University of Wisconsin-Extension

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FIELD WORK ON GLACIAL GEOLOGY OF EASTERN MARATHON AND WESTERN SHAWANO COUNTIES

by

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Open-File Report 26-3
36 p.

1926

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INTRODUCTION

Area surveyed. During the field season of 1926 10 townships in eastern Marathon County and 22 townships in Shawano County, all of that county except Range 18 East and the Menomoninee Indian Reservation, were surveyed, in all approximately 1180 square miles. Field work lasted from June 28 to Oct. 29, 114 days but was interrupted by visits to Madison and Neillsville. The writer was assisted by Loyal Durand, Jr., for 10 weeks and by Clyde G. Dickinson for the rest of the season.

Methods. Pleistocene geology is best studied along highways since they afford many exposures and pass through most of the cleared land. Work in the brush is at a great disadvantage since neither can the topography of the land nor the nature of the underlying deposits be determined satisfactorily. A shovel and pick were carried to supplement ready-made exposures and the use of these furnished much valuable information. In the brush, however, the presence of many roots combined with the depth to which weathering has obscrured the difference between gravel and till combined to limit their usefulness. The party was transported in a Ford sedan; only a Ford posseses the virtues of lightness, short turning radius, and high clearance, all essential to traversing side roads in the north country. In a season like 1926 a closed car is a necessity after the first of September. To travese roads accurately it is necessary to have a good speedometer and that one of the party devote his attention solely to driving. It has been found that the speed can rarely be raised above 15 miles per hour while the geologist is mapping and that the more stops for sketching and writing up notes even if the geologist does not alight, the better the results. To watch out in all directions is more difficult than one would imagine. It is difficult to estimate the miles of road traversed per day of work but is seems to have been something like 25. A large part of each days travel was backtracking. In addition to the road traverses sufficient foot work was done to reach

every section of land where it was believed that anything could possibly be observed. Much of this work was carried on along logging trails and only a small part by following land lines. The latter is the more accurate since the sections are very irregular in form and few angling traverses will close on corners, but as the trail affords a better view it seemed preferable. It must be recalled that in magnetic work readings obtained in swamps and brush justify the time spent, but that in glacial work traverses in country where the view is severely limited are a pure waste of time. In the drumlin areas it was found that views from hill tops served to locate the drumlins more satisfactoruly than would a traverse every quarter of a mile, therefore this was done. About 11½ square miles were surveyed on every working day.

Elevations. The elevation of every highway crossing of a railway was obtained from railroad profiles. Two of the old University aneroids, Nos. 5 and 208, were used being read by each member of the party. Checks were obtained from the foregoing elevations and by comparing readings at the same point taken at different times. The readings were adjusted by Lahee's method and in general the two instruments agreed within 10 feet. It was found that the assistant should do this work every evening and plat the results on a map at once. Some attempts were made at drawing contours in the field but the practice was not consistantly followed. It is interesting to note that although the correct elevations of Lund and Naverino were unknown at the time of the survey the adjusted readings proved to be for the most part correct and in no instance to be more than 10 feet in error.

Costs. The cost of the work was as follows:

Salaries	$1585.67	=62 percent
Travel	656.06	26 "
Living	295.95	12 "
Total	$2537.68	

For the entire time paid for this figures out at $2.15 per square mile but deducting time spent in Madison the result is $1.93 The first 69 days were spent in camp and the last 45 days in rooms. It is difficult to compare

the relative costs of these two methods of living but approximately the same amount of work was done every day. While living in camp the cost per square mile was $1.87 and while living in rooms this increased to $2.01. The living extense of the party per day in camp was $1.97 and in rooms $3.64. The writer is strongly of the opinion that the greater comfort of living indoors decidedly offsets the slight increase in cost. Maps are neater when done indoors. Had the weather been better during the last part of the season it would have been found that total costs decreased. It has been thought that living in camp would decrease the daily travel expense but the time and effort of moving camp offset any such economy. The total cost of the party was almost exactly $20.00 per day spent in the field. The travel per day of field work amounted to approximately 56 miles but if trips to and from the field be excluded this figure is reduced to about 51.5 miles.

BED ROCK

Pre-Cambrian rocks. All of the portion of Marathon County that was surveyed and all of Shawano County west of Wolf River are underlain by pre-Cambrian rocks. The bed rock geology of Marathon County was described by Weidman in Bulletin 16 and the writer can add little since no particular attention was given to the rock formations aside from their relation to the glacial deposits. The impression was gathered, however, that Weidman's mapping ignored both physiography and rock structure and laid too much stress on float bowlders in the fields. In fact the writer could not find many of the outcrops mapped by Weidman. It was also concluded that finer distinctions between granites of different types could have been made. For instance, a certain coarse granite which disintegrates into good road material was found to adjoin the dark schists of the Eau Claire River valley; this rock was given the field name of the Hogarty type of granite from the exposures near that settlement. Inside the terminal moraine in Marathon County exposures of bed rock are very rare. Judging from the few ledges of the Plover valley and the nature

of the drift bowlders most of the area southeast of the Hogarty granite is underlain by coarse granite and granite porphyry. In Shawano County rock exposures are much more abundant than in Marathon County. The vicinity of Tigerton, the Dells of the Embarrass, and the Dells of the Red may be mentioned as excellent outcrops. The rocks are all intrusive, and the oldest observed is a very coarse gabbro. This is cut by various types of granite and granite porphyry, which are in turn cut by dikes of fine grained aplitic granite and coarse pegmatites. Granite porphyry with feldspars over an inche in diameter is apparently the most abundant bed rock in Shawano County. The drift bowlders and pebbles show very definitely that no areas of pre-Cambrian sediments exist in Shawano County west of the boundary of the Paleozoic rocks.

Disintegrated granite. It seems to have been the idea of most geologists that disintegrated granite could be found only in an unglaciated area. The writer was therefore surprised to find large pits in this material many miles within the limit of the Wisconsin drift. Such are common in the vicinity of Tigerton and a few occur in the towns of Seneca, Bartleme, and Red Springs (T.27-13E, T.28-13E., T.28-14E.), that is along a NE-SW belt parallel to the strike of the rocks farther west. Outside the moraine, in the area of older or pre-Wisconsin drift, disintegrated granite and diorite are both common. It is evident that disintegration of the bed rock is not a criterion of non-glaciation as it was used by Weidman in Bulletin 16 when tracing the north limit of the Driftless Area. It must be noted that all these disintegrated rocks are coarse grained and are for the most part very rich in hornblende and mica. The writer is strongly under the impression that a large part of the mechanical disintegration of the granite in Shawano County is post-Wisconsin in age; this does not mean that the preliminary chemical alteration is also quite recent but that the rock was much harder during the last glaciation than it is today and that this hardness was not due to freezing.

