet; the latter going through the seam of water and not gaining in depth. This was put down for salt, but the tools were lost in the bottom of the hole. Near the level of the main streets the water comes within a foot of the ground, others have head up to 16 feet. The character of the water is hard, for it is in limestone. The surface rocks of the quarries are limestones of the Niagara.

[1]Clean white glass sand rock 223-384, light red 384-411.
[2]Coarse red conglomerate, grows coarser, 417-506; at 430 red le of Huronian quartzite; 506-51 510-527, material mainly Huronian.

At the Burrell Chemical Co. is a well 300 feet deep all the way through limestone; temperature of flow, 46° F. They used to pump this heavily, but at the time of my visit they were stopped by fire and all other flows had increased very much. This well is out at the end of Cedar street. Across the river is another well with a strong flow. One of the city wells at the corner of Geer street and Houghton avenue, 280 feet, has a temperature of 45° F. (July 14, 1902) to 45.5° (Aug. 26, 1903) and a strong flow.

During the summer of 1903 a number of new city wells were put down by Kenney and Coleman, as follows:—

1. Corner Garden avenue and Potter street, 6-in. pipe and a two foot pipe horizontal; just finished Aug. 26. There is a good flow of clear hard water at a temperature of 45° F., not more than 15 feet above lake, 226 feet deep, a very little water was struck at 140 feet but no head. Mr. Coleman gives the following notes of the hardness:—

0 to 80 feet, hard drilling.
80 to 140 feet, soft drilling.
140 to near end, hard drilling.
Then softer, but just over the water hard drilling, as almost always the case.

The record is as follows:—

| | | |
|---|---|---|
| Sand | | |
| Dolomite, light buff, massive | 2 | 2 |
| Light dolomitic limestone | 2 | 4 |
| Bluish white dolomite (harsh feel) | 9 | 13 |
| | 11 | 24 |

Above beds probably belong to Rominger's[1] third or uppermost member of the Niagara, and to the Racine or upper Coralline of Wisconsin, corresponding to the surface section and that in the quarry as follows:

| | | |
|---|---|---|
| Cherty dolomite bluffs (Pentamerus) | 10 | 10 |
| Solid dolomite | 5' 4" | 15' 4" |
| Bluish dolomite | 10 | 25 4 |

Blue clayey seam of partition which at points is full of small *Pentamerus oblongus* not over one inch in diameter.

| | | |
|---|---|---|
| Brownish crystalline granular beds with Favosites and other corals | 3 | 28 4 |
| With open druses, lined with calcite | 3 | 31 4 |
| Fine grained bluish dolomites with Syringopora | 5 | 36 4 |
| Open grained brown dolomite with purple cavities | 4 | 40 4 |
| Open grained brown dolomite | 4 | 44 4 |

| | | |
|---|---|---|
| Brownish crystalline dolomitic limestone. | 16 | 40 |

Compare quarry beds from 25 feet to 44 feet.

| | | |
|---|---|---|
| Light bluish dolomitic limestone | 12 | 52 |
| Buff crystalline cherty limestone | 13 | 63 |
| White limestone | 7 | 70 |
| Buff crystalline dolomitic limestone | 10 | 80 |
| White limestone | 27 | 107 |
| Mottled gray dolomite | 18 | 125 |
| Buff dolomite | 11 | 136 |
| Yellow dolomite | 22 | 158 |
| Gets harder and a little water, no flow at 140 feet. | | |
| Yellowish limestone | 30 | 188 |
| Yellowish dolomite | 12 | 215 |
| This may be base of coralline, top of Byron beds of Wisconsin, Rominger's lower division.[2] | | |
| White thin banded lithographic dolomite | 10 | 225 |

[1] Vol. I, Part 3, p. 37.
[2] Volume I, Part 3, p. 37.



Compare outcrops on sections 24 and 25 to the north.

| | | |
|---|---|---|
| At bottom white limestone | 15 | 240 |

2. Mackinaw avenue and Elk.
3. Cedar street, near L. Rice.
4. Garden avenue and Potter.

In this rock with a 30-foot string of 4-in. tools they made 15 to 20 feet a day.

The same contractors put down a well 240 feet deep at the Burrell Chemical Works, while across the river, i. e., on the northwest side of the town, are a couple of wells put down 208 and 210 feet.

North of Manistique, on the Manistique and Northern R. R., on sections 24 and 25, T. 41 N., R. 16 W., very white, hard limestone is exposed showing by bandings that weather out, that it was a limestone mud.

Apparently the well begins in the uppermost of Rominger's three fold division of the Niagara, and goes through the middle or coral beds of the Wisconsin Survey, and it is worth noting, showing some beds of real limestone, low in magnesia. The bottom appears to be in Rominger's lowest division, or the Byron beds of the Wisconsin geologists. If we suppose the top to be at 426 of the St. Ignace well No. 2, the bottom layers with water might compare to the water found there at 680 feet. The bottom beds may correspond with those found on sections 24 and 25 of the township immediately north.

It seems to me it would be desirable to put one well down into the Potsdam, that is over 1,400 feet deep—and see what kind of water could be obtained there. I don't consider the bare possibilities of oil in the recommendation, but the water might be softer than in the present, and if not it would be pretty sure to be a valuable and probably palatable mineral water. One would expect it to be of the same class as the deepest wells of Chicago, Milwaukee, Manitowoc and Sheboygan.

All of the present wells, except perhaps the Hiawatha House 800 feet well, which may be from the Trenton, are in the Niagara and the strata may be compared with samples which have been saved from St. Ignace. Probably the sandstone struck at 897 feet, the bottom of the first well there (pl. 63 of Vol. V), may be the horizon of many of these wells. The record of the second well is given on page 228 of the 1901 report and we notice that there are strong flows of water encountered in the Niagara from 575 feet, that is, 65 feet, below its top, down. On page 227 of that report is given the record of a flowing well on Neebish Island, Mr. Alden's correlation of which is given above; the sandstone near the bottom being like those near the bottom of the Rapid River well.

As I have said, flows and springs are found or may be expected for a good ways back from the Lake Michigan shore, as at Newberry. The surface deposits of the drift are commonly not very thick over the Niagara. Over the Lorraine and Utica shales they seem to be thicker. There are extensive swamps; there is a good deal of surface sand, and it is not difficult to get surface wells. Over on the north side of this region at Grand Marais, T. 49 N., R. 14 W., a well was put down in 1899-1900, 1,200 feet deep. It tapered from 8-in. to 6-in. in diameter and was cased for the first 100 feet. It is about 100 rods from Lake Superior and about 30 feet above the lake level. It was started on the strength of artesian wells at Newberry,

—citizens thinking that the same flow might be struck there and not appreciating that they were on the other side of the divide. It seems to have found some 1,100 feet of Potsdam, under 100 feet of drift. The well was 8 to 6 inches in diameter, cost $3,500, and the water did not flow. There was 100 feet of casing, but it has now been abandoned, and though the water was reported as extremely hard we cannot now tell its nature. Mr. Arthur D. Wood writes:—

"The Grand Marais well is located about 100 rods from Lake Superior, about 30 feet above the lake level. It was started on the strength of the Newberry artesian wells, the citizens of this city thinking that the same flow might be struck from here.

