GEOLOGY AND GROUND WATER OF THE TROUT LAKE REGION, VILAS COUNTY, WISCONSIN*

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From the Limnological Laboratory of the Wisconsin Geological and Natural History Survey. Notes and reports No. 81.

INTRODUCTION

The material for this report was gathered under the direction of the Wisconsin Geological and Natural History Survey in an effort to obtain information on ground water movement and the relation of the geology to the chemistry of the waters of several lakes in northeastern Wisconsin. The problem had been raised as to whether these lakes represent perched water tables or whether there is interchange of lake and ground waters.

The area studied lies in southern Vilas County, Wisconsin, and detailed work was limited to the southern half of T.41N., R.7E. The field work was done during July and August of 1936 near the Limnological Laboratory of the Wisconsin Geological and Natural History Survey at Trout Lake, Wisconsin. The geology was determined from road cuts, test pits, and well cuttings. The test pits were about three feet wide, five feet long, and four to twelve feet deep, permitting examination of the material in place. The well cuttings were used for determining the nature of the deeper drift.

The elevations of some of the lakes were determined under the direction of the writer by students of the Armour Institute of Technology in training in the summer camp at Trout Lake. Other elevations were obtained by the writer with a telescopic alidade, plane table, and engineer's rod. The chemical analyses of water samples were made by chemists of the Laboratory. Information on well depths and water analyses was obtained from the Survey records. Samples of well cuttings were taken from wells drilled during the summer. Numerous samples of soil and glacial deposits were collected and examined for size, assortment, and presence of calcareous material.

* This investigation was supported by a grant from the Brittingham Trust Fund.

Three samples of clay were analyzed quantitatively for content of calcium and magnesium. These came from the till in the Winegar moraine, the till in a drumlin west of Trout Lake, and a deep well east of Crystal Lake. The first two were screened through a 150 mesh screen, and the third was used as found. The material was dried at 100°c., and a five gram sample of each was stirred for five minutes in 30 cc. of 1:1 HCl. The solutions were neutralized and filtered, and the calcium precipitated as an oxalate and titrated with standard permanganate solution. The magnesium was then precipitated as magnesium ammonium phosphate, filtered, ignited, and weighed. The calcium and magnesium were calculated as carbonates and percentages were figured by weight. This procedure seems satisfactory for the purpose at hand.

Helpful criticism and suggestions were offered by W. H. Twenhofel, E. F. Bean, C. Juday, and R. R. Shrock. Aid in interpretation of glacial history was kindly offered by F. T. Thwaites.

Geology of the Area

The bedrock underlying the area studied seems to be entirely crystalline (Thwaites 1929). Inasmuch as crystalline rock excludes practically all free water, except that held in joints, a study of the ground water in this region is largely limited to a study of the overlying unconsolidated drift. This drift is largely composed of gray and pink granites, pink rhyolite, gabbro, basalt, gneiss, and schist. Lesser quantities of red sandstone, red slate, red iron formation, and quartzite are present. There is an occasional pebble of chert, but no limestone or dolomite was found near the surface. The known maximum depth of the drift, found by well drilling in section 7, T.41N.,R.7E. exceeds 225 feet.

Moraines

The Muskellunge moraine (Fig. 4) is an east-west trending ridge of discontinuous, irregular knobs. These knobs are composed of stony, ill-assorted material which contains many large boulders and very little clay. Much of the moraine is kame deposit of interbedded sand and stony gravel. The upper two and one-half feet of the material is light tan in color and is underlain by two feet of dark brown-red, oxidized drift. Below the zone of weathering, of which the depth is quite irregular, the color of the drift is light brown-red. This is not a calcareous drift. Steep-sided kettles are numerous. Few of these contain water, probably due to their comparative height and the porosity of the underlying material; they are not well enough sealed to hold water above the general water table. The highest part of the Muskellunge moraine is the knob on which the fire tower stands.

