University of Wisconsin-Extension

GEOLOGICAL AND NATURAL HISTORY SURVEY
3817 Mineral Point Road
Madison, Wisconsin 53705

M.E. Ostrom, State Geologist and Director

FIELD REPORT, GLACIAL GEOLOGY OF PORTAGE, WAUPACA AND OUTAGAMIE COUNTIES

by

F.T. Thwaites

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1927

FIELD REPORT

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INTRODUCTION

Area surveyed.- During the field season of 1927, 10 townships in eastern Portage County, the whole of Waupaca County (21 townships), and 6 townships in Outagamie County were surveyed (Pl. I). This area totals 37 townships or approximately 1392 square miles and is situated to the south of the district surveyed in 1926. Field work lasted from June 15 to September 10, interrupted by a six day visit to Madison at the end of July which was compensated for by work on Sundays and holidays. Work was also interrupted by (a) a visit to Brownsville on the trip out, (b) three field conferences with road material parties, and (c) 3 days when the car was being repaired.

Methods.- On account of experience gained during the previous season the methods of field and office work were materially improved. Entire charge of the elevation work was given to the assistant, R. J. Koplin. Road cuts were abundant enough so that little test pitting was required and a small shovel sufficed for the needs of the work. The party was transported in the same Ford sedan which was used in the previous year. On account of its greater age so much delay was necessitated by repairs that it was discarded at the end of the season. Wherever the geology was complicated, the speed was kept at or below 10 miles per hour, but the writer permitted 15 to 20 miles in outwash and other simple areas. Only two headquarters were used, Iola and New London, for it was thought that once a satisfactory living place was

BED ROCK GEOLOGY

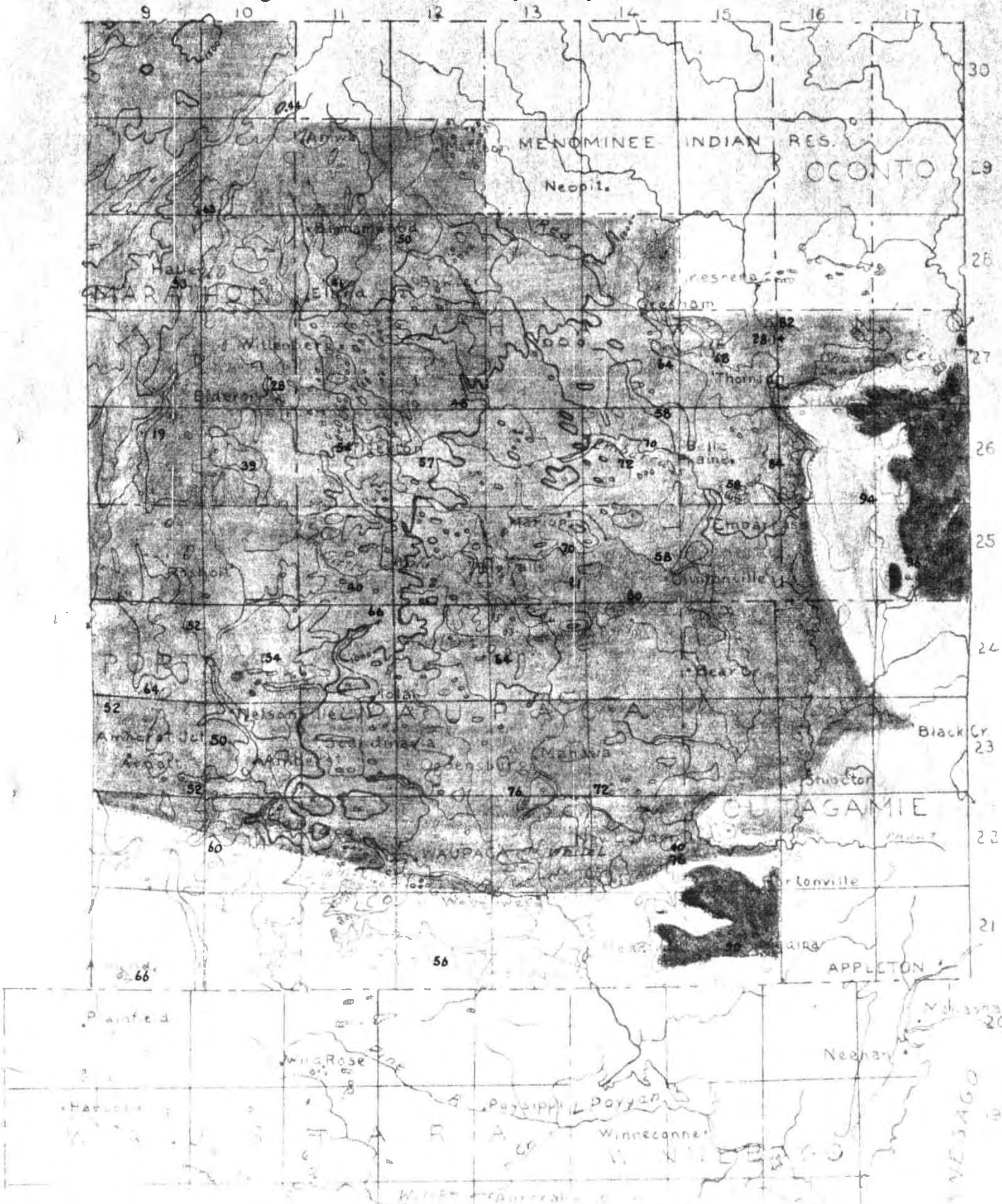
Galena-Black River dolomite

Lower Magnesian dolomite

Cambrian sandstone

Pre-Cambrian granites, etc.

Figures show percentage of dolomite and chert pebbles as shown in pebble counts.


MENOMINEE INDIAN RES.
OCONTO
Neopit
MARATHON
Gresham
Wittenberg
Tigerton
Marion
Clintonville
Embarrass
PORTAGE
WAUPACA
OUTAGAMIE
Scandinavia
Manawa
Ogdensburg
Iola
Shiocton
Black Cr.
Bear Cr.
Nelsonville
Amherst Jct.
Amherst
Weyauwega
Hortonville
APPLETON
Plainfield
Wild Rose
Poygan
Winneconne
Neenah
Menasha

secured the extra miles traveled to and from work would have more than been offset by the time and effort of moving. Some work was carried out about 25 miles from the base, but careful planning of work along the route reduced the dead mileage considerably.

An innovation was the use of an 18 foot auger while in the red till district. It had been hoped that the holes might serve to discover lake clays under sands, but the results obtained in 5 weeks trial failed to justify the trouble of carrying the rods and wrenches. Only one hole the full depth of this instrument was completed successfully as in all other tests layers of either quicksand or dry caving sand were encountered. A sleeve auger might get holes down through the latter, but no method without casing can cope with the former.

Photography.- The writer is particularly pleased with the improvement in photography effected in 1927. The innovations comprised (a) use of a really orthochromatic film, the German Agfa film, (b) use of Wratten filters K2 and G, and (c) invention of an improved hood to shade the lens and exclude unnecessary light. The results were best with (a) distant views and (b) pictures of gravel pits. The penetration of haze and smoke, which are so characteristic of summer in the north country, was quite satisfactory. In comparing results with those formerly obtained it must be realized that ordinary photographs are taken by blue and violet light only and that as a consequence our ideas of what is correct in a photograph are inherently erroneous. Ordinary photographs do not show the degree of contrast between light and shadow which the eye does. Therefore when pictures are taken with a filter which subdues the light values to something near to those apparent to the eye,we at first sight regard them as distorted and unnatural. In distant views it is desirable to exaggerate

color differences. With the materials and methods employed in 1927 this exaggeration can be secured to a considerable extent. All films were promptly sent to Madison by registered first class mail and were developed by McVicar's Photo Service at once. A glance at the album pages of 1926 and 1927 shows improvement conservatively estimated at 1,000 per cent.

Elevations.- The aneroid elevations secured by Koplin seem for the most part to be reliable to about 10 feet but certain exceptions were noted. Some of these were eliminated by office revision after the return from the field, but others must remain as (a) errors in reading or recording, (b) sticking of the needle, (c) pocketing of cold air over marshes and lakes, and (d) blows on instrument. Only one instrument was employed at a time, which proved a saving of time but a cause of some of the occasional errors noted above. The same instruments were used as in 1926 but were put in order at the factory.

Costs.- The cost of the work may be distributed as follows:

Salaries	$1,024.97	= 59 per cent
Travel (6546 miles)	458.22	= 26 " "
Living	208.77	= 12 " "
Photography	46.40	= 3 " "
Total	$1,738.36	=100 " "

Cost per square mile $1.25
Total miles per day 79
Living cost per day $2.52
Square miles per work day 19.3
Cost of party per day (total) about $21.00

The cost per square mile shows a reduction of about 35 per cent over the 1926 figures. This is accounted for by (a) the open country with abundant roads, (b) greater experience, (c) freedom from camp work and worries, (d) good weather, and (e) good base maps. It scarcely seems possible that the cost per square mile can ever be any

lower; it will certainly increase as the work is carried into the less cleared northern country where more foot work is needed. In open lake bottom country an entire township was surveyed in one day, a feat which could never be equaled in the north.