This view is favored by (a) the general destruction of glacial striae on all coarse granites while markings and polish are well preserved on the fine grained aplitic dikes in the same exposures, (b) deep disintegration (locally to depths of several feet) of knobs of granite which have a roche moutonnee form, (c) sharp contact of disintegrated granite with overlying drift without definite evidence of disturbance by moving ice, (d) almost universal disintegration of granite bowlders and pebbles which have coarse grain even in gravels where it is highly improbable that the stones were frozen when deposited, (e) the considerable depth (several feet) to which the Wisconsin drift has been highly weathered since its deposition, (f) the report that when a granite pit is opened the rock disintegrates with exposure to the air so that a "second crop" can soon be excavated, and (g) presence of considerable disintegration within postglacial gorges. How much older than the Wisconsin stage of glaciation is the preliminary chemical alteration cannot be stated but it seems clear that the wide-spread idea that little weathering has taken place since the last ice must be revised. Many of the field observations on which this idea was based were probably made far to the north where glaciation was undoubtedly much more recent than in western Shawano County. An interesting example of disintegrated granite reworked by glacial waters was found in the Outer moraine near Hogarity (Sec. 34, T. 30, R. 10 E.) It is possible that some of the disintegrated bowlders in till were transported in a frozen state.

Paleozoic rocks. East of the Wolf River rocks of Paleozoic age underlie the drift. Exposures of the Cambrian are few since its top lies beneath the level of the drift plains throughout most of the area. One sandstone ledge was found east of Shawano (NWNW Sec. 3, T. 26, R. 16 E.). This shows at the bottom some soft white sandstone which is apparently the Dresbach overlain by typical Mazomanie sandstone. The Trempealeau formation is undoubtedly present in places where drillers report "iron ore" in the basal

part of the dolomite which overlies these sandstones. Some exposures of gray, non-cherty dolomite with pink mottling strongly suggest the Trempealeau formation but the matter was given little attention. Throughout Ranges 16 and 17 East outcrops of the Ordovician dolomites are found. The drift in this region is not very thick and the rock topography stands out very clearly in many localities. Most of the outcrops are evidently of the Lower Magnesian formation but in the northeastern part of T. 25, R. 17 E. there are two ledges which appear to belong to the Black River group. The St. Peter sandstone was not discovered within the area but since the border of the Black River area is a marked escarpment it is probably present. Shawano County is not well adapted to the study of the Paleozoic rocks since aside from three or four long-abandoned quarries all exposures are mere small road gutter showings.

PREGLACIAL TOPOGRAPHY

Pre-Cambrian area. The surface of the granite can be seen near Tigerton and along many of the streams within the Wisconsin drift. In the area of old drift it is essentially the same as the present topography. Aside from the dissected area adjacent to the Wisconsin and Eau Claire Rivers the granite surface is one of very moderate relief and differences of elevation of 50 feet within a quarter of a mile are the exception rather than the rule. Well data in the concealed area within the Wisconsin terminal moraine agree with the above conclusions for in many localities the only difference in depth of drift between adjacent wells is explicable by the difference in surface elevation. Too much weight cannot be given to well records in a region of suchstony drift for many wells which are reported to strike rock may have been bottomed in large bowlders. So far as could be discovered there are no large rock valleys in western Shawano County or in the part of Marathon County which is covered by the Wisconsin drift. The pre-Wisconsin divide between the Wisconsin and Wolf drainage must have been in essentially the present location. In the older drift area there is no

suggestion of a preglacial drainage system different from that of the present time except for the abnormal course of Eau Claire River at the Dells This was explained by Weidman as due to superposition of the Eau Claire when the region was buried by Cambrian sediments but the extreme youth of the Dells and the obvious blocking of a south-leading depression east of there by the Outer moraine both point to a more recent origin. The writer suggests that the course of the river was brought about by the marginal drainage of the last ice sheet. A stream which formerly joined the pre-Wisconsin Plover was thus forced into the original Eau Claire basin. In the vicinity of the Dells it is plainly evident that a youthful valley has been cut into the bottom of a very mature valley of the same type as the remainder of the dissected pre-Cambrian peneplain.

Paleozoic area. The dominant feature of the area underlain by Paleozoic sediments is the Magnesian cuesta which is best seen at Limekiln Hill, east of Shawano. South of that point the escarpment becomes gradually lower until at the south line of the county it rises only a few feet above the lowland to the west. The border of the dolomite is trenched by deep valleys such as that in which Lake Shawano lies. Other valleys are known along the railway northwest of Bonduel, near Zachow, and near White Lake. It is not yet known in which direction the pre-Wisconsin drainage was in the Shawano valley; it might have been either west as at present or east to Oconto River. Throughout most of the area east of the escarpment the drift is less than 50 feet thick. West of the escarpment sandstone is reported in comparatively few wells as the drift is relatively thick. It probably underlies much of the area south of Shawano and east of Wolf River. Pre-Cambrian rock was probably reached in Shawano and presumably underlies all of the lake and much of the country north of it although there seem to be no deep wells to confirm this conclusion. It seems probable that the pre-Wisconsin course of the Wolf was close to its present one but this is as yet mere conjecture.

A reconnaisance south to Black Creek in Outagamie County, showed that the very deep rock valley at that place discharged to the west. If there is a subordinate Mazomanie cuesta between the granite border and the Magnesian escarpment little evidence of it could be discovered. In northeastern Lessor (T. 25, R. 17 E.) the Black River dolomite is bordered by a low escarpment.

OLDER OR PRE-WISCONSIN DRIFT

Distribution. Drift of pre-Wisconsin age is found in Marathon County outside of the terminal moraine of the Wisconsin drift. Inside of that boundary no exposures were discovered which displayed the old drift beneath the Wisconsin deposits. Exposures of till and gravels are confined to the towns of Harrison and Hewitt (Ts. 30, R. 10 E., 30, R. 9 E.) but erratics were found over the entire district. Weidman mapped much of that area as unglaciated but later repudiated that view in the course of conversation. The writer was unable to discriminate any line which could divide an area of proved glacial drift from one with no drift whatever.

Deposits. Exposures of old till are rare on account of the low relief of the region. The till is moderately stony and is excessively weathered. The deepest known exposure is on the west line of the SESE Sec. 24, T. 30, R. 10 E. In this place it is hard to differentiate between disintegrated bed rock and rotted bowlders. The finer part of the till is brown and is slightly cemented by iron oxide. There are some loose sandy spots. Cuts in Sec. 7, T. 30, R. 9 E. show brown and red till in which the stones are about 98 percent crystallines. In reaching conclusions as to what stones are erratics and what are local it must be remembered that in a granitic region this problem is vastly more difficult than in a sedimentary district. Felsite, red and purple rhyolite, basalt, red sandstone and red shale can be definitely identified as coming from rocks of Keewenawan age; no local rocks of these kinds can possibly occur. It is generally supposed that

glacial stones are more rounded than local material but the writer is not convinced that such is always the case. Many of the local granites weather into rounded forms and much of the common brown sandstone is also well rounded. The occurence of the latter in localities where no proved erratics could be found suggests that it is residual from the former Paleozoic cover. Some erratics have probably broken during weathering and particularly when being carried to the stone piles in which most stones can now be found, thus further complicating the problem. The writer is of the opinion that pebbles of quartzite, jasper, and iron formation are probably erratic although this cannot be stated with certainty for all parts of the district. Real outcrops are rare in the old drift area. Much of the soil is filled with angular rocks which are probably residual from the bed rock. Where the drift is thick such rocks are less abundant than where it is thin. The areas of thicker drift are mapped by the Soils Survey as Colby and the areas of abundant local material as Marathon. In both regions the finer part of the soil is a red, brown, or yellow clay locally mottled with gray at a depth of a foot or two below the original surface. Most of the drift seems to have been till but the excessive weathering makes this difficult to tell in shallow exposures. In Sec.14, T. 30, R. 9 E. weathered sandy gravel was found and wells in this region are reported to find other sandy layers below the surface clay. Some valleys have sand or gravel in them. Exposures show a fairly sharp contact between the drift and the underlying rock.

