University of Wisconsin-Extension

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

M.E. Ostrom, State Geologist and Director

NOTES ON THE GRAVELS OF MONROE COUNTY, WISCONSIN

by

G.H. Squier

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By G.H. Squier. 1905 March 23 1905

Introductory. It was, I think, in the year 1885 that I first became interested in the great deposits of chert gravel about Tomah, it being the occasion of my first visit to the place. But being unwell at the time, my studies were mainly confined to the immediate vicinity of the village. It was not until 1893 that I was able to again visit the place, at which time I occupied nearly a week inthe study of the surrounding region. I embodied the results of this study in an article which I sent to Prof. Chamberlin early in 1894. In his note to my published articles (Journal of Geology Vol.5, p.825) Prof. Chamberlin mentions this and states his reasons for not accepting it. These reasons I consider to have been just, and the objections well grounded. Nevertheless, it seemed to me that if the glacial hypothesis must be rejected there would be left many peculiar features without adequate explanation. It was, I think, in 1896 that I again spent a week inthe same locality, discovering many features not previously noted. I undertook to rewrite my article in the light of these new discoveries, but illness prevented its completion, and the increasing pressure of other work prevented my again undertaking it. Save, therefore, for the condensed statement made last summer which was intended as a summary of the various lines of study in which I have been interested the results of my later work in that region have never been stated. An attempt to do so is the purpose of this article. Before proceeding with this particular subject, I will note the result of recent studies at Trempealean and vicinity. These may be classified as (a) details showing clearly that various of the stone beds described in my articles in the Journal of Geology have reversed slopes. This feature has been brought out in fresh sections made either by excavation or by gullying. The sections show also that these ridges were built up by gradual accutions and not by a sudden tumultuous assembling like

a landslide and the many fragments of thin bedded limestone have tended to adjust their long axes to the surface on which they came to rest and that surface in some places shares a considerable slope (15° to 20°) up the valley. (b) Further study of the deposits on the bounding buttreses of Circs shows that they have considerable thickness and that the subordinate ridges referred to doubtfully (Journal of Geology, Vol.6,p.188) are a reality. They would seem indeed to indicate that the ice unable to adjust itself to the rapidly narrowing circs had overflowed and deposited its debris along lines diverging from the edge of the circ. (The high level deposit shown in Fig.7 (last cit) has on further study developed new and interesting features. At the time that article was written high grass and hazel brush made the outlines obscure. Since then sheep have been pastured there with the result of bringing out the features very distinctly.

Instead of a single unbroken patch of debris as shown in the earlier figure, there are three successive ridges separated by intervals in which the deposits are but scattering, as shown in the reconstructed figure above. The two larger ridges have a thickness of about four feet in the middle thinning out in a width of about thirty feet to mere scattering fragments at the edges and in the intervening spaces. The inner ridge is much smaller than the other two and not quite as sharply defined. The debris rests on the top of residual sand which it penetrates scarcely at all.

It appears to me that the net result of these added details is a considerable strengthening of the evidence for glaciation of the character supposed in my articles.

I have also examined several of the smaller valleys on the opposite (Minnesota) side of the river, and find the same type of deposits both in valley axes and at high levels. Some of the valleys which are both longer and deeper than any in the Trempealeau bluffs show the deposits on a

correspondingly larger scale. If the features which I have described give any ground for assuming the existance of glaciers due to wind drift accumulations in the valleys along the river, there is no assignable reason why similar accumulations should not have existed in scores or hundreds of valley heads throughout the driftless region which were equally well fitted to receive them. But it is only along the river that conditions have been such as to partially reveal the various features. Away from the river all such features are concealed by the mantle of Loess, and only such as were of sufficient prominence to show through that mantle can be looked for in evidence. Features which are at least possibly of this character are not wanting. I have in mind one near Galesville which I studied last summer. Near the outer end of an east-west valley about a mile long there is near the axis of the old valley a notable depression giving rise to a permanent pond hole, the bottom being several feet lower than the lowest part of the rim. Such closed basins have no place in normally developed water eroded valleys. We may be very confident, moreover, that whatever the concealed feature which can thus show itself even through the Loess, it is both in height and sharpness a much stronger figure than we could judge from its surface expression.

The present drainage from this valley follows a rock cut closely hugging one side of the old valley. But supposing the existance of glaciers of this character in any of the valleys of the driftless region. I would go one step further and say that if there is any portion of the region which more than another we should select as a fit place for their development, it is the high deeply dissected divide in southern Monroe County. It is situated on the crest of the low anticlinal from which the strata dip away to the west, south and east. The base of the Lower Magnesian limestone is something like three hundred feet higher than it is along the Mississippi between Trempealeau and LaCrosse. I have no

direct measurement of the height of the divide but if we add three hundred feet to the known altitude of the bluffs along the river we should get an elevation of something like 1500' which about equals the highest parts of the Baraboo quartzite range. We should not, however, regard this primarily as an elevated table land from which glaciers would descend into the valleys, but the valleys being filled with drifted snow it would present much the aspect of a plateau, and both on account of its relative height and the cooling effect of the extensive snowfields so produced, it would have a differential advantage in the matter of precipitation.