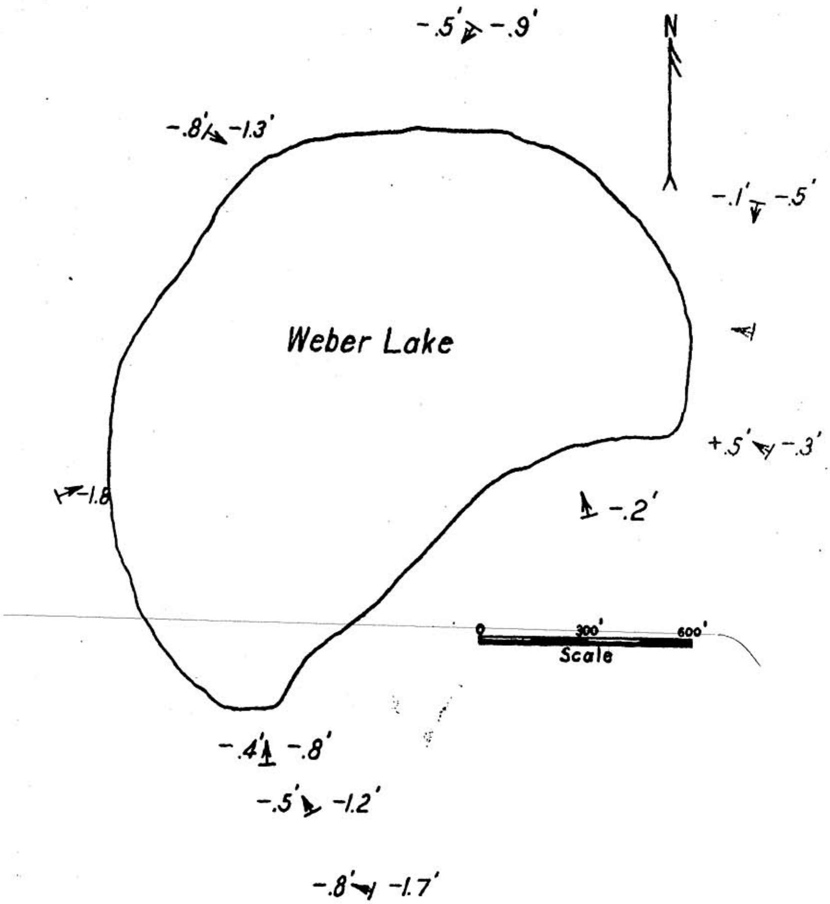

FIG. 1. Location of test pits around Weber Lake indicating relation between lake level and ground water table. The arrows indicate the direction of the dip of stratified sands in the test pits. Figures at the left of the arrows indicate the water table level relative to the lake level on August 31, 1936.

This is 1847 feet above sea level and two hundred feet higher than the sand plain north of the moraine in which Crystal and Weber lakes lie.

The Boulder moraine (Fig. 4) is even more discontinuous than the Muskellunge. Like the latter, it seems to be a typical recessional moraine composed chiefly of kames. It is lower in elevation, and much of it either is covered by outwash or was eroded away by water which drained from the melting ice to the north. North Trout Creek lies in a broad valley which cuts through the moraine.

The Winegar moraine is a broad, continuous ridge which extends across the northern portion of the county and is about six miles north of the Boulder moraine. It differs from the two southern moraines in that it is composed chiefly of till which is brighter red in color and contains a much larger percentage of clay. Analysis of the fine material from the till of this moraine which passes through a 150 mesh screen indicates that it contains 7.45% $CaCO_3$ and 0.51% $MgCO_3$ by weight. It is probable that this is a terminal moraine of the fourth Wisconsin (Mankato) substage (Leverett 1929). It may possibly cover a recessional third Wisconsin (Cary) moraine of red sandy till (Thwaites 1937). Striae on many outcrops of bedrock north of Winegar indicate that the ice which brought the red clay till moved S 10°-20°W.

Ground Moraine

The region east of Trout Lake, adjoining Allequash and Little John lakes (Fig. 4), is composed of material and has topography similar to that of the Muskellunge and Boulder moraines. The elevations of the hilltops are unequal and considerably higher than the surrounding outwash plains. Small patches of till are present, though much of the material is partially washed. The till, like that in the moraine, is low in clay content and is light brown-red in color. A large esker trending N 30°E extends from Allequash Creek, near Trout Lake, for a distance of about a mile.

Drumlins

A group of drumlins lies to the west and northwest of Trout Lake. (Fig. 4). These hills rise high above the level of the outwash plains and have their long axes trending about S 35°W. A large road material pit in a drumlin on Highway 51, west of Trout Lake, shows the material to be unstratified and unassorted drift. The weathered zone is like that of the till in the moraines. Many of the rounded stones of the coarser-grained igneous rocks are so weathered that they can be easily crumbled by hand. Glacial striae are excellently preserved on the large boulders. Analysis of the fine material which passes through a 150 mesh screen indicates that it contains 6.50% $CaCO_3$ and 0.47% $MgCO_3$ by weight, only slightly less than in the till of the Winegar moraine.