"The drill went through sand for the first 100 feet and then came in contact with hard pan of a sandstone nature of different colors. In some places this was harder than in others. During the drilling of the 1,200 feet several hardheads were met with, otherwise it was principally sandstone. The water in the well never flowed, but at times would rise to within a few feet of the surface and then it would not be seen again for a week at a time.

"The well is a thorough test that 1,200 feet will not strike a flow in the section.

"(Signed) ARTHUR D. WOOD.

"Grand Marais, Mich., 7/30, 1900."

The only reliable analysis of a well in the Potsdam sandstone is of the one put down by the Calumet & Hecla Company, near the Calumet & Hecla stamp mills at Lake Linden. They have drilled wells 1,500 feet deep, all the way through a monotonous series of sandstone strata. One has been analyzed. The same company have at their smelting works (section 7, T. 55 N., R. 32 W.) another well which goes down 500 feet, beginning 8 feet above the level of (Torch lake) Lake Superior. Water is usually quite clear, but occasionally brings up some red sand. There was much surface water cut off by a 10-in. casing for 30 feet. There was 90 feet of 8-in. casing down into the solid rock; 104 feet of solid sandstone followed. There is 200 feet of 4-in. pipe inside the 8-in. casing and 50 feet of 3-in. pipe below that; 200 feet of the well now having filled up with sand. When not pumping, the water stands at 25 to 30 feet below the surface, but can be pulled down with a pump to about 150 to 180 feet. It was drilled in 1887. The analysis by Mr. G. L. Heath, is as follows:—



*C. & H. Stamp Mill Well.*

| | Grams per ton. |
|---|---|
| Silica | 10.87 |
| Carbonate of iron ($Fe\ CO_3$) | 5.90 |
| Sulphate of lime ($Ca\ SO_4$) | 10.90 |
| Carbonate of calcium ($Ca\ CO_3$) | 43.59 |
| Carbonate of Magnesium ($Mg\ CO_3$) | 27.92 |
| (Salt) Chloride of sodium ($Na\ Cl$) | 52.69 |
| Traces of chloride of potassium and nitrate of sodium. | |
| | 151.87 |
| Loss on ignition, organic matter and carbonic acid of bi-carbonates | 32.33 |
| Total solids | 184.20 |
| Parts in 1,000,000, by weight, taking Sp. Gr. of this water as unity. | |

Compare the analyses on pages 163 and 164.

It is interesting to contrast this with the well at Freda, on the other side of the copper range, not so deep and also all the way through red sandstone, of which we will speak a moment later. In discussing the water of the copper country, we may give a group of analyses, showing the character of the surface waters and shallow mine waters. Most of these were made by Prof. Geo. A. Koenig or under his direction, and I owe them to him or the mine officers for whom they were made. The collection will be found valuable, I think, as showing what kind of boiler waters may be expected from various classes of water.

*Water from Old Estivant Property, Copper Harbor.*[1]

| | Grams per ton metric. |
|---|---|
| Calcium carbonate | 206.0 |
| Magnesium carbonate | 107.2 |
| Magnesium chloride | 36. |
| Sodium chloride | 26.4 |
| Sodium sulphate | 52.4 |
| Sodium carbonate | 41.6 |
| Silica | 83.2 |
| Organic matter (humus) | 166.0 |
| Total | 718.8 |

[1]Sent by Osgood to test for boiler use, figures raised from 250 cc.; strongly carbonated and low in chlorides, upper type. L.

*Well at Arcadian Mine location, Aug. 23, 1898.*

| | | Grams per ton metric. |
|---|---|---|
| Sodium chloride | | 2.15 |
| Sodium sulphate | | 9.76 |
| Sodium silicate | | 15.00 |
| Calcium carbonate | | 41.90 |
| Ferrous carbonate | | 1.40 |
| Magnesium carbonate | | 2.40 |
| $Na_2O$ | 6.99 | |
| $K_2O$ | 1.70 | |
| | 8.69 | |
| $C_{60}H_{54}O_{27}$ | | 20.90 |
| | | 93.51 |

This has about the same hardness as the Boston Pond, not far off, upper type.

The following are some figures of analysis of the water at the Tamarack dock.[1]

*Tamarack Dock.*

| | |
|---|---|
| Total solids | 177.2 |
| Organic loss by ignition | 22.8 |
| Inorganic solids | 154.4 |
| Sodium chloride (from silver chloride precipitated) | 9.6 |
| Sodic sulphate | 24.0 |
| Iron and aluminium oxide | 1.0 |
| Silica[2] | 16.7 |
| Balance probably mainly calcium and magnesium carbonates | 103.1 |

What the undetermined balance consists of is shown by the next analysis.

*Filtered Portage Lake Water.*[3]

| | Grams per ton. |
|---|---|
| Calcium carbonate | 63.7 |
| Calcium chloride | 30.7 |
| Magnesium chloride | 2.35 |
| Magnesium sulphate | 6.45 |
| Sodium chloride | 14.45 |
| Sodium silicate | 7.9 |
| $H_2SiO_4$ | 15.7 |
| | 139.75 |
| Albumenoid ammonia | .06 |

[1]Computed from figures per fourth litre.
[2]Silica, iron and alumina in two litres .0354 gr.
[3]Feb. 17, gave 279.5 mg. in 3 litres and by analysis.



Portage lake should, of course, be intermediate between Lake Superior and various other waters, except so far as it might be affected by the mine drainage of the Isle Royale, Quincy, and other mines and the towns and metallurgical operations. These introduce the earthy chlorides.

Here is an analysis of the water of Thunder River, near the Wolverine mill, which, however, does not affect it:—

*Thunder River.*

| | Grams per metric ton. |
|---|---|
| Calcium carbonate | 27.3 |
| Magnesium carbonate | 8.51 |
| Ferrous carbonate | 2.03 |
| Sodium chloride | 1.70 |
| Sodium sulphate | 2.84 |
| Sodium silicate | 14.48 |
| | 72.49 |

This has about the same amount of mineral matter as the Houghton water supply or the tank that used to supply the College of Mines, gathered from shallow springs, from the top of the hill back of the school.

*College of Mines.*[1]

| | Per million. |
|---|---|
| Alumina | 1.82 |
| Calcium carbonate | 16.25 |
| Ferrous carbonate | .49 |
| Magnesium carbonate | 15.82 |
| Magnesium sulphate | 4.69 |
| Silica | 8.20 |
| Sodium silicate ($Na_2K_2(SiO_3)_2$). | 3.90 |
| Sodium chloride | trace |
| Free ammonia | .03 |
| Albumenoid ammonia | .15 |
| Humus (organic) | 27.06 |
| | 78.40 |

The small artificial pond for the boilers of the Franklin Junior Mine,—Boston Pond, is about equally soft.

