Copy of thesis, "Geology of the southeast quarter of the Cross Plains quadrangle". [1908]

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CHAPTER I.

Stratigraphy.

Data. Upwards of 150 rock outcrops were visited and examined in more or less detail as their character warrented but in regions like the Driftless Area by no means all have been noted on the map or included in the table on p. . In districts of complex structure, however, an effort has been made to visit all the exposures and even in the densly wooded portions of the terminal moraine where the chance of finding an outcrop is very remote, the writer has been within a quarter of a mile of every spot on the area.

About 100 well records of satisfactory character have been collected entirely from the owners and their neighbors thus often securing valuable cheacks.

All of the above data, including a few sections of exposures of Quaternary deposits, has been tabulated on pp. .

Description of Formations. As a complete description of the general character of the several formations of indurated rocks exposed or known to be found beneath the area under consideration is contained in the Geology of Wisconsin (1), and the bachelor's theses of O.U.Stromme and the writer (2,3), it need not be repeated here and the present report will be confined to local details. However, the fauna of the Trenton or Plattville limestone, the unconformity of the St. Peters sandstone on the Lower Magnesian limestone (Praric du Chien formation), and some of the peculiar phenomena of the latter will receive more attention.

The formations of bed rock to be distinguished within the present area are the following:

Old Name	New Name
ORDOVICIAN	ORDOVICIAN
Trenton limestone	Platteville limestone
St. Peters sandstone	St. Peter sandstone
	CAMBRIAN
Lower Magnesian limestone	Praric du Chien formation
CAMBRIAN	
Madison sandstone	
Mendota limestone	Unnamed
Potsdam sandstone	

(1) Geol. of. Wis. Vol. II. (2,3) see p. .

As there is great dispute over this question of nomenclature neither column is to be considered as authoritative. The writer strongly favors placing the top of the Cambrian above the Lower Magnesain at the unconformity as there are no fossils to fix it elsewhere.

Potsdam Sandstone.

The Potsdam sandstone is not exposed within this area but comes quite near the surface in the western part of the Middleton--Cross Plains valley. It falls off so steeply beneath the glacial filling of the valley that it is peirced by but few wells even close to the bluffs. Its thickness is about 780 feet and it lies unconformably upon weathered igneous rocks (1).

Mendota Limestone.

Overlying the Potsdam is the argillaceous, glauconitic or sandy Mendota limestone. Only the upper thin bedded shaley layers are exposed in this area near the village of Cross Plains. Judging by the section exposee in the quarry at Pheasant Branch just east of the northeast corner of the map (2), the lower

(1) Stromme, thesis 1907.
(2) Ibid, sections of exposures.

half of the formation is more massivly bedded and would form a fair building stone if it were not for the objectionable motteling of red and green. The top beds of its 30 feet of thickness grade through calcareous sandstone to the overlying formation.

Madison Sandstone.

The Madison sandstone is frequently exposed in ledges along the Middleton valley. Topographically, it forms ridges and spurs much as does the Mendota but is on the whole more resistant. With regard to physical character, it is most often seen as a more or less case-hardened, semi-indurated, white to buff or brownish yellow sand. The bedding is variable with much cross lammination and flow and plunge structure. Frequently ~~silicious~~ calcareous concretions from two inches in diameter down to the size of coarse shot are met with not far below the summit, while calcite veins are less often found in this horizon. Locally near Cross Plains, broken or brecciated rock with quartz geodes and of uncertain origin, is met with. Just below the top, the formation is often calcareous as at Middleton where 18 feet is quarried (1). The total

(1) Findlay A. G., thesis see bibliography p. .

total thickness of the Madison is not known but is about 40 feet.

Lower Magnesian Limestone.

A more detailed treatment of the peculiar features of the internal structure of the Lower Magnesian limestone or Prarie du Chien formation, is given in Chapter II, p. . Its usual appearance is a hard grayish white, crystalline, dolomitic, cherty and silicious limestone. It underlies about three quarters of the area forming low rounded hills with few ledges to the south, but appears in rough crags on the bluffs near Cross Plains, while in the drift covered country to the east exposures are again rather inconspicious. It contains many caves (see p.) thus showing that it is denuded more by solution than disintegration. Fossils are rare being represented only by a few silicified Pteropod shells probably Hyolithus, which are locally abondant near the base of the formation. The Lower Magnesian is quarried for road metal at Middleton where the quality is rather good.

