University of Wisconsin-Extension

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FIELD REPORT, GLACIAL GEOLOGY OF OUTAGAMIE, SHAWANO, OCONTO, AND LANGLADE COUNTIES

by

F.T. Thwaites

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INTRODUCTION

Area surveyed.-- During the field season of 1928 the writer's work on glacial geology was much scattered. Work was done (a) in Outagamie County where 4 townships were surveyed and 2 reconnoitered, (b) in Shawano County where including the Menominee Indian Reservation 10 townships were studied, (c) in Oconto County where 19 townships were covered, and (d) in Langlade County where a little over 9 townships were completed. The year's total is 42 townships or about 1512 square miles. The area covered is hard to compare with that done in previous years, for a considerable portion (about 4 townships) was very sketchy reconnaissance. The western boundary of the survey in Langlade County was left in a ragged shape as it was intended to continue the work in 1929 when it would have been cheaper to work much of this region from a base farther west.

Time.-- Field work began June 20 and ended October 30. This period was interrupted by two visits to Madison which were compensated for by work on Sundays and holidays and by a visit to Madison for a field conference with Dr. Paul Woldstedt of the Prussian Geological Survey, August 28 to September 1. During the visits to Madison necessary work on well records was done without pay. Two days in October were devoted to finishing a gap left in the survey of Vilas County in 1927. In the total of 112 days, 105 days were occupied with field work and 7 with travel.

Acknowledgments.-- The writer was assisted by G. T. Owen, A. T. Eberhardt, and the late V. U. Hanson, each of whom worked about

six weeks. Thanks are due to William Heritage, logging engineer on the Indian Reservation, for transportation on the Indian railroad, and to other members of the Indian Forest Service for maps and information. Many other persons, too numerous to mention, assisted the party during the summer.

Methods.- No innovations in methods were adopted in 1928. The same Chevrolet coach was used as in the survey of Vilas County in 1927. The headquarters were Black Creek, Gillett, Lakewood, Langlade, Trout Lake, and Shawano. The principal difficulty encountered was the lack of accurate maps. In many localities it took more time to find out where one was than to make the necessary observations on the geology. One township (T. 33, R. 14 E.) has no roads whatever and others have only a few, none of which was shown accurately on maps which were available to the writer. It was necessary to traverse long distances of roads, trails, and logging railroads with the Brunton compass. On railroads this proved accurate, in fact much better than locations given by loggers, but on trails and winding roads closures were universally poor. The writer is firmly convinced that the use of a light plane-table and open sight alidade run by the assistant (as is the custom on the Soil Survey) would materially expedite the work and be a decided economy. In this connection it must be realized that no survey, however new and accurate, can possibly show all the logging trails and abandoned railroad grades which the geologist must travel if he desires to get even a passable idea of the glacial geology of the forested townships. Work in Langlade County was facilitated by the loan of a new and fairly accurate county atlas by the clerk of the Town of White Lake. It must also be realized that any mistake

in location which once gets recorded in the notes costs far more to correct than to spend a little extra time to get accurate locations at first. The reconnaissance of the Menominee Indian Reservation in the few days allowed for it was possible only because of the accurate topographic base map made by the Indian Forest Service. This map is out of date in culture and varies in accuracy in different places but is nevertheless infinitely superior to the best county maps.

Photography.-- The same high standard of photographic work inaugurated in 1927 was continued with the Kodak pictures. Some trouble was experienced at the photographers, however, for one roll was almost entirely destroyed by careless developing. As an experiment a Premo No. 9 camera using post card size cut films was tried. This instrument has a double extension bellows so that distant views can be taken much better than with a smaller instrument. Eastman panchromatic film was used in order to try out its haze-penetrating powers with strong filters. Many of the pictures with this camera were taken by A. T. Eberhardt. At first good results were secured, but on the photographer's criticism that the films were much overexposed, exposures were cut to such an extent that the results were extremely poor. Later exposures were somewhat increased, but the negatives were still underexposed. The only conclusions possible are: (a) the latitude of exposure of Eastman panchromatic film is very slight so that it is almost impossible to time the exposures accurately enough to get the intended length, and (b) the emulsions are not uniform, possibly because of a recent effort to speed up this film for portrait use. The last part of the season a little Agfa portrait film was used,

but trouble was experienced with (a) vibration of the film in the holder on windy days and (b) moisture attacking the films in the holders. The writer also experimented at his own expense with Imperial panchromatic roll film which is better than Eastman but not equal to Agfa orthochromatic film. It certainly is not worth the nearly doubled cost of film and developing. The writer cannot recommend the use for landscape work of any panchromatic film thus far tried.

Elevations.- Aneroid elevations were taken in the same way as during the two previous years. The best results were secured by Hansen and Owen who had previous experience with this work. Comparatively little office revision was needed and on the whole the results of the season can be classed as satisfactory. The same 50-foot contour maps were continued.

Costs.- The cost of the 1928 work is distributed under the same heads as in previous years on the assumption that the living costs of the assistants, which were paid out of their salaries, were the same as those of the writer.

Salaries	$1,363.87	= 59.5 per cent
Travel (8,065 miles)	645.28	24.6
Living	315.72	12.0
Miscellaneous	2.46	.3
Photography	94.62	3.6
	$2,621.95	100.0
Cost per square mile	$1.74	
Miles per day (including to and from Madison)	72	
Living cost per day	$2.81	
Square miles per work day	14.4	
Total cost of party per day from Madison	$23.42	

The increase in cost per square mile is mainly chargeable to the character of the northern part of the area. It is not far different from the $1.63 per square mile of the Vilas County work in 1927. It

must be realized that extensive foot traverses are expensive. The immense areas of terminal moraine north of Elton took several days foot work without adding anything to the scientific results. It seemed, however, that the railway grades should be traversed if for nothing else than that they served to check up the mapping done from the outside of this large unsettled area. The cost of surveying T. 33, R. 14 E., which was almost all done on foot, was about $3.90 per square mile if the average cost per day is used as a basis of computation. When this work was completed, the writer was still in considerable doubt as to the correct classification of some of the areas, so dense is the forest cover. During the work from Lakewood in cut-over country the cost figured on the same basis as above was about $2.13 per square mile. High living costs in the north are demonstrated in the table, but these did not increase the percentage that living bears to total cost. The persentage of cost of travel was notably decreased because more foot work was done and more headquarters were used. It should be noted, however, that this did not decrease total cost per square mile. An accurate base map would cut costs more than any other thing, for then it would be possible to plan work systematically instead of having first to map the main roadstand then go back and explore side roads and trails from that base. The visit to show Dr. Woldstedt some drift phenomena in southern Wisconsin, a necessary courtesy to a member of another geological survey, was at the writer's expense.

Late fall work.- It has been the custom to carry on with field work until the first of November, but the writer's experience in 1928 raised grave doubts in his mind as to the wisdom of such a practice. The advantages of such late work are absence of (a)

leaves, and (b) mosquitoes. The disadvantages are: (a) short days, (b) high percentage of rainy and foggy days when work in brush is almost impossible, (c) extremely poor roads off the main highways, (d) flooded swamps and streams. During 1928 surveys in the brush were always discontinued on rainy days and work along roads substituted, a policy which led to lack of continuity of work. It must be realized that in many seasons the leaves do not fall until the middle of October and that after that snow may come at any time. To quote Hansen: "In the summer you can see five feet into the brush and in the fall about 25 feet" demonstrates that the absence of leaves does not everywhere facilitate work to a material extent. It is doubtful if in northeastern Wisconsin it offsets the disadvantages of late fall work.

Cost of office work.-- It has rarely proved possible to complete all the office work in the field even when all the work on elevations has been given over to the assistant. In the case of certain assistants a large amount of help had to be given them in this work and after that their work has in some instances needed much correction in the office. After the field season it is also necessary to sort the notes into correct order of pages, finish coloring the plats, insert names of counties, check indexing of photographs, complete areal and topographic maps, make maps for report, and write the report. The two weeks pay allowed for this (not included in the foregoing account) does not begin to pay for the time occupied in these tasks. No drafting has ever been done in the office either to prepare maps for the field or for the report.

BED ROCK GEOLOGY

Pre-Cambrian.-- As in previous years no detailed study was made of the bed rocks. Numerous exposures of pre-Cambrian igneous and metamorphic rocks are present in the vicinity of Mountain and on the flanks of McCaslin Mountain on the north line of Oconto County. There are only a few outcrops in Langlade County and none in the region surveyed in Outagamie County although drilling shows granite bed rock at Black Creek. The rocks of the Mountain district consist largely of coarse grained pink granites. The granite porphyry which is so conspicuous further south in the Indian Reservation is not abundant. Some red rhyolite is present. The granites form hills up to more than 200 feet in height; the town derived its name from these. Large areas consist of a black basaltic rock commonly called 'greenstone', much of which is more or less schistose so that most outcrops are denoted as schist on the field maps. The best known occurrence is the striking Butlers Rock which rises to about 160 feet from a flat sand plain. Quartzite is found all along the north line of Oconto County and in the north part of T. 33, R. 14 E. where it has been mapped in detail by Wheelright in the search for iron ore. Thunder Mountain in Marinette County and McCaslin Mountain in Forest and Marinette counties were also visited. Both are hard vitreous gray and pink quartzite which resembles that of Rib Hill rather than that of Waterloo and Baraboo. The former reaches an estimated elevation of 1375, the latter 1605. Thunder Mountain is universally called Blue Mountain in Oconto County. No iron formation float or red drift was noted near either quartzite area and the writer suggests that both are inclusions in an immense mass of intrusive granite. It is highly

improbable that any merchantable iron ore will ever be found near them. Hornblende schist occurs in northern Langlade County and in the well at Gillett. The probable distribution of the bed rocks is indicated in Plate I (p. 9).