[1]Tank. Shallow springs from the top of the hill back of the school, analyzed by A. Formis.

*Franklin Junior.*[1]

| | | |
|---|---|---|
| Calcium carbonate | | 29.00 |
| Ferrous carbonate | | 1.16 |
| Magnesium carbonate | | 9.50 |
| Sodium silicate | | 1.16 |
| Sodium sulphate | | 2.75 |
| Sodium chloride | | 2.21 |
| $Na_2O$ | 1.32 | |
| $K_2O$ | 0.60 | |
| Humus (organic) | | 37.60 |
| | | 83.38 |

Some analyses of water near the Winona mine are:—

*Winona.*

(1) Yellow, with an unpleasant smell and color.

| | Grams per metric ton. |
|---|---|
| Calcium carbonate | 66.60 |
| Magnesium carbonate | 24.15 |
| Calcium sulphate | 14.55 |
| Silica | 3.25 |
| Sodium chloride | 31.50 |
| Potassium chloride | 7.50 |
| Humus (organic matter) | 25.05 |
| Free ammonia | 1.00 |
| Albumenoid ammonia | 3.40 |
| Total directly | 177.00 |

(2) Turbid with salt, but no smell nor color; pleasant taste.

| | Grams per metric ton. |
|---|---|
| Calcium carbonate | 131.25 |
| Magnesium carbonate | 26.45 |
| Ferrous carbonate | 20.40 |
| Sodium chloride | 9.65 |
| Free ammonia | .05 |
| Albumenoid ammonia | .29 |
| | 188.09 |

[1] Small artificial pond.



(3) A spring gives the following analysis in grams per metric ton:—

| | |
|---|---|
| Calcium carbonate | 45.06 |
| Magnesium carbonate | 11.76 |
| Ferrous carbonate | 0.153 |
| Sodium chloride | 3.41 |
| Sodium sulphate | .28 |
| Sodium aluminate, $Na_6\ Al_2\ O_4$ | .322 |
| Silicate, $Na\ H\ SiO_4$ | 20.980 |
| Ammonium nitrate, $NH_4\ NO_3$ | .108 |
| Albumenoid ammonia | 2.22 |
| Organic matter | 5.02 |
| Sum | 89.313 |
| Total directly determined | 93.4 |

The analyses of the pond at the Tamarack, and that by G. L. Heath on page 166, show the kind of contamination produced by the deep waters of the copper mines, one with earthy chlorides.

So far as the hardness goes, the amount of calcium, magnesium, and ferrous carbonates, does not fall below that in Lake Superior, say about 50 grams per ton and is not often more than double that, i. e., there should be from 3° to 6° of hardness. With this, agrees analysis 156 of the Hancock water by V. C. Vaughan, while No. 326 is extra high.

HANCOCK.

ANALYSES BY V. C. VAUGHAN.

| Number | 156 | 326 |
|---|---|---|
| Date | 9/20/92 | 7/29/96 |
| Color | | |
| Odor | (1) | (2) |
| Reaction | | |
| Hardness | 4° | 7° |
| Total residue | [1]12 | 170 |
| Inorganic residue | [2]10.5 | 110 |
| Organic residue | [1]1.5 | 60 |
| Na Cl | 2 | 4.95 |
| Permanganate reduced | 3 | 2 |
| Free ammonia | .07 | 0.028 |
| Albuminoid ammonia | .40 | 0.136 |
| Nitrates | Distinct trace | trace |
| Nitrites | 0.0 | trace |
| Bacteria in 72 hours | 575 | Liquefied |

[1] Slight offensive odor and markedly acid reaction; microscope shows indeterminate granules and a few fresh water algæ. Figures returned for inorganic residue, etc., are all ten times too small.
[2] Trace of sulphates and small deposit of vegetable debris.

We have had an analysis of Teal lake ice. It will be fit now to give analyses of this and other lakes of the iron bearing rocks. First near Ishpeming and Negaunee.

| | Ishpeming lake. | | Negaunee—Teal lake. |
|---|---|---|---|
| Number | 153[1] | 191 | 179[2] |
| Date | 7 14 92 | 7 8 93 | 9 22 93 |
| Hardness | 2° | | |
| Total residue | 42.85 | 33 | |
| Inorganic residue | 28.52 | 25 | |
| Organic residue | 14.33 | 8 | |
| Na Cl | 0.75 | 2 | 0.75 |
| Permanganate | 3.5 | 4 | |
| Free ammonia | 0.08 | .03 | 0.6 |
| Albuminoid ammonia | 0.09 | .10 | .40 |
| Nitrates | Distinct trace | traces | trace |
| Nitrites | 0.0 | traces | trace |
| Number of bacteria in 72 hours | 575 | 300 | 2,600 |

[1] Microscope shows indeterminate granules and bacteria.
[2] Reaction of inoculation positive; vegetable debris.

Compare analyses and remarks on page 121.

These are very soft. At Iron Mountain, on the other hand, the waters are hard and the Randville dolomite occurs around there. There may be mine water contamination.



IRON MOUNTAIN ANALYSES OF PUBLIC WATER SUPPLY.

| Location. | Outlet of lake Antoine. | Waterworks well. | City hydrant. | Lake. |
|---|---|---|---|---|
| Number | 84[1] | 82[2] | 83[3] | 120[4] |
| Date | 6 10 90 | 6 10 90 | 6 10 90 | 6 24 91 |
| Color | | | | slight sediment |
| Odor | | | | |
| Reaction | | | | |
| Hardness | 13° | 13.3° | 12° | 11° |
| Total residue | 120 | 150 | 164 | 125 |
| Inorganic residue | 69 | 69 | 118 | 58 |
| Organic residue | 51 | 81 | 46 | 67 |
| Cl as NaCl | 4.125 | 4.95 | 4.95 | 6.93 |
| Permanganate reduced | 29.402 | 32.149 | 25, 34.9 | 28.331 |
| Free ammonia | 00.358 | 0.388 | 0.502 | 0.11 |
| Albuminoid ammonia | 0.342 | 0.444 | 0.57 | 0.322 |
| Nitrates | | | | |
| Nitrites | | very faint trace | faint trace | |
| Bacteria in 72 hours | 3 | 6 | 6 | 2 |

[1] Algæ diatoms, *Draparnaldia, Diatoma vulgare* Foraminifera.
[2] Colorless amorphous matter, Dark colored amorphous matter, algæ, crystals, *Crenothrix, Diatoma vulgare, Zooglœa.*
[3] Colorless amorphous matter, yellow amorphous matter, algæ, a few diatoms.
[4] Microscope 100 and 500 diam., Diatoms, colorless amorphous matter, monads.