Topography. The old drift area is one of erosional topography with a dendritic drainage system. The relief varies from less than 20 feet to over 100 feet in a mile. In general the relief decreases toward the northeast although there are some extensive flat areas in the western parts of Ts. 26, and 27, R. 9 E. The summits between the stream valleys are out of harmony with the valley sides and look like remnants of a surface which dates from an earlier erosion cycle. The summit altitude declines from 1590

feet on the north line of Marathon County to about 1340 feet in the northwest part of the town of Ried (T. 27, R. 9 E.). Much of the uplands, and indeed some of the gentler valley sides, are either marshy or semi-marshy. In this respect, as well as in the presence of abundant granite bowldres, much of the old drift area strikingly resembles some of the Iowan drift area of northeastern Iowa. The larger valleys have flat bottoms from a few rods to a mile in width.

Thickness. Well records in the old drift area are decidedly uncertain since in many places the bed rock is deeply disintegrated. So far as could be ascertained there is nowhere over 30 feet of pre-Wisconsin drift.

Valley deposits. The larger valleys in the old drift area are partly filled with sands and gravels. In valleys which carried drainage from the Wisconsin ice sheet these are evidently outwash and will be discussed later. In other valleys, such as that of the Trapp River, the material was derived from the old drift. The accordance of some of these deposits with the level of the Wisconsin outwash suggests that they are analagous to the filling in unglaciated valleys consequent upon the change of local baselevel due to the glacio-fluvial aggradation of main valleys. From the very considerable amount of erosion which the old drift has suffered it scarcely seems possible that the Trapp River gravels are pre-Wisconsin outwash. Outwash of the old drift would surely have been eroded away long ago.

Interpretation. That the pre-Wisconsin drift is much older than the Wisconsin drift is demonstrated by (a) the deeper oxidation, and (b) the absence of constructional topographic features. Close study shows that the topography of the old drift is a reflection of that of the underlying rocks. The marshy spots are not in any way a sign of youthful topography but are due to the impervious bed rock which keeps the ground water near the surface. The slopes are so gentle on the uplands that it does not seem possible that they could have resulted from postglacial erosion and there is no sharp

topographic unconformity between a n upland drift plain and the valleys. It seems as though the pre-Cambrian peneplain had been dissected to much its present form long before the thin mantle of drift was deposited on this region. Erosion has removed nearly all of the drift from most of the steeper slopes. Amount of drift appears to be a function of distance from the Wisconsin and Eau Claire Rivers. It follows that the age of the old drift is not so great as might at first sight appear from its scarcity; it could never have been very thick and may always have been less stony than was the later drift. It was largely derived from preglacial residium. The absence of chert from the Lower Magnesian and other dolomites of eastern Wisconsin shows that the pre-Wisconsin drift was brought from the north. There is no suggestion of a pre-Wisconsin Green Bay lobe such as Weidman postulated. The writer observed no phenomena which could justly be used to subdivide the pre-Wisconsin drift of eastern Marathon County into deposits of more than one glacial stage.

YOUNGER OR WISCONSIN DRIFT

Introduction. The younger or Wisconsin drift is characterized by (a) stony character, (b) youthful topography, and (c) relatively slight weathering. It also seems to contain far more glacio-fluvial deposits than the older drift ever could have.

Till. In eastern Marathon County and western Shawano County the till of the Wisconsin drift is a mixture of granite bowlders with pebbles, sand, and relatively little clay. Anyone coming to this region from a district of clay till would find difficulty in recognizing the difference between this excessivly sandy and bowldery till and assorted materials. When the sandy till is rubbed between the hands little clay is found but the very poor assortment of the stones coupled with the ability of the till to stand in fairly steep slopes in excavations enables the geologist to discriminate between it and ill-assorted gravels. In eastern Shawano County

the till is very clayey and is red or pink in color instead of gray or buff as it is farther west. The clay till is much less bowldery than is the sandy material found to the west. In the western type of till, and to some extent in the clay till west of Wolf River, the bulk of the bowlders are obviously derived from the local granites and granite porphyries. These rocks are easily distinguished from the gray granites, gray gneisses, and basic igneous rocks which form the bulk of the bowlders east of Wolf River. Erratic bowlders are rare in the western district and one soon learns to distinguish them from the local material. This predominance of local bowlders is due to the hard crystalline bed rock which broke mainly into large fragments instead of the pebbles such as were formed where the ice passed over limestone. The sand was in part derived from the Cambrian and in part from weathered granites. The fact that much of the sand is feldspar and hornblende is made evident in the weathered zone of the drift. The silty soils of the crystalline rock district are due to the alteration of these constituents in the drift and not to concentration by wind or water. The Kennan soils are strictly residual. In the case of glacio-fluvial deposits rotting has proceeded so far that it is difficult at first sight to discriminate between weathered gravel and real till. The better grading of the remaining stones in gravel is the best criterion of an assorted deposit.

Glacio-fluvial deposits. In eastern Marathon County and western Shawano County there is an immense amount of assorted drift. This is explained by the large amount of sand and stone in the till rather than by any different conditions of origin during the Wisconsin stage of glaciation than obtained at an earlier date. Most of the glacio-fluvial deposits are very sandy and the surface weathered zone which is from two to six feet thick is for the most part more stony than the bulk of the underlying deposit.

In eastern Shawano County the gravels are very stony and resemble those of southern Wisconsin. There the pebbles are mainly dolomite whereas in the district west of Wolf River that rock forms only a minority of the pebbles.

Terminal moraines. The terminal moraines, including the recessional moraines, of the Wisconsin drift may be divided into the following groups: (a) Outer moraine, a unit ½ to 2 miles wide, (b) Second moraine, locally divisible into two moraines, 1½ to 4 miles wide, merging on the east into (c) the Elderon morainic series of 5 more or less distinct members, in all with a width of about 5 miles, (d) Bowler morainic series of four distinct moraines with a total width of about 2½ miles, (e) Caroline morainic series of four distinct members with a total width of 6 miles, (f) Thornton moraine, ½ to 2 miles wide, (g) Belle Plaine morainic complex, and (h) Briarton moraine with known width of over 5 miles, the east border not yet having been mapped. Of these different groups the first four consist of the very stony sandy gray till described above, with a few kames. The amount of assorted material increases toward the east. The till of the Caroline moraines is essentially the same as that found farther west but has patches on red stony clay on top of it. The Thornton and Belle Plaine moraines consist of red till with much sand and gravel, and the Briarton moraine is made of a pink stony till which over wide areas contains very few bowlders. All of the moraines exhibit typical rough topography with many knobs and sags. Slopes are steep and are very bowldery in the western moraines. The topography of the Briarton moraines is very uneven although the relief is somewhat less than in the moraines of Marathon County. Many of the smaller moraines are hard to map since they are lower than the associated outwash plains west of each one, a fact which renders them invisible when approached from the west. In some moraines there are mesa-like elevations made of sand; such were noted in Sec. 26, T. 29, R. 10 E., and Sec. 19, T. 26. R. 9 E. These areas are patches of outwash which was formed in re-entrants in the ice margin.