The upper surface of this formation varies without referance to the bedding, which is itself very irregular (cf. p.). A difference of 100 feet in elevation is often noted in a half mile or less; the significance of this will be explained on p. under the head of Physiographic History.

St. Peters Sandstone.

Overlying the Lower Magnesian and filling the irregularities in its surface is the St. Peters sandstone, a semi-indurated, pure white, to yellow, pink or red, ferruginous sandstone which is almost always case-hardened. Its bedding is very irregular ranging from nearly massive to thin or shaley with much cross bedding and large examples of flow and plunge structure so that the bedding planes are more often inclined than horizontal' The iron is arranged along joint planes, other fissures, or just below the surface; in the top few inches are many iron concretions which are less common below as is also disseminated iron coloring. On the weathered surface this ferruginous induration produces the most fantastic fretted surfaces, projecting knobs, ridges and the like. Glauconite also is sometimes met with.

A glance at the map is sufficent to show the unconformable relation of this formation to its basement; this inference is confirmed in the field by the finding of chert fragments and pebbles in its basal layers which are plainly derived from the Lower Magnesian limestone and definitly indicate an erosion interval. At other points outside of the present area a bed of red or gray shale is seen to occupy the same position (1).

Owing to its friable character the St. Peters does not underlie any considerable hills but appears in rough ledges, cliffs, and crags. Upon disintigration the soil is very poor and the areas of outcrop are hence usually forested. On account of its softness also the formation is worthless as building stone but the softer parts are often used for sand.

Trenton Limestone.

The Trenton (or as some now call it the Platteville) is the best exposed formation upon the area; it caps the highest hills with its edge marked by an escarpment even where the St. Peters is very thin. The best single sections are shown on the accompanying diagramatic sections on pp. . With regard to

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(1) Bain, Bull.294. p. ; Thwaites, thesis.

physical character the Trenton is more earthy textured than the Lower Magnesian and more prevailingly buff colored on the weathered surface. The bedding ranges from very thick (28" in one case) to almost shaley while frequently thin bandsof glauconitic shale divide the purer beds. Concretions of altered iron sulphide (probably marcasite) are found while red to whitish chert is seen at certain horizons whose position were not definitly determined. The fresh rock is white or bluish with none of the peculiar phenomena of the lower limestone barring an occasional rough surfaced layer. Fossils are extremly abundant especially in the more thinly bedded parts and above the lower ten feet of the formation near the extremly sharp contact with the underlying sandstone which may represent an unconformity as suggested on p. . The collection of fossils is far from complete and accurate indentifications are hindered by their poor preservation as moulds and casts; those given are by Prof. Blackwelder and are largely tentative.

The full thickness of the Trenton is not known to be present but if the northwesterly dip at the East Middleton Quarries means anything, it may reach 140 feet in the hill to the west and thus possibly include some of the Galena. The subject of possible higher formations now eroded away is discussed on p. .

Quaternary Deposits.

The eastern three quarters of the area is covered by glacial formations which rest unconformably upon the indurated Paleozoic sediments. Upon these, in large part conformably are more recent lake and marsh deposits together with a little alluvium. These beds consist of unconsolidated gravels, sands, and clays (locally semi-indurated) all covered for the most part by a mantle of clay-loam soil which in many localities carries large numbers of erratic boulders but is more often nearly stoneless; it is regarded for reasons stated on pp. as in large part of eolian origin. The details of the composition and mode of origin of all the Quaternary deposits will be considered in Chapter III.

Structure.

The structure of the bed rocks of the present area is by no means so complex as that described in the writer's thesis on the country to the east. It has been determined by the same methods: the elevations of contacts rather than dip measurments which are unreliable in the irregularly bedded sandstones and limestones. Most of the elevations were determined with a hand level and are correct to within a very few feet. The chief difficulty lay in the scarcity of outcrops in the center of the area combined with the fact that the same horizon is not everywhere accessable, and no more than one can be measured at one place. Hence two, the bases of the Trenton and Lower Magnesian limestones have beene combined on the assumption that they are perfectly parallel and 200 feet apart. In fact the combined thichness of the two unconformable formations between may vary widly through deformation of the loer rocks, irregular deposition of the St.Peters, as well as the possible unconformity at its top, and irregular settling. Nevertheless, the distortion of the contours where they pass from one to the other is probably not great and the areal geology is based on the structure sheet.