IRON MOUNTAIN.—CONTINUED.

| Location. | Lake. | Well. |
|---|---|---|
| Number | 134[1] | 135[1] |
| Date | 1891 | 1891 |
| Color | | |
| Odor | faint | |
| Reaction | | |
| Hardness | 8.6° | 1 |
| Total residue | 150 | 260 |
| Inorganic residue | 100 | 140 |
| Organic residue | 50 | 120 |
| Cl as NaCl | 1.3 | 1.0 |
| Permanganate reduced | 7.584 | 10.428 |
| Free ammonia | .15 | .08 |
| Albuminoid ammonia | .34 | .106 |
| Nitrates | | trace |
| Nitrites | trace | strong trace |
| No. of bacteria in 72 hours | 4 | 2 |

[1]Trace of sulphates.



IRON MOUNTAIN.—CONTINUED.

| Location. | Public water supply. | Water works. | Water works. | Public water supply. |
|---|---|---|---|---|
| Number | 131[1] | 128[2] | 67 | 182[3] |
| Date | 1/28/92 | 11/23/91 | 4/14/90 | 8/25/93 |
| Color | | | | |
| Odor | | | | |
| Reaction | | | | alkaline |
| Hardness | 13.7° | 13.2 | 8.5° | |
| Total residue | 130 | 220 | 210 | |
| Inorganic residue | 88 | 150 | 130 | |
| Organic residue | 42 | 70 | 80 | |
| Cl as Na Cl | 0.42 | 2. | 4.5 | 0.2 |
| Permanganate reduced | 7.9 | 0.15 | 7.8 | |
| Free ammonia | 0.7 | 0.005 | 0.26 | .006 |
| Albuminoid ammonia | 0.05 | 0.025 | 0.27 | .04 |
| Nitrates | | | | |
| Nitrites | | trace | trace | |
| Bacteria in 72 hours | 4 | 13 | 9 | 250 |

[1]Microscope shows indeterminate granules.
[2]Microscope shows fine grains of sand. Trace of sulphates.
[3]Microscope shows a few vegetable fibres.

IRON MOUNTAIN.—CONTINUED.

| Location. | |
|---|---|
| Number | 189[1] |
| Date | 7/93 |
| Color | |
| Odor | |
| Reaction | alkaline |
| Hardness | |
| Total residue | |
| Inorganic residue | |
| Organic residue | |
| Cl as Na Cl | 0.2 |
| Permanganate reduced | |
| Free ammonia | .005 |
| Albuminoid ammonia | .05 |
| Nitrates | |
| Nitrites | |
| Number of bacteria in 72 hours | 3,500 |

[1]Microscope shows a few vegetable fibres.



IRON MOUNTAIN.—CONCLUDED.

| Location. | Lake. | Water works. |
|---|---|---|
| Number | 121[1] | 123[2] |
| Date | 6/24/91 | 7/2/91 |
| Color | slight sediment | Contain much floc'lent matter |
| Odor | | |
| Reaction | | |
| Hardness | 11.2° | 11° |
| Total residue | 143 | 120 |
| Inorganic residue | 67 | 72 |
| Organic residue | 76 | 48 |
| Cl as NaCl | 7.09 | 4.0 |
| Permanganate reduced | 35.522 | 20 |
| Free ammonia | 0.092 | 0.03 |
| Albuminoid ammonia | 0.314 | 0.15 |
| Nitrates | | |
| Nitrites | | |
| Number of bacteria in 72 hours | 2 | 4 |

[1]Microscope—Diatoms—Colorless amorphous matter. Monads.
[2]Microscopic appearance—Vegetable fibres and bits of decayed wood.

Norway is very similarly located to Iron Mountain and the analyses of wells and other sources are similar, but a shade less hard, from 10° to 12°.

NORWAY.

| Number | 124[1] | 125[2] | 126 | 183[3] | 184[3] |
|---|---|---|---|---|---|
| Date | 7/2/91 | 7/2/91 | 11/8/97 | 8/16/93 | 8/16/93 |
| Color | ........ | sediment | ........ | ........ | ........ |
| Odor | ........ | ........ | ........ | ........ | ........ |
| Reaction | ........ | ........ | ........ | feebly alkaline | feebly alkaline |
| Hardness | 10° | 12° | 10° | 9° | 11° |
| Total residue | 120 | 126 | 101 | 280 | 340 |
| Inorganic residue | 111 | 111 | 95 | 220 | 270 |
| Organic residue | 9 | 15 | 6 | 60 | 70 |
| Cl as Na Cl | 1.0 | 3.0 | 0.5 | 1.6 | 1.4 |
| Permanganate reduced | 3.2 | 3,5 | 1.2 | 3 | 3 |
| Free ammonia | 0.01 | 0.02 | 0.005 | 0.005 | 0.005 |
| Albuminoid ammonia | 0.03 | 0.15 | 0.01 | 0.10 | 0.08 |
| Nitrates | ........ | ........ | ........ | 0.05 | 0.06 |
| Nitrites | ........ | ........ | ........ | 0.0 | 0 |
| No. of bacteria in 72 hours | 3 | 5 | 2 | 480 | 150 |

[1]Microscope—Deposits.
[2]Bits of vegetable fibres.
[3]Sulphates 2, microscope shows only indeterminate granules.

| Number | 185[1] | 377[2] |
|---|---|---|
| Date | 8/16/93 | 11/19/97 |
| Color | ........ | Milky |
| Odor | ........ | Ammoniacal on warming |
| Reaction | feebly alkaline | alkaline |
| Hardness | 11.5° | 9.2 |
| Total residue | 240 | 430 |
| Inorganic residue | 160 | 255 |
| Organic residue | 80 | 175 |
| Cl as NaCl | 1.2 | 16.5 |
| Permanganate reduced | 3.5 | 2- |
| Free ammonia | 0.02 | 1.4400 |
| Albuminoid ammonia | 0.30 | trace |
| Nitrates | 1.0 | ........ |
| Nitrites | 0 | ........ |
| Number of bacteria in 72 hours | 300 | liquefaction |

[1]Trace of sulphates. Microscope shows specks of vegetable matter.
[2]Some sulphates present—considerable amount of amorphous material, probably a salt of ammonia.



There was a flood of water in the Vulcan mine, near Norway, in the fall of 1903, which almost drowned them out (did drown two mules), and analyzed as follows, in grams per metric ton:—

| | |
|---|---|
| Insoluble matter, clay and $SiO_2$ | 4.4 |
| Solid solubles | 340.00 |
| Organic matter | 52.3 |
| Carbon dioxide | 37.3 |
| Non volatile solids | 250.4 |
| In solution. | |
| Silica | 5.8 |
| Alumina | 4.4 |
| Ferric oxide | trace |
| Calcium oxide | 84.4 |
| Magnesium oxide | 62.8 |
| Sulphur anhydride, $SO_3$ | 36 |
| Chlorine | 61 |
| Potassium | trace |
| Sodium present not determined, very small. | |
| Strontia and lithia | 0 |
| Total by addition | 254.4 |

We may consider this combined as follows:—

| | |
|---|---|
| $Ca\ SO_4$ | 61.2 |
| $Ca\ CO_3$ | 85 |
| $Ca\ Cl_2$ | 26.6 |
| $Mg\ Cl_2$ | 73.3 |
| $MgO,\ SiO_2$ | 9.7 |
| $MgO,\ Al_2O_3$ | 6.2 |
| MgO representing bases combined with organic matter | 30.6 |
| | 292.6 |

E. E. Ware, laboratory of E. D. Campbell, Ann Arbor.

Compare non-volatile solids and $CO_2$=250.4 plus 37.3=287.7. The hardness of 308 grams per metric ton would be equivalent to about 18°.