Ground moraine. In contrast with most glaciated regions ground moraine is of relatively slight extent in the region here described. The largest area is that near Limekiln Hill, east of Shawano, where the dolomite is covered by a thin layer of drift. Farther west there is a little ground moraine adjacent to some groups of drumlins and in a narrow strip along the Plover valley. In the region of crysalline rocks the ground moraine areas are even more bowldery than are the terminal moraines. In many places one can walk for long distances without setting foot on anything but bowlders.

Drumlins. The drumlins of western Shawano County were first discovered by the writer. Weidman regarded these hills as knobs in a terminal moraine while Licking and Bean recognized their prevailing trend without using the workd drumlin. In Ranges 10 to 15 East the drumlins trend toward the west or northwest, that is normal to the nearby moraines. The group of drumlins in Ranges 16 and 17 East is abnormal in trending to the southwest which is at a considerable angle to the north-south moraine west of them. In the western group of drumlins the topographic forms are fully as perfect as anywhere in the state but the forest cover of a large part of this area conceals this fact over wide areas. In some areas, indeed, it is very difficult to distinguish drumlins at close range although from a distance their crests are distinct. It is unlikely that all the smaller drumlins of this district have been mapped except where they happen to occur in clearings. These western drumlins are excessivly stony and this condition is most apparent where they have been cleared or cultivated. Exposures show that the till is similar to that of adjacent moraines so that the concentration of bowlders is evidently the work of recent erosion. A unique topographic feature is the coalescing of several drumlins into drumlin uplands which have nearly level tops although the ends show distinct drumlin heads and tails. Drumlins merged to some extent with one or more neighbors are very common and forms with more than one crest along the same axis are very abundant.

As a general rule neighboting drumlins are slightly offset. The longest observed drumlin measures 2¼ miles and the highest is close on 200 feet above its base but such figures are exceptional. A length of ½ mile and a heigth of 50 feet are nearer the average. Most drumlins are broad and blunt-ended but there are some very narrow steep-sided forms. The natives call the drumlins "hogbacks". In the eastern area of drumlins the forms are much less perfect and some of those mapped might justly be regarded as mere flutings of the ground moraine. On the crest of one such drumlin-like ridge it is reported that sandstone was reached at a depth of 4 feet but no showings were observed in the road gutters. There are some large and well marked drumlins as on the State Highway south of Bonduel near Slabtown. Where drumlins lie in the course of terminal moraines few of them show a cover of later marginal deposits. In fact many perfect drumlins are completely surrounded by terminal moraine topography.

Outwash. The outwash deposits of the area may be divided into (a) outwash beyond the Outer moraine, (b) older outwash within the Outer moraine, (c) eroded outwash, (d) outwash with cover of red clay, (e) deltaic outwash, and (f) younger outwash plains. The reason for the abundance of outwash has been explained above.

Outwash outside the Outer moraine. Two areas of outwash occur in Marathon County outside the Outer moraine, (a) in the Eau Claire valley and (b) in the Little Eau Claire valley. The former area represents the outlet from the well-known Antigo plain. Although this plain borders the Outer moraine for a long distance the gravels consist almost entirely of crystalline pebbles. This fact shows that the waters came from the Langlade moraine to the north and not from the Green Bay lobe where from 40 to 60 percent of the pebbles are either dolomite or chert. There is no trace of outwash or of glacial waters in several small valleys which lead down from the Outer moraine into the Eau Claire valley. It may be presumed that these [illegible]

were largely responsible for Weisman's idea that the ice did not give off any water. The true explanation, however, is simple: the land beneath the Green Bay lobe sloped to the east so that drainage was subglacial toward the south. A confirmation of this explanation is the fact that little outwash is present in the valley of the Little Eau Claire River south of Ringle. There the land sloped away from the moraine but is much higher than it is to the east and hence little water escaped from the Outer moraine. The gravels of the Little Eau Claire valley are probably only a few feet thick. Weidman stated in Bulletin 16 that there is no gravel above the Dells of the Eau Claire but this fact was not confirmed by the writer. There is much gravel only a short distance above the Dells and the absence of deposits within the gorge is explained by (a) too rapid a current for deposition and (b) erosion of what was deposited in the narrow channel during the maximum of the ice by the clearer waters derived from the Langlade lobe during its recession. Weidman regarded the Antigo plain as an interglacial river deposit which had been overridden by the "Third Drift." That the deposits are really outwash of the last ice is demonstrated by (a) the presence of large ice-rafted bowlders, as well as by (b) the coarseness of the gravels which is entirely incompatible with the nature of sediments deposited by a sluggish stream during a depression of the land. The features of this plain which Weidman must have regarded as criteria of subsequent glaciation appear to consist of (a) ice-rafted bowlders, and (b) sags which are evidently abandoned stream channels. In some places the surface of the outwash is at nearly the same level as that of adjacent tracts of old drift. The glacial streams crossed patches of old drift which project through the outwash and there eroded considerable valleys. The outwash deposits have been terraced into two to three distinct benches which are most prominent in the lower course of the Eau Claire River.

Older outwash within Outer moraine. A very large part of the country within the Outer moraine is covered by outwash; the recessional moraines are divided by outwash plains, and similar deposits occur around and between the drumlins so that little ground moraine escaped being covered by assorted material. Sand is by far the most abundant material and most of the gravels have so many layers of sand in them that the stones are subordinate in total amount. In most instances, the amount of sand increases with depth; in fact the stoniest portion of most outwash deposits of this class is the top five or six feet, although in some places a coating of a foot or two of sand is the topmost deposit. This surficial sand layer is probably a wind deposit. The topography of the outwash plains varies widely; nearly all are more or less pitted and most show at least two terraces. In many places the higher outwash terrace is represented only by small isolated remnants of a former surface. The larger pits have till and bowlders in their bottoms and in places the number and size of such pits are such that it is a question whether the area should be mapped as pitted outwash or as terminal moraine. Locally only small mesa-like remnants are left to suggest the former development of outwash which elsewhere was destroyed by melting of underlying ice and by erosion following on removal of obstructions to glacial drainage. The forest and brush cover combined with the lack to topographic maps renders the solution of many questions of glacial drainage lines very difficult if not impossible. Add to this the abundance of ice-rafted bowlders and the difficulties of the geologist in such a region can be more nearly realized. An instance of the difficulty of mapping was found on new S. T. H. 16 in the town of Norrie (T. 23, R. 10 E.). Here exposures were good but brush is thick along the highway. The first traverse missed several narrow belts of pitted plain which later work in adjacent cleared areas showed to exist. It is not to be wondered at that most former investigators failed to realize the true extent of the outwash deposits of this region. Weidman recognized the fluvial origin of these deposits but regarded them as having been overridden by