Paleozoic rocks.- Exposures of Paleozoic sediments were found in southern Oconto and in Shawano and Outagamie countiee. These belong to the Black River dolomite, St. Peter sandstone, Lower Magnesian dolomite, and Jordan (?) sandstone. No lower formations were seen on account of the drift cover. The mapping of the higher formations by the older geological survey was reasonably correct, but the border between the sandstone and pre-Cambrian formations was entirely erroneous. This border was revised on the basis of wells which strike pre-Cambrian bed rock at Black Creek, Gillett, and Suring, plus the evidence of local granite bowlders. It is recognised that there are many isolated outliers of sandstone within the general pre-Cambrian area, but the number of wells bottomed in rock is entirely insufficient to permit of accurate mapping of these. No good sections of Paleozoic rocks were found in the area surveyed in 1928.

PREGLACIAL TOPOGRAPHY

Pre-Cambrian area.- As in previous years no detailed studies of preglacial topography were possible. Much of the area is unsettled with few wells of any kind. Where there are wells most of them are shallow and end in drift. The numerous bowlders of the pre-Cambrian area make it uncertain in many instances that bed rock has been reached. Around Mountain the present configuration of the country is apparently not far different from the preglacial

PLATE I

BED ROCK GEOLOGY OF PART OF NORTHEASTERN WISCONSIN
F. T. Thwaites, 1926-1928

Galena-Black River dolomites

St. Peter sandstone

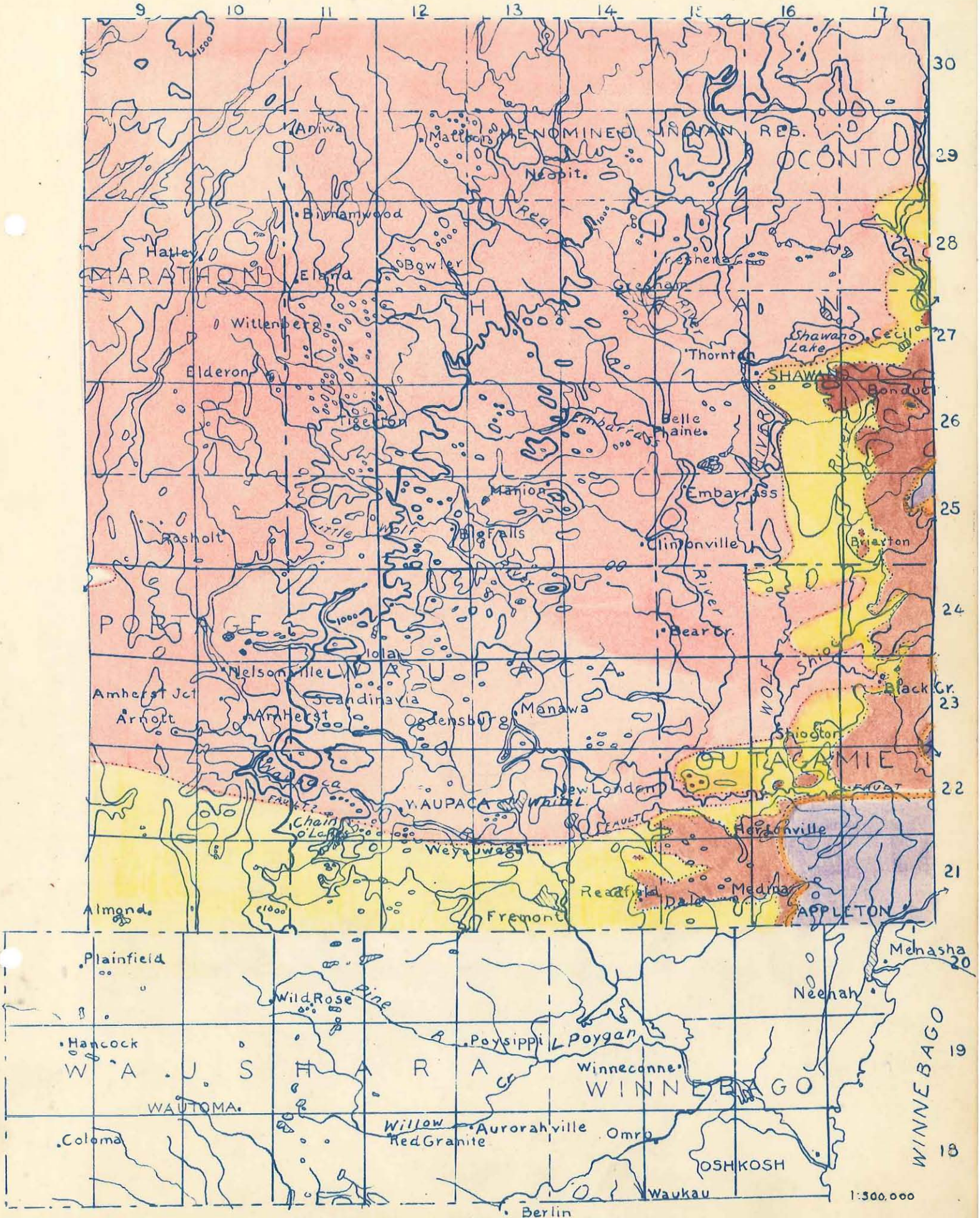
Lower Magnesian dolomite

Cambrian sandstones, undifferentiated

Pre-Cambrian-mainly granite

Scale 1 inch = 8 miles

Contour interval = 100 feet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MENOMINEE INDIAN RES.
OCONTO
SHAWANO
PORTAGE
WAUPACA
OUTAGAMIE
WAUSHARA
WINNEBAGO
APPLETON
OSHKOSH
Antigo
Mattoon
Neopit
Birnamwood
Hatley
Elcho
Bowler
Wittenberg
Elderon
Tigerton
Thornton
Shawano
Cecil
Bonduel
Belle Plaine
Embarrass
Manion
Rosholt
Little Wolf
Big Falls
Clintonville
Brillion
Bear Cr.
Iola
Nelsonville
Amherst Jct
Arnott
Amherst
Scandinavia
Ogdensburg
Manawa
Shiocton
Black Cr.
New London
Chain O'Lakes
Weyauwega
Hortonville
Readfield
Dale
Medina
Almond
Fremont
Plainfield
Wild Rose
Pine R.
Poysippi
L. Poygan
Neenah
Menasha
Hancock
Winneconne
WAUTOMA
Coloma
Willow R.
Redgranite
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topography, but to the west and north little information is available. It is apparent, however, that the relief of the granite surface is for the most part much less than that of the present topography as throughout most of the area outcrops are confined to lowlands. The deep valley at Black Creek was investigated with care, for the rock elevation there is less than 280 feet above sea level. As noted in previous reports, no outlet to south or west seems possible. A recent well at Seymour along the low ground to the northeast found rock at about 600 feet elevation. The country to the southeast, so far as now known from information given by well drillers, has no deep filled valleys. Any outlet to either northeast or southeast seems too narrow. If this conclusion is correct, the area near Black Creek is a hole which might be explained either by (a) glacial erosion, or (b) warping of the land.

Glacial erosion west of the dolomite ridges seems improbable. Down-warping to the northeast as suggested by the depth of the Great Lakes seems at present the most plausible suggestion. Under this view the former outlet of the valley was to the west via Wolf River.

Paleozoic area.- For the most part the drift is thin in the Paleozoic area. Most of the wells reach rock at less than 100 feet and outcrops are abundant. No attempt was made to map the details of this rather monotonous topography. A deep valley passes through Gillett, but its extension to the east is as yet unknown. Another filled valley which certainly discharged toward the west is found just north of Nichols.

GLACIAL GEOLOGY

Middle Wisconsin or Gray Drift

Introduction.- The Middle Wisconsin or Gray Drift was studied in northern Oconto County, Langlade County, and in the northern portion of the Indian Reservation of Shawano County. Drift of both the Green Bay and Langlade lobes was observed.

Material.- The Gray Drift of the Green Bay Lobe contains a considerable percentage of dolomite pebbles; that of the Langlade Lobe has none. The northern drift is also characterized by the large amount of trap and other rocks derived from the Keweenawan. All the till is very sandy and deep cuts in which it may be studied are rare. Nearly all the pebble counts are from outwash. It is difficult to get good pebble counts in much of the northern country on account of lack of coarse unweathered stony material. Nine counts from drift of the Langlade Lobe indicate that granite is about 41 1/2 per cent, basic igneous (gabbro, diabase, and basalt) about 22 per cent, and quartzite about 10 1/2 per cent of the pebbles. The remainder is largely composed of Keweenawan felsite, rhyolite, and red sandstone, as well as diorite and iron formation. The northerly derivation of these rocks is evident. The drift of the Green Bay Lobe does not differ markedly from that discovered in former surveys. Over considerable areas, however, outwash from the Langlade Lobe entered territory vacated by Green Bay ice and picked up more or less material from the local moraines. For instance at White Lake an esker shows 36 per cent dolomite pebbles although within less than half a mile the outwash contains only 6 per cent of the same kind of rocks. Mixed gravels with only a few dolomite pebbles extend down the Wolf Valley to within a few miles of Shawano. Data on differentiation of

the lobes must be derived from counts in eskers, kames, and till. Within the northern part of the district the percentage of dolomite pebbles in the drift of the Green Bay Lobe varies from 92 on dolomite bed rock to 26 on the granite. Still lower percentages are undoubtedly mixtures with Langlade Lobe drift. Differentiation can be made only on the basis of dolomite pebbles, for drift from the Butlers Rock greenstone is very abundant in Oconto County and quartzite from local sources is also conspicuous.

Topography.- The Gray Drift displays its characteristic rough topography throughout the district surveyed in 1928. The excessively rugged moraine and pitted plains of northern Oconto County are known locally as "Red Lands". Terminal moraines, ground moraines, drumlins, outwash, eskers, and lake beds are mapped.