BED ROCK

Pre-Cambrian.- No detailed study was made of the bed rocks of the area which is characterized by very few outcrops. A rough sketch of the bed rock geology is given on Plate I (p. 2). It will be noted that (a) by far the greater part of the district is underlain by rocks of pre-Cambrian age and (b) this area is considerably increased over that shown on any published map. Outcrops are found from Tigerton through Marion and thence southwest through Big Falls to Waupaca. Two isolated knobs of granite occur out in the plains to the east: (a) Hoppes Rock near New London, and (b) an outcrop which is new to science in the sand dunes east of Weyauwega. The greater portion of the pre-Cambrian is coarse granite and granite porphyry; there is considerable fine grained aplitic granite near Waupaca. Hoppes Rock is a fine grained pink granite which is unusually hard. The Weyauwega ledge is a gray, fine grained granite with scattered hornblende crystals larger than the [illegible] average. These rocks are both exceedingly resistant to weathering. The granites were formerly exploited by quarries at (1) Big Falls, (2) Waupaca, (3) north of Waupaca at Granite Quarry School, and (4) Hoppes Rock. Of these only the second and third ever passed the exploration stage and both have been abandoned for many years. The granite quarry north of Waupaca produced porphyritic rock of very striking appearance. The boundaries of the pre-Cambrian have been traced mainly by bowlders of the local granite whose character

contrasts sharply with the gray granites of Canadian origin which are found east of the Paleozoic outcrop. Records of granite wells in and northeast of New London were also obtained. Granite is known beneath the drift as far east as Black Creek. Disintegrated granite is rare in this region and so far as observed has been exploited only southwest of Marion.

Paleozoic rocks.- Paleozoic rocks are exposed (a) in Portage County and (b) south and east of New London. Their presence south of a line from Weuauwega westward through Waupaca is surmised from the scarcity of local granite bowlders although few wells are known to strike sandstone in this district. Two wells north of Iola are reported to strike sandstone, but as no samples were seen, this report is considered doubtful. The Portage County outcrops are Cambrian sandstone of either the Mount Simon or Eau Claire formations. They do not indicate that the country between them is necessarily underlain by sandstone; it is more probable that they are only isolated outliers. East and south of Wolf River there are abundant outcrops of Jordan sandstone and Lower Magnesian dolomite. The latter is exploited by numerous quarries, most of which are now idle. The Mosquito Mounds, east of New London, exhibit poor exposures of the Trempealeau dolomite and Mazomanie sandstone. Some of the former formation has been mistaken for iron ore by well drillers. There are no good sections of the Paleozoic rocks in the area surveyed in 1927.

PREGLACIAL TOPOGRAPHY

Pre-Cambrian area.- No extensive studies of the preglacial topography are possible in the area surveyed in 1927 since few wells reach rock. The greatest relief is in the vicinity of Weyauwega and

New London where it is at least 100 feet. So far as can be found from information now available there are no large valleys in the pre-Cambrian surface. A good idea of its topography can be gained from the sections of Plate III (p. 13). The cause of the very low elevation, less than 200 feet above sea level, at Black Creek can only be surmised at present. No outlet for such a valley seems possible to either the west or south.

Paleozoic area.- The most notable preglacial valley discovered in the portion of the area which is underlain by Paleozoic rocks is that along the New London fault, which is in part followed by Wolf River. Over 300 feet of drift with no rock is reported in this valley. It is probable that the drift is very thick south of Dale, but no data was secured. The relief of the Paleozoic bed rock surface is about 500 feet.

OLDER OR PRE-WISCONSIN DRIFT

Introduction.- Pre-Wisconsin drift (Pl. II) was discovered west of the Outer Morains of the Wisconsin drift as there are no exposures east of that line which are deep enough to pass through the younger deposits. In Portage County the pre-Wisconsin drift is confined to a series of ridges which rise from outwash of the later glaciation; this ridge was named by Weidman the " Arnott Moraine"[1].

Topography.- The Arnott Moraine consists of a north-south ridge which is divided into four principal and several minor sections and which extends from a point a few miles northeast of Stockton south to a point east of Bancroft, a distance of about 16 miles. The maximum width of individual ridges is about two miles and the greatest measured height is approximately 65 feet. The moraine is devoid of kettles

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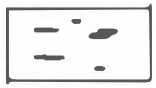
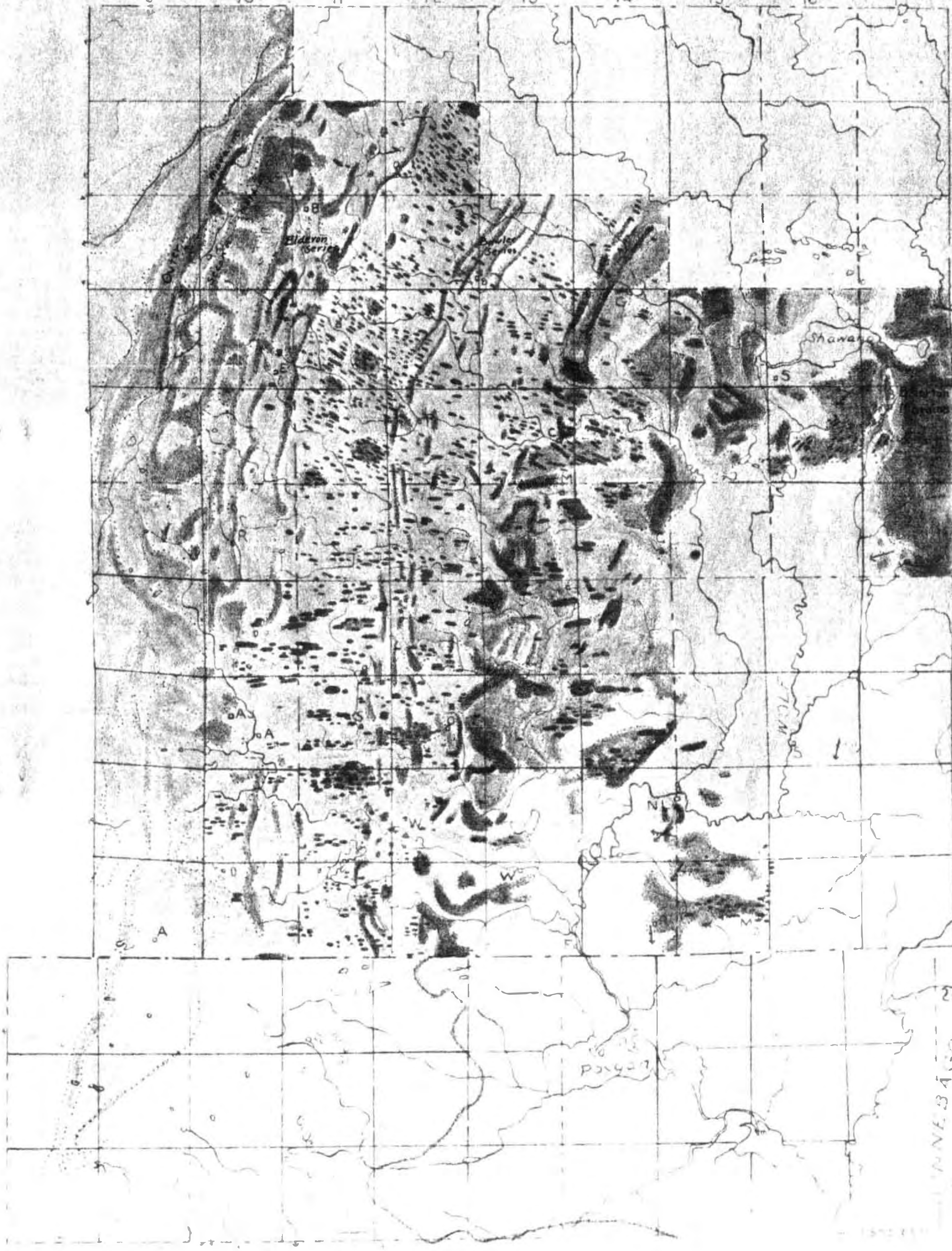
[1] Weidman, Samuel, The geology of north central Wisconsin: Wisconsin Geol. and Nat. Hist. Survey Bull. 16, pp. 456 - 459, 605 - 606, 1907.

Wisconsin Geological and Natural History Survey Plate II

GLACIAL GEOLOGY

Late Wisconsin	Terminal moraine	
	Ground moraine	
	Lake bed	
	Outwash	
Middle Wisconsin	Terminal moraine	
	Ground moraine	
	Drumlins	
	Lake bed	
	Outwash	
Pre-Wisconsin	Undifferentiated	

Striae shown by arrows.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23
22
20
Shawano

although there are marshy spots on its creet. The flanks are dissected by ravines but save for the three large breaks the crest is almost unbroken. Only a small part of the moraine has been cleared and very little of that has ever been cultivated. Most of the farm houses on the moraine have been abandoned.

Material.- The Arnott Moraine consists of very stony, sandy till. All of the moraine is thickly strewn with bowlders of crystalline rock. At the type locality, the railway cut west of Arnott, diorite predominates, but elsewhere granites are much more abundant. Coarse granites and granite porphyries are present in less amount than in the younger drift. The till is non-calcareous and is of a brownish yellow color to the bottom of the deepest excavations, about 15 feet. No dolomite pebbles could be discovered. Oolitic chert from the Lower Magnesian is common.

Interpretation.- Weidman interpreted the Arnott Moraine as the deposit of a pre-Wisconsin glacier and correlated it with his so-called Second Drift northwest of Marshfield. Later Martin and Hotchkiss visited the type locality and declared in conversation with the present writer that the drift is no different from that of the Wisconsin moraine to the east. Since the writer has been obliged to differ radically with the interpretations of Weidman in so many matters, it is a pleasure to say that in the case of the Arnott Moraine his predecessor was entirely correct. The (a) weathering of the till and (b) erosional topography of the moraine prove definitely that it is much older than is the Outer Moraine a few miles to the east. The Arnott Moraine was deposited by the Green Bay lobe of a pre-Wisconsin glacier and not by an ice sheet from the Keewatin center as it contains granite porphyry and oolitic chert, both derived from the east. In one place a small remnant of its outwash apron is preserved on the west side.