ice. He evidently thought that the bowlders, pits, and unstratified weathered zone were evidences of such a history. The fact that the deposits were actually contemporaneous with glaciation is shown by (a) coarseness of some of the gravels, (b) presence of ice-rafted bowlders in undisturbed sediments, (c) presecnce of enclosed pits with no associated till, (d) slope of plains away from moraines, (e) elevation of the plains at such heigths that they could not possibly have been deposited unless glacial ice had been present to block the modern drainage, (f) gradation between the brown and yellow rotted surficial zone and the unaltered sands and gravels beneath, (g) texture of the surficial zone where the presence of more clay than at depth is simply explained as due to weathering of dolomite and feldspar, there being no other difference than this, (h) composition of the pebbles in the surficial zone where the absence of dolomites is a natural consequence of weathering and could hardly be explained in any other way, (i) greater depth, five feet or more, of weathering in the plains is explicable by the level topography and high porosity which has resulted in both more weathering and less erosion than on adjacent drumlins and moraines, (j) direction of dip of cross bedding which in general does not agree with the direction of present drainage. The different outwash terraces form a gigantic stairway rising from east to west, the risers composed of moraines and measured in tens of feet, the steps, which are marred by drumlins and pits, measured in miles. No attempt was made to define the limits of the several terraces except as they coincide with moraines.

Eroded outwash areas. Northeast of Tigerton between the south and middles branches of the Embarress River is an area of about a dozen square miles most of which is lower than adjacent outwash plains. Within this area are many marshes and rock outcrops interspersed with mesa-like remnants of outwash, as well as tracts of excessively bowldery drift. Much of this might properly be mapped as ground moraine but since it all must have been

buried under outwash at one time the writer has mapped it in a way to express its history rather than the present conditions.

Outwash covered by red clay. In the towns of Red Springs, Herman, Seneca, and Grant (Ts 28, R. 14, E., 26, R. 14, E., 27, R. 13, E., 26, R. 13 E.) is a belt which roughly coincides with the Caroline morainic series in which are numerous areas with the topography of pitted outwash but which have a covering of a few feet of red clay. The red clay areas are for the most part separated from one another by moraines and by outwash plains of the normal type. A similar red clay also occurs in small patches on the adjacent moraines. The altitude of the plains which have the clay coating varies from 920 feet on the south county line to a trifle over 1000 feet in the town of Red Springs. The thickness of clay varies from less than one foot to over 15 feet. The latter figure is known in a small area in SW¼ Sec. 34, T. 26, R. 13 E. The clay is dark red to deep pink, rather silty, and contains pebbles and bowlders, some of them striated. Near the bottom there are pockets and layers of fine sand few of which are more than two inches in thickness. A covering of sand is found over the clay in many places; it rarely exceeds a foot in thickness. Aside from the sand lenses there is little evidence of bedding in the clay. An obscure horizontal lamination can be detected in many places. The lower fresh part of the clay is dolomitic and is somewhat lighter colored than is the leached part which extends on the average to a depth of 2½ feet. On one hillside leached clay 8 feet thick was found but it is not certain that this deposit is not slopewash. Where the plains are covered with clay there are many marshy pockets and the topography is smoother than on normal pitted plains. The underlying sands and gravels are exactly like those found farther west except that there are some layers of gray or buff silt near the contact with the red clay. The origin of the clay is not easy to determine for the usual criteria do not seem to meet the case. It is either (a) a lake deposit with ice-rafted stones, or

(b) a clay till. These two explanations will be considered under the heading of glacial history.

Deltaic outwash. Along the west line of Range 15 E. and in Sec. 36, R. 26, R. 14, E., there are plains very similar to those described above which are better explained as deltas covered by lake clay. They occur as a shelf 10 to 40 feet higher than the country to the west which borders the west side of the Thornton moraine. No exposures are deep enough to confirm the suggestion that these plains are deltas. Unmistakable delta were found in Sec. 6, T. 27, R. 16, E. and in Secs, 5, 6, and 27 of T. 26, R. 16, E. In each of these foreset beds are well exposed. In the last named locality the bedding has been disturbed for the dip is nearly vertical in part of the pit; the hypothesis that this deposit may be a gravel bowlder is worthy of consideration. These deposits were mapped as moraines since they were evidently deposited along the ice border. In several places delta bedding was seen in the midst of normal pitted outwash and is probably the filling of pits where ice blocks melted before glacial drainage ceased. In some cases large foreset beds may have resulted from filling of abandoned stream channels. Deltas were undoubtedly formed along the west side of the Briarton moraine but are concealed beneath lake deposits so that they cannot be recognized.

Younger outwash. Outwash plains are also found cutting indiscriminately across all of the foregoing deposits. Some of these follow the courses of the present streams. That they were deposited by these streams when larger than at present is indicated by the accordance of the prevailing direction of dip of the cross bedding with the direction of existing streams. Other plains run from north to south diagonally across the modern streams. The extensive plain of sand and gravel west of the Briarton moraine, which as mentioned above is probably in part deltaic, should properly be classed with the younger outwash. These plains are notable for the excellent assortment of many of the gravel deposits. West of Wolf River pits are known only in Sec. 23, T. 27, R. 15 E; a few depressions at other places are clearly

abandoned stream channels. The plains east of Wolf River are extensively pitted and contain many lakes. The surface of these plains has been altered to a great extent by postglacial dunes which were quiescent before white men settled the country. True ice block pits may be distinguished from depressions in the dunes by their greater depth. Some of the lakes are nearly 50 feet deep. These eastern plains are accordant in level with the western ones and the presence of pits combined with ice-rafted bowlders definitely prove that the deposits are of glacial and not postglacial age. The only large commercial gravel pit in the area, that of Marston Brothers at Clover Leaf, is in the younger outwash. Cross bedding in this pit shows that the material was derived from the northeast. North of Shawano some of the gravels, particularly in Sec. 12, T. 27, R. 15 E., are remarkable for the low content of dolomite pebbles. This fact has not as yet been explained. For the most part the younger outwash is free from a clay cover but near Shawano (Sec. 36, T. 27, R. 15 E.), along the south shore of Lake Shawano, and in the Wolf valley in Sec. 9, T. 26, T. 16 E. there are pink and blue clays. These clays are laminated but not varved. At the pit of the Larson Brick and Tile Co., Shawano, the clay fills a depression in the sands which covers about 150 acres. The maximum thickness is reported as 32 feet. Above the clay is two or three feet of very fine silty yellow sand. There are no stones in these clays, those reported proving to be calcite concretions. Spruce branches are found some of which are said to have decayed so that only a mould is left. According to analyses reported by Buckley the content of calcium is very high in proportion to the magnesium. These evidences led the writer to conclude that these clays are postglacial. In the city of Shawano layers of red clay are found beneath about 10 feet of sand but there was no opportunity to examine such a deposit. Other clay layers are reported at greater depth. Some of these may be till older than the outwash and others may be glacial lake deposits buried by outwash or by dune sands. In conformity with the policy of ignoring postglacial deposits the Shawano clays have not

been mapped. A deposit of different type is found on the bank of the Embarrass River in NESE Sec. 13, T. 26, R. 14 E. This consists of a pocket a few rods across which contains 8 feet of laminated silt and fine sand. The prevailing color is gray; there are thin laminae of dark red clay suggesting thick varves. Leaching extends to a depth of 6 feet. This deposit rests on well-graded outwash gravel. It is probably a slack water deposit of a glacial stream.