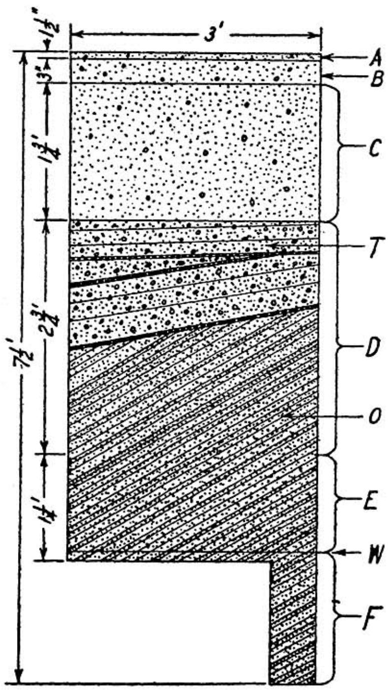

FIG. 2. Composite diagram illustrating material and structure of deposits surrounding Weber and Crystal lakes. The letter A represents sand blackened with organic matter; B unstratified, light-gray, leached sand; C unstratified fine- to coarse-grained, dark brown sand containing numerous pebbles; D fine- to coarse-grained, light yellow sand containing pebble beds, well defined stratification with topset overlying foreset beds; E zone of iron concentration, banded, mottled, bright rusty-yellow sand, partially cemented; F laminated, fine- to coarse-grained, uncemented, pale yellow sand; O foreset beds, fine- to coarse-grained, light yellow sand without pebbles, well defined stratification; T topset beds; W water table.

Color and calcareous content suggest that there is a genetic relationship between the two drifts. Only one striation indicating direction of ice movement has been found south of the Winegar moraine. This is on a bedrock ledge in section 34, T.43N.,R7E. and trends about S 50°W. (Thwaites 1929).

A unique feature of the drumlin observed is a well defined cleavage concentric to its surface. The layers are one-sixteenth to one-eighth inch in thickness. The cleavage surfaces curve up over and down under the pebbles and bowlders. All observed material below the active zone of weathering shows this pseudo-bedding. The till is extremely hard packed, stands in vertical faces, and is easily separated into thin layers along these cleavage surfaces. Alden (1905) has described this feature in till of drumlins in southern Wisconsin. Many of the pebbles and bowlders in the till are coated with iron oxide which gives them a dull blue-gray sub-metallic luster. This coating is not present on pebbles in the outwash.

Outwash

The greater part of the surface material south of the Winegar moraine is water-sorted, stratified sand and gravel. This material offers a minimum of resistance to ground water movement. It forms southwestward sloping plains of varying elevations which were determined by the drainage outlets available at the time of its deposition, and the majority of the lakes lie in depressions in this outwash. The plains exhibit erosional and ice contact terraces. The former are well developed along Little Trout River; ice contact terraces border Stephenson Creek. The highest plain, against the south edge of the Muskellunge moraine, lies at an elevation of about 1700 feet. A similar high plain, bordered by ice contact terraces on the south, lies north of Trout Lake. A lower plain, about 1655 feet in elevation, extends east-west just north of the Muskellunge moraine. A third plain, at about 1620 feet, surrounds Trout Lake and extends westward along Little Trout River.

Deep Drift Deposits

Information on deep drift deposits was obtained from well drillers and from examination of a few samples from wells drilled during the summer. The description of the material is given below in tabular form. The wells are located by number in Figure 4.

Well No 6

East end of Crystal Lake. Elevation 1650 feet, 5 feet above water table.

Description	Thickness (feet)	Depth (feet)
Yellow sand	30	0- 30
No information	50	30- 80
Laminated, rubbery, calcareous, gray clay	8	80- 88
Gray sand with thin laminae of gray clay	7	88- 95
Gray, sandy gravel	7	95-102
Coarse, well washed, gray gravel, plentiful water supply	5	102-107

Quantitative analysis of the clay from this well shows it to contain 31.65% $CaCO_3$ and 2.52% $MgCO_3$. These percentages contrast significantly with the clays of the upper drifts. The sand and gravel below the clay contain a much higher percentage of dark-colored, ferro-magnesian minerals than does the surface material. This gray gravel also contains pebbles of dolomite, whereas none was found in the upper drift.

Well No. 5

Between Crystal and Muskellunge lakes. Elevation 1650 feet, 5 feet above water table.

Description	Thickness (feet)	Depth (feet)
Well driller reports material similar to that in No. 6		98

Well No. 4

Just south of Allequash Creek along the shore of Trout Lake. Elevation 1622 feet, 8 feet above water table.

Description	Thickness (feet)	Depth (feet)
Yellow, gravelly sand	10	0-10
Poorly sorted, yellow to brown sand, silt and gravel	25	10-35
Gray, sandy gravel, good water supply	5	35-40

The gray, sandy gravel contains occasional pebbles of dolomite and is composed of a higher percentage of ferro-magnesian minerals than is the yellow sand and gravel above it.

Well No. 3

Near Trout Lake shore at Laboratory. Elevation 1620 feet, 5 feet above water table.

Description	Thickness (feet)	Depth (feet)
Brown to yellow sand and gravel	35	0-35
Gray, sandy gravel	22	35-57

Well No 2

One-eighth mile north of Stephenson Creek along shore of Trout Lake. Elevation 1620 feet, 6 feet above water table.