MIDDLE WISCONSIN OR GRAY DRIFT

Introduction.- The young or Wisconsin drift is divisible into two parts: (a) the Middle Wisconsin (of Leverett) or "Gray Drift" and (b) the Late Wisconsin (of Leverett) or "Red Drift". The former is the same as the drift at Madison and is equivalent to Chamberlin's original "East Wisconsin Drift". There can be little question but that this drift is decidedly younger than Leverett's original Early Wisconsin Drift of central Illinois. The Late Wisconsin or Red Drift is the same as the Red Drift of Alden, not the Red Drift of northwestern Wisconsin and Minnesota[2].

Material.- The surficial part of the Gray Drift consists of (a) very sandy outwash and (b) exceedingly sandy till which in the area underlain by the pre-Cambrian rocks is filled with granite bowlders. Persons coming into the district from a clay region would scarcely recognize the till of western Waupaca County as an unassorted product. On the other hand some geologists seem to have confused the weathered sands of the outwash with true till.

The percentage of dolomite and chert pebbles derived from the eastern part of the district (Pl. I, p. 2) was determined by counts of material from the unweathered portion of the drift only. Over large areas no cuts deep enough to obtain unaltered material were found. Some facts stand forth clearly: (a) the percentage of dolomite and chert pebbles is over 90 where the bed rock is dolomite, (b) the percentage decreases westward where the rock [illegible] west of the dolomite is mainly granite at the rate of approximately 1.5 per cent per mile,

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[2] Thwaites, F. T., The development of the theory of multiple glaciation in North America: Wisconsin Acad. Sci., Trans., vol. 23, pp. 64, 69, 108, 1928.

(c) the rate of decrease is much less where the bed rock west of the dolomite is sandstone and averages less than half the figure named above, (d) the decrease in content of dolomite pebbles is very irregular and is apparently influenced by the amount of broken granite present in certain localities, (e) many more pebble counts are needed than have heretofore been made if accuracy is to be obtained, and (f) the composition of the pebbles is a valuable but not infallible guide to the character of the bed rock.

Topography.- The Gray Drift is characterized by very rugged topography. The marginal portion in Portage County is largely very rugged stony terminal moraine. Farther east in western Waupaca County the landscape consists of pitted plains dotted with drumlins both (a) isolated and (b) in large groups. In few places are there any extensive flats like those west of the border of the young drift in eastern Portage County. Flat areas are most common near the east margin of the area of Gray Drift where some lake deposits are present.

Terminal moraines.- The terminal moraines of the Gray Drift are the direct continuations of those studied in Marathon and Shawano counties in 1926. They comprise (a) the Outer Moraine, (b) the Second Moraine, (c) the Elderon Morainic Series, and (d) the Bowler Morainic Series. Only slight traces could be found of the Caroline Morainic Series which was distinguished in Shawano County in 1926, for in this latitude almost all such moraines have been overridden by the Red Drift.

Drumlins.- Drumlins are by no means as abundant as they are in Shawano County to the north. They are characteristically arranged in great groups whose longer axes trend east and west; some of these groups are several miles in width and contain well over a score of separate crests. In some groups the drumlins coalesce into plateau-like

"drumlin uplands"; in such cases the observer can get a better idea of the topography from a distance of a mile or more than when actually on the crest. Most of the drumlins are wooded which fact also troubles the geologist although not to the extent that the forests of Shawano County do. Outwash gravels are found beneath several drumlins.

Ground moraine.- There is very little ground moraine in the area of Gray Drift save around the bases of some of the drumlin masses and between the mappable drumlin crests of such masses or groups.

Outwash.- The greater part of the area of Gray Drift is outwash. West of the Outer Moraine there are extensive areas of flat outwash which shows a moderate degree of weathering in contrast with the adjacent Arnott Moraine. Within the Outer Moraine virtually all the outwash is pitted. In many localities the kettles are so close that little or no original plain is left. In such areas (a) the sandy nature of the deposit and (b) the horizontal bedding serve to discriminate the true nature of the deposit. There are several distinct outwash terraces in the vicinity of Amherst Junction (Pl. III). These terraces form a gigantic staircase which rises to the west. The treads are miles in width and the risers, for the most part the several recessional moraines, are measured in a few tens of feet. In addition to the terraces well-defined valleys with flat floors run back into and through the higher terraces and drumlin groups. That of the Waupaca River, which is so well seen at Amherst, connects through a low col with the head of Little Wolf River south of Hosholt. Another prominent channel whose bottom contains lakes in kettles and no definite stream lies west of Iola. Southwest of

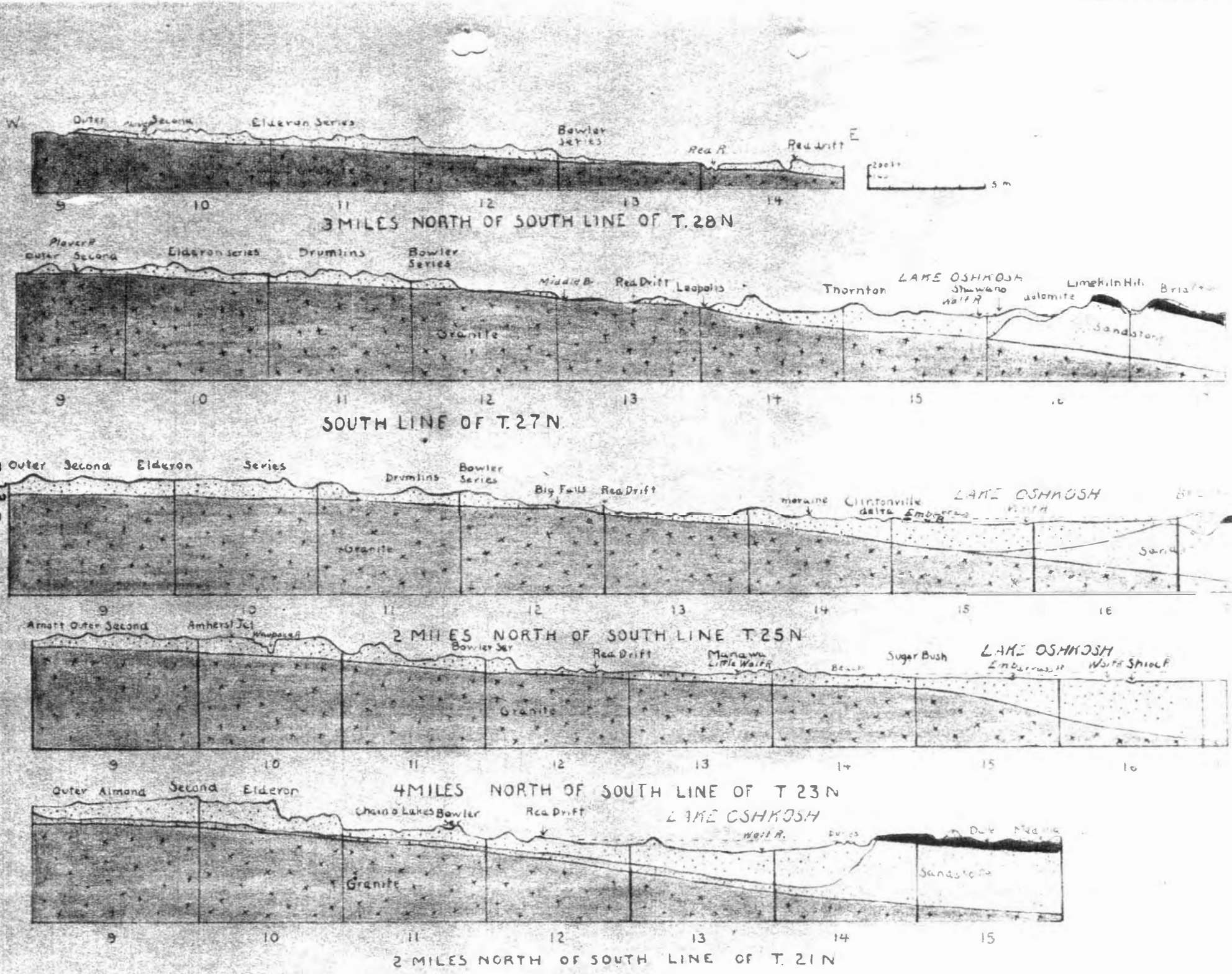
CROSS SECTIONS

Glacial drift

Lower Magnesian dolomite

Cambrian sandstone

Pre-Cambrian granite


W
Outer
Second
Elderon Series
Bowler Series
Rea R.
Rea Drift
E
9
10
11
12
13
14
3 MILES NORTH OF SOUTH LINE OF T. 28 N
Outer
Second
Elderon series
Drumlins
Bowler Series
Granite
Middle R.
Rea Drift
Leopolis
Thornton
LAKE OSHKOSH
Shawano
Wolf R.
dolomite
Limekiln Hill
Sandstone
9
10
11
12
13
14
15
SOUTH LINE OF T. 27 N.
Outer
Second
Elderon
Series
Drumlins
Bowler Series
Big Falls
Rea Drift
moraine
Clintonville
delta
LAKE OSHKOSH
Granite
9
10
11
12
13
14
15
2 MILES NORTH OF SOUTH LINE T. 25 N
Arnott
Outer
Second
Amherst Jct
Bowler Sdy
Rea Drift
Manawa
Little Wolf R.
Sugar Bush
LAKE OSHKOSH
Granite
9
10
11
12
13
14
15
4 MILES NORTH OF SOUTH LINE OF T 23 N
Outer
Almond
Second
Elderon
Chain o Lakes
Bowler
Rea Drift
LAKE OSHKOSH
Wolf R.
Dunes
Dale
Granite
Sandstone
9
10
11
12
13
14
15
2 MILES NORTH OF SOUTH LINE OF T. 21 N

Iola a veritable network of such channels is found. One of them is followed by both U. S. 10 and the Soo Line part of the way between Amherst and Waupaca. South of this latitude numerous flat-bottomed ravines head west of the Chain o' Lakes Plain in high outwash terraces west of the Bowler Moraines; several of these contain streams fed by large springs. A striking feature is that the division between the high outwash area north of Nelsonville and the lower plains around Iola is not a moraine; this escarpment can be traced from the south line of Waupaca County nearly to the north line and may be correlated with the similar features in Shawano County as shown in Plate III (p. 13).