My purpose in giving these preliminary statements is to show that there is an interrelation between the different parts of the region which requires that it be studied as a whole and should make us cautious about drawing positive conclusions from incomplete observations.

Monroe County. General Characteristics.

To a person familiar with the residual cherts of the Lower Magnesian near the Mississippi where it occurs only as scattered fragments or if locally it forms a constituent of aggregations, it is still altogether subordinate to other constituents, and even such aggregations do not become conspicuous topographical features. It comes as a surprise to find in Monroe County deposits miles in length, hundreds of feet wide and many feet in thickness.

It is, I think, a conservative estimate to say that of all the material coarser than sand occurring in the region as visible surface deposits ninety-five per cent is chert, the remainder being mostly residuary sandstone nodules.

Such an unasual abundance of the chert necessarily supposes an abundant supply and such there is. In ascending the ridge by the road from Council Creek Valley we cross for a considerable distance an almost un-

interrupted outcrop in the basal portion of The Lower Magnesian showing that there is a very thick layer of almost solid chert. I encountered no outcrops of the upper half of the formation, but the abundance of cherts in and on top of the soil shows that the entire thickness of the formation is characterized by an unusual development of chert. My impression is that if we estimate the total thickness of chert in the formation at fifty feet, we shall be below rather than above the truth. It is difficult to say over how large an area the limestone was thus characterized, but such evidence as is available seems to point to a greater extension northward than in other directions from the present divide.

A body of chert of such thickness overspreading any considerable portion of the area of my map would have been sufficient could it have been assembled in the present valleys to account for the highest of the high level deposits, but such a supposition involves a manifest impossibility, since the deepening of the valleys could have continued only as all material was removed sufficiently to allow the streams to act on their bottoms.

It follows as a corollary that the greater portion of the chert liberated during the early stages of valley growth have been reduced to transportable size and carried away. It also follows that up to the time of the last stage of valley deepening no more loose material of all kinds existed in the valleys than was consistent with the existance of a working contact of the streams with the deepest portions of their rock troughs. Carrying the reasoning a step further, we may say that if at any time subsequent to this last and deepest stage of valley erosion there was a refilling of the valleys by a deposit of which chert formed the principal component, as is the case with various ridges, this chert beyond the moderate amount which might have remained over from the preceding period of erosion must have been derived de novo from the limestone.

Since any hypothesis which should seek to explain the gravel ridges or any part of them as erosion remnants of an axioly deposited gravel body would have to account for a filling of anywhere from one hundred and thirty to two hundred feet, it is necessary to ask what was the possible supply. All the limestone above the valley areas was of course gone. It had long since been removed from the subordinate divides. Even the western divide which separates the Wisconsin from the Mississippi basin was virtually denuded. There remained only the divide which is the present source of such material. The amount of material in existing gravel ridges great as it is is a mere trifle compared with the enormous amount which the hypothesis required. Could it have been furnished? It would by a rough computation have required two or three times as much material as the present total chert content of the divide.

But we must carry this questioning somewhat further. The present axial deposits are alluvial in character. In all the exposures I have encountered I have seen no rock fragments in thin layer than an inch cube. These more frequently than otherwise are sandstone, cherts being comparatively scarce. Even such fragments as these are very sparingly shown. If these streams have been able to transport material up to several hundred cubic inches volume for miles along their agrading valleys, why did they cease to do so? They have the same source of supply. They must have practically the same volume and the same gradient. It must be observed that the transportation of heavy material in agrading valleys is a very difficult thing from its transportation in valleys in process of degradation. In the latter the fragment remains near the surface where it is subject to repealed forward impulses. In the latter it soon becomes buried under later deposits and its forward movement arrested. It should be observed also that angular material freshly liberated from the limestone ought not during its comparatively short stay at the surface to suffer any notable amount of abrasian.

But even if we assume the existance of such great axial gravel deposits, we are confronted by the most glaring discrepancies in the amount of erosion required in various places to bring about existing conditions.

Palaeaxial Deposits.

This seems to be a convenient term under which to group deposits belonging to earlier stages of valley degradation as against those belonging to the last stage.