Description	Thickness (feet)	Depth (feet)
Brown to yellow sand	35	0-35
Reddish-brown till	40	35-75
Water-bearing, coarse gravel	10	75-85

Well No. 1

Point Campsite, about 300 feet from Trout Lake shore. Elevation 1640 feet, 25 feet above water table.

Description	Thickness (feet)	Depth (feet)
No information	200	0-200
Rubbery, gray clay	?	200- ?
Coarse, water-bearing gravel	?	? -223

In all of the records of these deep wells it is notable that gravel deposits underlie either clay, till, or outwash of a different character. The deep drift is gray in color, contains pebbles of dolomite, and is composed of more basic rock than is the surface drift. It will be shown that the character of the water coming from the deeper horizons reflects the changed composition of the material.

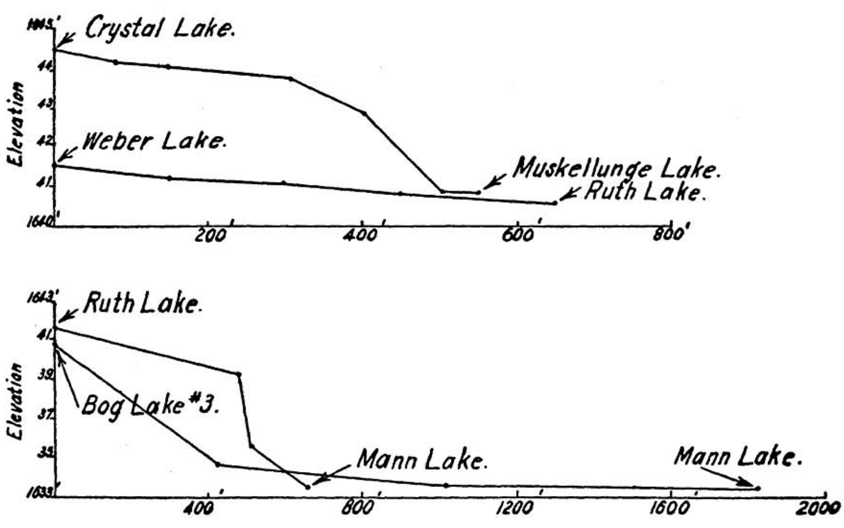

FIG. 3. Diagrams illustrating the irregular drop of the water table between lakes. Dots represent elevation of water table in test pits.

Material Around Weber and Crystal Lake Basins

Weber and Crystal lakes lie in a flat, sandy plain north of the Muskellunge moraine. (Fig. 4). The material of this plain is principally sand and silt which shows fair sorting. The locations of test pits dug around Weber Lake are shown in Figure 1. The arrows indicate the direction of dip of the stratified sands. The lower beds dip at an angle of 30° to 35° and these are overlain by nearly horizontally stratified sands. (Fig. 2). No stratification is observable in the weathered zone extending down-