Eskers. Eskers are rare in Marathon County. Only one was discovered in the Wisconsin drift and none in the pre-Wisconsin drift. In Shawano County they are much more common and are found throughout the drumlin-outwash belt. Most of these eskers are less than ½ mile in length and 30 feet in heigth, so that the forest cover doubtless had a considerable number from the eyes of the party. In the crystalline rock district the eskers are composed of very coarse, ill-assorted gravels. They wind among the drumlins and in rare instances cross small drumlins. Since many eskers rise in elevation toward the west the streams must have been subglacial. In outwash areas eskers survived for two reasons: (a) heigth too great to be buried, and (b) protection by ice masses. Many of thse eskers which do not project above the outwash plain level may represent the ice-confined portions of the streams which elsewhere deposited outwash. Eskers are absent throughout most of the red clay belt but appear again east of the Wolf River and are especially well-developed in the Briarton moraine. There they follow the present valleys and are longer, more continuous, and finer textured than are those farther west. Locally the eastern eskers are mainly sand but the presence of some stones serves to distinguish them from elongated sand dunes some of which are deceptively like eskers.

Lake deposits. The lake deposits of Shawano County present more perplexing problems than any other subject thus far discussed. Study of ancient lakes is handicapped in this region by (a) absence of an accurate map, and (b) scarcity of good exposures. It is probable that with a larger

area is covered many problems which are now difficult will be cleared up. The red clays on pitted plains and adjacent moraines have been discussed above. In Ranges 14 and 15 there is a considerable area of gently rolling land which is underlain by a mixture of sand and bowlders. Under a layer of this material from a few inches to several feet in thickness is red stony clay. This clay ranges in thickness from a few inches to 40 feet. It is leached in some places to a depth of over 5 feet. Where the red clay is thin it grades below into horizontally bedded sands and silts. Clay of this type is clearly a lake deposit but the thicker and more stony deposits are more likely of glacial origin. At no point within Shawano County was any distinct bedding or varving noted. In the town of Navarino (T. 25, R. 16 E.) considerable areas are underlain by pink calcarous clays. In all probablity these clays extend under the neighboring sand dunes. In an exposure on Wolf River just south of the county line well-developed varves were observed. This latter type of clay was deposited in Glacial Lake Jean Nicolet. Exposures and well records show silt below the pink clay which is leached to a depth of only a few inches. It is reported that another clay layer is found below the silt but for the most part wells find only quicksand. In a few places there are terraces which suggest beaches but with the (possible) exception of a deposit in Sec. 18, T. 26, R. 16 E. no beach gravels could be discovered. In some instances steep banks seem to border deposits of mixed sand and bowlders which might possibly be interpreted as built terraces. Few of these could be followed for any distance and no bars, hooks, or spits could be distinguished. The sand-bowlder mantle with associated red clays reaches a maximum elevation of about 1005 feet. In Sec. 19, T. 27, R. 15 E. a drumlin is entirely concealed beneath such a cover; its crest is over 1000 feet. Some other isolated hills show faint benches or shelves which might be regarded as temporary beaches. The best-marked terraces are below elevation 930 and may represent the margin of Glacial Lake Jean Nicolet.

GLACIAL HISTORY

Older drift. The ice invasion which deposited the older or pre-Wisconsin drift was marked by a greater development of the ice from the north than during the Wisconsin stage. This might have occured either (a) during the Kansan stage when the Keewatin ice had such vast extent or (b) during the Illinoian stage when the Green Bay lobe was weak. It is certain that none of this drift was deposited by a pre-Wisconsin Green Bay lobe. The older drift was probably largely composed of old residual material and having less stone than did later drifts little assorted drift was made. As there was no nearby sandstone to the north the sand content of the old till was less. This deposit could never have been very thick as shown by the present low slopes and the lack of stream diversions.

Interglacial conditions. The older drift must have been eroded and weathered into virtually its present condition before the advant of the Wisconsin ice. No evidence of any other kind was found which might bear on either time relations or interglacial conditions.

Outer Wisconsin moraine. As noted above, the stand of the ice at the Outer moraine of the Wisconsin stage was of considerable duration and in the area now described was not accompanied by much drainage of the west. The waters flowed underneath the ice and it is not unlikely that they escaped through the break in the moraine at Shantytown, Portage County, just south of the Marathon County line. No subglacial gravels deposited at this stage are now preserved for they must have been buried by later marginal deposits. South of Antigo outwash from the Langlade lobe reached the Green Bay lobe moraine and escaping to the southwest crossed an interglacial divide into the basin of the Eau Claire River thus forming the Dells. Retreat of the ice from the Langlade lobe unburdened the waters and caused terracing of the gravels as well as further erosion of the Dells gorge.

Second moraine. The retreat of the ice front to the Second moraine was rather rapid and was not followed by [illegible] for the Plover outwash

plain is much pitted. This plain is the only place inside of the Outer moraine where glacial and postglacial drainage coincide for so long a distance. The Second moraine appears to mark the longest halt of the ice at any of the western moraines. Slight recessions led to the formation of the Pike Lake and Mayflower Lake pitted plains. The former has at least three outlets to the Plover plain and the latter only one, that followed by the railway at Hatley. At this time the Plover plain was terraced for the waters were cleared in passing over the plains to the east.

Elderon morainic series. In its last stages the Mayflower Lake plain was contemporaneous with the westernmost plain of the Elderon series of moraines and pitted plains. This southern plain appears to have drained westward to the Crooked Lake outlet for a time. Aside from this retreat of the ice front to the Elderon series of moraines put a stop to westward drainage. Instead streams flowed southward along each successive ice front thus forming a series of pitted plains. In some places when lower outlets were opened by ice retreat farther south the changed baselevel eroded both moraines and earlier outwash. Some of the very bowldery flats of this area represent the ruins of moraines thus destroyed. Others are concentrates from the erosion of outwash or bround moraine beneath the outwash.

Bowler morainic series. Retreat of the ice from the last Elderon moraine to the Bowler moraines left only a few scattered morainic areas east of Birnamwood. Most of the outwash between the drumlins of this area was apparently laid down when the ice stood at the Bowler moraines, the terracing resulting from the opening of successive lower and lower outlets as the ice front retreated from one moraine to another. The exact details of this process cannot be worked out at present. A further effect of this lowering of outlets was diversion of streams from southwestward to southeastward courses. This took place because of the steeper gradient thus found, and developed terraces which slope toward the southeast. No attempt was made to map these

small features.

Caroline morainic series. During the earlier stages of the Caroline series of moraines an extensive outwash plain was laid down by southwestward flowing streams. Then a readvance of the ice occured which blocked the former drainage. To what extent this readvance is marked by till and to what extent it resulted in the formation of temporary lakes in which red clay with ice-rafted stones was deposited cannot be stated at present. Some of the clays are certainly lacustrine and were probably not varved an account of rapid deposition. The thicker deposits near the Waupaca-Shawano County line look much more like till and in some places the soil on the adjacent drumlins is decidedly red. Deep cuts in general failed to show two distinct tills as they do in districts farther south and southeast so that the writer is still in doubt as to the reality of an ice readvance to the margin of the red clays. It is certain that these deposits were formed after the melting of the ice blocks in the pitted plains and before the last dissection of the area by glacial drainage. This erosion was probably due to opening of the deep outlet in Sec. 32, T. 26, R. 13, E. At this time all three branches of the Embarrass must have discharged via this outlet and their combined volume led to the extensive erosion of the outwash plains northeast of Tigerton. East of the fourth and best-developed Caroline moaine, there are a few scattered moraines most of which have some red clay covering.