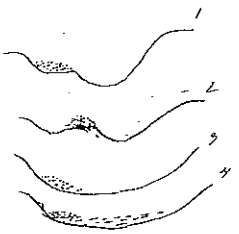
A discussion of this phase of the question requires some notice of valley topography, especially as it may relate to any remnants of old base plains. Some writers seem to regard the great plain of the Wisconsin as a base plain (R.D. Salisbury, Journal of Geology, Vol.4,p.936) but were the late filling removed from the valleys the subordinate divides would show heights of from one to two hundred feet. The valley of South Fork in its present state appears to be four or five miles wide, but the main valley is on the east side, and the removal of the filling would show the streams and their subordinate divides brouching off to the westward. This feature is not shown in Council Creek Valley nor in Bear Creek Valley which consequently appear much narrower. In none of these valleys do the sides display any notable shelves as of an older base plain incompletely removed. Intermediate base plains may have been formed, but if so the last stage of erosion was long enough to practically remove them.

There is. however, a upland belt several miles in width beginning just east of Council Creek and extending to Camp Douglas and beyond which the Salisbury (above citation) describes as an old base plain. I have myself regarded and spoken of it in that light. Lately, I have come to question whether it be not rather due to stratigraphic peculiarities. If it be an old base plain we might reasonably expect to find considerable deposits of chert on its top, but such parts as I have

visited are quite destitute of it. Also regarding it in this light, we should as a consequence have to believe that even at that early stage the limestone had retreated to nearly its present limits.

Along the western divide northwest of Tomah there are some features which appear to be remains of a base plaine. On some parts of it there are occurrances of gravel. Whether they were palaeoxial deposits or of later introduction will have to be determined by their specific features.

This suggests the question what are the driteria if there be any whereby we may recognize such deposits.



Should we find a valley having a rock offset on either or both sides like the first diagram in the accompanying figure, we should have good grounds for believing that any gravel deposit on the shelf might be palaeoxial. The same would be true even though erosion had progressed so far as to have removed much of the hill back of it leaving the gravel covering in the form of an isolated knob as in the second diagram. But should we find the gravel resting on the bottom and adjacent side of a valley which had attained its full typical contours (diagram 3) we should be certain that though it might be an axial deposit it could not be palaeaxial. The same would be true did the gravel rest wholly or in part on an older alluvial deposit instead of the rock bottom (diagram 4). Should we encounter gravel covered hills of considerable elevation above the valley bottom and of considerable area, we should have to be guided largely by the underlying topographic features in determing the age of the gravels. Since the topography covered by an axial deposit is necessarily that of the valley bottom with so much of the immediately adjacent slopes as the thickness of the deposit may determine it follows that when in the progress of

valley development a portion of this comes to exist as a remnant we shall have preserved a portion of the older topography which, to use a term recently introduced by the Salisbury (Journal of Geology, Vol.12,p.707) would be unconformable to that surrounding it. The slopes of the hill would naturally show more or less gravel which had fallen from the deposit at the top. But since these slopes are wasting, material falling upon them does not tend to accumulate, but is borne away with the wasting slope. (diagram 5). If, however, instead of such a relic of older topography we find the gravel covering a series of sharp conical hills whose contours are those of mature divides and conformable to the latest topographic forms with the gravel spread over the whole like a mantle, but usually thicker on the lower slopes and in the hollows (diagram 6) we should have no reasonable ground for regarding such deposits as palaeaxial, especially if the hills are of considerable height.

Besides these criteria of general application we shall meet here and there with phenomena in connection with some particular occurrence of gravel whose relation to it is such that it has an important, if not decisive bearing on the question of age and character of the deposit.

Descriptive Detail. Bear Creek Deposits.

(The sketch maps which I present being made from memory and height and distances being mostly estimates are not as accurate as I could wish. They are the best that the circumstances permitted, but they will, I think, help to make descriptions more intelligible.)

Bear Creek is one of the three largest streams which form the southerly headwaters of Lemonweir River. Its valley compared with the valleys of Council Creek and South Fork some miles further west is remarkably narrow, not over a quarter of a mile wide. This feature seems to be the result of some peculiar quality in the sandstone by virtue of which it possesses considerable resistance to erosion and a tendency to weather into vertical escarpments. This quality seems to begin just

east of Council Creek (see map) and characterizes the elevated table between there and Camp Douglas, appearing also to extend into the valley of the Baraboo. It probably gives rise to the plateau feature. The gravel deposits of Bear Creek as here described belong to the lower mile or two of the valley and a portion of the outlying plain. As yet I have not visited the upper valley. Entering the valley by way of the wagon road from Bonah gravel appears conspicuously on both sides, but most abundantly on the east. The most notable deposit on the west side occurs in a sharp angle of the valley which faces up stream (pl 2 a). The angle is well filled and the gravel is piled against the hillside to a considerable height well toward the top. On the east side the entire hillside is heavily covered up to half or two thirds its height. A little further down the valley there is on this side also an abrupt bend but facing down (b). But instead of finding the gravel piled up in the angle it withdraws somewhat from the hillside and begins to segregate into an independent ridge. It has, however, a tendency to mount the hillside again entil it rounds the point (c) where the ridge makes a rather abrupt bend outward from the valley axis across the alcove (d). It is here a broad and high ridge entirely closing the alcove save for the narrow drainage channel cut through it. The crest of the ridge is some fifteen or twenty feet higher than the surface of the swamp just above, and but for the drainage channel it would impound a lake of that depth, as the alcove is unoccupied by alluvial or other axial filling above the ridge save such as is embraced in the swamp.