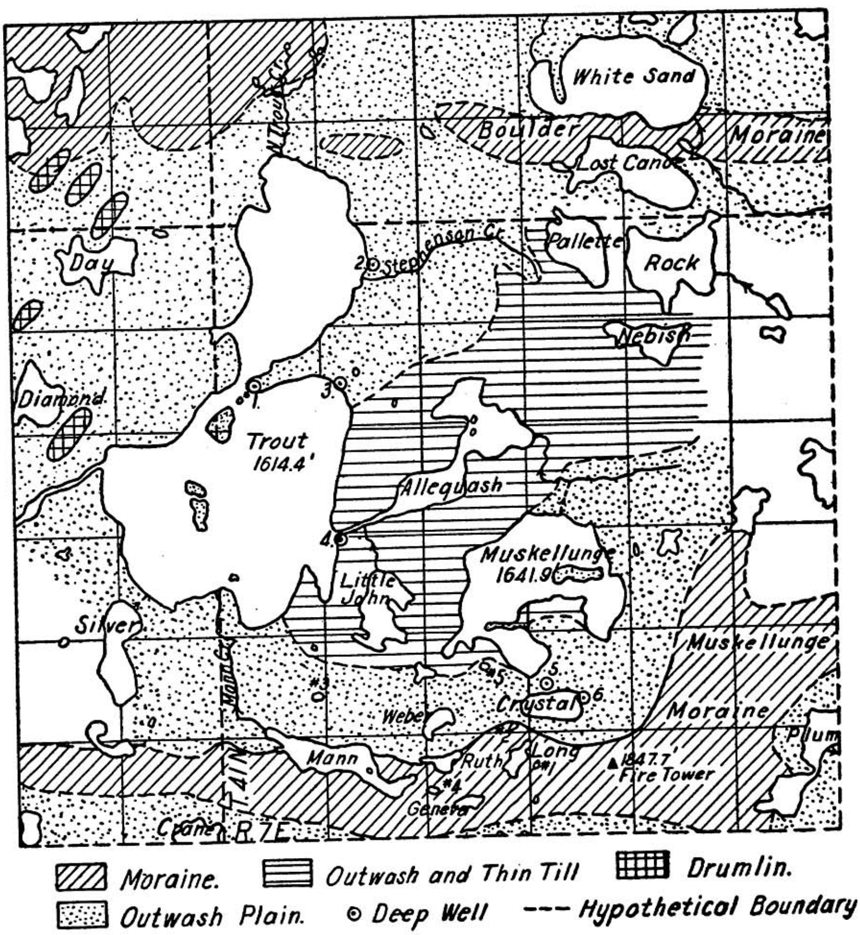

FIG. 4. Glacial features of Trout Lake region. After F. T. Thwaites, 1929.

ward for two and one-half to three and one-half feet from the surface, probably due to disturbance by roots and chemical alteration. The top two to three inches of the material grades from black, through gray to brown. The remainder of the weathered zone is dark brown in color and contrasts with the light yellow unaltered sands below. Bright yellow and brown, irregular bands of iron concentration are present at or just above the water table, four to eight feet below the surface. Test pits around Crystal Lake reveal the same type of material and structure. Between the two lakes the sands dip toward Weber Lake.

Two test holes were made with the use of a small casing and bailer near the west shore of Crystal Lake in about four feet of water. The depth of the holes was from three to five feet. Neither clay nor gravel was found, but only gray to yellow sand containing small quantities of organic matter. This seems to be leached beach sand derived from the shores by erosion during periods of high water. With the apparatus available it was not possible to go deeper.

It is possible that this region was a large lake which received melt water from blocks of ice to the north, south, and east. The present basins were preserved by stagnant masses of ice. Drainage from the lake was toward the west around the southern side of the huge ice mass which must then have occupied the Trout Lake basin. Inasmuch as the bedding of the sands around Crystal and Weber lakes is apparently undisturbed, it is suggested that glacial drainage continued a short time after the ice blocks in the basins had melted, thus causing partial fills by sands. This would account for absence of till near the surface, absence of a till seal around the sides of the basins, and absence of lake clays.

Summary

Study of the materials in well cuttings, test pits, and road cuts indicates that three types of drift overlie the crystalline bedrock of this region. The deep drift is gray in color and contains a high percentage of dark-colored minerals. In it are pebbles of gray dolomite and deposits of gray, calcareous clay. This drift is found only in deep wells and is not known to be at the surface anywhere in the area. It is possibly of Tazewell age or older.

A second type of drift is brown-red in color. It contains very little clay. The percentage of dark-colored minerals is small and dolomite seems to be absent. The fine material passing a 150 mesh screen is low in carbonates. From the information available, it appears that its thickness is extremely variable. This drift occurs at the surface south of the Winegar moraine. It is probably of Cary age.

A third type of drift contains a high percentage of clay and is bright red in color. Calcareous content is low. This drift is present at the surface in and northward from the Winegar moraine. It is probably of early Mankato age. (Leverett 1929).

The evidence is sufficient, the writer feels, to conclude that these drifts represent three separate advances of glacial ice; the first may have come from nearly east, and the second and third came from the northeast and the north-northeast.

The lakes in the Trout Lake region do not lie in basins whose sides are sealed by till or clay. Sand and gravel are mixed with small quantities of silt and clay, thus permitting slow movement of water.

Chemistry of Lake and Ground Waters

Samples of water taken from lakes, wells, and pits were analyzed at the Survey Laboratory at Trout Lake throughout the summer. These analyses indicate the parts per million of bound carbon dioxide, calcium, magnesium, iron, and silicon dioxide which are in solution in the water. Figure 6 shows the locatons from which these water samples were taken; the figures represent the parts per million of calcium plus magnesium.

Lake Waters

All the lakes in the area are classified as soft water bodies. The bog lakes which are isolated from drainage, regardless of elevation, are by far the softest, and their waters are almost as pure as though distilled. The seepage lakes—Crystal, Long, Geneva, Weber, Ruth, Little John, Jr., and Muskellunge—form a second group with slightly more mineral matter in solution. The drainage lakes—Allequash, Little John, Mann, and Trout—have the greatest quantity of dissolved minerals and form a third group. (Table I).