Terminal moraines.- As shown in Plate II (p. 13), the Outer Moraine of the Green Bay Lobe was found in T. 31, R. 12 E. and traced into the great morainic complex of eastern Langlade County between Elton and Wolf River. This vast area is the largest rugged moraine thus far discovered by the writer. The entire morainic complex rises 300 to 400 feet above the Wolf River to the northeast; needless to say its rendering on the topographic map by the writer was very much generalized. The highest elevation appears to be in the NE. NE. sec. 18, T. 32, R. 13 E. where a hill by the side of County Highway "E" rises to approximately 1800 feet. An area of over two townships is virtually uninhabited and is crossed only by two county trunk highways which connect Pearson and Lily respectively with Antigo. Most of the moraine has been logged off, but there is much standing timber whose removal is very expensive on account of the complex topography. One cannot but admire the ingenuity of the engineers who laid out

PLATE II

GLACIAL GEOLOGY OF PART OF NORTHEASTERN WISCONSIN

F. T. Thwaites, 1926-1928

Terminal moraine

Ground moraine including overridden outwash

Drumlins of red till

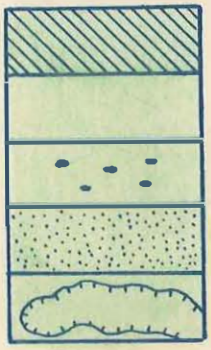
LATE WISCONSIN (Red drift)

Outwash

Terminal moraines of gray till overridden by Late Wisconsin ice

Drumlins of gray till overridden and slightly altered by Late Wisconsin ice

Shore lines of marginal lakes



Terminal moraine

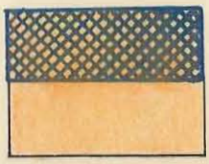
Ground moraine

MIDDLE WISCONSIN (Gray drift)

Drumlins

Outwash

Shore lines of marginal lakes



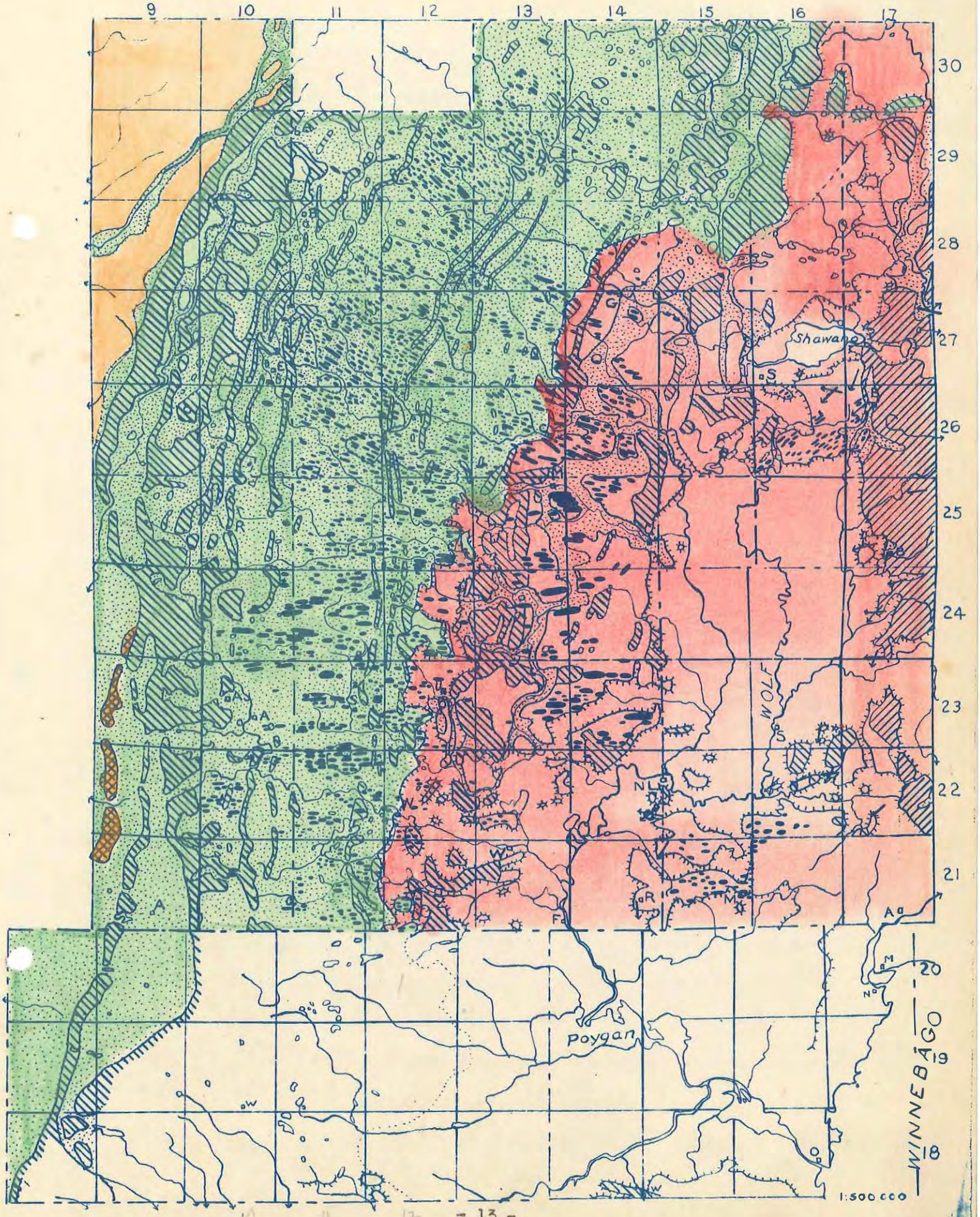
PRE-WISCONSIN

Terminal moraine

Ground moraine
Striae shown by arrows

Eskers not shown

Scale 1 inch = 8 miles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1:500 000

the logging railroads as this work must have been done before the timber was removed. The burned-over parts of this morainic complex are some of some of the widest landscapes to be seen short of the western desert. The moraine is largely till although cuts show some kame gravels. A few small patches of pitted outwash are interspersed among the bowldery hills; most of these sandy spots are so small that they had to be omitted on the final map. In one place (line between secs. 15 and 16, T. 32, R. 12 E.) red and yellowish gray, possibly varved, silts and clays were found associated with sand. Rain forced abandonment of work in the vicinity, however, before full observations could be made.

Northeast of Wolf River the moraines trend northeast-southwest and are far less complex in topography. The moraine which trends northeast from the narrows of the Wolf Valley below Lily to the northeast corner of Langlade County is relatively smooth and contains only a comparatively small number of kettles. Its great height (about 1755 feet) at Ada Lake Firetower, is evidently due to the fact that it overlies a quartzite hill. Farther east along the north line of Oconto County the high hills are relatively smooth although the sides are gullied. Mapping as terminal moraine is largely based on the presence of some coarse kame gravels. A large area of the upland in northeastern Langlade County is so flat that it was excluded from the terminal classification although it forms a distinct drift ridge. Recessional moraines are of a confused and indeterminate character within the area of the Langlade Lobe. Some of the higher hills are probably drumlins like those found near Crandon, but the fact that the work in this region was almost entirely done on thick rainy days prevented final conclusions from being reached. It had been

hoped to reach this area in 1929 under more favorable weather conditions so that work back from the roads could be completed.

Within the Green Bay Lobe area the recessional moraines are for the most part weak in Langlade County. In the western part of the Indian Reservation the "green timber" even when bare prevents sufficient view to be absolutely certain of the mapping given. This mapping was based upon observations along roads and trails with the help of contours on the timber classification map. Farther east, however, a series of rugged, although in many places flat-topped, moraines extends from the border of the Red Drift in T. 28, R. 15 E. to the northeast corner of Oconto County. These moraines connect with the Caroline Series of the 1926 report on Shawano County. As they are so much better developed to the north, it seems as if they are better given a new name, the Mountain Morainic Series.

Ground moraine.- Very little ground moraine is found within the area of Gray Drift. The smooth uplands of T. 33, R. 14 E., where the Oconto Company is now cutting, are nearly level and very bowldery. A well at Camp 25 is about 100 feet deep in drift. Some rock outcrops were found both by the writer and by Wheelright, nearly all of which are on the lower land. Were this area clear, there would be no doubt of its classification, but under the circumstances the writer wishes to reserve final judgment until more of the area has been seen farther north. Several small areas of smooth bowldery ground moraine were mapped in the southern part of the Reservation. As similar smooth areas are not at all uncommon on the crests of undoubted terminals in this area, discrimination is most difficult. In general only smooth lowlands were mapped as ground moraine. Some smooth till areas near Breed are now mapped as lake bed although described in the notes as ground moraine.

Drumlins.- Discrimination of drumlins in cut-over or forest country is not easy. An instance is the non-recognition of the drumlins around Wittenberg by several experienced glacial geologists who visited the country previous to 1926. The writer for some time failed to recognize the few imperfect drumlins of southern Langlade County and was not at all sure of the drumlins in T. 34, R. 12 E. until he had seen some better cleared examples farther north when going to Trout Lake. In the Indian Reservation, however, drumlins are numerous and perfect. Their mapping in so brief a time was possible only on account of the accurate bass map. These hills are not rock cored and show absolutely no rock outcrops although ledges are common in low ground between the drumlins. Many of these drumlins are imperfect on account of recessional morainic deposits. A good example of such a modified drumlin group is at Kinepoway Firetower in T. 29, R. 15 E.

Outwash.- A very large part of the Gray Drift area is underlain by pitted outwash. A little non-pitted outwash was studied at the eastern end of the Antigo Plain in T.'s. 31 and 32, R. 12 E. As in areas farther south the moraines and associated outwash terraces form a giant staircase rising toward the northwest. Along Wolf and Oconto rivers the stairs are mutilated by non-pitted terraces of northern or Langlade Lobe gravels. These terraces are very well shown in the cleared areas along Wolf River near Langlade in T. 31, R. 14 E. and in some of the Reservation.

Eskers.- Eskers are not common in the Gray Drift although the conditions of forest and brush cover make their recognition very difficult. The gravel pit just north of White Lake is in an esker which lies within a recessional moraine. The gravel pit near the school house in Lily may be in a short esker but was mapped as a kame.