After the bend made at this point the deposit resumes its course of general parallelism to the valley axis, and becomes for some distance a high irregularly rolling ridge which rises from thirty to about fifty feet above the level of the open country to the east. Its eastern front is somewhat lobular. The slope is usually rather steep in some places about as steep as the material can assume. At about (e) the rolling

summit gives way to a level one of greater width and less average elevation. Most of the added width of this part seems to have been made to the eastward and its beginning is marked by a projecting steep sided lobe. This portion of the ridge is in all perhaps a mile and a half long. It falls off gradually at the north end to the level of the plain.

The railroad cutting at Oakdale is about a quarter of a mile long and twenty to twenty-five feet deep. This is however considerably less than the full height of the ridge as the road surmounts it by a rather heavy grade. The cutting which has been used as a source of gravel for ballast and is of considerable width it nowhere encounters rock, but at a distance of not much over a hundred feet south a well encounters rock at an elevation several feet higher than the grade. There is little doubt that the gravel covers the summit of a low divide and it seems probable that the divide shares the irregular summit level characteristic of its class. On the west side of the valley below the point (a) there is some gravel, but insignificant in amount compared with that on the east side. Passing out onto the plain the surface is level and swampy. The absence of a visible deposit does not, however, necessarily mean that there is none. That is evidently the deeper side of the old valley and a deposit formed in its depth might well be covered by later alluvium.

Tomah Deposits.

The city of Tomah is built on a sandstone outlier whose length north and south is a little less than a mile, and its width about half a mile save that the projection at the NW corner somewhat increases this width. (The length of the map Plate 3 is about 1½ miles). It is divided by a broad shallow depression into two parallel summit ridges of unequal size and height, the western being much the largest. Every part of these hills down to the bounding swamps on either side, also the median depression is covered by a sheet of gravel whose thickness as shown by

wells is from eight to fourteen feet although both less and greater thicknesses occur. Whether the gravel passes out under the swamp on the west side is not known, but it appears not to do so on the east side as the waterworks well (1 Pl 3) encountered nothing but swamp muck in the ten feet to the rock. On the north, the gravel extends to an unknown distance under alluvial deposits. A well a few hundred feet north of the railroad (2) passed through sand and gravel until at sixty feet it struck an old swamp deposit. This fact besides showing that the gravel has a greater extension along a north and south line than we could judge from surface indications, also shows that it was deposited after the valleys had become partly filled by other material. More than half of the south end of the deposit as shown on the map is a flat topped ridge save that for a distance of several hundred feet there is a gap perhaps twenty feet deep apparently due to erosion. The eroded material has seemingly all been carried westward where there is a gradually sloping surface having the appearance of an outwash plain which forms a delta like projection into the extensive swamp area in that direction. A portion of this delta is occupied by the fair ground, and the well in the grounds (5) went through forty feet of sand and gravel. At this depth it struck a swamp deposit encountering a log (Tamarock) two feet in diameter. This gap with its outwash plain appears to me to be a feature of special significance since the conditions which could have brought about the erosion must have been very peculiar. The bed of Council Creek lies much below the bottom of the gap (15' or 20'). Even the alluvial terrace in the valley falls much short of its level. The valley of Council Creek is broad and open with nothing whatever to suggest a possible diversion of the stream through the gap and had such a thing occurred it would naturally have become permanent. Failing of any explanation by normal stream flow, we are justified in asking whether the glacial hypothesis would offer any help.

The first step in such enquiry is to understand those topographical features which would have determined the size, length, form etc. of glaciers occupying the respective valleys. South Fork has but few of its headwater sources in the deep valleys of the limestone divide, most of them coming from the low divide to the westward. Council Creek, on the contrary, heads almost entirely in such deep valleys gathering into itself two or three times as many as South Fork. Its glacier should therefore have been larger and have projected further into the plain as a consequence. It had besides a course quite open and free from obstruction along which to advance, while the valley of South Fork although equally open and even broader in the main becomes suddenly contracted to less than a fourth of its previous width at a point a little south of the Milwaukee R.R. (P.13) the hills converging from both sides. It is possible that this gap was once only a low col and has but recently come to be occupied by the stream, but this is not certain. There are indications of a somewhat wider gap south of Jomah now filled with gravel, but occupying approximately the space (C.D.Pl.3). There are two wells near the south end of the valley (3 & 4 Pl.3) of which one strikes rock at sixteen feet while the other about two hundred feet further and goes sixty feet before striking it. There are no other wells between these and the one at the cemetery at the extreme south end of the map which reaches rock at fourteen feet. But whichever of these gaps may have been the earlier channel of the stream, a glacier descending South Fork and finding its course in front nearly closed would have to adjust itself to the new conditions. If If it had sufficient height and volume it might surmount the obstructions and continue its course, but if it had reached nearly its greatest length it would tend to deploy somewhat in the directions of least resistance. In doing this there would be open to it a wide unobstructed passage for two or three miles westward while a lake of it would naturally have advanced through the gap. Although I am somewhat