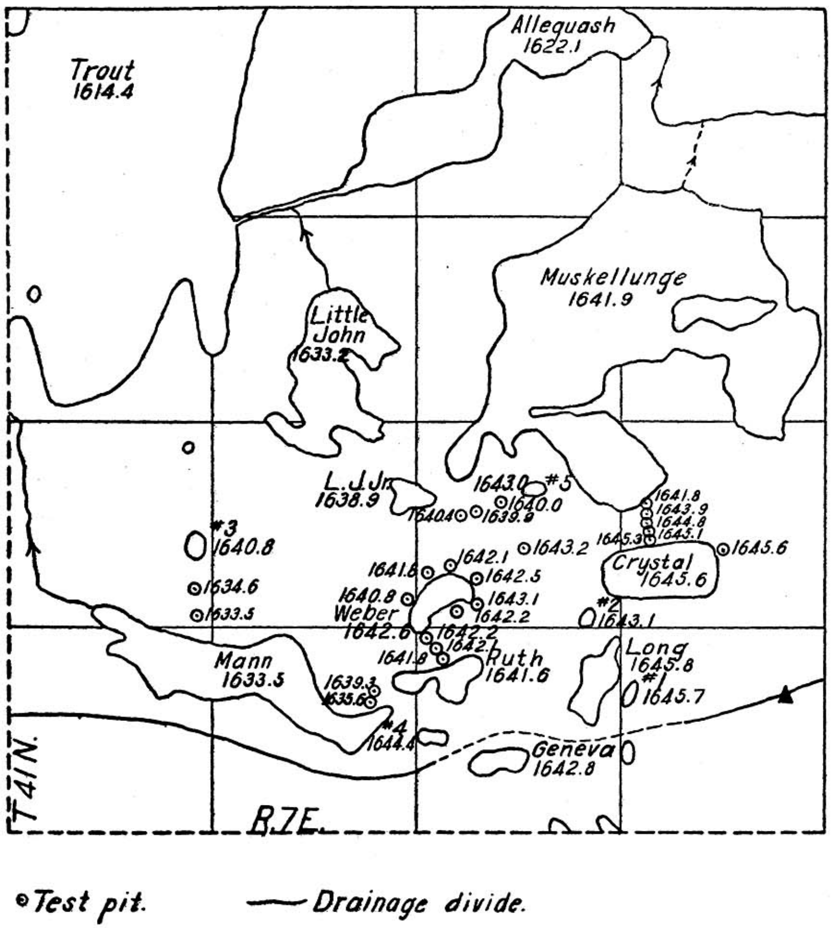

FIG. 5. Water table elevations in test pits and lake elevations.

The bog lakes are almost totally sealed from the surrounding ground water by accumulated organic matter on their sides and bottoms. They receive a small amount of run-off, and precipitation in the form of rain and snow. Thus but little mineral matter is brought into them. The abundant organic matter growing in these lakes undoubtedly uses some of that supplied and locks it up in the bottom deposits.

The lakes with neither inlets nor outlets, but which are not yet sealed by organic matter, apparently receive and deliver water through their basins. The rate or extent of flow can not be determined, and that it takes place is purely hypothetical. Further evidence rests in water table and lake elevations. At any rate, these waters are, in general, harder than the bog lakes.

The drainage lakes are notably harder than the other types of lakes. It must be inferred that these lakes receive a plentiful supply of water by seepage, inasmuch as some of them do not have inlets, yet they supply constant outlet flows.

TABLE I

Chemical analyses of different types of lake waters. The results are stated in milligrams per liter of water.

	Bound CO_2	Ca	Mg	Fe	SiO_2	Ca+Mg
Bog Lakes						
No. 1	3.00	1.00	0.60	0.08	1.00	1.60
No. 2	3.00	0.80	0.10	0.18	2.00	0.90
No. 3	1.50	0.44	0.30	0.06	0.50	0.74
No. 4	1.35	0.60	Tr.	0.04	0.35	0.60
Seepage Lakes						
Crystal	1.50	1.08	0.60	0.05	0.20	1.68
Long	1.50	0.76	1.74	0.05	0.35	2.50
Geneva	1.75	0.68	0.50	0.30	0.20	1.18
Weber	2.25	1.07	0.58	...	0.20	1.65
Ruth	1.00	0.28	0.50	0.50	0.24	0.78
Little John Jr. ...	1.30	0.60	...	0.08	0.50	....
Muskellunge	9.90	5.72	...	...	...	....
Drainange Lakes						
Allequash	20.70	12.24	4.00	0.32	5.20	16.24
Little John	17.80	14.00	4.00	0.23	3.00	18.00
Mann	25.80	14.60	5.09	0.14	7.50	19.69
Trout	18.50	10.90	...	...	6.70	....