Lake beds.- Beds of glacial lakes which were formed during the retreat of the Gray ice have thus far not been distinguished except possibly in Oconto County. Stretching from T. 29, R. 16 E. north-northeasterly along the foot of the easternmost moraine (La Belle Moraine) of the Mountain Series is a nearly level sand plain almost wholly without kettles. Exceptions are (a) the basin of Anderson Lake which lies near to one of the several isolated hills which rise from this plain, and (b) a district south of Fredenburg (T. 30, R. 16 E.). The "islands" consist of both terminal and ground moraine of the Gray Drift as at Breed and farther north of granite and greenstone as at Waupee Rock. Large parts of this area are covered with sand dunes. Toward the southeast, north of Suring, red varved clays are abundant but may be, and indeed probably are, of Red age. This same plain extends up to the northeast corner of Oconto County but is there pitted and contains several lakes. The entire area was described in the notes as outwash and it is probable that a portion of it, like the typical pitted plain near Fredenburg, is of that origin. It is suggestive, however, that (a) the non-pitted plain is bordered by the 900 foot contour, the Fredenburg plain being just at that level, (b) the entire area of sand plain, with the above exception, is nearly devoid of pebbles or gravel, (c) the plain does not slope uniformly to the southwest as do the higher true outwash plains farther west but is decidedly rolling in longitudinal section, and (d) the soil on till areas below the 900 foot line is much heavier than is common. The writer after long consideration of the data assembled in the field, therefore, maps all the land below about 900 feet as a lake bed. As no beaches or definite deltas were discovered at this level, this conclusion must be held subject to revision, if work is ever resumed.

Buried lake deposits.- Deposits of Early Lake Oshkosh have been found in sec. 4, T. 22, R. 16 E. and in sec. 18, T. 22, R. 18 E. The former occurrence is at elevation 835 and the latter at 845. Both were disturbed by the later or Red Glaciation but may be presumed to mark the 850 foot stage of the lake. On a glacial geology field trip in 1929 the writer also found beach gravels east of Lake Winnebago near the W. 1/4 corner sec. 16, T. 16, R. 18 E. at considerably above 820 feet and a delta at 1000 feet in sec. 29, T. 16, R. 18 E. The former may mark the 850 foot level, but the latter must assuredly have been deposited in a marginal lake formed while the ice still rested against the Niagara Escarpment at Oakfield. In Oconto County delta gravels were found south of Gillett on S. T. H. 32 at elevation about 880. The gravel terrace west of Underhill at elevation 880 strongly suggests a delta in Early Glacial Lake Oshkosh. It is distinct from the outwash terrace at the old railroad gravel pit between Underhill and Mosling which is graded to a much lower level. It is true no red till was discovered on top, but so many instances have been discovered where this deposit is so thin as to be unrecognizable that the few cuts examined cannot be considered as decisive evidence. The delta of the northwest part of T. 27, R. 16 E. in Shawano County which was discovered in 1926 has a summit elevation of at least 875. Deltas south of New London reach altitudes of about 865 feet. These data demonstrate that Early Glacial Lake Oshkosh extended much farther east than was at first thought possible. The subject is discussed more fully under glacial history.

Waupaca clay pit.- An interesting exposure of clays of Early Glacial Lake Oshkosh was discovered in the valley of Waupaca River

by Ganson in the course of road material work. The writer did not visit this locality in 1927 as he was satisfied that the area is the bed of Later Glacial Lake Oshkosh and saw no reason to follow the river on foot. No sign of the pit could be seen at that time from the route traversed. The finding of this exposure, interesting as it is, did not in any way change the writer's mapping or interpretation of the geologic history of the region as given in the 1927 report. Failure to find it is explicable because the vicinity is devoid of features important for the purpose of the survey. For the same reason little work was done at the New London pit. When visited in October 1928 the Waupaca pit showed a good exposure of varved clay, the lower part of which is highly folded. This deposit was studied in detail by E. W. Ellsworth for a bachelor thesis. The varve curve made by him has been correlated by DeGeer with both New London and Manitowoc. Buckley[1] states that when he visited this locality a stripping of 3 to 30 feet of "boulder clay" was being removed.

A visit on June 20, 1929 in company with Ellsworth disclosed the following section in the bank north of the pit and in borings made by the owners:

		Feet
4.	Till, red, pebbly, formerly worked for brick clay	3
3.	Sand, silty, reddish brown to gray, stoneless	40
2.	Clay, varved, summer layers gray, winter red	176
1.	Bed rock (?)	--

At the pit on the floodplain of the Waupaca the clays are covered

1. Buckley, E. R., Clays and clay industries of Wisconsin: Wisconsin Geol. and Nat. Hist. Survey, Bull. 7, p. 129, 1901.

with a few feet of postglacial river gravel. The stripping seen by Buckley was a mixture of Nos. 3 and 4.

Late Wisconsin or Red Drift

Introduction.- The border of the Late Wisconsin or Red Drift crosses the area diagonally from the west line of T. 28, R. 15 E. to the east line of T. 31, R. 18 E. near White Potato Lake. It was also seen in T. 32, R. 19 E. by the writer while on a trip to Marinette to repair the car. This border is indefinite and irregular by reason of (a) thinness of the marginal deposits, (b) cover by sand dunes, and (c) burial by lake deposits. Terminal moraine, ground moraine, drumlins, outwash, deltas, eskers, and lake deposits were mapped.

Till.- Considerable study was made of the character of the fine material of the Red Till as compared with that of lake clays. It was found that it is much more silty and gritty than are lake sediments. The color varies, particularly with the moisture conditions, but on the whole is decidedly lighter than the dark red till of the Wolf-Fox Basin. This accounts for the conclusion of the earlier soils men not to map the Red Drift of Oconto County as "Superior" or "Kewaunee" but instead as "Coloma". Study of these deposits at depth, however, leaves no doubt as to the identity of the Red Till of Oconto County with that found farther south. The writer noted when on an automobile trip to Manistique, Michigan, that the till north of Menominee, Michigan, is not red but that a pink color is apparent in the surficial till near Manistique.

Terminal moraines.- It is now recognized that there is no

definite terminal moraine at the border of the Late Wisconsin. The Caroline and Thornton moraines of the 1926 and 1927 reports are positively recognized as the southern extension of the Mountain Morainic Series superficially modified by the Red Drift. It is, therefore, concluded to abandon the use of these terms and to change the mapping of this district to show overridden Gray moraines instead of Red moraines. The high morainal hills west of Suring are known from the expesures in gravel pits on the east side to be Gray deposits modified by the Red Drift. The only terminal which is mainly composed of red till is the Briarton and within even that deep cuts commonly show gray drift. This moraine has not been traced from the southeast corner of T. 22, R. 17 E. to the east line of T. 31, R. 19 E. In the south the Briarton Moraine is about 35 miles east of the border of the Red Drift but at the north this distance cannot possibly be more than a few miles although a covering of lake deposits and outwash prevents exact measurement. A point of particular interest which could not be finally settled is the southeastern extension of the Briarton. The mapping near Mackville in T. 22, R. 17 E. clearly shows, however, that this moraine turns southeasterly and crosses Fox River below Appleton. It may be presumed that the Briarton is to he correlated with the broad moraine which reaches Lake Michigan just north of Two Rivers and which is the same thing as the Manistee Moraine of Michigan, but the northeastward extension of the moraine cannot he forecasted with present knowledge. It is hard to draw the line between the terminal and ground moraine of the Red Drift. In eastern Shawano County knolls of red till with steep sides become progressively farther and farther apart with nearly flat till between until one

can no longer justly generalize the whole as a terminal.

Ground moraine.- Larger areas of ground moraine occur in the Red Drift than in the Gray Drift region. This is explicable by (a) the more clayey character of the till and (b) the presence of large areas of dolomite upland. Typical red ground moraine is gently rolling to flat; locally steep-sided dolomite capped hills rise above the general surface. The fact that the major portion of T. 28, R. 16 E. and a portion of the north part of T. 27, R. 16 E. has been mapped as ground moraine may excite surprise. This district superficially resembles a pitted plain but the surface soil is dune sand. Lakes of considerable depth occupy some of the kettles and around them pebbles are common. On the southwest near Keshena the dunes die out upon typical red till ground moraine. Two test pits were put down within the sand dune area. One was abandoned in sand at 8 1/2 feet; the other struck glacial gravel. The writer is convinced that this is a pitted plain of Gray age, later overridden by the Red ice and after that modified by wind-blown sand.

Drumlins.- North of Gillett in T. 28, R. 17 E. there are some faint imperfect drumlin-like ridges which trend northeast-southwest; these are the only vestige noted of true red drumlins. In part of T. 22, R. 16 E. there are gray drumlins which have east-west axes and have been partially reshaped by the Red Ice which here moved in a southwesterly direction. This reshaping of drumlins by a changed direction of ice movement is a fascinating subject for future study because of the bearing it may have on the origin of drumlins.

Outwash and deltas.- Throughout Outagamie County the Red Drift is almost devoid of outwash and deltas. In Oconto County several deltaic outwash plains occur, some of which are pitted. The largest lies mainly in T. 30, R. 18 E. and has a length of 6 miles and a

maximum width of nearly 4 miles. It contains some well-sorted, stony gravel. A smaller deposit in T. 31, R. 19 E. is greatly altered by sand dunes. The elevation of these northern deltas is about 860 feet. A sandy and locally gravelly terrace and flood-plain extends along Oconto River from north of Suring to the east line of the area surveyed. At Underhill the terrace gravels lie at elevation 830 on top of the red till which rests in turn on partially cemented Gray outwash. Southwest of here a low pass connects the valley of the Oconto with the basin of Shawano Lake. The bottom of this at 830 feet elevation is floored with sandy gravel with cross bedding which dips southwest to northwest. A small terrace remnant east of Hintz in T. 28, R. 7 E. has an elevation of 830 and a terrace southeast of Suring has an elevation of about 845 feet. Southeast of Gillett there is stony gravel on a terrace about 20 feet above the water level. Throughout the entire distance the flood plain appears to be sandy. An area of about two square miles near Krakow in eastern Shawano County was mapped as outwash although possibly deposited in a shallow lake.

Eskers.- Eskers are abundant in the Red Drift of Shawano, Outagamie, and southern Oconto counties. The largest occur in T's. 26 and 27, R. 18 E. A large number are found near Pulcifer, but the largest lies just north of Green Valley. Another large esker is found west of Krakow where it is called, to use the local pronunciation of ginseng, "Jing Jang Ridge." Most of the known eskers are quite stony gravel, but some of them, including the two largest, are very sandy. A noteworthy feature is the occurrence of esker-like ridges which are composed almost wholly of yellowish gray silt. Eskers are not shown on the small scale maps but must be located from the plats and notes.