anticipating the course of my article, I may say that such was indeed the end of the South Fork glacier, assuming that the gravel belt is of glacial deposition. The outmost deposits of a Council Creek glacier supposing this to be of that character are the ridges in locality No.7 Pl.1. Supposing then that glaciers existed in these adjoining valleys they would probably have been in contact for a time along the line represented by the Tomah deposit. But when wastage of the glaciers began there would be first an embayment between them which would become filled with gravel, and from which the water would escape to the northward along the median depression tending to produce the thick deposit shown in the well 2 Pl.3. Later as wastage still continued the smaller South Fork glacier would soonest retreat from the hills so as to allow the escape of water at a lower level. In seeking this new course the drainage from the Council Creek glacier would cross the gravel ridge previously deposited eroding it in doing so and of course carrying the material to the westward.

Hill Group.

The main axis of South Fork is that followed by the present stream, but in one sense the valley may be said to have width of three to four miles. The subordinate divides between its western affluents have been so reduced in height that coupled with the apparent reduction due to the filling of the valleys they have been almost eliminated from the topography save as some remnants of them still remain as isolated hills. The most conspicuous of these is the one at 3 Pl.1 also shown in Pl.4. It may be described as a group of summits having a common base. The elevation of the two larger summits I should take to be about eighty or one hundred feet above the plain at its base, that of the smaller summits being somewhat less. Three of these four summits are gravel covered, the gravel being spread as an unbroken sheet over all the summits, sides and intervening bottoms down to the level of the plain

or below. The slopes are rather gentle, and as there is a foot or two of Loess over the gravel the entire surface even to the sharp points of the smaller hills is under cultivation. The fourth hill is quite bare of gravel. On the top the thin sandy soil only partly covers the rock. The sides are steep showing outcropping ledges of rock on the north and west. The gravel does not end quite at the bottom of the hollow separating this from its neighbor hill on the east, but extends a short distance up the slope of the uncovered hill. There are no wells anywhere on these hills from which the thickness of the gravel may be known. If the rock topography of the covered hills is at all like that of the uncovered one it would indicate a considerable thickness twenty five or thirty feet on the lower slopes and in the hollows. There is but one section to the rock, that isthe road cutting near the south end of the long summit. It shows a couple of feet of gravel over the summit, but indicates rapid thickening on the sides. It shows also a rather fresh even rock surface on which the gravel rests without the intervention of sand or other disintegration products. This is true even of a shallow fissure a few inches wide and deep. Gravel also covers an area of less elevation perhaps twenty acres in extent and twenty or twenty-five feet high extending north from the base of the hills. An extensive swamp extends all along the NW side of the group also along the east side and the gravel extends to the edge and apparently passes under it. This group shows in their fullest development the conical sharp pointed hills characteristic of mature divides and its lines of slope are conformable to the latest development of valley topography and however the gravel may have been deposited on them, it must have been after the development of these topographic features. It may be added that the group is located just west of the main valley, and supposing a glacier to have overspread any part of it without covering the whole, that should be the eastern part.

Locations No.4-5-6.

Since we have in these localities a continuous belt of gravel some four miles in length they are best described as a single group. It will be noted by consulting the map (Pl.1) that the extensive area of swamp which extends about the east and north sides of the group last described. It is everywhere of considerable width and to the NW it extends well into the alcove which forms the head of a small valley. Whether or not the gravel underlies the swamp it forms extensive deposits all along its north edge. These deposits throughout their whole extent show a more or less abrupt transition to the non gravel covered territory north of them. They show, however, great difference in form - are superimposed on a considerable variety of topographic features and are variously related to these features.

The conditions in locality 4 are shown in Sec.Pl.4. From the north edge of the swamp the valley bottom rises with a moderate slope toward the bluff on the north side of the valley. This slope is gravel covered throughout, the front of the gravel approaching to within about twenty rods of the foot of the bluff at which point it breaks off abruptly with a very steep front, perhaps twenty feet high. It rises so sharply indeed, and its front is so nearly straight for a considerable distance that it has much the aspect of an artificial embankment. Except for a small amount of outwash material the gravel seems to end abruptly at the foot of this slope. At the east end of this ridge between it and the hill(5) there is a rather deep col in which there is abundant gravel, but it does not take the form of a ridge. It then rises onto the hill (5) which is about one hundred feet high, has a broad cultivated top and a length of a couple of miles extending nearly to Tomah. The gravel so far as one can judge - there being a couple of feet of Loess above it - covers all the south slope of this hill and extends for a consider-