Looked at in a broad way the beds of the area dip gently to the south at the rate of about 20 feet per mile but with minor east and west swells or interrupting ridges. The most marked feature is that one south of the Middleton valley especially near Cross Plains where the absence of the drift enables it to be observed with fair accuracy. The significance of this and other valleys which are related to synclines is considered on p. . The unusually steep dip in Sec. 18, Middleton may be an error or due to a fault. The origin of these features is probably original inequalities of deposition accentuated by deformation.

The subject of the jointing was not investigated but no essential difference from that to the east was noticed (1).

Slumping is common and must be guarded against in the measurments of contacts.

(1) Harder, Stromme, Thwaites, thesis see p. .

GENERALIZED STRATAGRAPHIC SECTION.

QUATERNARY. Thickness, feet.

Recent.

Residual Soil---loam, cherty clay, sand, and talus; found chiefly in Driftless Area; in part older..........0-20

Alluvium ---soil, sand, gravel, and clay recently transported by streams....0-10

Peat---usually sandy or earthy; shown only in wet marshes...............0-10

Lake Beds---fine gravel, sand, clay, shell bearing or marly, with some peat and dune sand........................0-5

-----------Local Unconformity----------

Pleistocene.

Wisconsin Drift---glacial and glaciofluvial deposits of till, boulders, gravel, sand, and clay; statified and unstratified.......................0-250

---------------Unconformity------------

Pre-Wisconsin Drift---scattered erratics.0-1

---------------Unconformity-------------

ORDOVICIAN.

Trenton Limestone---buff to blue or white argillaceous limestone; shaley to thick bedded; locally cherty; highly fossiliferous...............125? max.140?

St. Peters Sandstone---red to pure white ferruginous sandstone; bedding thin or cross to massive; many iron concretions towards top; base chert conglomerate and shale............1-150

ORDOVICIAN or CAMBRIAN.

----------------Unconformity--------------

Lower Magnesian Limestone---hard, white cherty, silicious, dolomitic limestone; shows domed layers, breccia, concretions, oolite, and geodes; bedding massive to irregular or folded; fossils rare......................50-200

CAMBRIAN.

Madison Sandstone---soft buff to white calcareous to silicious sandstone; bedding massive to thin with cross bedding and flow and plunge structure; silicious concretions at top........40

Mendota Limestone---shaley, red and green spotted limestone; bedding thin but more massive in lower part; grades into adajecent formations..........30

Potsdam Sandstone---soft, white to buff, glauconitic sandstone; bedding thin.780

----------------Unconformity-------------

ARCHEAN?

Capitol Basalt---dark, finely crystalline basic, weathered igneous rock; veins of quartz and calcite.....unknown....?

CHAPTER II.

Some Notes on the Lower Magnesian Limestone.

The Lower Magnesian Limestone (see p.), an impure, cherty, dolomitic limestone of disputed age(probably Cambrian but now classed as Ordovician) posses many interesting features, on which it is hoped that the following notes will throw some light, to the aid of some future investigator who may arrive at their complete explanation. With this view a tentative hypothesis is presented. The field work during which the observations were made was conducted in the vicinity of Madison during the years 1905-7 and covered an area of about 170 square miles in which about a dozen outcrops were found where these peculiar features could be profitably studied. A list of the reports covering this area will be found in the bibliography on p. .

Previous Investigations. Although numerous geologists have studied the formation in question, none of these peculiarities have been adequatly described. A bibliography on the general subject of limestone conglomerates is here given; it is fairly complete but undoubtedly this subject is mentioned incidentally in many other works. No attempt has been made to investigate foreign literature on the subject.

The peculiar structures here described may be classified as:

(1) Breccia and conglomerate beds.

(2) Domed layers.

(3) Folded and contorted beds.

(4) Concretions and oolite.

(5) Mud cracks, cross bedding, geodes, cherts, etc.