Lake deposits.- Lake deposits within the area of Red Drift consist of beach gravels, sands, clays, and silts. There seem to be two distinct basins: Later Glacial Lake Oshkosh and Glacial Lake Oconto. Lake Oconto occupied the valleys of Oconto River and Peshtigo Brook north of Suring. Its varved red clays are abundant throughout a considerable area north and northeast of Suring, although large portions of the lake bed are covered with sand dunes. Deltas described above indicate a level of about 860 or slightly lower. No beaches were discovered.

South of Suring lake deposits were also found in the Oconto Valley. In sec. 4, T. 28, R. 17 E. a pit discloses typical beach gravels at elevation 815. Judging from a delta farther east this lake must have stood most of the time at about 830. It must have connected with Later Glacial Lake Oshkosh through the low pass southwest of Underhill.

In Outagamie County beaches of Later Glacial Lake Oshkosh were seen in a number of places in T. 22, R's. 16 and 17 E. Elevations range from 820 down to below 800 with a large number close to 810. Most of the bottom of the lake basin is composed of silt or sand. No good exposures of varved clays could be found although they were not especially searched for. In this connection it seems worth while to mention that DeGeer[1] has correlated the varves at New London and Waupaca with the section in the clay pit at Manitowoc (See Ellsworth's thesis). Studies by the writer while on a glacial geology field trip definitely show that apart at least of the Manitowoc clays are older than the Red Drift. If the varve correlation is correct, a thin layer of Red Till should be present above the New London clays. A careful search on June 20, 1929, however, failed to reveal any such till layer. The New London deposit is moreover entirely unlike

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1. Geer, Gerard de, On the solar curve ----: Geografiska Annaler vol. 8. pp. 253-283. 1926.

that at Waupaca in chemical and physical properties.

Deep borings.- It seems worth while to assemble here the logs of some deep borings within the area of Red Drift.

Log of wells at Borden Company, Black Creek

Based on samples sent by C. H. Hauver and on log by C. L. Green

	Thickness Feet	Depth Feet
Red clay hardpan, apparently red till	54	54
Sand, mostly quicksand	56	110
Clay, variously described as red, blue, and black	58	168
"Hardpan", probably gray till (sand, gravel, bowlders)	100	268
Sand with some water	10	278
"Hardpan", probably till	53	331
Sand	2	333
Bowlder, called "bed rock"	12	345
Sand and gravel with water	20	365
"Hardpan", blue and gray (till)	5	370
Gravel, coarse to fine, glacial, streaks of red clay, water	76	446
Bowlder	3	449
Sand, coarse, gray, cemented, called "shale hardpan", beds of hard clay called "shale" or "shell rock"; water	42	491
Clay, red, dolomitic, pebbly	7	498
Bowlder of granite	10	508
Gravel, pebbles of dolomite, sandstone, trap, and rhyolite	4	512
Granite, gneissic, pink	18	530

It seems as if the material from 54 to 168 may be deposits in Early Glacial Lake Oshkosh.

Log of Louis Blake well, SW. sec. 32, T. 24, R. 17 E.

Data from Frank Planert, driller

Clay, red, stoneless	58	58
Quicksand	82	140
Clay, red, stoneless	141	281
Sand, water	96	377

It is probable that the top clay is mainly red till but it is entirely probable that much of the lower material is deposits of Early Glacial Lake Oshkosh.

Log of wells at Gillett Canning Company, Gillett

Data and samples from C. L. Green and J. J. Faust

	Thickness Feet	Depth Feet
No record, probably red till	6	6
Till, red, dolomitic	64	70
Sand, with pebbles of sandstone, probably glacial sand cemented by calcite; flow of water	20	90
Clay, red, very dolomitic (lacustrine?)	19	109
Sand, coarse to medium, and gravel, fine	16	125
Clay, red, very dolomitic (lacustrine?)	60	185
Gravel, stony, coarse, with layers of sand, big flow, well delivery 750 g.p.m. with pump	40	225
Hardpan and undescribed drift	156	381
"Shale, white sandstone, and limestone", sample of fine grained red sandstone - probably drift gravel cemented by calcite	31	412
Hard black rock, no samples	13	425
Hornblende, quartz, mica schist	100	525

For comparison it seems worth while to repeat the log of the railroad well given by Weidman[1].

Log of abandoned well at Gillett Junction (Northern Junction)

Sand	75	75
Clay	18	93
"Shale Rock"	2	95
Quicksand	78	173
Clay	2	175
Quicksand	3	178
Clay	107	285
Quicksand	5	290
Clay	11	301
Quicksand	19	320

The logs at Gillett show that lakes existed in the deep pre-glacial valley previous to the Late Wisconsin glaciation. The coarse gravels from which water is secured at the cannery well are probably of Gray Age. The first clay at the Junction is probably the red till and the thick clay beds of lacustrine origin (125 to 185 and 178 to 285) are apparently the same in the two wells. Just south of Gillett on S. T. H. 32 a pit shows red till overlying finely laminated silty sands which strongly resemble deposits in a shallow lake.

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1. Weidman, Samuel, and Schultz, A. R., The underground and surface water supplies of Wisconsin: Wisconsin Geol. and Nat. Hist. Survey Bull. 35, p. 482, 1915.

GLACIAL HISTORY

Middle Wisconsin

Outer Moraine.-- The Outer Moraine of the Green Bay Lobe was deposited at the same time as the Outer Moraine of the Langlade Lobe. This is demonstrated by (a) merging of the two moraines in the interlobate angle, (b) presence of both northern and eastern gravels in the Antigo Plain, (c) lack of glacial drainage channels from the high level plain through either moraine to the lowlands of the Wolf Valley, and (d) pitting of northern outwash within area of Green Bay Lobe. Weidman[1] regarded the Antigo Plain as much older than the Wisconsin glaciation stating:

"This tract is generally characterized by gravelly loam, with some boulders, with an occasional depression or sag, and by swells of coarse drift. This plain about Antigo has the characteristic features of an old alluvial plain over-ridden by the Third drift----. It is difficult to separate the gravel and sand of this older plain from that which may have been formed as outwash from the Wisconsin ice, but material of the latter sort is believed to be insignificant in amount. The slope of this gravelly plain in front (north) of the Green Bay moraine in this vicinity is downward to the south, thus sloping downward towards the moraine, a condition of slope inconsistent with the theory that any important part of it was deposited by streams issuing from the Green Bay ice lobe."

Such a theory is utterly untenable. There is no till or unasserted drift above the sandy gravels. In the interlobate angle outwash came from both lobes and the plain slopes up to both moraines. The outwash is coarsest close to the moraines. There are several outlet channels in the moraines like that followed by the railway to White Lake. It is true that farther west most of the outwash came from the north since drainage from the Green Bay ice escaped subglacially,

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1. Weidman, Samuel, Geology of north-central Wisconsin: Wisconsin Geol. and Nat. Hist. Survey Bull. 16, pp. 498 - 501, 1907.

as explained in the 1926 report, but the position and elevation of this high plain is absolutely inexplicable unless it is realized that ice filled the adjacent lowlands during the time of deposition of the sandy gravels. The distribution of the gravels and the slope downward toward the Green Bay Moraine could be explained by a younger age of the northern or Langlade Moraine, but the evidence cited above proves that such is not the case. It seems certain, however, from the terraced outlet channels in the Langlade Moraine seen when returning from Trout Lake that outwash continued to escape from that moraine long after the ice had retired from the Green Bay Moraine. This is explained by the general slope of the country to the south. For this reason a slight retirement of the Green Bay Lobe resulted in cessation of drainage to the northwest while the Langlade Lobe melted back a long distance before drainage to the south was stopped by the uncovering of the Wolf Valley.

Interlobate moraine.- It is apparent from the distribution of dolomite pebbles that Green Bay ice reached the vicinity of Lily but no farther. The interlobate area is different from that between the Green Bay and Lake Michigan (Illinois) lobes. The valley of the Wolf bounds the high morainic complex which has been referred to in the notes as an "interlobate moraine." Northeast of the Wolf a ridge trends to the northeast, but search in the forest which covers most of it failed to reveal the complexity of knobs and kettles which is so marked to the southwest. Instead there are relatively smooth ridges with gentle sags and a few steep-sided knolls, on whose lower slopes granite and quartzite outcrops are abundant. If this is an interlobate moraine, it is unlike our common conception of such a feature. The writer could find little evidence of the concentration

of drainage which normally occurs in such situations. Further study must be made of this moraine where the country is better cleared before final conclusions can be made.

Second Moraine.- In Langlade County the Second and Outer moraines appear to join and no attempt was made to separate them.

Elderon Morainic Series.- The Elderon Morainic Series is faintly developed in Langlade County and the Indian Reservation. It appears to join the great morainic complex at Elton. West of this is the head of the series of high level outwash terraces of western Shawano and Waupaca counties. At the highest place the elevation is 1530 feet. In the narrow angle between the head of the Elderon Moraine and the inner margin of the Outer Moraine (which here is joined to the Second Moraine) drainage was closely confined and extremely coarse stony gravel was deposited. In fact, were it not for (a) the level uplands between the kettles and (b) the horizontal bedding, this area would doubtless be classed as kames by many geologists. In the vicinity of Mueller Lake, however, there is some of the most perfect pitted plain topography which the writer has ever seen. Excellent examples of terracing may be seen in the southeastern part of T. 31, R. 12 E. The cause of the terracing was the retirement of the ice farther south and melting of isolated ice masses both of which opened new and lower outlets. Formation of the morainic complex evidently continued until after the deposition of the easternmost Elderon Moraine, for the isolated moraines near White Lake evidently belong with this rather than with the Elderon Series.