Thornton moraine. The Thornton moraine is a single massive ridge, a feature in marked contrast with the series of small ridges of the three morainic series to the west. It also differs from the western moraines in being composed of red clay till with much sand and gravel. Local granite bowlders are much less conspicious than farther west. Some of the till is sandy and has a brownish red color. One well is reported to show 190 feet of red till. The Thornton moraine trends more nearly north-south than do the western moraines. East of this moraine is a ground moraine area with many

low drumlins which trend from northeast to southwest. The till of these drumlins is less red than that of the moraine and in many places resembles the gray till which occurs farther south in the state. Several facts suggest that the Thornton moraine was formed by a considerable readvance of the ice front, probably Aldens red till readvance. (a) So marked a change in ice direction as that shown by the drumlins and the younger striae of eastern Shawano County could best be explained by a readvance. (b) In Sec. 21, T. 26, R. 16 E., northwest of Lund, deltaic gravels are overlain by a drumlin of red till. (c) In several places there are either bowlders of sand and gravel or disturbed gravels which definitely prove readvance. (d) The color of the red till can only be explained by readvance over red lake clays. (e) In Sec. 5, T. 25, R. 16 E. there are outwash gravels below the level of Glacial Lake Jean Nicolet. (f) The lacustrine red clays of the vicinity of Tilleda demonstrate a readvance which blocked former drainage. It may prove, however, that the extreme margin of the readvance was west of the Thornton moraine; this hypothesis was carfully considered in the field and rejected both on account of (a) the character of the western red clays, and (b) the evident affinity of the Caroline morainic series to the western rather than to the eastern moraines. There is no marked red till moraine west of the Thornton so far as present information shows.

Lakes in front of Thornton moraine. When the ice stood at the Thornton moraine there must have been lakes to the west whose level was fixed by outlets in Waupaca county which have not as yet been studied. It seems improbable, however, that the water level could have reached that of the faint beach in Sec. 6, T. 27, R. 14, E. An afternoons reconnaissance southwest of Clintonville showed that much of this country is high enough to account for lakes at the faint beach lines discovered at 950 and 915. The plain immediately west of the Thornton moraine suggests a lake at about 900 feet. Judging from the position of the outermost young outwash plain southwest

of Gresham a comparatively low water level to the south seems to be demonstrated at a time when the present courses of the Red and Embarrass Rivers were still closed. Moreover, the great flat along Pigeon River, northeast of Marion, shows a terracing of an older outwash plain whose southern extent can now only be guessed at. Abandoned courses of the Embarrass south of Pella also demonstrate that no lake could have existed during one stage of the Thornton moraine. It is concluded that in view of the contradictory evidence the lakes either (a) did not exist throughout the time of deposition of the Thornton moraine, or (b) existed only during the first retreat of the ice and not at all during the readvance. Work to the south will probably clear up these points.

Belle Plaine morainic complex. The moraines of the town of Belle Plaine (T. 26, R. 15 E.) for the most part trend parallel to the drumlins of the later readvance. As yet no satisfactory explanation can be advanced for this fact. It may be that during retreat of the ice front from the Thornton moraine lobation developed on account of the freer flow of ice through Shawano Lake valley than farther south in the lee of Limekiln Hill. Just how this could explain the numerous isolated moraines south of the moraine which runs through Asylum station is doubtful. It may be that there was another lobe south of Limekiln Hill which formed the moraines just west of the Wolf River in the town of Waukechon (T. 26, R. 16 E.). The deltaic deposits of Sec. 6 of this town suggest the presence of ice on the southeast side. What lakes were formed during this stage can only be surmised. There are lake clays and silts on the sides of the moraines but these might have been deposited in local pools. During the maximum stage of Glacial Lake Lean Nicolet arms of the lake may have extended between some of these moraines and formed the low level red clays found along S. T. H. 29. The moraines themselves seem to be red till overlying an older series of sands and gravels which extends to the underlying granite.

Briarton moraine. The Briarton moraine is the widest thus far discovered and if width is any criterion of duration it marks a very long stand of the ice front. It is probably to be correlated with the faint water-laid moraine north of Lake Winnebago, that is with the time of Glacial Lake Jean Nicolet. The only fact which suggests a readvance of the ice is the peculiar color of the till which differs from that of much of the ground moraine till between the Briarton and Thornton moraines. This difference is not marked at all places and is probably to be ascribed to the location of the Briarton moraine on dolomite bed rock rather than to extensive plowing up of lake clays. Besides, the till of the moraine is much thicker than that of the ground moraine and there are more cuts so that a better idea of its character can be obtained than of the ground moraine till to the west. The idea of a considerable readvance is ruled out when it is considered that the outwash plains of the Briarton moraine are pitted.

Younger outwash. After the waters west of Shawano fell to the level of Lake Jean Nicolet, presumably at the time of recession of the ice from the Belle Plaine moraines, the Red and Embarrass Rivers broke through the Thornton moraine. For a time a channel just north of Thornton (that followed by the Northwestern Railway) was occupied and a large meander scar was formed in the side of the moraine; this formed the gravel deposit at Thornton. Farther south the Embarrass left its two temporary channels through the drumlin upland and assumed its present course. The source of the waters in the streams at this time is difficult to determine; it seems certain that the volume was much larger than at present so that glacial drainage must have fed them. Waters from the Briarton moraine must have entered the Wolf system somewhere north of the area thus far surveyed or from other lobes further north. The pitted outwash plain through the center of the town of Richmond (T. 27, R. 15E.) must have been formed very soon after the draining of the lake in which the delta of Sec. 3, T. 27, R. 15 E. was

deposited. Just why the Wolf River took its present course instead of following the pitted plain to the Clover Leaf Lakes is not yet clear. The beach of Glacial Lake Jean Nicolet could not be discovered but it was probably not higher than 820 feet. It is possible that the supposed 825-830 beach is really this shore-line. In any event the lake must have included the basin of Lake Shawano. It is worthy of note that although this lake was one of the earlier marginal lakes its beach does not show a high degree of tilt for it is at elevation 810 near Fond du Lac. When the ice retreated from the Briarton moraine Lake Jean Nicolet came to an end.