The water is not unlike Vaughan's waters 183 and 184 in hardness and inorganic residue, but has a comparatively large amount of chlorine, and yet a very small amount of sodium, which is very peculiar, but reminds one of the deeper waters of the copper country much diluted.

The temperature of the water at the 12th level, 1,000 feet from the surface, was: at the shaft, 57.°2 F.; at the first winze, about 100 feet west of the shaft, 60.°6; and the west end, almost 300 feet west of the shafts, 58.2°.

See annual for 1901, p. 246. According to the observations there, the mine water at 1.210 feet was 56°, and at 270 feet, 45.°8. This water is then, abnormally warm,—either from working up(?) or the heat from casing, friction, and decayed timber.

The question arose whether it had any immediate surface source, and accordingly, analyses were made of the surface waters.

1 is from Lake Hanbury, into which the mine water drains.
2 is from water in the gravels at Norway, from the Aragon mine sand shaft, used for city supply.
3 is from Pine creek.

Comparing them with the deep mine water, there is a large amount of carbonates, a variable amount of sulphates, and much less chlorine than in the mine water, which, therefore, is probably not derived from any of them.

Feb. 19, 1904.

| | Lake Hanbury. | | Sand shaft. | | Pine creek. | |
|---|---|---|---|---|---|---|
| Total solids | 301.4 | | 762.5 | | 205.2 | |
| Inorganic solids | 268.1 | | 668.1 | | 172.7 | |
| Carbon di-oxide | 82.8 | 1.88 | 100.5 | 2.28 | 56.2 | 1.28 |
| Lime | 63.9 | 1.14 | 195.2 | 3.48 | 57.6 | 1.022 |
| Magnesia | 52.5 | 1.325 | 88.0 | 2.2 | 33.4 | .835 |
| Chlorine | 3.6 | .1019 | 3.8 | .1074 | 1.0 | .028 |
| Sulphuric anhydride | 33.6 | .42 | 245.8 | 3.07 | 9.5 | .118 |
| Alkali chlorides | 13.8 | | 14.0 | | 2.4 | |
| Potassium oxide | ........ | | 1.7 | | ........ | |
| Sodium oxide | ........ | | 6.7 | | ........ | |
| Total | 250.2 | | 655.7 | | 160.1 | |
| Silica, iron and alumina by difference | 17.9 | | 12.4 | | 12.6 | |

Examination for potassium, showed its presence in all three waters. Determined as grams per ton.

(Signed) L. KIRSCHBRAUM.

Made at the Chemical Laboratory of the University of Michigan, E. D. Campbell, supervising.



An Ishpeming mine water, coming out of a diamond drill hole at a depth of 825 feet, gave the following results, which are quite different from the Vulcan mine water, and more nearly like surface waters:—

| 1. | 2. | 3. | 4. |
|---|---|---|---|
| Lime as carbonate | 55.8 | (Oxide determined) | 31.3 |
| Magnesium as carbonate | 17.0 | " " | 8.1 |
| Iron and alumina carbonate | .5 | " " | .7 |
| Requiring $CO_2$ ........ 33.2 | | " " | 34.3 |
| Total encrusting solids | 73.3 | | |
| Chlorides as sodium chloride | 56.2 | Chlorine determined | 34 |
| Sulphates as sodium sulphate | 67.0 | $SO_3$ " | 33.4 |
| Total corrosive solids | 123.2 | | |
| Silica | 10.5 | | |
| Water of crystallization[1] | 3.2 | | |
| Excess of $CO_2$ | 1.1 | | |
| Combined $CO_2$ | 33.2 | | |
| Sodium chloride | 56.2 | | |
| Organic matter by difference from ignition loss | 19.9 | 19.9. Ignition loss | 113.6 |
| Total by computation | 229.1 | | |
| Total by evaporation at 105° C | 232.2 | | |
| Difference (minor errors, extra weight of potash over soda and undetermined) | 3.1 | | |

[1]The sulphates are probably in large part calcium sulphate, etc., and the soda correspondingly carbonate, reducing the amount of crystallization water.

Analysis by Kirschbraum, computation by Lane.

IRONWOOD.

From Ironwood, Dr. Vaughan has tested three kinds of water. The Montreal river, which is the public water supply, Nos. 130, 180; Pine Lake, 181, and various wells, 153, 188, etc., as follows:—

(The inorganic residue is probably, in part, silt.)

IRONWOOD.

| Location. | Pine lake.[1] | Well. | River.[3] | River.[4] | Well.[5] | Well.[6] |
|---|---|---|---|---|---|---|
| Number | 181 | 153[2] | 130 | 180 | 188 | 194 |
| Date | 9 1 93 | 4 29 90 | 1 25 92 | 9 20 93 | 8 8 93 | 6 29 93 |
| Color | yellowish | .......... | .......... | yellowish | .......... | .......... |
| Odor | musty | .......... | .......... | .......... | .......... | musty |
| Reaction | .......... | .......... | .......... | .......... | feebly alkaline | .......... |
| Hardness | 9° | 4° | 6.5° | 7° | 8° | 6.5° |
| Total residue | 550 | 117.5 | 190 | 540 | 212 | 850 |
| Inorganic residue | 470 | 70.0 | 100 | 490 | 200 | 350 |
| Organic residue | 80 | 40.5 | 90 | 50 | 12 | 500 |
| Cl as Na Cl | 1.0 | 9.9 | 5.6 | 0.50 | 3.0 | 44.58 |
| Permanganate reduced | .......... | .......... | 46.136 | 12.5 | 12 | .......... |
| Free ammonia | 0.018 | 0.176 | .103 | 0.08 | 0.10 | 0 |
| Albuminoid ammonia | 0.30 | 0.248 | .116 | 0.35 | .20 | .066 |
| Nitrates | .......... | 2.315 | trace | .......... | traces | large amount |
| Nitrites | .......... | 2.687 | trace | .......... | traces | .90 |
| Number of bacteria in 72 hours | 500 | 12 | 960 | 250 | 600 | 450 |

[1]Microscope shows vegetable fibres and algæ.
[2]Duplicate number in Vaughan's list—Microscope 100 diam.—Brownish algæ and particles of inorganic matter.
[3]Sulphate trace—Microscope—Fresh water algæ.
[4]Microscope shows vegetable debris.
[5]Indeterminate granules; bacteria.
[6]Microscope shows vegetable fibres, Diatoms, etc.