Bowler Morainic Series.- The isolated morainic areas of the central part of the Indian Reservation must be the continuation of the Bowler Morainic Series of Shawano County. The forest cover, most of which is hardwoods, prevents detailed examination. Mapping, there-

fore, is based primarily on the contouring of the Forest Service map. In Langlade County the outwash along the Wolf River has almost entirely destroyed these moraines but judging from their alignment, they correlate with the moraines along the east border of the county and those west of Lakewood in Oconto County. West of the Bowler Moraines, another series of outwash terraces, all of which are much pitted, tell of glacial drainage toward the west of south. Around Townsend the highest levels are about 1385 although in eastern Langlade County (T. 32, R. 14 E.) plains occur up to 1425 feet. For a considerable time during the terracing of the plain around Townsend waters must have escaped via the marked valley from sec. 5, T. 32, R. 15 E. to sec. 31 of the same township. Southwest of Wolf River the same series of plains has a maximum elevation of about 1350 and declines toward the southwest. The Bowler plains at their maximum level were about 150 feet lower than the Elderon plains to the northwest. Terracing obscures the relations to such an extent and the region is for so large a part covered by forest and brush that definite conclusions are difficult to reach. Throughout the Indian Reservation the outwash streams must have meandered among so many drumlins that their velocity was checked and little but sand was deposited. In most of T. 30, R. 14 E. the Bowler Moraines have been nearly buried by later outwash so that correlation of the terraces with moraines is very difficult.

Mountain Morainic Series.- Judging from the size and complexity the Mountain Morainic Series records a very long halt of the ice margin which not unlikely correlated with Alden's Waupun, St. Anna, and Rush Lake moraines. It may be suggested that this morainic series is the product of a readvance, for in many places its topography somewhat resembles an overridden pitted plain. It was in many places in

Oconto County called a "flat topped moraine" in the field notes. Exposures of outwash beneath the till are present west of Bonita. During the formation of the Mountain Series, outwash terraces were developed to the west. The highest known level is near Lakewood at 1285. Escape for waters was offered by both the channel now followed by the railroad in sec. 4, T. 32, R. 16 E. and, at a lower level, a pass in the same section once used by a logging spur. South of these passes flow was unobstructed save for some morainic remnants in T. 30, R. 15 E. which area was not studied in detail on account of its inaccessability. Later the broad valley southwest of Mountain must have carried drainage to Wolf River at its great bend on the west line of Oconto County. It may be presumed that the waters did not follow the Wolf very far at this time but continued southwest through the low ground of the western part of T. 28, R. 15 E. at elevation 885 to 865. The origin of the breaks in the easternmost or La Belle Moraine in T's. 29 and 30, R. 16 E. is not clear from present knowledge. They may mark preglacial valleys or they may have carried glacial waters when the ice stood not far to the east at the discontinuous moraines east of the La Belle stand. It was at this time that the pitted plain at Fredenburg in T. 30, R. 16 E. was formed. This plain doubtless extended south as far as T. 27, R. 16 E. where it had an elevation of about 850 feet as contrasted with 900 feet at its northern extension. A similar plain along the eastern line of Oconto County declines from over 1050 feet to 900 feet in about 15 miles. The most easterly moraine of this stage is the high drift hill east of Butlers Rock (sec. 4, T. 31, R. 18 E.)

Early Glacial Lake Oshkosh.- It was at first thought that Early

Glacial Lake Oshkosh could not have had a 900 foot level after the ice cleared the col south of Fond du Lac between the basins of the Rock and the Fox. Study of the topography at Horicon as interpreted from notes by Alden, however, shows that it is entirely possible that the moraine at the south end of Horicon Marsh may have constituted a temporary dam, for Horicon station has an elevation of 881 and seems to lie in an erosion valley. This possibility remains to be tested out before final acceptance. It is certain, however, that an 875 foot stage could have been maintained until the ice cleared the escarpment at the northeast end of Lake Winnebago when the waters would have escaped to Lake Michigan at a level of about 800. Evidences of 850 to 880 foot levels of Early Glacial Lake Oshkosh have been cited before and definitely prove that this lake was far longer lived than seemed possible before their discovery. If the Gray Ice occupied a moraine in essentially the same position as the Briarton of Red Age, then a 900 foot lake of the same age as that farther south is distinctly possible in part of Oconto County although its existence is not positively proved. It seems more likely that if there really was a 900 foot lake in that region, it was of later age. The level of the highest Gray outwash at Keshena is only 865 and that of the deltas in secs. 6 and 7, T. 27, R. 16 E. is about 875. These deposits seem to indicate that at the time of the La Belle Moraine Early Glacial Lake Oshkosh had fallen to 875. The deltas near Underhill and south of Gillett indicate an 880 foot level. When the great outwash plain east of La Belle Moraine was formed, the lake level must have been 850. The delta at Readfield (T. 21, R. 14 E.) indicates a very low stage of this lake, in fact no higher than the 825 foot level of Later Glacial Lake Oshkosh. In all deductions from beach levels the factor of postglacial or late glacial earth movement has been neglected as not yet proved in

this locality. It is probable that the somewhat conflicting evidence can be untangled only by studies farther to the northeast.

Recession of the Langlade Lobe.-- Sufficient study has not been given to the area occupied by the Langlade Lobe to determine the significance of the moraines which have been observed. It seems significant that many of the areas mapped as moraine show a northeast-southwest orientation of the hills which suggests that they are altered drumlins. It is possible that the ice here did not move at right angles to the so-called interlobate or Lily Moraine but parallel to it. As soon as the valley of the Wolf was cleared by ice, glacial drainage began to follow that route and to cut terraces. Near Pearson the highest observed pitted plain is at 1550; it has been terraced to a depth of about 50 feet, apparently in a short space of time as the lowest levels are also pitted. North of Langlade the highest terrace of Green Bay outwash is at elevation 1400. A prominent pitted terrace there is at elevation 1310 to 1315; at the Town Hall in sec. 10, T. 31, R. 14 E. its material is all of northern origin. This level is about 65 feet above the river and at least two non-pitted levels intervene between it and the river, of which the most persistent is 40 feet above the water. In places these terraces contain some Green Bay drift which was evidently picked up locally by the glacial streams. In sec. 24, T. 30, R. 15 E. terraces are well developed. Northern gravel within the area of the Green Bay Lobe is also found along the Oconto and some of its tributaries as far south as Mountain. It is clear from the pitted topography of the terraces of Langlade outwash within the Green Bay area that the two lobes must have been melting back at essentially the same time.

Late Wisconsin

Time relations.- The subject of the time relations of the Middle and Late Wisconsin glaciations has been discussed in previous reports. The writer is convinced that a comparison of depths of weathering in outwash of the two drifts would be a valid means of comparison of relative ages. Time, however, has been lacking to make the tabulation of data necessary before any definite conclusion can be drawn. Although large numbers of exposures of the contact of Red and Gray tills have been examined, no evidence of interglacial weathering or soil development has been observed except at the Forest Bed near Two Creeks. The recent rise in the level of Lake Michigan has shown definitely that the organic deposits at that place rest upon imperfectly varved silty clays which have been much disturbed by the work of the Red ice. These sediments are 7 to 20 feet thick and rest upon gray clayey till which may be presumed to be of Middle Wisconsin age. Essentially the same section is also shown in the cement works clay pit at Manitowoc except that the forest remains are absent.

Wolf River Lobe.- Data now available indicate that the Wolf River Lobe of the Late Wisconsin or Red Drift was merely a local excrescence on the west side of the Green Bay Lobe. It was doubtless directed by the valley which may have then been considerably deeper than now. This lobe did not last long enough to make any moraines or large outwash plains of its own although several deltas, like those east of New London, were formed during its recession. The supposed Red Drift moraines of Waupaca and western Shawano counties are overridden moraines of the Mountain Series. Many Gray drumlins were overridden and altered to such a small extent that it seems plausible to infer that the Wolf River Lobe did not last very long. This conclusion is also supported

by (a) the thinness of the till, and (b) the relatively slight modifications of the older moraines and pitted plains.

Early marginal lakes.- When the Wolf River Lobe was at its maximum, the ice border reached an elevation of slightly over 1000 feet in T. 28, R. 14 E. This stand of the ice would have shut in a lake in the valleys of the Wolf and Oconto which would have covered a vast territory extending up to north of Mountain. Save a few sporadic occurrences of a little red clay, no definite evidence of such a lake could be found. The outlet would have been at elevation about 1015 through sec. 35, T. 28, R. 13 E. and secs. 2, 11, 13, and 23, T. 27, R. 13 E., thence along the west line of the Red Drift as outlined in previous reports. As the existence of such a lake was not suspected at the time of survey, this possible channel was not examined critically In view of the proof outlined above of the relatively brief duration of the maximum of the Red ice, it is not surprising that such a lake would have left little trace, for as the ice front retreated its level would have constantly fallen. It is probable that many of the silts noted below or on top of the Red till in Shawano County are relics of this marginal lake during the advance and retreat of the Wolf River Lobe.

Glacial Lake Oconto.- In Oconto County the Briarton Moraine certainly does not mark the farthest stand of the Red ice, for it is fronted with pitted deltaic outwash. Evidence of the maximum stand of the Red ice in Oconto County is obscured by later lake and wind deposits It is plausible to suppose that a 900 foot lake was enclosed in the valley of the Oconto and its tributaries as long as the ice margin rested against the La Belle Moraine at Keshena. This lake could have drained to the Wolf via the low ground at its great bend on the west line of Oconto County and thence southwest through an area in T. 28, R. 15 E. which had been only recently vacated by ice. The lines of

drainage south from this point are varied. The highest is southeast of Gresham at elevation about 910, thence to, at first the valley of the Little Wolf, and later the Clintonville delta. Later and lower outlets were via the Thornton outlet to the vicinity of Belle Plaine, and by way of a sand plain west of Shawano. Now that the true explanation of these outlets is apparent, they deserve more critical study and better elevation readings. Byt the time the ide had retreated to the Briarton Moraine or very close to it, the level of the marginal lake fell to about 860. The outlet may then have been to the southwest through the district which is so much altered by later sand dunes. It is possible, although not probable, that the 880 foot gravels west of Underhill were deposited as a fan in a re-entrant of the ice margin at this time. They, however, seem too clean and somewhat too high for such an explanation; they look much more like a Gray than a Red deposit. Unfortunately their western extension is covered with sand dunes and as presence of a Red till cover is not proved, this question must be left open. The level of this stage of Glacial Lake Oconto is measured by the break in slope at the edge of the delta on its east side. Until Oconto River had eroded the drift ridge west of Underhill, where the outlet may have been situated, this stage existed. Its areal distribution has not been mapped in all of T. 28, R. 17 E.