Postglacial. When Lake Jean Nicolet ended the water level fell and left Lake Shawano in an eastern extension of the old basin which was blocked by younger outwash and sand dunes. There are abandoned beaches at levels from 6 to 12 feet above the modern water level. In Sec. 17, T. 27, R. 17 E. gravel bars of the highest distinguishable postglacial level contain many shells. Such a great part of the shore has been altered by sand dunes that these old beaches were not traced clear around the lake. Some large dunes are found on the south shore as well. Some of the pink clays like those at the brick pit in Shawano are undoubtedly postglacial. Erosion of the outlet of Lake Shawano and of the Wolf River was responsible for lowering the lake level. The dam now holds it much higher than it would otherwise be. The plains of the Clover Leaf Lakes region have also been much altered by dunes, and deposits of the same origin have buried much of the lake clays and deltas of the town of Navarino (T. 25, R. 16,E.). Dunes, postglacial lake clays, and swamp deposits were not mapped since they would serve only to confuse the map of Pleistocene deposits and besides their exact discrimination would add enormously to the cost of the work. The amount of postglacial weathering suffered by the drift of this region may surprise some geologists whose ideas have been formed in regions of less pervious and possibly much younger drift. Dolomite pebbles are commonly

absent to depths of four or five feet and in even the dense red clays leaching has locally reached at least five feet. In the Briarton moraine leaching is much less than it is farther west but no comparison of age should be based on this fact on account of the profound differences of material and topography. Weidman explained all red material and all weathered material as pre-Wisconsin drift on which no later material had been deposited but very slight study demonstrates that this view could not explain the facts. It is evident that there is no till on the large outwash deposits of the western district and these show as much alteration as any part of the Wisconsin drift.

ECONOMIC GEOLOGY

Gravel. The gravels of eastern Shawano County where the bed rock is of sedimentary origin are essentially the same as those of southern Wisconsin. Stony gravel with 85 to 99 per cent dolomite pebbles is very abundant. Excellent outwash gravels are found in the young outwash plains as far west as Marston Brothers pit near Clover Leaf Station. Some of the best deposits are found in drainage outlets as near Slab City and Briarton. The eskers of the Briarton moraine have fair to good gravel although inferior to that found in nearby outwash deposits. The low ground from the eastern margin of Lake Jean Nocolet to the drumlin uplands farther west is almost devoid of good gravel. An exception is the young outwash deposit at Thornton and another is the delta in Sec. 6, T. 27, R. 16 E. In the crystalline rock district the proportion of dolomite pebbles declines gradually with increase of distance from their parent formations until in parts of Marathon County they make up less than 20 percent of a count. Their place is taken by granite much of which is disintegrated. The amount of sand is so high in the drift of this district that coarse stony gravels are rare. The material most generally employed for road surfacing in western Shawano and eastern Marathon

Counties is the rusty rotted top of the outwash. This is the only material from the drift of this region which will pack easily but it lacks sufficient stone to wear under heavy traffic. On highways like S. T. H. 26 wet weather causes extensive wash boarding; unless some of this road is paved it will soon be nearly impassible after heavy rains. The gravel of kames and eskers is much more stony but has thus far been used very little. Almost the only job of this character is a part of C. T. H. Q south of Shepley. Search for concrete gravel is further complicated by the abundance of rotted granite pebbles. It seems almost hopeless to expect to find all the granite pebbles sound anywhere above the water table since the same kinds of granites are found throughout the region. Frank Zoromski at Hatley showed us that the gravel below the water level in his pit is sound. It is suggested that explorations be made in low outwash areas where water is near the surface. Eroded bowldery tracts should not be eleiminated because the stones may have been concentrated from overlying beds. Test pitting by ordinary methods is out of the question in such localities so that recourse must be had either (a) to a well drill, or (b) to a portable drag line. Favorable points for such exploration may be obtained from a study of the field notes and maps. In looking for more eskers which were not discovered by the present survey it is well to bear in mind that these features are mainly found in low ground and along streams. They may also be discovered in the pits of outwash plains. It is probable that many deposits of outwash gravel are concealed by a thin coating of dune sand so that exploration is recommended in low areas of the dune-covered plains. Favorable locations in outwash terraces are just downstream for meander scars as at Thornton. It is probable that where such eroding streams cut into drumlins and moraines stony gravels were formed but that since such localities are in low ground they have mainly escaped discovery.

Water. Public water supplies have been developed at Birnamwood, Wittenberg, and Shawano. All three of these towns are supplied from drift wells, some of them dug, some screened, and others gravel walled. No detailed study was made of the capacities of these wells. The Wolf River Paper and Fiber Co., Shawano, has also developed a large supply of water from the drift. Flowing drift wells are found west of Briarton and along Wolf River south of Shawano, as well as on the east and west shores of Shawano Lake. Many of these are shallow sand point or bored wells. Some good flows are found at depths of less than 20 feet. The water is retained by a layer of red clay or till, some of which is possibly the ground moraine of the Thornton readvance. Throughout the entire region drive wells are common in all sandy or gravelly areas. Where clay layers occur augers are employed to penetrate to underlying sands. Little geologic information can be gained from wells made in this way although some are as much as 100 feet deep. Drilled wells are used in eastern Shawano County and in the rocky region on the crystalline rocks where drive wells have failed. Along Wolf River few wells reach rock although some are over 200 feet deep. Most deep wells find sand and few have been finished in such a way as to make them permanent. The Shawano County asylum abandoned a deep drift well in favor of a shallow well on the site of a shallow flowing well from just below the red till. In the stony drift area deep dug wells are not uncommon. One of these north of Marion is reported to be 219 feet deep but it has now been lined with pipe. The most difficulty in finding water occurs where granite is encountered above the water table. In such locations it is necessary to drill into the rock which is often very tedious and expensive. If no water is found in the first 50 feet of rock the chances seem to diminish rapidly. Dry holes up to 400 feet in depth are reported in some localities. It is the opinion of the writer that few drillers in this region have sufficiently heavy rigs to do efficient drilling in the harder kinds of granite. It is reported that water is rarely encoun-

tered in gray granites. It is probable that the coarse grained granites which disintegrate easily contain the most water.

Soils. The writer followed the soils classification with a view to finding its relation to geology. It was discovered that the basis of the division of the older drift into the Marathon and Colby soils is apparently one of thickness of clay. Where the soil is rocky is was called Marathon and where it is clayey, especially if mottled with gray spots, it was denominated Colby. No vestige of loess could be found in either of these soils. The Kennan soils are supposed to be confined to the Wisconsin drift but the obvious error in mapping near Hogarty is probably due to errors in proofing the map rather than to field mistakes. Distinction between Kennan and Vilas must have been made largely on the basis of texture. Much of the Vilas is outwash which has not rotted to as great a depth as have other areas where the name Kennan was applied. The clay and silt of the Kennan soils was formed mainly by the weathering of feldspar in situ. One of the most serious criticisms of the soils mapping is that no difference was recognized between the very bouldery drumlins and moraines of the Wittenberg region and the more level and vastly less stony outwash plains. The difference in agricultural value is very great; indeed the stony till soils are not capable of being used under the present economic conditions. Only a few of the outwash plains inside of the Outer moraine were correctly mapped as Antigo or Plainfield. Possibly the soils classification needs amplification to form a new series to take care of these weathered outwash plains. In eastern Shawano County the mapping of the Superior soils is also very hard to understand. North of Marion the mapping failed to take any account of the red clay cover over the sands although it is shown to the south in Waupaca County. In places Superior is mapped where no red clay can be found for miles about, and yet in adjacent regions what is obviously red like clay is called Kennan. In the Bellamy moraine the soil is called Superior loamy loam near the south

line of Shawano County although farther north the same identical material with the same agricultural conditions and the same topography was mapped as Miami. Errors in proof reading are apparent in many parts of the region.

F. T. Thwaites, Feb. 18, 1927.

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