IRONWOOD.

| Location. | Waterworks. | | Waterworks. | Filter. | Well. |
|---|---|---|---|---|---|
| Number | 199[1] | 200[1] | 201[2] | 222[3] | 229[4] |
| Date | 6/17/93 | 6/10/93 | 6/4/93 | 7/27/94 | 8/23/94 |
| Color | brownish red | brownish red | brownish red | slightly yellowish | slight milkiness |
| Odor | .......... | .......... | .......... | .......... | .......... |
| Reaction | slightly acid | slightly acid | slightly acid | alkaline | slightly alkaline |
| Hardness | 2.5° | 2.5° | 2.0° | 5° | 6° |
| Total residue | 75.0 | 75.0 | 75.0 | 90 | 170 |
| Inorganic residue | 12 5 | 12.5 | 12.5 | 64 | 100 |
| Organic residue | 62.5 | 62.5 | 62.5 | 26 | 70 |
| Cl as Na Cl | 5.0 | 5.0 | 5.0 | 1.98 | 7.42 |
| Permanganate reduced | .......... | 0.0 | .......... | .......... | .......... |
| Free ammonia | 0.052 | 0.075 | 0.0084 | 0.33 | 0.018 |
| Albuminoid ammonia | 0.10 | 0.18 | 0.0528 | 0.51 | 0.200 |
| Nitrates | 0.70 | 0.6 | 0.6 | .......... | trace |
| Nitrites | 1.80+ | 8.0 | trace | .......... | faint trace |
| Number of bacteria in 72 hours | .......... | 384 | 231 | liquefaction | 1,000. |

[1]Microscope shows bacteria—Diatoms—Monads.
[2]Microscope shows Diatoms—threads of bacilli and Desmids.
[3]Microscope shows vegetable debris and bacteria.
[4]Microscope shows small deposit of inorganic matter, vegetable debris, and a few Infusoria.
In Nos. 199 and 200 the reaction was positive,—the water dangerous. The brownish red color is due to swamp water, and humic acid, as the reaction shows.

IRONWOOD.

| Location. | Well. | Well. | River. |
|---|---|---|---|
| Number | 231[1] | 232[2] | 233[3] |
| Date | 8/24/94 | 8/24/94 | 8/27/94 |
| Color | milky | slgt. milkiness | brown |
| Odor | stale, musty | ........ | ........ |
| Reaction | feebly alkal'e | slightly alk'e | slightly alk'ne |
| Hardness | 7° | 6.5° | 3.5° |
| Total residue | 200 | 210 | 120 |
| Inorganic residue | 150 | 140 | 30 |
| Organic residue | 50 | 70 | 90 |
| Cl as NaCl | 4.12 | 4.95 | 1 |
| Permanganate reduced | ........ | ........ | ........ |
| Free ammonia | 0.18 | 0.01 | traces |
| Albuminoid ammonia | 0.191 | 0.12 | 0.18 |
| Nitrates | trace | traces | faint trace |
| Nitrites | large amount | large amounts | ........ |
| Number of bacteria in 72 hours | 800 | 200 | 120 |

[1]Trace of sulphates. Vegetable debris, diatoms, algæ, infusoria. Inorganic matter.
[2]Microscope shows inorganic matter, bacteria, algæ.
[3]Microscope shows inorganic matter, a few algæ. Desmids.

| Location. | | Well.[2] |
|---|---|---|
| Number | 253[1] | |
| Date | 2/7/95 | 4/29/90 |
| Color | ........ | ........ |
| Odor | ........ | ........ |
| Reaction | alkaline | |
| Hardness | 15° | 4° |
| Total residue | 400 | 117.5 |
| Inorganic residue | 340 | 70.0 |
| Organic residue | 60 | 47.5 |
| Cl as Na Cl | 3.30 | 9.9 |
| Permanganate reduced | ........ | ........ |
| Free ammonia | 0.005 | 0.176 |
| Albuminoid ammonia | 0.04 | 0.248 |
| Nitrates | trace | 2.315 |
| Nitrites | ........ | 2.687 |
| Number of bacteria in 72 hours | ........ | 12 |

[1]Trace of sulphates. Microscope shows deposit chiefly inorganic matter.
[2]Microscope shows algæ, Infusoria, vegetable fibres, and inorganic matter.



SAULT STE. MARIE.

| Location. | | | |
|---|---|---|---|
| Number | 89[3] | 100[1] | 101[2] |
| Date | 10/28/90 | 11/17/90 | 11/17/90 |
| Color | ........ | ........ | ........ |
| Odor | ........ | ........ | ........ |
| Reaction | ........ | ........ | ........ |
| Hardness | 2° | 5° | 4.9° |
| Total residue | 89 | 153 | 107 |
| Inorganic residue | 21 | 117 | 59 |
| Organic residue | 68 | 36 | 51 |
| Cl as NaCl | 3.30 | 6.6 | 8.25 |
| Permanganate reduced | 0.632 | 5.99 | 5.372 |
| Free ammonia | 0.224 | 0.058 | 0.05 |
| Albuminoid ammonia | 0.168 | 0.104 | 0.12 |
| Nitrates | very faint trace | 0.77 | 0.965 |
| Nitrites | 0.1085 | ........ | very slight trace |
| Number of bacteria in 72 hours | 2,500 | 7 | 12 |

[1]Sulphates 5. 46. Microscope 100 diam.: Colorless amorphous matter, yellow amorphous matter, crystals,—algæ.—Desmids. 500 diam.: Colorless amorphous matter, yellow amorphous matter, crystals of Na Cl. Diatoms. Sciadium. Compsopogon.
[2]Microscope 100 diam. Colorless amorphous matter. Fibres, algæ 500 diam. Colorless amorphous matter, fibres. Draparnaldia.
[3]Microscope 100 diam. Algæ, germs, animalculæ, yellow amorphous matter. Draparnaldia and other algæ. Zooglœa, Paramecia, red spores of algæ, yellow amorphous matter, positive reaction.