able distance onto its summit, but does not cross it. Descending the east end of this hill the gravel occurs in considerable thickness on the lower ground as shown by wells and again rises onto another hill somewhat in echelon with the preceding a little to the N.E. This hill is a narrow crest and is entirely overspread, the gravel passing it to a distance which I have not yet determined. Near the summit of this hill, there are quite a good many blocks of sandstone which although probably derived from the hill itself appear to be more or less mixed with the gravel. Some have been hauled away for building purposes. On the lower ground at the east end of the long hill (5) there is a considerable thickness of Loess such that at one time a brick yard was established on it. A well, however, shows twenty-five feet of gravel under the Loess which brings us to within perhaps a thousand feet of the NW corner of the Tomah gravel area. It may be fortuitous, but to me it appears a significant circumstance that the gravel instead of occurring as isolated patches belonging essentially to the tops of hills, and liable to occur in any portion of the valley should be confined almost entirely to a particular part of the valley, across which it forms a practically continuous belt independant of topography.

Council Creek.

I have already described those topographic features on account of which had glaciers existed, the one in this valley would naturally have been larger and longer than one in its companion valley. It is at least true that for any deposits which in position and trend are such that they might be regarded as end moraines, we must look far outward to the position marked 7 (Pl.1). Before describing these, however, the deposits within the valley proper require some notice. The Tomah deposits already described may be regarded as belonging to the valleys jointly. Those deposits, however, do not end at the point of the

divide, but parting extend more or less up the sides of the respective valleys. The road passing up the west side of the Council Creek valley crosses numerous spurs projecting out from the hills, often at considerable heights, these were all abundantly covered with chert at the greatest heights attained. It is noteworthy that a large proportion of this chert is in good sized masses up to a couple of feet long very little or scarcely at all deangulated. This is true as far out as the Tomah cemetery nearly five miles from the limestone area. On the east side of the valley, at least at the outer end there is no gravel to be seen, though I was informed that it is encountered in wells a little out from the valley side. In the locality numbered 6 Pl.1, there is a considerable area of gently rolling country of no great elevations a sandstone platteau onto which the gravel transgreses for a variable distance, perhaps a half mile or more at the most, but the gravel border following a general northeasterly course finally passes off of the eastern edge. Within its limit of occurrance the gravel shut is unbroken, belonging so far as could be judged to the stream courses as well as to the upland.

In following the line of the Wisconsin Valley R.R. we encounter at about four miles from Tomah a very extensive gravel deposit whose width is something like two thousand feet, and its length perhaps a mile though I do not know its full extent to the westward. The R.R. cutting which has also been used as a gravel pit is about as deep as the telegraph poles say twenty to twenty-five feet - this is probably much less than its full thickness. The ridge has a quite noticeable slope from east to west, This becomes considerable east of the railroad and gradually increases until the ridge mounts a conical sandstone hill which marks its eastern end. This hill is heavily gravel covered on the south and west and on its top, but is gravel free onthe north and northeast. In Fig.2 Pl.1 I give a section of this ridge in the

direction of its length. Immediately north of this ridge is a considerable area of swamp land, and again north of this another heavy gravel deposit several hundred feet in width and of undetermined length. It is piled against the south side of a sandstone ridge, but does not reach its top. A transverse section through the entire group is shown in Fig.3 Pl.1. These two ridges show a gradual change in the character of the material. In the inner ridge although chert is still sufficiently abundant to give it character the proposition of sand has largely increased over that in deposits previously described. In the outer ridge the chert although still present is in rather subordinate quantity being exceeded in abundance by the harder residuals of sandstone, and both together greatly exceeded by sand. In fact, both these ridges might better be called sand ridges if named from the most abundant component. Consulting the map it will be seen that the area covered by this group belongs topographically to a subordinate divide of which the various hills form a part, two of these rise like islands from the swamp which extends further west than is shown. This swamp is itself a feature of considerable interest. On account of the height of the land on either side, its surface appears much depressed. The banks are quite steep especially on the north side. It is a peat bog and has much the aspect of a filled up lake. There is no stream running through it though a small one flows out at the east end. There are no grounds on which we could ascribe the formation of this deep basin to erosive action. It is indeed not improbable that were the peat removed its bottom would be found lower than the outlet. Its formation may or may not have been connected genetically with that of the gravel ridges.

Gravel Sheet.