(1) Breccias. The intraformational conglomerates and breccias are simalar to those which have provoked so much speculation elsewhere without anyone arriving at a thoroughly satisfactory explanation. Here unfortunatly, weathering has generally gone so far along these relatively porous beds that their exact structure is often indeterminate. So far as could be ascertained from the weathered surface and from a few polished sections, they are composed of angular to subangular, although seldom rounded,

pebbles in a matrix of virtually the same material which occasionaly contains broken Pteropod shells (O-17, Dunn 23). All gradations from clearly marked breccias to mere roughness of the rock surface are seen, as well as from beds extending for a mile or more (Madison quarries) to mere irregular patches or lenses. Breccias associated with domed layers are also found.

The contacts above and below a breccia layer are equally varied in character: some rest on an inclined surface cutting the beds below (O-17, Middleton 16), others are truncated above, but most present no definite boundaries seemingly grading into the massive rock.

A conglomerate of rounded limestone pebbles in a matrix of sand isseen near Black Halk's cave on Lake Mendota (1) while occassional indications of a sandstone conglomerate are also seen at the top of the Madison sandstone (Madison quarries). Other typeses of brecciated rock are met with in the drift; they include the chert and sandstone breccias which (2)

(1) O'Connor, thesis see p.
(2) Thwaites, thesis.

appear to come from the unconformity at the top of the Lower Magnesian (see pp..). Less often, a chert-limestone breccia is met with (see p.).

(2) Domes. The domed layers seen in the accompanying sketches are by far the most puzzeling of all theproblems presented by this (pp.) complex formation. In shape, naturally they are most commonly seen only along a vertical plane where they resemble a series of arches like those of a bridge (see photograph of 0-17 in writer's thesis), but when exposed in three dimensions, they are found rather to be a collection of domes, most frequently of nearly circular outline. There are naturally variations including such compound forms as are shown in the sketches. In size these domes range from a few inches in heigth to one beneath which a man can nearly stand upright; they may stand alone with massive rock on every side or occur in groups which may either pinch out or end suddenly; they are composed of pure, often thin bedded limestone, or may be largely chert nodules or banded with chert layers; they may have breccia, solid limestone, chert, or sandy glaucon-

itic material within; they may have breccia, be truncated, or grade into massive rock above. There is also every gradation from perfect domes to mere undulations of limestone or shaley sandstone layers; in oother words their forms are infinite in variety. The undulating sandstone layers were noted best in the Madison quarries in the basal transition beds but wavy layers in pure sandstone are not uncommon. No relation to joints is seen where the domes are far enough below the surface to escape disintegration along the planes of weakness afforded by their junctions.

(3) Folded Layers. Folded and contorted layers are generally found in the otherwise massive and fairly pure limestone. The accompanying sketches show some of their characteristics as seen in two dimensions for it is usually impracticable to get at them any more. When this is done however, it is often found that the folding is nearly as intense. From the extreme of contortion there is every gradation to the undulating layers mentioned above. The minute differences in hardness between the laminae

are only brought out by weathering and are best seen either on the natural or a polished surface as fracture destroys all traces of them.

(4) <u>Concretions and oolites</u> Concretions and oolite, both calcareous and siliceous, are characteristic of the base of the Lower Magnesian although oolitic chert is also found at its summit where, along with much ordinary white chert, it is frequently found incorporated in the overlying St. Peters conglomerate. The calcareous nodules locally attain a size larger than a man's head while the silicious grains seldom exceed the size of a pin head. Nodules of the latter form of chert are found in the massive basal layers; they are usually less than an inch in length and lie with their longer diameters parallel to the bedding. So far as could be ascertained, the smooth surface often cuts through the grains of the oolite. No very detailed study was made however of the subject of oolites for they have been amply investigated elsewhere.

(5) <u>Mud cracks etc</u>. Among other characteristic features of the formation are mud cracks, cross bed-

ding, and geodes. The forst two are not very common as weathering and disintigration readilly obscure their character. Ripple marks have also been noted in the Madison quarries (Stevens'). The bedding of the rock is sometimes very indistinct but is more often extremly irregular with knobs, undulations, and so on, as has been mentioned before. Shaley or glauconitic layers are common as is sandstone and chert. The last occurs in two distinct forms: bedded in layers up to a foot thich and usually white colored, and nodular which is more often pink or yellow. In some beds also, the entire rock is of a flinty character. Geodes abound being predominately quartz and calcite, less commonly other carbonates and limonite after marcasite; they have been treated more fully in the writers thesis. Sometimes they are very large and enclose fragments of the country rock thus resembeling a breccia.