Ground Water at the Water Table

The ground water at the water table is related to nearby lake waters in mineral content. Crystal Lake has 1.7 parts per million of calcium plus magnesium in its water. The ground water at the east end of the lake contains 2.3 parts. Samples of ground water around Weber Lake contain 2.2, 2.5, 5.5, 2.2, 2.2, 1.9, 1.3, 3.6 parts, and the lake contains 1.7 parts. Figures for Little John Lake are 18.0 for the lake and 21.1 for the ground water at the north end of the lake near its outlet. Mann Lake contains 19.7 parts and the ground water varies from 6.3 to 15.9. The figure for Mann Creek is 20.6 and for the ground water nearby 20.0. (Fig. 6).

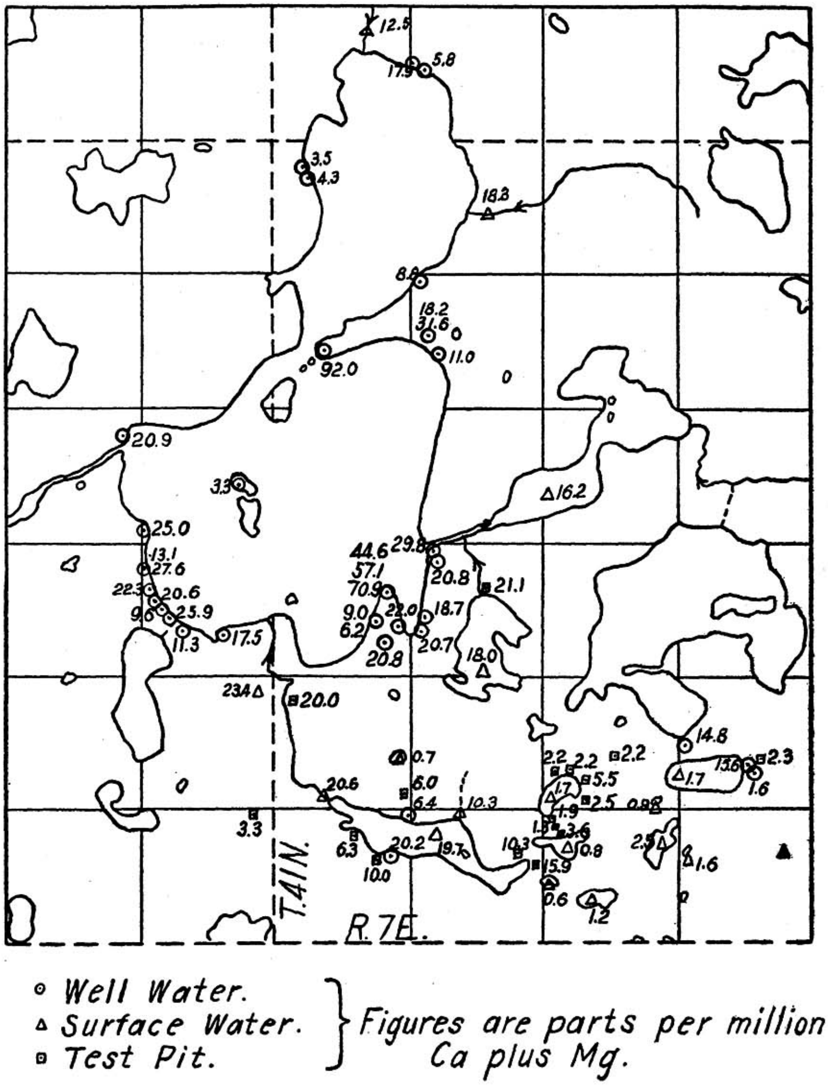

FIG. 6. Calcium and magnesium content of waters from wells, test pits, and the surface of the lakes.

From the figures quoted above it is apparent that the ground water is similar to the adjacent lake waters, with the exception of the bog lakes which are in a special category. This similarity suggests that there is interchange of lake and subsurface water, even though there are no visible surface inlets or outlets. We may conclude, then, that the lakes do not lie in sealed basins.

Well Water

The greatest number of the water analyses were made on samples taken from wells. The depth of only a small percentage of the wells is known. These are chiefly the wells which have been drilled within the past few years. In all known cases the shallow wells are notably softer than the nearby deep wells. At the east end of Crystal Lake, a very shallow well has 1.6 parts of calcium plus magnesium per million, while a well with a depth of 107 feet, within 30 feet of this shallow well, has water which contains 15.6 parts. A similarly deep well at the north side of the lake tests 14.8 parts.

On the southwest shore of Trout Lake, a shallow well was deepened during the summer from 22 to 140 feet. The hardness of the water increased from 13.1 to 27.6 parts of calcium plus magnesium. The wells at Rocky Reef on the southeast shore of Trout Lake are peculiarly hard, even though they are shallow. This may possibly be due to surface contamination by sewage, inasmuch as wells of similar depth nearby are much softer. A 225 foot well on the Point between the north and south portions of Trout Lake contains 92.0 parts of calcium plus magnesium per million. This is the hardest water known in the region.