Eskers.- Eskers are not very abundant in the Gray Drift of Waupaca and Portage counties. These ridges are composed of exceedingly stony, bowldery gravel which is very different from the adjacent sandy outwash. One of the best-studied eskers is that which crosses S. T. H. 49 in the northern part of Iola; it was traced for over two miles. It is quite possible that other eskers occur among the drumlins but were not discovered on account of woods. The discontinuous nature of eskers makes them very hard to discover and to follow.

Lake deposits.- From a point east of Big Falls to the south line of Waupaca County is a series of plains which are only slightly pitted. These plains are now drained by several different streams which discharge to the southeast and are not portions of continuous southward-sloping plains. At no point was any lake clay distinguished although it is by no means improbable that such is present in some places beneath the sandy soil. In the SW. NE. sec. 13, T. 21, R. 11 E. a gravel pit shows fine gravel which is exceedingly well sorted. This deposit lies at an estimated elevation of 875 feet and is probably a beach deposit. It is probable that some of the slopes which

separate these flats from adjacent highlands are beach cliffs but as this interpretation was not held at the time they were mapped, the idea was not tested out.

LATE WISCONSIN OR RED DRIFT

Introduction.- The Late Wisconsin Drift as defined in this report is not the same as the Late Wisconsin Drift defined by Leverett in 1897 but is the same as the Red Drift of Alden's Professional Paper 106. On the State Soils Maps the area of Red Drift is mapped as the Superior Series, level and rolling phases; and as the Kewaunee Series and the Superior Series when the maps were published by the United States Bureau of Soils. The Soils Maps were a great help in defining the border of this drift.

Till.- The till of the Red Drift differs markedly from that of the Gray Drift. It is of a dark red to brownish red color and is so clayey that in 1926 the hypothesis that some of it was of aqueous origin was considered. In some exposures there is a faint lamination parallel to the surface which at first sight suggests bedding and in a few places lenses of sand complete the illusion. (a)The abundant stones, some of them glaciated; (b) the grit scattered through the clay; and (c) the surface configuration which in many places is higher than areas to the west without red till, however, leave no doubt of the glacial origin of the deposit.

Glacio-fluvial deposits.- The glacio-fluvial deposits of the Red Drift area differ very little from those found farther west and indeed many of the exposures clearly show materials deposited previous to the coming of the Red Ice. Large areas of nearly level or pitted red till are evidently pitted plains which were formed during the first retreat of the ice and were later overridden by the Red Ice. In

Shawano County these were mapped separately but their lesser area in Waupaca County coupled with the greater thickness of the red till caused the writer to omit this distinction and classify most of them as ground moraine. In other places the red till rests on older lake deposits, a fact which proved very confusing in Shawano County. It is now realized that the occurrence of silts or stratified clays below the red till has no bearing on the origin of the latter. An interesting feature of the outwash of the red till area is the occurrence of some fine gravels which are so well assorted as to closely resemble beach deposits. These are common along the valley of the Little Wolf above Manawa.

Terminal moraines.- Inasmuch as the Red Drift is very clayey, it should not be expected to form as rough or as stony terminal moraines as does the Gray Drift. Notwithstanding this fact many areas of Red Drift are very rough. As cuts in these areas show that the red till is only a few feet in thickness, it is obvious that the rough topography was inherited from (a) gray terminal moraine and (b) gray pitted plains. This fact makes the mapping of real Red Drift moraines a well-nigh hopeless task. The moraines which are shown near the western border of the Red Drift are in all probability the overridden Caroline Series of Shawano County. No continuous terminal ridge can be found at the edge of the Red Drift whose border is lobulate and sinuous in a form rather suggestive of Calvin's Iowan drift (Pl. VII, p. 30). Viewed broadly, the border of the Red Drift lies diagonal to the gray moraines and extends relatively much farther west in southern Waupaca County than in Shawano County. No attempt has been made to give a name to the outermost moraine of Red

Drift. The recessional moraines of the Red Ice are much better marked (Pls. II, p. 8, and VIII, p. 32). The Thornton Moraine of Shawano County is no longer correlated with the moraine north of Clintonville but instead with the isolated morainic hills formerly termed the "Belle Plaine Morainic Complex" and thus forms a discontinuous loop across the Wolf Valley (Pl. VIII, p. 32). The moraine south and west of Embarrass River cannot be traced south of Clintonville but may turn east into the lake basin and connect with an isolated hill east of the city and with a gravel hill near Leeman still farther east. The moraines west of New London are so irregular that they cannot be placed in any system. The ridge east of Mosquito Bluffs near New London is probably a subaqueous moraine although here mapped as lake bottom.

Ground moraine.- There are large areas of ground moraine in the Red Drift area, most of which are so flat that they seem clearly to be overridden outwash or lake deposits. In many places well records and cute confirm this explanation. The presence of occasional kettles in these deposits is thus accounted for, but discrimination from terminal moraine is very difficult. South of New London is a large area of thin drift on dolomite and sandstone.

Drumlins.- The Red Drift area is characterized by relatively few but very large drumlins which reach a maximum height of 250 feet. Some drumlin groups occur in which the individual members are distinctly offset or en echelon. All but a few drumlins trend either east-west or northwest-southeast. Many are imperfect in form. Cuts in these show that they have a core of gray till covered with a few inches to 10 or 15 feet of red till. Drumlins which trend northeast-southwest occur (a) near Lund in Shawano County, (b) southwest of

Clintonville, and (c) near Hortonville. Cuts in these appear to show nothing but red till. Near the margin of the Red Drift numerous drumlins appear to have formed nunataks; at least they have no discernible red till on them.

Outwash.- Outwash is not as common in the Red Drift as it is farther west. A notable example is the series of plains which extend from east of Marion down (a) the Pigeon and (b) across to the Little Wolf. Another plain follows the Little Wolf from the vicinity of Big Falls down to the level of Glacial Lake Oshkosh.

Eskers.- Eskers are rare within the Red Drift area of Waupaca County although they are common in the Briarton Moraine of Shawano County. At Medina (T. 21, R. 15 E.) there is an esker which is unique in showing gravel which in certain beds is as well assorted as a beach; it is interpreted as one which discharged into standing water so that the material was reworked by the waves and locally interbedded with red clay. The ridge is too well sheltered to be regarded as a bar.

Lake deposits.- The largest area of lake deposits lies within the area of the Red Drift; these occupy the bed of a lake which was formerly called Glacial Lake Jean Nicolet but is now to be renamed Glacial Lake Oshkosh. The material consists of (a) varved red and gray clays, (b) gray, pink, and yellowish gray silts, and (c) sands. Much of the lake basin is covered by sand dunes. The first class of deposits can only be distinguished in deep, fresh cuts. Dunes are most abundant east of Wolf River and near the Shawano County line; some of them reach a height of about 30 feet. Large portions of the lake basin contain no lake deposits whatever and bowldery red till forms the surface material.

Beaches.- Two glacial lakes of different ages may be distinguished. The older occurred before the red till was deposited and is known by beach gravels which were noted at elevations of 850, 875, and 900 feet. No marked topographic features are associated with any of these high-level occurrences. The later lake is younger than the red till and shows beach gravels at 790, 825-830, and possibly 840. Such deposits are confined almost entirely to isolated hills which formed islands or shoals in the lake; most of the shoreline shows neither depositional nor erosional features but may be approximately defined by the transition from smooth lake flats to more rolling glacial topography.

Deltas.- Several deltas were discovered particularly (a) where Pigeon River entered the lake at Clintonville, (b) east of New London (sec. 15, T. 22, R. 15 E.),and (c) north of New London and east of S. T. H. 26 (sec. 18, T. 23, R. 15 E.). The Clintonville delta contains several kettles. The two latter were ice-margin deltas or delta-kames. Buried or older deltas were found in 1927 (a) south of Readfield (SE. SE. sec. 26, T. 21, R. 14 E.) and (b) west of Clintonville (NE. NE. sec. 25, T. 25, R. 13 E.).

GLACIAL HISTORY

Pre-Wisconsin Drift

Arnott Moraine (Illinoian?).- There can be no question that the Arnott Moraine was deposited by a pre-Wisconsin Green Bay lobe. That the time of deposition was probably the Illinoian stage is indicated by (a) the moderate dissection and (b) by the fact that during the aforesaid stage the Laboradorian center had its greatest extension. It is true that there is no trace of an Illinoian Green Bay lobe in southern Wisconsin but this was no doubt due to interference by the Lake Michigan lobe in the region around Madison which held back the

offshoot to the west. No means is known by which the Arnott Moraine may be correlated with the drift from the north which occurs in northern Marathon County or northwest of Marshfield.

Interglacial time.- The lapse of time between the formation of the Arnott Moraine and the coming of the Middle Wisconsin glacier comprised not only (a) the interval between the maximum of the Illinoian but also (b) the entire duration of the Earlier Wisconsin of Illinois as now defined by Leverett and Leighton. The marked difference in amount of weathering which is shown by the two drifts of eastern Portage County should therefore excite no surprise even if it seems much greater than the difference displayed near Madison.