Later Glacial Lake Oshkosh.- After the ice had retired nearly to the Briarton Moraine, erosion of the Oconto Valley at Underhill joined Lake Oconto with Later Glacial Lake Oshkosh through the broad gap now used by the railway. At this time an elevation of about 830 feet was reached in both bodies of water. The lake level was lowered both by (a) erosion of the Portage outlet to about 800 feet and (b) uncovering of the low pass to the head of Manitowoc River just north-

east of Lake Winnebago at about 805 feet. No beaches as high as 825 to 830 are known close to the Briarton Moraine. It, therefore, seems probable that the ice at that stage cleared the Niagara Escarpment at Sherwood and allowed a two outlet stage at about 810. This idea has not been checked up in the field, but no definite outlet channel could be expected in the flat country north of Sherwood. A number of beaches at 790 to 795 suggest that erosion of the sandy drift below Portage soon put a stop to easterly drainage.

Later lakes.- Very flat areas near Hickory Corners in T. 29, R. 18 E., east of Gillett, and at several places in eastern Shawano County as near Krakow strongly suggest that other lakes were formed at later stages of the retreat of the Red ice. If so, no positive data on their extent or levels is available.

Wind directions.- The subject of wind directions during the formation of the late glacial marginal lake beaches has not received the attention which it deserves. Alden[1] thought that beaches east of Fond du Lac at about 805 to 815 were formed by southwesterly winds. A visit to this locality convinced the writer that northwesterly or northerly winds are more probable. So far as can be seen, all the bars on the east side of Lake Winnebago are longer on the north than on the south sides of the old bays. In Outagamie County the evidence is more convincing. Some bars south of Bear Creek suggest southeasterly or easterly winds. East of New London, northerly winds are shown, although a southwesterly direction could also be considered as possible. Westerly winds are indicated by some beach gravels about two miles northeast of Stephensville, but the bar just north of that village definitely shows northerly winds. Farther

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1. Alden, W. C., Quaternary geology of southeastern Wisconsin: U. S. Geol. Survey, Prof. Paper 106, p. 324, 1918.

east among the islands, north, northeast, or possibly east winds are the only possible ones which could explain the deposits. A bar south of Shiocton strongly indicates northerly winds. The writer is convinced that the winds during the time of Later Glacial Lake Oshkosh blew off the glacier and were decidedly different from those of the present time in that region. Absence of beach deposits along much of the shore line of this lake is doubtless to be explained in large part by packs of floating ice which damped wave action.

Postglacial

Dunes.- The sand dunes which are so conspicuous near to and in the beds of glacial lakes in this region occur for the most part east and north of streams and lake beaches. Locally they lap up onto moraines and rock hills east of the glacial lake basins. Cross bedding in the dunes also indicates with one possible known exception deposition by southerly or southwesterly winds. The dune material was derived from lake sands which had been in large part reworked by existing streams and lakes. The vast area of dune sand in T. 28, R. 16 E. was obviously blown up from the basin of Shawano Lake by southwesterly winds. The dunes are, therefore, all or nearly all of postglacial rather than late glacial origin. Whether the dunes imply a period of greater aridity than the present, the writer is not prepared to say.

Earth movements.- It is not at all certain that any late glacial or postglacial earth movements have affected this area. Trainer[1] independently found evidence of beaches near Berlin at 820, 850, and

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1. Trainer, D. W., Jr., Moulding sands of Wisconsin: Wisconsin Geol. and Nat. Hist. Survey, Bull. 69, pp. 38, 42, 1928.

900. The phenomena at the outlets of both Early and Later Glacial Lake Oshkosh do not require northward elevation of the land to explain the levels of known beaches.

ECONOMIC GEOLOGY

Introduction.- Several fundamental facts must be appreciated in considering the glacial economic geology of the area surveyed. First, there is a striking difference between the clayey gravels which were formed in the streams and lakes of the time of the Red Drift and the clean gravels of Gray age. Second, distinction must be made between gravels suitable for surfacing and those good for concrete. Third, the gravels of the Green Bay Lobe contain abundant dolomite pebbles and are much preferable for concrete aggregate to the northern or Langlade Lobe gravels. Fourth, the poorer northern gravels occur to a considerable extent within the area of the Green Bay Lobe in some places close to better local gravels. Fifth, opportunities for the establishment of commercial pits are limited to points within half a mile of a railroad, and preferably within the yard limits of a large town. Sixth, Gray gravels may in many places be found beneath the Red Drift. An innovation in this report is the summarizing of the gravel possibilities of each township which was examined in 1928.

T. 22, R. 16 E.- A large deposit of beach gravel caps the hill in sec. 25. Another large bar deposit is south of the dolomite hill in sec. 17. Other beach gravels occur in secs. 9, 16, and 25. Kames are abundant, but the deposits are mainly very small, except in secs. 1 and 13. Some gravels along the creek in secs. 28 and 33 were mapped as outwash, but their origin is not clear.

T. 22, R. 17 E.- Gravel deposits in this township are confined

to a few small kames and to beach and bar deposits. The latter are found in secs. 28, 29, 30, and 33.

T. 23, R. 17 E.- The north half of the township is virtually devoid of gravel. The largest deposit is that in sec. 31 which is at present operated by the Center Valley Sand and Gravel Company. The material is a kame which was reworked by the waters of Later Glacial Lake Oshkosh. Much of the gravel is so covered with red clay that the operators have never been able to wash it clean. When visited in 1928 no concrete gravel was being shipped. Fair deposits of beach gravel occur in sec. 20. Kames throughout the rest of the southern part of the township are virtually worthless.

T. 24, R. 17 E.- Gravel is found in eskers and kames in this township, but most of the deposits are small. An esker in sec. 2 has been developed on a large scale and another fair deposit is in sec. 15. Many of the kame pits reported by the road material survey have been abandoned. A few small pits in beach gravel were found in sec. 36.

T. 25, R. 18 E.- Gravel is very scarce in this township except in the far western part. An esker in secs. 19 and 30 and a kame in sec. 18 are all the important known deposits.

T. 26, R. 18 E.- West of Krakow in secs. 1 and 2 there is rather sandy gravel mapped as outwash. In secs. 2, 3, and 9 is a huge esker in which some pits display fair gravel; the western portion, however, is nearly all sand. Several small eskers furnish small deposits of good gravel. The few kame pits which were discovered are of poor quality.

T. 27, R. 18 E.- Excellent esker gravels are found in secs. 5 and 6. The immense Green Valley esker, which was once investigated by Dr. Nutt for a commercial pit, extends through secs. 10, 11 and 12. A

large town pit and several road cuts show that the material is exceedingly sandy and very unfavorable for large scale development. There is a smaller esker near the railroad in sec. 1. The kame gravels are of inferior quality and small quantity in this township. A large portion of secs. 25 and 36 is underlain by a thin layer of gravel mapped as outwash although its origin is not yet clear.

T. 28, R. 15 E.- Some gray gravels of poor quality are found below the Red Drift in secs. 7 and 18. A large pit in sandy Green Bay gravel has been worked in the west part of sec. 16. More stony gravel occurs just west of Keshena Falls in sec. 22. This gravel is also of Green Bay Lobe origin although on a low terrace of the Wolf. A good pit is found at the Indian Fairgrounds in sec. 26. Most of the outwash is too sandy for use and exposures along S. T. H. 55 are not encouraging for the resources of either moraine or adjacent outwash. The southeastern part has a thin cover of Red Till over older outwash which is not known to be of good quality.

T. 28, R. 16 E.- The sole gravel pit in this wilderness of dunes is between Watohsah and La Motte lakes in sec. 19 and it is so small that the quality of material can only be guessed at.

T. 28, R. 17 E.- Beach gravel is found in sec. 4 along the side of a stream. In the SE. of sec. 12 there are good outwash pits in coarse stony gravel. Throughout the Briarton Moraine kames are abundant. The Chicago and Northwestern Railway formerly operated a large pit in rather sandy gravel between Underhill and Mosling. Although a large part of this outwash from the Briarton Moraine has been exhausted, it is probable that a commercial pit could be operated here if the material is clean enough to wash. Most gravels of Red age are much too clayey for use for concrete even after thorough washing. The

deposits in sees. 26, 27, 34, and 35 are of most interest for possible development of a commercial pit. The writer investigated this locality in company with Dr. C. A. Nutt of Plymouth. The eastern portion of the triangular upland is a moraine which presumably is a portion of the Briarton. West of this a level tract suggests the topset beds of a delta. Cuts north of the School House on the west line of sec. 35 show very sandy material, but farther east two or three small gravel pits display good clean stony gravels. Pits in the morainal portion show coarse stony gravel.

T. 28, R. 18 E.- Esker and kame gravels are abundant throughout all but the southeastern portion of this township. The largest kame pits are in the east part of sec. 29. The upland south of Gillett appears to be a Gray delta overlain with Red till. Good gravels are shown in several places as in sec. 27. Outwash gravels are less important, but there are good shows at Mosling and in sec. 25. A fair pit is operated in sec. 26, but the deposit is thin. A deposit on the south side of the river was visited with Dr. C. A. Nutt to whom it had been recommended by R. A. Amundson, County Agent. The place had also been visited by road material men. The deposit is of fair grade but is small. It is probably material reworked from adjacent sandy gravels by the Oconto River since the last glaciation. The only chance for a commercial pit here would be north of the river, but the prospects do not seem encouraging.

T. 29, R. 13 E.- Exploration in this township was confined to the near vicinity of S. T. H. 47. No usable gravels were found.

T. 29, R. 14 E.- Exploration was confined to the Soo Line near Askenett and south of Neopit, the Indian logging railroad, and S. T. H. 47. There is a fair pit in sandy outwash in SW. SW. sec. 18.