AMASA.

| Number | 158[1] | 159[2] | 160[3] | 161[4] | 162[5] |
|---|---|---|---|---|---|
| Date | 11 3 92 | 11 3 92 | 11, 3 92 | 11 3 92 | 11/3/92 |
| Color | ........ | slightly turbid | ........ | ........ | yellowish |
| Hardness | 8.8° | 9.7° | 13° | 7.5° | 9.50 |
| Total residue | 100 | 200 | 190 | 420 | 110 |
| Inorganic residue | 75 | 170 | 150 | 295 | 80 |
| Organic residue | 25 | 30 | 40 | 125 | 30 |
| Cl as NaCl | 12.5 | 6.7 | 1.1 | 1.1 | 1.2 |
| Sulphates | ........ | trace | ........ | heavy traces | trace |
| Permanganate reduced | 20.54 | 25.28 | 31.60 | 18.96 | { 32.5 / 48 } |
| Free ammonia | 0.016 | 0.032 | 0.036 | 0.016 | 0.02 |
| Albuminoid ammonia | 0.113 | 0.36 | 0.15 | 0.23 | 0.23 |
| Nitrates | ........ | heavy traces | ........ | ........ | ........ |
| Nitrites | ........ | heavy traces | ........ | ........ | ........ |
| Number of bacteria in 72 hours | 44 | liquefied | liquefied | liquefied | liquefied |

[1]Microscopic appearance: Pigment granules, carbonate of lime, vegetable detritus.
[2]Mass of pigment, inorganic crystals, diatoms
[3]Microscope shows pigment granules, woody fibre. Bits of cotton fibre.
[4]Woody fibres. Pigment granules. Fresh water algæ.
[5]Under microscope. Pigment granules. Diatoms.

AMASA.

| Number | 163[1] | 164[2] |
|---|---|---|
| Date | 11/3/92 | 11/3/92 |
| Color | ........ | ........ |
| Hardness | 9° | 10.2° |
| Total residue | 460 | 170 |
| Inorganic residue | 270 | 120 |
| Organic residue | 190 | 50 |
| Cl as NaCl | 7 | 2.9 |
| Sulphates | ........ | faint trace |
| Permanganate reduced | 28.62 | 44.08 |
| Free ammonia | 0.026 | 0.03 |
| Albuminoid ammonia | 0.24 | 0.24 |
| Nitrates | ........ | ........ |
| Nitrites | ........ | ........ |
| Number of bacteria in 72 hours | countless | innumerable |

[1]Cotton fibres. Indeterminate granules. Carbonate of lime.
[2]Pigment granules, algæ, woody fibre, reaction with inoculation positive, the previous analyses negative.



The Upper Peninsula being as yet a comparatively undeveloped region, there are many wells which are very shallow and superficial. The Amasa analyses are probably of this character. The hardness, like that of Iron Mountain, is noteworthy, and suggests that the surface deposits may have come largely from the east rather than the north.

At times, however, the surface deposits and wells in them, are quite deep.

At Sidnaw, wells go through 100 feet of quicksand. Schwartz Brothers at Pentogan, T. 42 N., R. 34 W., put down a well 4 feet by 4, 43 feet deep, through till (stone, gravel, and loam), at 32 feet a two foot seam of coarse sand was dry, at the bottom a quicksand was encountered, and drilling to a depth of 195 feet encountered nothing but quicksand.

On the other hand, at the Mass City brickyard, a well over 200 feet deep encountered nothing but clay. The surface deposits of the Upper Peninsula are quite irregular in distribution. On the Copper Range, just north of the Tamarack mine there is a large deposit of irregular gravel, with marked kettles, a sort of kame deposit, probably in an angle in front of the continental ice sheet. The same phenomena are repeated at Wheal Kate south of the Atlantic mine, and for a long ways south on the crest of the range, while the country not over 600 feet above the lake has been more or less worked over by the former extension of Lake Superior, and is liable to be clay with streaks of gravel or sand along old terrace lines. The areas of Laurentian rocks are large areas of bare knobs with pocket swamp between. On the whole, large areas of the Upper Peninsula and many of its streams have very soft water, which is an important item in many manufactories.

About 3° to 4° hardness is as soft as is to be expected.

I have previously remarked that the structure of the Lake Michigan shore belt is favorable to flowing wells, and that there is a probability that such wells drawing from the Potsdam sandstone will have fairly soft water. The structure of the Lake Superior shore, on the other hand, is not favorable to flowing wells east of Marquette. From Marquette around to Pequaming some should be obtained in the sandstone that skirts the Huron mountains. Thence to the end of Keweenaw Point, flowing wells need not be expected, though they may perhaps, be obtained in the low belt of land marked by the Sturgeon and Otter, Torch lake, Gratiot lake, and Lac Labelle.

We may insert here appropriately the following analyses:—

WATER ANALYSES NEAR CALUMET AND HECLA SMELTER, TORCH LAKE.

| | 2 | 3 | 4 |
|---|---|---|---|
| Suspended sediment slight | | | |
| Silica | 3.7 | 9.5 | 24.8 |
| Iron oxide (exists as carbonate) and alumina | 2.7 | 1.1 | 1.5 |
| Calcium sulphate | 5.8 | 7.0 | 2.0 |
| Calcium carbonate | 47.7 | 79.8 | 79.1 |
| Magnesium carbonate | 30.5 | 31.2 | 21.2 |
| Sodium chloride | 21.3 | 10.7 | 4.8 |
| Potassium chloride | trace | trace | 0.8 |
| Nitrates | trace | .035 | $K_2CO_3$ 1.3 |
| Difference (organic or undetermined matter) | 34.1 | 9.0 | 1.4+ |
| Loss on ignition direct | (23.1) | (14.3) | |
| Total solids | 145.8 | 148.3 | 137.0 |

Parts per million.

These three analyses were all by G. L. Heath.

2. 10/1/1900, from the outside casing, down into solid stone, in parts per million.

3. Water from 80-foot wells at the C. & H. smelting works, Sept., 1900, driven just to sandstone, through the following strata:—

| | Thickness. | Depth. |
|---|---|---|
| Soil and reddish sand............... | 6 to 10 ft | 6 to 10 |
| Red hard pan...................... | 6 to 10 ft | 16 to 20 |
| Clear white beach grit, some pebbles and boulders ..................... | 50 to 60 ft | 78 to 88 |
| Gravel and red sandstone........... | 2 ft | 80 to 90 |

Wells from the base of the drift are characteristically harder and have less salt, the total solids being about the same, yet this water though about twice as hard as Lake Superior, is only about half as hard as a normal Lower Peninsula water.

4. A driven well sunk in the beach near the Calumet & Hecla Mining Co.'s pumping station, on the west shore of Keweenaw Point, is evidently not at all Lake Superior water, but much like No. 3 and drift water. The water must come from the land side, and in fact, has a head of one foot above the lake. It illustrates the same principle as that of the well known fact that fresh water can often be found by digging down into a salt water beach. Outside the casing of the 500-foot well, comes a water very similar but with slightly less salt. The 1,500-foot well, it is said, never struck salt water, or indeed, very much water anyway, at the bottom. This 1,500-foot well, is, however, now filled up several hundred feet, so that it is now pumped (air lift or Pohlé system), the water coming from the first 500 feet. There was also a well at Mills, 500 feet deep, furnishing water of the same composition as that from the deep one.