Middle Wisconsin

Outer Moraine.- The Outer Moraine marks the outermost stand of the ice during the Middle Wisconsin glaciation; it seems probable that it correlates with Alden's Johnstown Moraine of Professional Paper 106. During the formation of this moraine waters flowed from a number of breaks, starting with the notch from which Plover River now flows, south as far as the survey has extended. These waters had free escape to the west and southwest and therefore deposited a smooth outwash plain which to the south grades into the deltaic plain seen east of the Dells of the Wisconsin at Kilbourn. In Portage County the altitude of the country was too great for lake deposits. The relatively fresh gravels of this plain contrast sharply with the old oxidized drift of the Arnott Moraine although leaching does extend to a depth of three to five feet.

Second Moraine.- Following the formation of the relatively weak Outer Moraine the ice margin fell back rather rapidly for three to five miles and the Second Moraine was deposited. This moraine averages

considerably larger and presumably represents a longer time of stationary ice margin. Near the north line of Portage County the two moraines are separated by the very sandy pitted Plover Plain which is about two miles wide. Farther southeast of Arnott the two moraines join. A much pitted plain with/the moraine will here be termed the Custer Plain; it is unusually gravelly for this region of excessively sandy outwash. South of this complex of morainic deposits is another pitted plain which near the south line of the county reaches a width of about 5 miles and is called the Almond Plain. Near Almond this plain is terraced by an erosion channel which leads from an outlet which is now followed by the Northwestern Railway from Wild Rose. The Almond Moraine possessed several outlets to the west through breaks in the Outer Moraine. Its formation was completed before all the ice masses left when the glacial front retreated could melt. The Second Moraine is undoubtedly Alden's Milton Moraine.

Elderon Morainic Series.- When the ice margin began to fall back from the Second Moraine, no continuous moraines were deposited but instead a complex of moraines and pitted plains in some localities dotted with drumlins. In Marathon County this series was named the Elderon Morainic Series; it probably corresponds to Alden's Lake Mills Morainic System although Alden's mapping in Waushara County was too incomplete to admit of a definite conclusion on this point. The associated outwash plains form two distinct levels as far south as the central part of Township 22 (Pl. IV) where a marked eroded stream channel now followed by S. T. H. 54 cuts through the Outer Moraine, the outwash to the west of it, and the Arnott Moraine. From aneroid readings it is not clear that this outlet carried all the drainage to the north of it, but as no other course is possible, it would seem that some of these elevations must be in error. The deep eroded and terraced valley of Waupaca

Wisconsin Geological and Natural History Survey Plate IV

CONDITIONS AT TIME OF FORMATION OF YOUNGEST ELDERON MORAINE

Middle Wisconsin	Terminal moraine	
	Ground moraine	
	Drumlins	
	Outwash	
Pre-Wisconsin	Undifferentiated	

Glacial drainage shown by arrows. The outlet southwest of Amherst Junction via Keene must have been used until this time.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River could not have been developed until after the abandonment of the easternmost Elderon Moraine.

Bowler Morainic Series.- The recession of the ice border from the easternmost Elderon Moraine to the Bowler Morainic Series was interrupted by at least two halts during which faint discontinuous moraines were built. These are best developed in southeastern Portage County but are also recognizable in some scattered morainic areas east of Birnamwood in Shawano County. Although this halt is only faintly recorded in moraines, it marked the end of an important stage of drainage. The waters escaped southward and developed at least two definite outwash levels. The eastern side of these terraces forms an escarpment which may be clearly recognized across the entire width of Waupaca County and at some points within the drumlin area of Shawano County as shown in Plate V. Abandonment of this position by the ice border opened a lower outlet to the south which was used by the drainage from the Bowler Morainic Series. At this time the striking erosion channels around Amherst Junction and Iola were formed. Their courses were determined by the drumlin uplands. On account of these obstructions the drainage lines meander to a considerable extent and correlation of the several terrace levels is difficult. In southwestern Waupaca County the very extensive Chain o' Lakes Fitted Plain evidently was the result of degradation of an outwash terrace which lay about 20 feet higher and of which only isolated remnants can now be seen. Farther north conditions were much more complex as may be seen west of Iola and among the Shawano County drumlins. Further recession of the ice during the formation of the several Bowler Moraines introduced complexity by opening still lower outlets.

Dissection of high terrace.- There can be no question that most

CONDITIONS AT TIME OF FORMATION OF BOWLER MORAINIC SERIES AND DISSECTION OF HIGH OUTWASH TERRACES

Middle Wisconsin	Terminal moraine	
	Ground moraine	
	Drumlins	
	Outwash	
Pre-Wisconsin	Undifferentiated	

Glacial drainage indicated by arrows. Lines of drainage shifted from time to time probably in part on account of melting of isolated ice masses. All drainage escaped south of the area and reached Early Glacial Lake Oshkosh.


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of the eroded channels through the high outwash terraces of western Waupaca County were formed by glacial floods. In the southwestern part of this county, however, there are several valleys which discharge eastward and have no connection with glacial outlets. The question then arises as to the time of erosion, is it postglacial or late glacial? If the former, we would expect to find large alluvial cones where the streams debouch on the gently sloping Chain o' Lakes Plain. As no such cones are found, it is apparent that the erosion was in large measure completed before the lower outwash plain was abandoned by glacial streams. The size and width of the valleys seems to preclude their erosion by ordinary rainfall alone even granting the weakness of the sand and a possible, although not probable, humid climate. An extra supply of water may very well have come from the melting of ice masses buried in the plains to the west.

Caroline Morainic Series.- As noted previously the Caroline Morainic Series is only faintly developed in Waupaca County and correlation of such scattered remnants is naturally very difficult.

Early Glacial Lake Oshkosh.- The sandy plains associated with the Caroline moraines are in many places nearly or quite free of kettles. Some of these areas were probably lake beds as has been shown on the Waupaca County map, but lack of sufficient accurate elevations in Shawano County renders a decision on this point very difficult to reach. Gravel which is so well sorted as to suggest a lake beach was found at only two points, namely sec. 13, T. 21, R. 11 E. and sec. 3, T. 22, R. 12 E. If these flat areas were actually submerged by standing water, the depth could nowhere have been much over 10 feet and it seems very unlikely that any lake waters extended appreciably above 900 feet. Within the area covered with Red Drift well-developed lake gravels

have been found at elevations ranging from 850 up to or slightly above 900 feet. The presence of lake waters up to an elevation of 900 feet is thus well established. The explanation of the absence of beaches along the west margin of this Early Glacial Lake Oshkosh may be found in the fact that such beach deposits are rare on the same side of the later or post-Red Drift Glacial Lake Oshkosh as will be explained below.

The name, Glacial Lake Oshkosh.- The glacial lake which overflowed through the low divide between the Fox and Wisconsin Rivers at Portage was named "Glacial Lake Nicolet" by Upham in 1903[3]. Then it was discovered that the name had been preempted by Winchell[4] so that the change to "Glacial Lake Jean Nicolet" was made[5]. Years later Alden[6] stated, "If the name Glacial Lake Jean Nicolet is to be retained for the glacial lake discharging across the divide to Wisconsin River at Portage, it should be used only for the lake having the elevation and extent described in this present paper. Personally, the writer would prefer the use of some other name...." The present writer therefore suggests that not only the low level glacial lake which Upham and Alden had in mind be named "Glacial Lake Oshkosh" following the precedent of Glacial Lake Duluth and Glacial Lake

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[3] Upham, Warren, Glacial Lake Nicolet and the portage between Fox and Wisconsin rivers: Am. Geologist vol. 32, p. 105, 1903.

[4] Winchell, N. H., Glacial lakes of Minnesota: Geol. Soc. America Bull. vol. 12, p. 122, 1901.

[5] Upham, Warren, Glacial Lake Jean Nicolet: Am. Geologist vol. 32, p. 330, 1903.

[6] Alden, W. C., Quaternary geology of southeastern Wisconsin: U. S. Geol. Survey Prof. Paper 106, pp. 324-325, 1918.

Chicago, but also that because of its geographic location and the fact that so little is yet known of it, the higher and earlier level of glacial waters in the same basin be termed "Early Glacial Lake Oshkosh."