Hypotheses of Origin. Although the writer has not had an opportunity to examine a great number of exposures and hence have grounds for the formation of a definite explanation of the various phenomena just described, he nevertheless wishes to suggest a hypothesis which may some day aid in their determination of their true origin.

It will readilly be seen from the features described especially the mun cracks, ripple marks, cross bedding, and the unoonformity at the top of the formation, that the Lower Magnesian limestone was deposited in very shallow water with ocoassional emergences from the sea. We therefore have to deal with forces which have not operated on ordinary limestones.

Theories. Numerous theories of the origin of limestone breccias have been suggested and may be classified as follows:

(1) that they are original sediments mechanically formed. Under this head it has been urged that they are (a) normal conglomerates formed by the action of the waves upon portions of the same or other formations which were temporarilly lifted above water and indurated, or (b) that theywere formed by the induration and breaking of beds beneath the water or not far above it.

(2) that they are original sediments formed by some kind of organism. There is little to support this view save that they are most common in Cambrian and Ordovician beds.

(3) that they are of secondary origin. Under this last it has been suggested that they were (a) formed by dynamic action during folding, (b) by the collapse of caves, or (c) by ordinary settling of a partially indurated formation, or (d) by contraction caused by dolomitization or recrystalization.

In view of the great variation in the character and geologic relations of breccias it is very probable that all are not of the same origin and that many of the causes stated above may have been operative even in the same formation. Where the fragments are rounded, however, an original sedimentary origin is certain. Some of the chert and sandstone breccias are probably basal conglomerate from the unconformity which has been silicified by the waters following the contact; in some the limestone fragments (cf. p.) may have been entirely replaced. The character of most however, is such that even speculation as to their origin is idle at the present stage of the investigation.

The only features at all resembling the domed layers which the writer has found described in American works are the domes of calcareous tufa of Extinct Lake Lahontan (ref. on p.   ). Of these Russell says that those in the vicinity of Carson desert and Pyramid Lake are "polygonal blocks having rounded summits" and that "each block in these closely set pavements is a mushroom-shaped growth of tufa from ten to twenty inches or more in diameter. These blocks were at first circular in outline, but pressed against one another as they enlarged, and thus received an angular outline, as seen from above." He further states that the reason for the concentric arrangement of these masses which are often not at all symetrical and extremly fantastic, is the tendancy of the calcium carbonate to precepitate around a neucleus such as a pebble. He was not decided as to the exact chemistry of the formation of this precipitate and it is possible that modern knowledge would require a revision of some of the conclusions as he did reach.

Neither has the writer found any satisfactory explanation of the wavy and crumpled layers; in all regions of folded rocks they have naturally been ascribed to readjustment between the beds or to general crumpeling of incopetent layers. Here, in flat-laying rocks such an explanation is inapplicable. It is most probable that they are mere incidents in the settling, induration, or dolomitization of the formation.

Some of the concretionary limestone beds resemble the structures of sponges and other marine organisms and some at least, may be due to such a cause obliterated by subsequent changes especially dolomitization. Others may be original sediments like the oolite or due to secondary causes of unknown character. Much of the banding seen in the Mendota limestone (Ferwell's Point, Lake Mendota) is seen to cut bedding planes and hence cannot be original.

As the subject of the origin of oolites has been amply discussed in many works, it has not been included here. The occurance of both white chert and silicious oolite in the St. Peters conglomerate is interesting, however, but no conclusions have been drawn from it. If the "pebbles" of oolite are of mechanical origin and are cut through the grains another important fact may have been observed. As with oolites, however, the subject of the origin of chert is too well known to require discussion.

The writer suggests that the breccias and domed layers are normal products of the surface induration and cracking of the limestone whenever its surface was exposed to the air. It is certain that crustal deformation could have plaid no part in their formation while the uniformity of some beds precludes their origin from the collapse of caves. The data at hand are insufficent to conclude anything about the other changes which the formation has undergone in its several emergances from the sea. It is quite probable that some beds of breccia are due to settling of the partially indurated rock and so on, but it seems quite certain that an appeal to organic agencies is not necessary.