Another in the north part of Neopit in sec. 17 contains some gravel in the lower part under a heavy sandy stripping. The ridge in the center of sec. 17 suggests an esker, but no step could be made at it. Coarse kame gravel is found in sec. 29 along the track. Pits in sec. 19 are too sandy for use. By all odds the best pit is that at Camp 16 in sec. 2. The concrete saw mill at Neopit was built from this pit. Transportation via the Indian railroad will be available for many years. The pit is in outwash of the Green Bay Lobe.

T. 29, R. 15 E.- All but the northwestern six sections were fairly well explored, but no gravel fit for use was discovered. It is probable that exploration in the moraines would uncover kames and there may be coarse outwash close to the moraines.

T. 29, R. 16 E.- No usable gravels were discovered in the terraces of the Wolf, but thorough exploration ought to show some. Kames do not seem to be abundant in the moraine, but the hill on which La Belle Firetower stands is made of coarse gravel. Much of the lake bed farther east covered an older outwash plain, but no cuts in anything but very sandy gravel were found.

T. 29, R. 17 E.- Good gravel is very scarce in this township and is almost wholly confined to the hills west of Suring. It occurs there in both (a) kames of Red age, and (b) kames or outwash of Gray age under and disturbed by the Red Drift. A good deposit, now almost exhausted, occure in NW. NE. sec. 20 at the edge of a swamp which was once a lake. It looks, however, more like outwash than a beach deposit.

T. 29, R. 18 E.- Kame and esker gravels are well distributed in this township. The largest pit is in the south part of sec. 21. Some gravels of Gray age may be found locally below the red till. It seems probable that coarse outwash could be found in sec. 20 near to an outlet from the moraine.

T. 30, R. 13 E.- This township was explored only along and near to S. T. H. 47. Nothing but excessively sandy outwash was discovered.

T. 30, R. 14 E.- This township was explored along the Soo Line and the Indian logging railway. There is some gravel in sec. 4, but most of the outwash is entirely too sandy for use. A kame was noted in sec. 28 and others doubtless occur in the small areas of terminal which project through the sandy plains.

T. 30, R. 15 E.- Exploration was confined to the route of S. T. H. 55 with a few side trips and a visit to parts of secs. 19 and 30. The outwash is mostly sandy. A fair pit is used by the State in sec. 24, but the method of exploitation wastes the larger stones which are the most valuable part of the deposit. It is probable that test pitting would discover other similar deposits in the terraces along the Wolf.

T. 30, R. 16 E.- Exploration in this town was fairly thorough for such wild country. Reasonably good stony outwash gravels are found in sec. 23 at Fredenburg. Most of the outwash is sandy and kames, if present in the moraines, have not been opened up.

T. 30, R. 17 E.- Almost all of this township is lake bed or low flat sand plain, probably a lake bed. The higher areas are ground moraine, possibly once submerged by a lake. Some kame gravels are found in secs. 32 and 36. Outwash gravel of fair quality is found on a terrace in the lake bed in sec. 32. Similar but better gravel is found in sec. 19, but the pit shown by the road material party was not seen. Some of this gravel may be a beach deposit, but it is more likely of postglacial stream origin.

T. 30, R. 18 E.- The bulk of this township is a lake bed and is devoid of anything but a little sandy postglacial gravel along

the larger streams. The best chances are in the delta of the southeastern part. Good gravel is shown in road cuts betweensecs. 13 and 24.

T. 30, R. 19 E.- Only the western two miles of this township was surveyed. Good gravel is abundant especially in secs. 6 and 7 (outwash in moraine re-entrant), secs. 18 and 19 beneath the Red till, sec. 17 in an esker and some kames, sec. 9 in a kame, secs. 28, 29, 32, and 33 in kames and beneath the Red till. The last named locality seems to have a vast reserve of good gravel.

T. 31, R. 12 E.- Kames in this township have not been much developed since the outwash of secs. 13, 14, 15, and some other areas in the southeastern part is so stony. The best pit is in SE. NW. sec. 14 and a fair pit is found at the W. 1/4 corner sec. 25.

T. 31, R. 13 E.- Coarse outwash and kame gravels are found all along S. T. H. 64 west of Elton. Stony outwash gravels were noted in secs. 21, 22, 27, 28, and 29. There is a distinct chance for a commercial pit in either sec. 21 or 22. Kames are very abundant in the terminal moraine areas.

T. 31, R. 14 E.- Much of the outwash is of northern derivation and is low in dolomite pebbles. Fair to good outwash gravel is found in secs. 10, 12, 16, 30, and 35. A short esker has been developed in sec. 16. No good kames were seen. It is probable that good gravel could be found in the terraces of the Wolf.

T. 31, R. 15 E.- Stony gravel seems to be scarce in this township, but this is largely because of slight development. Coarse outwash gravels were noted in secs. 6 and 29. The outwash gravels developed along S. T. H. 55 are rather sandy.

T. 31, R. 16 E.- This township is poor in gravel except in secs. 3 and 4. The gravel on the side of Oconto River in sec. 4 is northern.

Some concrete gravel could be found in the pit in sec. 3. A little fair gravel is found in NE. sec. 13.

T. 31, R. 17 E.- This township is very poor in gravel deposits. Pits on C. H. "W" in sec. 6 are the best which were discovered, but the reserve is doubtful. The problem of surfacing for new S. T. H. 64 is apparently not solved. The writer suggests that kames might yet be found in the moraine which crosses the route in sec. 13. West of this moraine the hills suggest outwash rather than lake bottom and it is possible that further exploration in this district might yield results better than those obtained by a former road material party.

T. 32, R. 12 E.- Survey not completed. Kames are common in the terminal moraine and one has been exploited in sec. 26 although lower part of cut is in till. Outwash is very sandy where developed but offers much better possibilities near to terminal, especially near the drainage outlet in south part of sec. 26.

T. 32, R. 13 E.- There are no large pits in this township, but kames offer the best chances for coarse gravel. There are possibilities for commercial pits on the Soo Line in secs. 3 and 25. The outwash is very sandy even just below the narrows of the Wolf in sec. 3.

T. 32, R. 14 E.- As in the township preceding the only possibility is kames. There is a large pit in a kame in the NE. NE. sec. 29 on Nine Mile Hill.

T. 32, R. 15 E.- The terminal ridges contain numerous kames which have not been much exploited. The outwash offers the best possibilities along the abandoned glacial stream valley in secs. 5, 8, 7, 18, 19, 29, 30, 31, and 32; elsewhere it is sandy.

T. 32, R. 16 E.- The best gravels are in kames as in the SE. of sec. 5. There are opportunities for a commercial pit in secs. 4 and 5

along the Northwestern line. The old railroad pit in sec. 33 seems to have been very sandy. Outwash along the Oconto in secs. 23 and 26 looks favorable, also some of the outwash in sec. 27 adjacent to the moraine.

T. 32, R. 17 E.- No gravel was discovered in this township. The best chances are in the moraine, for the outwash appears to be more sandy than usual for this region.

T. 33, R. 12 E.- Survey not completed. The best pit was observed in NW. NW. sec. 1; it is kame gravel and used on S. T. H. 55. Outwash is nowhere developed on account of excessive sand, but there is a show of coarse gravel at the N. 1/4 corner sec. 3.

T. 33, R. 13 E.- The best gravel pit is near Lily in SE. NE. sec. 34 in kame or possibly a short esker. Coarse kame gravels are very abundant in terminal areas as in sec. 33. No stony outwash was observed and it has nowhere been developed on a large scale.

T. 33, R. 14 E.- No public roads in this township and therefore no pits; the railroads have brought ballast from outside. There is some outwash along the creek in the northwest part, but it is probably very sandy.

T. 33, R. 15 E.- Moraine in northwest part shows much kame gravel. A large pit is situated on Oconto Company Railroad in sec. 8. There are possibilities for a commercial pit on the Chicago and Northwestern Railroad in secs. 4 and 25 . Fair to good outwash gravel is found in secs. 10, 22, and 23. The outwash is largely northern. Small kames or coarse outwash deposits near moraines were seen in secs. 31 and 32.

T. 33, R. 16 E.- Glacial geology is complicated with northern and local gravels intermingled in many places. There are a few gravel pits; one of the best is in the SW. NW. sec. 32 in a delta kame or very high outwash terrace. Much of the outwash is northern gravel. There are

cuts and small pits in stony northern outwash in secs. 27 and 11.

T. 33, R. 17 E.- A large part is terminal moraine in which kame gravels are abundant. No large pits observed. Gravel possibilities are fair in outwash of secs. 5, 6, and 18, but elsewhere deposits are very sandy and deeply covered with sand. No northern gravel was observed, but it must be present in sec. 1 at least.

T. 34, R. 12 E.- Survey not complete. Coarse kame gravels are abundant and have been developed in secs. 8 and 10. Outwash appears to be excessively sandy.

Summary.- As the purpose of the work by the writer was to map the glacial deposits and outline the glacial history of the region, no attempt was made to discover all the gravel pits or to try out the gravel showings by test pitting. No gravels were screened or otherwise tested quantitatively. Such work was left until it should be needed for definite highway projects. Some of the area had previously been surveyed by road material parties and their notes were used. It was found that in the years which had elapsed since this former work many old pits had been closed and filled and new deposits had been opened up. In a few instances the locations given by early parties must have been erroneously placed on the map. All things considered, it must be realized that whoever follows in the writer's footsteps will not see things just as he did. Still other changes in development will have been made, new roads will have been graded, and old cuts filled or grassed over. Some omissions and errors by the writer will be discovered from time to time as no work can be perfect at all points and all times. The writer endeavored to combine economy and accuracy, things not always compatible.

It is regrettable that road material parties have no access to the

plats of the writer's survey on which the mapping of roads and streams has been corrected so far as funds and instruments would permit. Differences in base maps will account for many failures to find what the writer saw or to recognize the same locality. Moreover, newly discovered facts will necessitate revision of some of the writer's explanations. Nevertheless, the road material man who carefully reads reports, maps, and notes should find many hints from beach elevations, mapped shore lines, glacial drainage outlets, outwash terrace outlines, etc. etc. It must be realized that the notes alone can not tell the whole story.

In many instances further work changed the interpretations and in some instances copying has not been accurate on account of hasty writing in the field. There has never been time to read over <u>all</u> the notes.

F. T. Thwaites,

June 21, 1929.