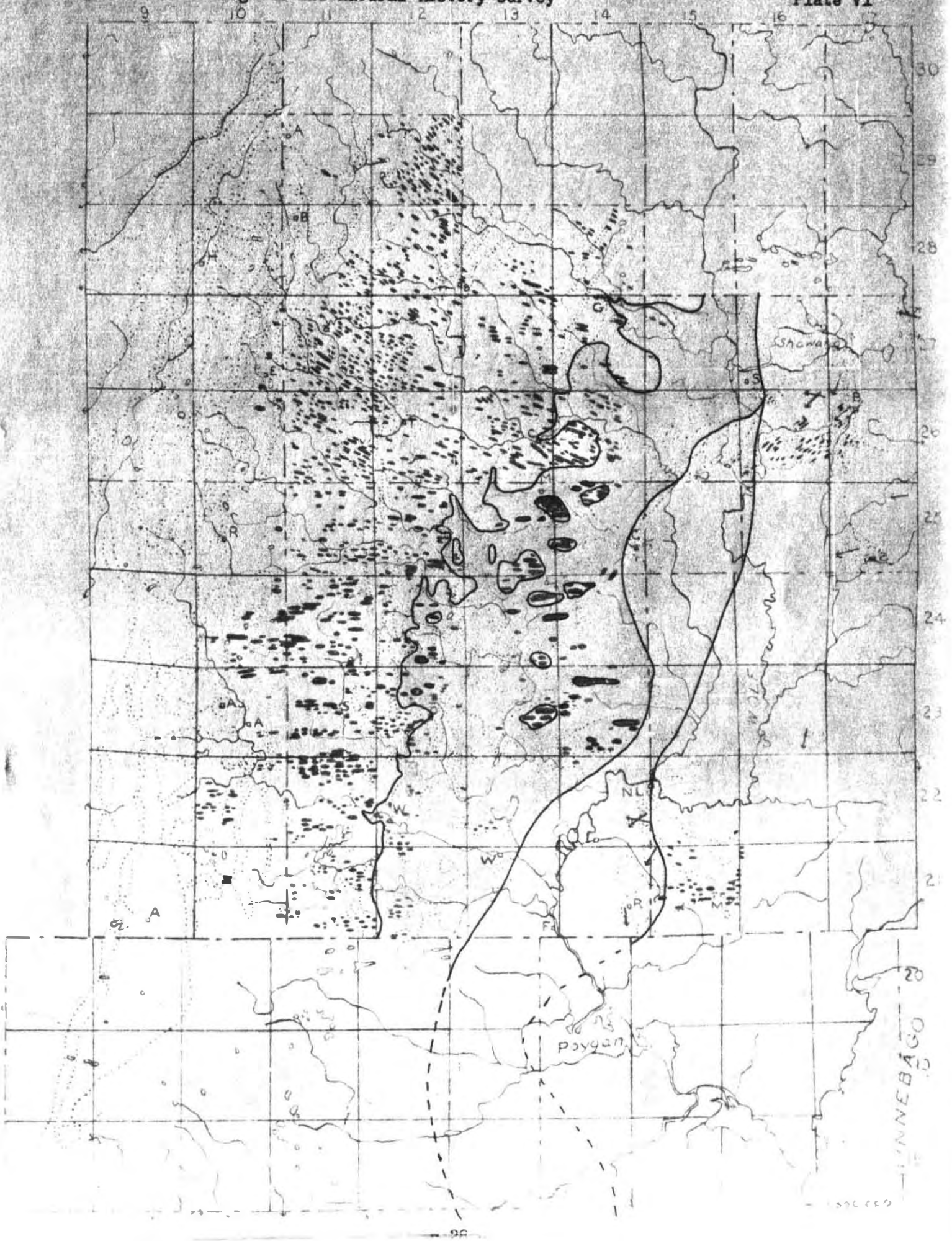
Early Glacial Lake Oshkosh.- The highest known beaches of Early Lake Oshkosh (Pl. VI) are fully 100 feet above the shore lines discovered by Alden and Upham. Inasmuch as the latter are graded to the level of the col at Portage and there is no evidence of more than about 25 feet of stream erosion in any of the low openings between the hills south of that city, it would at first sight seem impossible that beaches at 900 feet in Waupaca County could have been associated with this outlet unless displaced by subsequent earth movement. Study of the Baraboo quadrangle, however, shows that before erosion of the moraines northeast of Prairie du Sac, waters above that place were ponded to the elevation of at least 875 feet. It should be noted in this connection that the elevations on such an old map as Baraboo were determined with an aneroid barometer. In order to maintain a 900 foot level it was necessary, however, that the ice not yet have cleared the low col south of Fond du Lac; this correlates the highest level of Early Glacial Lake Oshkosh with either Alden's Waupun, St. Anna, or Rush Lake moraines (Pl. VI). The Waupaca County beaches therefore require little or no northward tilting of the land.

Interval between Gray and Red Drifts.- Within the area thus far surveyed there seems to be no means of estimating the length of time between the retreat of the Gray Ice and the return of the Red Ice. It may strongly be presumed that this interval corresponds to that during which the forest bed at Two Creeks was formed and the ice front retreated clear of the Straits of Mackinac. This does not agree with the inter-

CONDITIONS AT TIME OF HIGHEST LEVEL OF EARLY GLACIAL LAKE OSHKOSH

Lake bed 

This lake reached an elevation of about 900 feet when either Alden's Waupun Moraine or St. Anna Moraine blocked the col south of Fond du Lac. Further recession of the ice front caused a fall in level to about 875 feet which was reduced by erosion of the outlet to about 850 feet.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pretation of Alden[7] who stated: "It is probable that the refilling of the basin (of Lake Michigan) to this level (the Toleston stage) was occasioned by a readvance of the ice that closed the Straits of Mackinac.....The limit of the readvance is marked on the Wisconsin side of the basin by a red till moraine, which extends southward to the lake shore just east of Two Rivers...." It is not possible to compare the ages of the red and gray tills by measuring the leaching since the porosity is so widely different. It does seem as if the amount of weathering shown by glacio-fluvial deposits is decidedly less in the Red Drift area than farther west in the region of the Gray Drift, but the writer is convinced that such a comparison is so obscured by differences in local conditions that definite conclusions are hazardous. In any case it can scarcely be that the ice recession lasted anywhere near as long as did some of those earlier in the history of Pleistocene glaciation.

Late Wisconsin

Red till readvance.- When the ice front returned to Waupaca County (Pl. VII), it passed over extensive deposits of red clay in the basin of Early Glacial Lake Oshkosh. Since the glacier did not extend far beyond the lake basin or remain very long, this red clay gave its color to the till as long ago demonstrated by Alden[8]. The red color of the lake clays is best shown by the very fine or winter layers. It is a natural consequence of the fact that the

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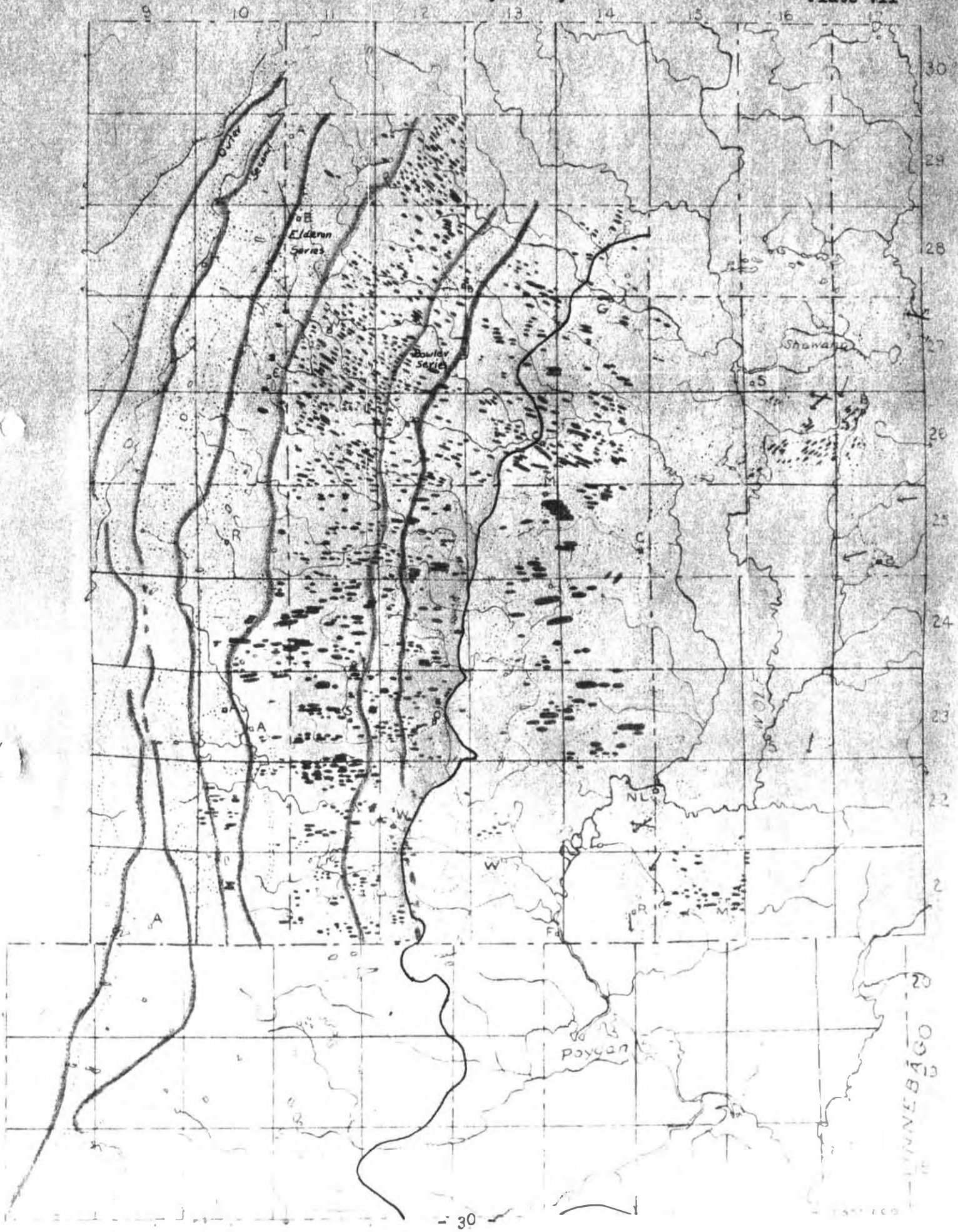
[7] Alden, W. C., Quaternary geology of southeastern Wisconsin: U. S. Geol. Survey Prof. Paper 106, pp. 332 - 335, 1918.

[8] Alden, W. C., U. S. Geol. Survey Geol. Atlas, Milwaukee folio. No. 140, p. 6, 1906; Quaternary geology of southeastern Wisconsin: U. S. Geol. Survey Prof. Paper 106, pp. 310 - 324, 1918.