Mud Crack Theory. An examination of the large mud cracks formed in the marl filling of Henry Vilas Park (Madison) was made by the writer with a view to determining their behavior when rewet. The contraction causing them is brought about by sun drying and is often sufficient to open cracks nearly six inches in width and more than that in depth between cakes several feet across, in a material which is composed more largely of clay than of carbonates. By this process, a surface layer about two inches in thickness is partially indurated and begins to turn up at the edges. Meanwhile the cracks below fill by caving along the sides. When wet again by a rain (standing water is needed, however), this surface layer expands to its original size while below this is not possible as the cracks are now filled. As a result the edges of the polygonal cake turn down thus forming a more or less perfect dome.

Unfortunatly we do not know what the behavior of a pure calcareous mud or silicious ooze would be but it may be presumed that the process od drying and rewetting would go on somewhat as stated above.

Such a process is evidently capable of great variation especially if the surface is considerably indurated. Quiet wetting would produce the neucli upon which later sediment, organic or chemical, would be deposited in fairly symetrical domes. Even if the surface layer did not turn down but was broken up as it is shown to be in some pictures of large mud cracks(in the Salton Sea) the result might well be the same. Slight disturbance of the underlying material would in any case result in the breccias which often fill the domes. Again, some cakes might be broken into angular peices and deposited between the surviving domes thus forming the overlying breccias; still more vigorous wave action might cause the extended breccia or conglomerate beds which in most cases would be laid down of soft material thus showing no unconformity below unless locally where the fragments had been considerably rounded.

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Urges dynamic action.

Campbell, M.R.; Paleozoic Overlaps in Montgomery and Pulaski Counties, Va., Bullitin of the Geological Society of America, vol.5, p.171.
Describes conglomerates at local unconformities.

Chamberlin, T.C.; Geology of Wisconsin, vol.I, p.139; vol.IV, p.409, and incidental references.
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Russell, I.C.; Geological History of Lake Lahontan, U.S. Geological Survey Monograph XI, p.188 et seq.
Describes sediments in L. Lahontan.
Physiography of the United States, (National Geographic Society), p.128.
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Sardeson, F.W.; Intraformational Conglomerates in the Galena Series, American Geologist, vol. 22, '98, p.315.
Suggests that they are products of weathering or solution and lie below unconformities.

Walcott, C.D.; The Cambrian Rocks of Pennselvania, U.S. Geological Survey, Bullitin 134, '96, p.34.
Suggests mud crack theory in shaley rocks backed by actual observations.
Shale Conglomerates in Connecticut, U.S.G.S. Annual Report, 21st., part III, p.60.

Willis, Bailey, and Blackwelder, Eliot; <u>Resarch in China</u>, <u>Carnegie Institution of Washington</u>, pp.386-390.

Names following theories favoring last.

(a) autoclastic rocks.
(b) concretions formed after or during solidification.
(c) fossils.
(d) mechanical pebbles.
(e) lenses of incipient solidification in part rearranged by waves.

CHAPTER III.

Physiographic History.

Pre-Cambrian. The oldest record that we have of the topography and conditions of the area under discussion, is inscribed in the rocks found in the deep borings of the city of Madison about five miles to the east (1); these are of igneous origin being probably lava flows and show signs in their mineral-gical composition of having been greatly weathered previous to the deposition of the overlying sandstone, which has a bed of red clay at its base which pre-sumably represents a part at least, of the old resid-ual soil. The borings show that this contact is a gently undulating one and therefore these and other facts have led to the conclusion that the sea in which the Potsdam sandstone was laid down encroached over a nearly plane surface, the pre-Potsdam peneplain described by Weidman (2).

Cambrian. As the waters advanced over this plane they reworked the old soil, the material brought

(1) Geol. of Wis., Vol.II.,p. ;Stromme, thesis.
(2) Weidman, S., Pre-Potsdam Peneplain of the Pre-Cambrian of N. Central Wisconsin, Journal of Geology vol. 11, p.289, 1903.

down by streams from the unsubmerged parts(although if Weidman's conclusion that this buried plain is continious with the present upland of north central Wisconsin is correct, it cannot have amounted to much) and that worn from the monadnocks by the waves to form the great thickness (780') of sandstone, shale, and glauconitic and calcareous sandstone which we call the Potsdam. The last type of sediment increased towards the top thus indicating a progressive clearing of the waters which culminated in the deposition of the thin, shaley, glauconitic Mendota limestone. Next succeded a recurance of the conditions for the deposition od sand to form the Madison sandstone, a formation which bears abundant evidence of shallow water origin but passes into calcareous rock at its summit, The deposition of the last shortly gave place to that of oolite, probably also within the reach of the waves. The succeding formation, the Lower Magnesian limestone, indicates clear but shallow water, for if the observations noted in Chapter II are correctly interpreted it was often raised above water, sun baked, broken, eroded, and redeposited to form the peculiar structures there described,