Beginning from the end of Keweenaw Point, however, the conditions of strata dipping toward the lake are once more favorable to flowing wells clear to the Wisconsin line. I accordingly favored putting down a well near the lake shore at Freda, the stamp mill site of the Copper Range Company, Sec. 25, T. 35 N., R. 35 W. The results were disappointing. It was 18 feet to bed rock, and the well is said to have flowed slightly in the first 100 feet,—possibly from the surface deposits. The strata were red all the way down, sandstone but more or less basic, calcareous and much cemented, and this feature probably accounts for the relatively poor yield of water, and more or less shaly. In particular, from 910 to 950 feet, the beds were shale, making a regular red mud under the drill and underneath this the water was decidedly brine. The record is given below. It is obvious that this well is important in many ways. It indicates that, as was long ago held by [1]Irving, the sandstones east and west of the Copper Range are not of the same character, the character of this Freda water being much more like those of the deep waters of the Copper Range than like that of the Lake Linden well.[2]

[1]Copper Bearing Rocks, chapters V and VII.
[2]Above, pp. 143, 163.



RECORD OF FREDA WELL.

Drilled by Chas. Coryell for Champion Mine.

Surface, muck, sand, etc., thickness, 18; total, 18.
Temperature of strong spring near by, 45° F.
Surface puddles, 50° F., June 22, 1902.
Top beds, dark maroon sandy shales, with much basic matter.
Water ever since, surface water not entirely cased off, water came to surface one day, in first 150 feet, but only once.
Temperature at top of water, 45.5° F., at about 100 feet.
March 5, at 150. Cased.
Water level about 50 feet down at 500-600 feet after stopping the drill over Sunday, March 28, at 400.
Temperature observed by Sheldon 51°, at 480; thermometer, 9111.
Temperature observed by Sheldon 51.5°, at 550.
Temperature observed by Sheldon 51.5°, at 636.
Alternate hard and soft streaks at 600.
Temperature after 12 hours suspension of work, 50°, at 730.[1]
Temperature after 8 days suspension of work, 49°, at 730.
Red shale, 40, 950.
Average speed, 1 foot in 3 hours.
June 22, finished at 970 to 950 feet.
Water level at 100-150 feet below ground on Monday, and bailing 18 to 20 times made no appreciable difference in the height.
Temperature, 49° at 730 feet.
Temperature at bottom, 55° (950), by 9109 Greene's thermometer.
Temperature 55.6° at bottom by 9111.

The temperature observations are not satisfactory, but the increase of 4° to 4.6° in 950—480=1° in 80 feet, to 1° in 87 is about equivalent to the total increase of 55.6° to 55°—45° to 43=1° in 85 feet to 1° in 80 feet.

The water from the bottom June 22, was found to have a sp. gr. of 1.07, and the sample taken for analysis a week or two before gave Dr. Koenig: sp. gr. 1.0511.

| | Grams per kilogram. |
|---|---|
| Ca $Cl_2$ ........................................ | 44.51 |
| Na Cl ........................................ | 19.29 |
| K Cl ........................................ | 0.56 |
| Mg Br ........................................ | 0.24 |
| Mn ........................................ | 0.57 |
| | 65.47 |

The Midland Chemical Co. also tested the same (Jan. 23, 1903) and found sp. gr. 1.049, Br .35 grams per kilogram, equivalent to Mg $Br_2$ .40.

This relative to the specific gravity is about as strong as the Midland water, and reminds one at once of the waters from the Tamarack and Quincy mines given above.

[1]Observed by driller, perhaps warmed too much in putting in and out. Thermometer at those low temperatures must be handled very promptly as the drill house is very hot often.

To compare with the Freda water, the Quincy water, and the Tamarack water, we have the following interesting analyses of the water from the bailer of the Vertical or Whiting shaft of the Calumet and Hecla, 4,960 feet deep. The water pumped from the Hecla end of the mine at much less depth, is "even more saline." These waters are in contrast with the shallower carbonated waters, say those of the Winona or Arcadian. It is noteworthy how small is the percentages of sulphates, as well as carbonates. That, to my mind, militates against any theory of origin of these deposits from sulphides. The minute quantities of nickel, copper and zinc with iron, point rather to olivine, or some such ferro-magnesian (femic) silicate as the original source.

| Details of probable compositions in sediment. | Mine water, C. & H. Vert. shaft. | | Atlantic ocean. |
|---|---|---|---|
| | Grams per liter. | Grains per U. S. gallon. | Grains per U. S. gallon. |
| Insoluble silica | .0222 | 1.29 | ............ |
| Insoluble oxide of iron | .0127 | .74 | ............ |
| Dissolved silica ($SiO_2$) | .0033 | .19 | ............ |
| Dissolved chloride of iron | .0045 | .26 | ............ |
| Zinc chloride (with trace nickel) | .0290 | 1.69 | ............ |
| Copper chloride ($CuCl_2$) | .0045 | .26 | ............ |
| Magnesium chloride | .0875 | 5.10 | 276.5 |
| Sodium chloride (salt) | 1.88 | 109.37 | 1,522.85 |
| Potassium chloride | .074 | 4.31 | 53.25 |
| Potassium bromide (in ocean only) | ............ | ............ | 33.65 |
| Calcium chloride | 3.138 | 182.87 | 90.10 |
| Calcium sulphate | .0555 | 3.23 | ............ |
| Sodium sulphate (in ocean only) | ............ | ............ | 261.30 |
| Calcium carbonate (dissolved by free carbonic acid) | .248 | 14.46 | ............ |
| Loss on ignition (actual determination) | 1.08 | 63.0 | ............ |
| No lithium. Undetermined balance traces carbon, etc. | ............ | ............ | ............ |
| Sum of all constituents | 6.65 | 386.77 | 2,237.65 |
| "Total solids" on evaporation as weighed {354+ / 383+} | 6.32 | 368.5+ | 2,238.72 |

G. L. HEATH.

While, therefore, there is a possibility of artesian wells along the Lake Superior shore of Keweenaw Point and the Porcupines, unless they are not deep the water is likely to be a mineral water,—perhaps even valuable for the manufacture of bromine and other salts.

## WATER POWER.

In regard to the question of water power, that subject has been in the hands of Mr. R. E. Horton of the U. S. Geological Survey, to whom I have given various assistances at different times. Mr. W. M. Gregory



and W. V. Savicki have also aided him. The result of his work in this state will be found in the U. S. Geological Survey Water Supply Papers, No. 30, No. 49, pp. 239-260; No. 65, p. 315; No. 75, p. 111; No. 83, pp. 241-297; and the Michigan Engineer for 1901. In an official letter, correcting No. 83, we have the following discharge measurements on the Au Sable river at the gauging station at Bamfield, Michigan:—

| Date. | Hydrographer. | Gage height (feet). | Discharge (sec. ft.). |
|---|---|---|---|
| August 14, 1902 | Horton & Gregory | ............ | 1,133 |
| August 26, 1902 | W. M. Gregory | 0.82 | 1,026 |
| September 17, 1902 | W. M. Gregory | .80 | 998 |
| October 7, 1902 | W. V. Savicki | 0.72 | 981 |
| March 6, 1903 | Horton & Roundy | 1.10 | 1,176 |
| March 13, 1903 | E. P. Roundy | 2.60 | 1,999 |