CONDITIONS AT TIME OF MAXIMUM EXTENT OF RED ICE

Gray moraines 

The remnant of Early Glacial Lake Oshkosh not covered by the Red Ice 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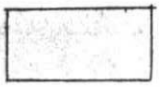
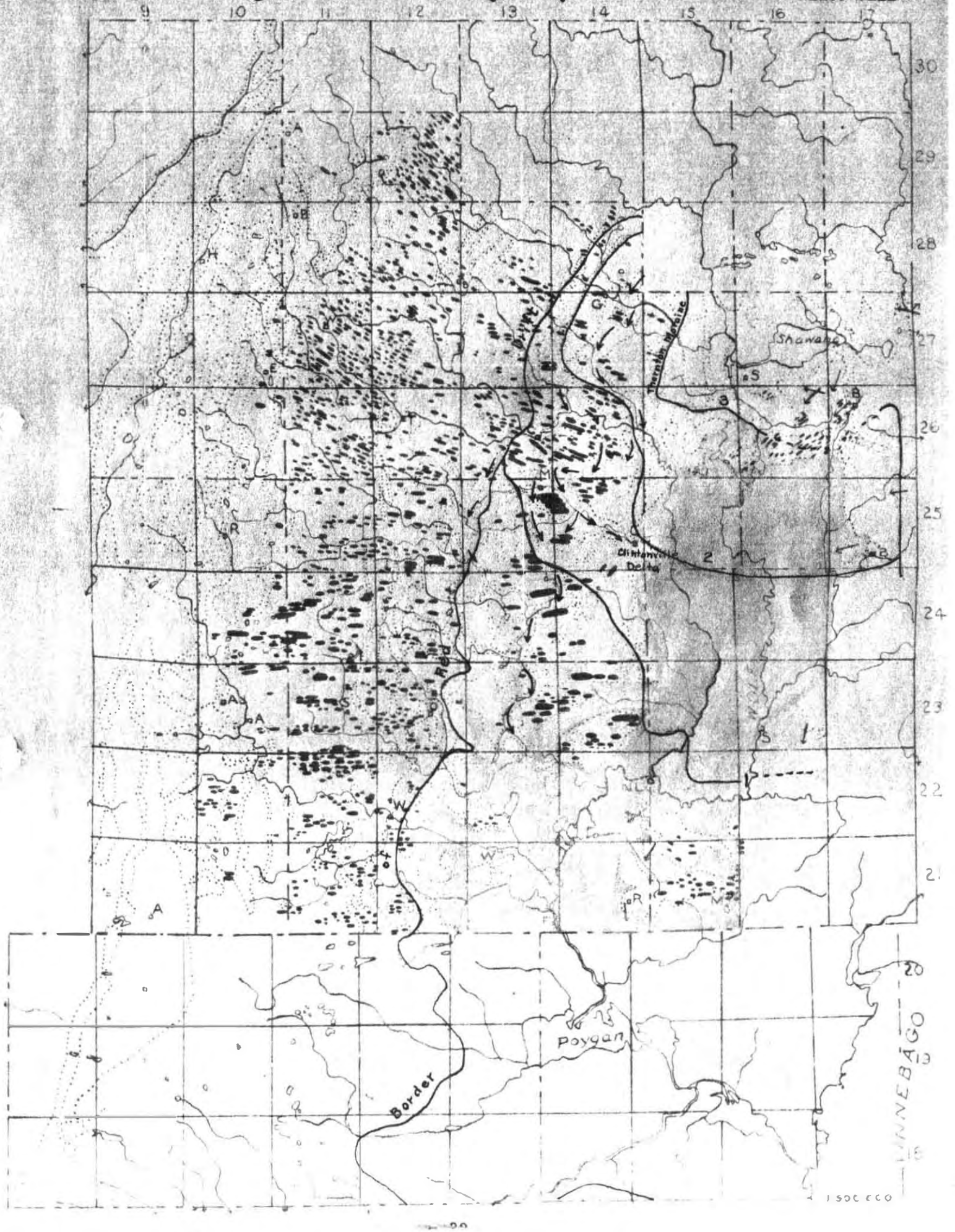
ferric oxide in the till which came from the red rocks of the Upper Peninsula of Michigan is very finely divided. Assortment of the finer washings from the till concentrated the red minerals in the lake clays and thus affected the till which was formed from them. The way in which the till is spread into kettles of older outwash and over the moraines definitely shows that the ice masses which formed these had long since melted. The Red Ice did not last long enough or have strength enough to sensibly erode even the higher drumlins. The most that it seems to have done was to reshape some of the drumlins so that they now trend southwest instead of west. The Red Ice also built some entirely new drumlins, a few of which are known to overlie older deltas formed in Early Glacial Lake Oshkosh. The readvance also plowed up large masses of older assorted deposits and made sand and gravel bowlders within the till. These are recognized by (a) vertical or overhanging boundaries and (b) disturbed, folded, and faulted stratification.

Lobation of Red Ice.- As demonstrated by (a) striae and (b) moraines, the lobation of the Red Ice was entirely different from that which prevailed during the more extensive invasion by the Gray Ice (Pl. VIII). The youngest striae all trend southwest to south instead of the earlier course of northwest to west. Although the survey is as yet incomplete, this can only mean that an offshoot from the Green Bay lobe passed southwesterly down the valley of the Wolf to the moraine noted by Alden near Berlin. The east-west moraines of southern Shawano County which so puzzled the writer in 1926 can now be seen to be recessional deposits of this Wolf River lobe. Moreover, the irregular course of the west limit of the Red Drift may be better understood when it is realized that the primary motion of the lobe was southerly rather than westerly.

LATER GLACIAL LAKE OSHKOSH AND STAGES IN THE RETREAT OF THE WOLF RIVER LOBE OF THE RED ICE

Lake bed at time of Thornton-Belle Plaine Moraine 

Glacial drainage indicated by arrows. This lake does not appear to have ever stood higher than about 830 feet.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Recession of the Red Ice.- Three distinct halts during the recession of the Red Ice from the Wolf Valley can be recognized (Pl. VIII, p. 32): (a) moraines and deltas north and east of New London whose eastward extension has not yet been mapped,[1] (b) the Clintonville-Leeman Moraine which farther north must join the Thornton Moraine of Shawano County,[2] and (c) the Thornton-Belle Plaine Morainic Series.[3] The outwash plains of Little Wolf River doubtless were formed by marginal drainage and local precipitation when the ice was at the first or New London stage. The Pigeon River plain and Clintonville pitted delta were deposited later when recession to the second or Clintonville stage had freed this outlet. During the third, or Belle Plaine, stage, the waters may have used this outlet for a time, but later they must have followed the course of Embarrass River. The gravels of Marston Brothers pit in Shawano County which were formerly interpreted as ordinary outwash may be deltaic outwash which was deposited in the border of a shallow glacial lake during the Belle Plaine stage. The delta northwest of Shawano Lake mapped as moraine in 1926 is now recognized as a deposit of Early and not Later Glacial Lake Oshkosh and not therefore a recessional of the Red Ice. Still later the Thornton Moraine was cut through by glacial waters at Thornton and outwash, now much modified by sand dunes, was deposited north of Shawano Lake after the ice front had retired north of the territory thus far surveyed.

Later Glacial Lake Oshkosh.- It is now known that the post-Red-Drift glacial lakes west of the Thornton Moraine which were postulated in the 1926 report had no existence or are Early Lake Oshkosh beaches modified by glaciation. The supposed beaches of bowlders and sand are really deposits associated with the Red Drift. Recession of the Wolf River lobe (Pl. VIII, p. 32) of the Red Ice led to the formation of Later Glacial Lake Oshkosh, Upham's original Glacial Lake Jean Nicolet.

This lake is known by varved clays and massive silts which form a very smooth topography. Its shore lines are poorly marked at almost all points; beach gravels are found only on points and shoals. It is suggested that anticyclonal winds from the ice kept floating ice so constantly packed in bays and along most of the western and southwestern shores that waves could not reach land. The largest gravel deposits thus far discovered are deltas formed by streams from the glacier; such are found east and north of New London, both (a) at 825 to 830 or (b) at about 790 feet elevation. The elevation of several of the cols south of Portage as determined by the very inaccurate Poynette quadrangle is about 825 feet. As the present divide is not far from 795 feet, the lower beaches evidently resulted from erosion of the early outlet. The existence of beaches above 830 feet is questionable since based solely upon aneroid readings; if such do actually occur, the divide must then have been some distance southwest of Portage. Shawano Lake is a remnant of the most northerly part of Later Glacial Lake Oshkosh which was apparently dammed in by deposits brough down by the Wolf River although no delta is present, probably because the Wolf then carried no glacial drainage.

Briarton Moraine.- The very wide Briarton Moraine of Shawano County was only barely touched in the 1927 survey but is known to extend south at least 12 miles into Outagamis County. It might be interpreted as either (a) a recessional moraine of the Red Ice or (b) an interlobate moraine between the Wolf and Green Bay lobes of the Red Ice. Beyond much doubt such an interlobate must have existed, but studies to the east will be necessary to prove this. The existence of (a) eskers discharging west, and (b) gravelly outwash deposited by streams flowing in the same direction seems to demonstrate that if it is an interlobate, the ice remained longer on the east than on

the west side. In any case this moraine must in part, at least, correspond to the maximum of Later Glacial Lake Oshkosh. It probably correlates with the low water-laid moraine north of Lake Winnebago although it is possible that it swings west to the ridge north of Oshkosh.