Although wells vary in hardness at the same depth from place to place, in every known case the hardness increases with depth, discounting possible surface contamination. The solvent action of water increases with depth, but the enormous increase in hardness in the well waters in the region cannot be thus explained. Evidence indicates that it is due to material which contains more limestone or dolomite than does the surface drift. This increase is explicable if a calcareous drift of different age and origin underlies the surface deposits.

WATER TABLE ELEVATIONS

Lakes

The Muskellunge moraine forms the drainage divide between the Manitowish River to the north and the Wisconsin River to the south. (Fig. 4). It is apparent from the map that there is a regular decrease in elevation of the lakes from the divide northward and westward. It seems probable that Trout Lake receives drainage from the south, east, and north by both run-off and seepage. The lakes are thus connected and form parts of a sloping water body whose flow is retarded and regulated by the nature of the surficial deposits, which in this region are chiefly sand and gravel with varying small quantities of silt. Bog lakes No. 3 and No. 4 are several feet higher than would be expected. (Fig. 5). These lakes are small and lie in basins lined with many feet of organic matter which serves to nearly seal them. Thus they do not drop as rapidly as the water table during the dry season of the year when the latter is being lowered by seepage and plant life. Readings taken early in the spring and late in the autumn would more clearly reveal the relation between the bog lakes and the water table.

Water Table

Figure 5 shows both water table and lake elevations. A cursory study of these elevations strikingly brings out the relation between the two. It is shown that the water table slopes gradually between two lakes of different elevation, indicating drainage from one to the other. (Fig. 3). It is also noticeable that although the water table is lower than a lake on one side, yet it is higher than the lake on some one of the other sides. Figure 1 illustrates relative readings taken early and late in the summer around Weber Lake. In every case the reading of the water table taken in early July was higher than that taken at the end of August. The early reading showed the water table to be higher at the east end of the lake. In late August, however, all readings showed the water table to be below lake level. The lake was raised by rains during the last two weeks in August. All of this water was probably absorbed by the dry sands around the lake before reaching the water table. Thus the effect was noticeable on the lake level while the water table continued to lower by seepage. There is an apparent lag in equalization between the two.

The foregoing evidence from elevations of water table around the lakes studied leads us to the conclusion that the basins in which they lie are not sealed; they do not represent perched water tables; they are integral parts of the ground water of the region.

Conclusions

The region under consideration has been found to be one of surficial stony, sandy, non-calcareous drift. This drift contains little clay. A lower, calcareous drift of different age and origin is shown to underlie this at varying depths. It contains lenses of calcareous clay, sand, and gravel.

Upper ground water is notably soft, but there is an increase in hardness with increase in depth, undoubtedly due chiefly to the character of the lower drift. The hardness of the lake waters increases relatively to their distances away from the divide, since the ground water must pass through greater quantities of drift. The hardness of the water in Mann Lake is explicable if the calcareous drift lies higher than lake level under the moraine to the south.

The seepage and drainage lakes in the region, although in ice-formed kettles, are not sealed by till and do not represent perched water tables. The only evidence of any seal from ground waters lies in the organic matter which lines the basins of the bog lakes. Evidence points to exchange of lake and ground water, slight in the case of seepage lakes and pronounced in the drainage lakes. The water table does not descend away from the divide at a uniform gradient; it is characterized by irregular drops. This can be expected only where materials are heterogeneous as they are in this region.

Suggestions for Future Research

Little is known of the glacial history of this region prior to the retreat of the last ice. For a better understanding of the character of the ground water it is suggested that the number, age, and origin of the different drifts be studied, in conjunction with their lithological composition. Tracing of moraines and location of bedrock outcrops in the neighboring territory may aid in revealing direction of movement of glacial ice. Arrangements should be made with well drillers to secure samples taken at five foot intervals from all new wells. Detailed analysis of mechanical and mineralogical composition of these samples might reveal the exact source of the minerals in solution in the waters, as well as aid in deciphering glacial history.

In the study of ground water movement it is suggested that observation wells be established around several of the lakes, extending below the water table and so constructed that measurements of elevation can be made frequently throughout the year. Gauges should be established on some of the lakes and frequent checks made on changes of level. Precipitation data can be correlated with these results. Dyes or chemical solutions may be introduced into the ground in an attempt to gain positive evidence of movement. This may be found effective particularly where the slope of the water table is greatest and movement is at its maximum.

Further study on the problem of lake basin seal is suggested. Inasmuch as the material surrounding the lakes contains no evidence of any seal it is suggested that careful analysis be made of material taken from test holes into their bottoms in an effort to locate the position of the till which dropped from the melting ice blocks which formed them. This study should include analysis and determinations of thickness of organic matter and sediments in the deeper parts of the lake basins.

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