Just north of the locality last described there is an area whose extent I do not yet know, but amounting to several square miles at least, which is covered as far as my observations extend by an unbroken

sheet of gravel, forming with the exception of a covering of Loess the most recent deposit within the limit of its occurrence. The best section met with is at the place called Water Mills where there is a considerable exposure both of this and of the underlying beds. The section shows the gravel about two feet thick resting on alluvial beds with an abrupt transition. The underlying beds are of fine material containing a very few intervolated stony fragments of small size none exceeding an inch cube and mostly sandstone. I do not recall seeing any cherts. The overlying sheet is nearly all chert gravel some quite coarse as large as a man's head or larger, and there is a remarkably small content of fine material barely sufficient to fill the interstices. The surface over which this sheet is spread so far as I have traversed it is as nearly a dead level as any portion of the great plain, swamp, areas excepted. It is an upland surface of apparently more than the average elevation, judging by the depth to which Mill Creek has cut its bed. From such data as I could gather I judge that the sheet is of fairly uniform thickness over the area that I traversed.

For the source of the gravel we must probably look to the southward, although there is a small area of limestone on the divide near the head of Mill Creek. But from whatever source the material may have been derived, the feature which most claims our attention is the agency by which a sheet of such character and thinness could have been spread so evenly over so large an area of nearly level surface.

Assuming it to be a fluvial deposit, we are confronted at the outset by the doubt already alluded to as to the ability of the streams to transport materials of such coarseness. But even granting that they might do so, there would be the further difficulty of accounting for the abrupt transition. Even though the various headwater branches in their down cutting had suddenly encountered heavy gravel deposits - which was

not the case - it would not offer an adequate explanation. Moreover, deposits so formed should have assumed something the form of alluvial cones. Assuming a slope as low as one fourth of a degree the difference in thickness of the deposit between Water Mills and Valley Junction would be about one hundred feet. In these remarks I have assumed that the material came from the west and had Mill Creek as the distributing agent. If we assume it to have been brought from the south by stream agency, we encounter all the difficulties above mentioned and others of an equally serious nature.

It would seem to me that the deposition of such a sheet is well within the competence of floating ice, supposing it in any way to have become burdened with such material. We may suppose it to have been either floe ice or fragments from a glacier. Assuming it to have been the former, we encounter two difficulties. 1st insufficient supply. With any water surface of sufficient height to have afforded flotation the only available sources of supply would have been the various deposits which I have described in the course of this article which would have constituted a very insignificant part of the total share line. 2nd, that between these sources of supply and the sheet there is an interval of three to five miles where no such sheet occurs.

Regarding it as an iceberg deposit, there is at least one feature that harmonizes well with the indicated development of hypothetical glaciers, its southern edge coincides quite closely with the line marking the greatest extension of the assumed glaciers. The material itself however, is quite unlike that constituting the outmost ridges. It is perhaps not unreasonable in itself to suppose that these ridges might have represented the material pushed forward at its first advance and that there was at that time not sufficient water for the flotation of bergs. That later when the water had become deeper, the glacier was bringing forward material from higher up the valleys in which chert was

more predominant.

Swamp Deposit.

At the locality numbered 4 Pl.1 there is a swamp perhaps a quarter section in area, on the surface of which I noted quite a large number of chert fragments. They are rather above the average in size, some exceeding a foot in largest dimensions. I did not ascertain whether they formed part of a larger deposit underlying the swamp. There was some chert rising onto the higher ground around, but the neighboring hills were not so covered so far as I discovered. The nearest source of supply was apparently the deposits N.W. of Tomah, but I did not trace out the connection.

Disconnected Gravel Deposits.

In two localities I have encountered gravel covered conical hills perhaps forty or fifty feet high and of relatively small section. One is in sight of the Milwaukee R.R. at Tunnel City (10). The other near the mouth of a small valley east of Council Creek (11). They are quite dissevered from all connection with the gravel ranges which I have described and are in regions otherwise free from gravel. They are probably palaeaxial deposits. There are also three gravel tongues projecting from the hills between Oakdale and Camp Douglas. The Milwaukee R.R. makes cuttings through them. Beyond what I could see from the railroad I have not studied them. They are evidently connected with valleys opening out from the hills.

Loess.

In an article on "Loess in the Wisconsin Drift Formation" (Journal of Geology, Vol.4, p.936) Mr. R.D. Salisbury mentions an occurrence of clay loam on the upper plain about four miles N.W. of Camp Douglas which he thought might be referred to one of the earlier glacial invasions. I have not seen the particular occurrence to which he refers which is

about half way between Camp Douglas and Bear Creek. It is somewhere near the eastern limit of a deposit which has anextensive development further west, in fact, the most westerly occurrence is also the largest. It is that of South Fork and the large area extending northward from that, skirting the western divide more or less closely. I have already alluded to the fact that west of the main axis of the valley the degradation of the subordinate divides has greatly increased the apparent width of the valley. All of this western half two or three miles in width with the alcones forming the western heads of the old valleys and the hillsides and spurs up to a certain height is covered with a sheet which for brevity I will call Loess. It shows its greatest thickness in the heads of the valleys next the limestone divide where thicknesses of eight or ten feet are shown by gullies. (Note) The average thickness is not easy to state since it shows the same tendency to collect in hollows which is so noticeable a feature near the Mississippi. I should think that four feet might be a fair estimate. North of this valley it extends for a number of miles over the somewhat broken region east of the western divide. I do not know how close the connection may be between this area and another which beginning on the Mill Creek gravel sheet extends according to reportfor many miles northward. The deposit overlies indifferently rock, sand, gravel, talus deposits, or alluvium. The contact plane wherever I have seen it is perfectly distinct. One section showed it resting on sandrock at the crest of a ridge, while a few feet to one side it rested on residual sand without a trace of intermingling. The gravel is in fact the only underlying deposit with which it shows any tendency to mingle. In this case, it does not so much suggest that they were deposited simultaneously as that the gravel had been so recently deposited that there was a rough surface with many unfilled interstices into which the fine material could insinuate itself. It is at least true that wherever a Loess covered gravel deposit is---