Postglacial time.- The events of postglacial time comprise (a) stream erosion in favorable places, (b) meandering of streams on flat lake beds forming oxbow and other flood-plain lakes, (c) weathering of the drift, (d) formation of peat, and (e) formation of sand dunes. The last were studied with some care to determine, if possible, the winds which transported the sand. So far as could be discovered, these came from the south and southwest and so must have been postglacial and not the anticyclonal winds from the ice sheet. Observations are, however, as yet meager in number and to some extent contradictory. It is worthy of note that over wide areas where the drift is less than two feet thick weathering has destroyed the striae on underlying dolomite ledges. An interesting fact which was noted in southeastern Portage County is the recent "come-back" of the water table. Weidman[9] reported that cultivation had reduced the level of the water table in this region from 20 to 40 feet. Recent rainy years, however, have restored the waterlevel both underground and in enclosed ponds and lakes. Water is now killing trees over 30 years old.

ECONOMIC GEOLOGY

Gravel.- Commercial gravel plants have been developed at (a) Clover Leaf Lakes in Shawano County in deltaic(?) gravels, (b) north of Waupaca in very sandy outwash, (c) Lake Emily near Amherst Junction in gravelly outwash, and (d) Bear Creek in a Gray kame under red till. Good deposits of stony gravel are rare in the region surveyed as so large a portion of

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[9] Weidman, Samuel, Geology of north central Wisconsin: Wisconsin Geol. and Nat. Hist. Survey Bull. 16, pp. 584 - 585, 664, 1907.

the drift was derived from sandstone and disintegrated granite. Excellent deposits of gravel which, aside from the local presence of disintegrated granite pebbles, is suitable for coarse aggregate was discovered in a number of places; most of these have been developed to some extent for local use. Among others, exact locations of which can be secured from the field notes, may be mentioned (a) county pit northwest of Shawano Lake (sec. 6, T. 27, R. 16 E.), (b) county pit at Bear Lake south of Manawa (NW. SE. sec. 32, T. 23, R. 13 E.), (c) county pit north of Waupaca on S. T. H. 49 (SW. NE. Sec. 18, T. 22, R. 12 E.), (d) pit on S. T. H. 22 near the Soldiers Home (NE. 1/4 sec. 35, T. 22, R. 11 E.), (e) the undeveloped Custer Plain in T. 23, R. 9 E., (f) undeveloped outwash gravels south of Bonduel in secs. 20 and 21, T. 26, R. 17 E., and (g) a large kame out in the basin of Lake Oshkosh in the NW. NE. sec. 36, T. 26, R. 16 E. Surfacing gravel is for the most part secured from the weathered zone of the outwash deposits where disintegration of dolomite and feldspar has made a clay and iron oxide binder. Such material is not good enough for heavily traveled roads, for it "washboards" very easily. On main roads it has been replaced to a large extent by crushed gravel. Some of the lake gravels are excellent for surfacing and those beneath the red till, the deposits of Early Glacial Lake Oshkosh, have been worked to a considerable extent. The large pit used in 1927 for the fine aggregate for U. S. 10 south of Readfield belongs to this class. For the most part the gravels which are younger than the Red Drift are entirely too clayey for concrete.

Water.- The region which was surveyed in 1927 is for the greater part very well supplied with ground water. Within a large area below an elevation of 800 feet flowing wells or "fountains" as they are called by the natives are very abundant. All of the cities and villages in the entire area which have public water supplies depend upon wells in the

drift. Very few wells are positively known to reach bed rock and for that reason, as well as the untruetworthy character of records given by owners, comparatively little attention was given to well records. A very large proportion of the wells are "tubular", that is they consist of a pipe, rarely over two inches in diameter, which is driven down by a light rig until clean sand or gravel is found. A sand point is then inserted at the bottom and the "foot-valve" installed on top of it. The drive pipe serves as a pump cylinder in most instances although in localities where driving is easy and the wear on the pipe is therefore moderate a brass cylinder is installed at the bottom of the steel pipe. Such wells cost about $1.50 a foot and, if fortunate, a driller can complete an 80 foot well in a single day. Instead of a solid drill a combined sand bucket and drill is used; some rigs can also be used with either (a) jetting tools or (b) self-cleaning hollow rod tools. "Fountains" are drilled with either tubular or standard tools. A striking feature is that no more than one or two lengths of casing were used in the majority of such wells, the remainder was left as an open hole. Such uncased wells have been known to last for 40 years or more without causing trouble. Holes in clay stand well, but where sand beds are passed through it is necessary to maintain a continuous flow to prevent them from caving. Even a momentary stoppage such as caused by holding the hand over the pipe when taking a drink may result in "bridging". The well is put in service either (a) by cleaning with tools or (b) by placing a pump on top of the pipe and thus increasing the pressure until the bridge is broken. Most "fountains" were installed many years ago and authentic logs are exceedingly difficult to obtain; total depths differing by 100 feet are often ascribed to the same well. Contrary to earlier

reports[10] there are no definite continuous water-bearing formations and the logs of no two wells correspond closely unless very near together. Instances of inclined aquifers are reported as inferred from interference between two wells which tap "veins" at widely different depths. There is little authentic data on the capacities of flowing wells. Large wells at New London are reported to flow 50 gallons per minute and under the pump could undoubtedly furnish much more. The work at New London was called off before the city wells were examined. Contrary to popular belief there is little evidence of permanent impairment of head save at New London where large wells have much reduced the pressure. Many instances of dry holes on low ground are reported, all such are explicable by the absence of suitable water-bearing sands or gravels. Some wells derive their flow from very fine silts. Many temperatures of water were taken, but as accurate data on the depths of the wells ware hard to obtain, this information has not yet been correlated with certainty. A very few deep wells have been drilled into granite and some of these are completely dry. There are only a few drill rigs in the district which are capable of making such holes economically. The principal area of granite wells is near Tigerton, Big Falls, Marion, and Waupaca where the drift is quite thin. A deep test at Clintonville went into granite and was dry. Test wells at Shawano are not definitely known to reach granite although from similarity of depth to hard rock it is inferred that ledge was reached. Tubular rigs cannot drill through large bowlders and are forced to give up when stones too big to break by blasting are found. The presence

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[10] Weidman, Samuel, and Schultz, A. R., The underground and surface water supplies of Wisconsin: Wisconsin Geol. and Nat. Hist. Survey Bull. 35, pp. 95 - 96, 488, 562, 620, 1915.

of granite bowlders is the greatest hindrance to drilling. It is next to impossible to get a pipe down without either (a) falls of rock which break or bend it, (b) accidents in blasting, or (c) bending or breaking by driving past stones. Hard driving is almost certain to lead to disaster. On the whole, the region west of Wolf River is one to be shunned by conservative drillers. It is reported that an especially difficult hole near Marion was recently completed by using an open hole with mudded walls made by putting in clay during drilling. This method is worthy of further trial. After the open hole reaches sand, casing can be installed.

Soils.- The area surveyed in 1927 has all been covered by detailed soils maps. These give abundant evidence of careful, painstaking, expensive work but of exceedingly limited knowledge of the origin of the surficial deposits. The following correlation table gives (a) the soil series, (b) the origin ascribed by the soil men, and (c) the origin as concluded by the present writer.

SOIL SERIES	ORIGIN ASCRIBED IN REPORT	ORIGIN DETERMINED BY WRITER
Kennan	Glacial drift derived from crystalline rocks	Terminal moraine (where bowldery), drumlins, pitted outwash, some lake silts.
Vilas	Glacial drift derived from crystalline rocks and sandstone - sandy soils	Terminal moraine, drumlins, pitted outwash, sand dunes
Coloma	Glacial drift derived from sandstone	Terminal moraine, ground moraine, pitted outwash; some sand dunes
Miami	Glacial drift derived from limestone	Ground moraine on dolomite
Plainfield	Outwash derived from sandstone	Sandy outwash generally not pitted; lake sands and sand dunes
Waukesha	Outwash derived from sandstone and crystalline rocks	Outwash, generally not pitted
Antigo	Outwash derived from crystalline rocks	Outwash (weathered) in Waupaca and Portage counties; lake silt in Outagamie County
Superior	Interglacial red lake clay largely reworked by ice	Rolling phase - mainly red till terminal or overridden pitted outwash; level phase - mainly lake clay; both phases locally overlain by pebbly, bowldery sand.
Marathon	Residual from crystalline rocks	Residual from crystalline rocks
Colby	Old drift	Weathered old drift
Boone	Residual from sandstone	Residual from sandstone
Vesper	Residual from sandstone	Not seen
Poygan	Dark red clay	Marshy, red lake clay or red till
Whitman) Dunning) Genesee) Clyde)	Dark soils on low ground	Floodplains and marshes

From the inspection of the table it may be seen that some of the soil series as mapped by no means conform to the announced description, but that in practice they include soils of exceedingly diverse character, agricultural value, and origin. It is presumable that superficial resemblances in color and texture led to this confusion. It is very hard to see how anyone could possibly think that sand dunes, which will scarcely grow grass, should be mapped in the same series with the till soils of drumlins and terminal moraines. Field inspection also shows that some of the soil boundaries were drawn arbitrarily without any consideration of their form as determinable from origin; for instance drumlins are shown in all sorts of shapes instead of the elliptical form which they should have. In many instances drumlins which rise from sandy outwash plains and which have very different soils were not mapped at all. In other places outwash within drumlin areas was not separated. It is the opinion of the writer that a knowledge of glacial geology on the part of the soils men would (a) improve the accuracy of soils classification, (b) increase the speed of the work, and (c) lead to more accurate appraisal of subsoil conditions. It makes a great difference in drought resistance if a soil lies on till or on assorted deposits. There is obviously a vast practical difference between the type locality of the Antigo series, a weathered outwash plain, and the yellowish-gray lake silts of the Outagamie County map which were also mapped as Antigo.