(Note) This statement was intended to apply to the west side of South Fork.

under cultivation we are apt to find numerous fragments of the chert scattered about the surface. While the most of these were doubtless brought to the surface by the plow it shows that with a thickness of Loess of from one to two feet the gravel must have interpenetrated the Loess to a considerable extent to have been within reach of the plow.

Its close association with the gravel is shown also in the relatively greater proportion of gravel surface that has a Loess covering than of the general surface. It also shows a marked tendency to be more abundant immediately adjoining valleys hypothetically occupied by glaciers than in the space supposed to have been actually occupied by them. The second largest deposit is that associated with Bear Creek. The wagon road from Tomah to Oakdale winds along the northern base of the elevated plain. For several miles east of Council Creek no Loess is encountered at the base nor yet so far as I have visited it - on the summit of the table. As we approach Bear Creek the road crosses the divides more or less instead of rounding then.

In the last valley just west of Bear Creek we find the Loess covered, and the non Loess covered surfaces meeting at the bottom of the valley. We then find Loess all the way up the hillside and overspreading the top of the hill. Looking southward from the road across the plain there is a long perspective of fine farms. The significance of this fact is apparent when we know that on the non Loess covered surface of this plain the soil is almost worthless and but little cultivated.

The Loess covered surface above described must extend well across the plain for it is nearly all cleared and the view unobstructed.

The general impression gained from a study of all the occurrences is that the movement has been outward from the limestone divide. That it was a comparatively recent movement is certain from the fact that

it overlies so many deposits that are themselves recent. Its distribution is practically the antithesis of what we should expect had it been of external origin as from the encircling continental glacier, its lines of deposition radiating outward from the limestone divide and showing the greatest average thickness in the neighborhood of that divide. The case described above in the valley west of Bear Creek where the Loess extends down the hill to the deepest part of the valley strongly suggests that the material was carried in suspension by water flowing across the hill and down the hillside.

Finally, I would call attention to the fact that the course of Bear Creek is such that its headwaters nearly meet those of Council Creek, whereby a large triangular area of the high plain is virtually dissevered from the limestone area. With Bear Creek an open valley no outwash material could have reached this triangle from the limestone area, but with that valley occupied by a glacier such an outflow over the adjacent uplands would have been a natural and probable result. I have not traversed the high plain east of Bear Creek, but at the northern base the Loess extends for a considerable but unascertained distance eastward.

General Remarks.

I have endeavored in the above to state the facts in regard to the gravels with as much care and accuracy as was possible under the circumstances. I can hardly hope that a few errors due to incompleteness of observations may not have crept in, but on the whole I believe it to be a correct presentation of the case. The gravels might be regarded as the depositional work of glaciers. But if there was depositional work there must have been its complement erosional work. On this phase of the question, however, I must for the present speak briefly and with

reserve because of the very small amount of study that I have been able to devote to it. There are a few points however which it may be well to state.

1st. As to the thickness and slope of glaciers of the assumed size. The greatest indicated length is that of the Council Creek glacier about ten miles. The general present level of the plain at the terminus is about 930'. The highest points in the limestone divide probably exceed 1500' giving a difference in round numbers of 600'. Assuming that this glacier rose but little above the rest of the ridge it could have had a thickness at the outer end of 200' and a surface slope of 40' to a mile. This would permit but a very slow rate of motion, but if at the same time ablation was small a glacier might attain to a considerable length.

2nd. The surface over which glaciers would have moved must have been that of a partly agraded valley for as I have stated old swamp growths are found underlying the gravel. If glaciers existed much of their bottom work was expended on this unconsolidated material and should have left their impress on it, but such impress would have become more or less concealed by later deposits. Without going into details I may say that there are certain features in the topography of the present valley bottoms such as the swamp in locality 7 whose genesis is by no means clear considered as normal developments under sub aerial conditions. These peculiarities are the more noticeable when we realize that they do not occur in otherwise similar positions about the edge of the great plain as for example between Camp Douglas and Kilbourn City. The features need, however, very careful study before we can be prepared to draw conclusions from them.

G.H. Squier. Mar.22,1905.