Ordovician Erosion Interval. This culminated in a longer uplift during which a fairly mature system of valleys was eroded and a residual soil of cherty clay formed. In the absence of fossils, the writer favors the conclusion of the old state geological survey inpplacing the division between the Cambrian and Ordovician systems at this horizon(1). However, he interprets the course of events somewhat differently than did Chamberlin (2) when he ascribed the brecciation of the limestone beneath the inclined beds at its summit as due to the action of the waves of the reencroaching sea followed by renewed deposition of limestone. As no such structure is observed within the present area and the exposures where it was observed (3) were rather limited, the writer considers it quite probable that what Chamberlin saw were simply large domed layers such as are described in Chapter II of the present report; an alternative hypothesis would be to ascribe them to slumping during the uplift. It would appear that the St. Peters sea was not very violent in its wave action for no

(1) Geol. of Wis., I, p ; II, p. . (2) Ibid, II, p .
(3) Ibid, II, p. .

limestone conglomerate has been discovered at the contact although some broken "chert breccia" or "sandstone breccia" may represent it after subsequent solution of the limestone fragments. As is natural this contact is seldom seen at the bottom of the old valleys, (cf. p.) just where we would expect to find the clearest evidence of unconformity in the shape of a residual soil; nevertheless, there is found the chert-sandstone grit and conglomerate mentioned before (p.) quite well up on the sides of the buried limestone hills although frequently the contact is perfectly sharp. On the Historical Geology sheet an attempt has been made to represent the topography of theis erosion interval by means of contours drawn on the present top of the Lower Magnesian limestone ignoring subsequent deformation which in this locality has largely consisted in a simple inclination to the south. A large valley is disclosed for the most part followed by a tributary of the modern Sugar River.

The extrordinary roundness of the grains of the St. Peters is ascribed by modern investigators to wind action in dunes on the old shore.

<u>Ordovician</u>. Following the deposition of the St. Peters sandstone whose characters have been just described, the extremly sharp contact with the overlying Trenton may well mark an unconformity such as has often been suspected and has been definitly made out near St. Louis (1). The massive and uniform bedding of the formation together with the abundant remains of marine organisms indicate clear water and fairly continious sedimentation broken only by the occassional incursions of muddy water which formed the shale partings.

<u>Younger Formations</u>. All younger sediments have been been swept away from this area by erosion but studies elsewhere show, however, that sedimentation continued to the close of the Niagara epoch of the Silurian if not throughout the Devonian and Missicipian periods (2).

<u>Deformation</u>. Both at the close of the Missisipian and Carboniferous condiderable deformation is known to have affected the rocks of the Missisipy

(1) Bain, Bull.293, p. ; Fenneman, N. M., unpublished notes on St. Louis Quadrangle.
(2) Grant, U.S., Lead and Zinc Dep. of S.W. Wis., W.G.S. Bull. XIV, p.51.; Bain, Bull. 293, p. .

valley and while we cannot correlate the slight folding and well marked jointing of the present area, the presumption is strong that they date from one or both of these periods.

<u>Lancaster Peneplain</u>. Little if anything is known of the long period of erosion which reduced all of southwestern Wisconsin to a peneplain some considerable time before the earliest glacial epoch. Even the existance of this surface is not evident within the area; but if one ascends any of the highest hills on its western border, which rise to a little over 1200 feet ablve tide, it is at once apparent that they are the dissected remnants of a broad plateau of the ame heigth, whose even sky line forms the southwestern horizon. Above this, at its northern end, the bold monadnock of Blue Mounds rises some 500 feet. This upland is continicus with the Lancaster Peneplain of the Lead and Zinc Region of the Driftless Area (1). Within the district now under discussion several hills rise above 1200 feet A. T. quite irrespective of the structure or char-

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(1) Bain, Bull. 293, p. .

acter of the underlying rock. The date of the formation of this peneplain is entirely uncertain as its relation to the non-glacial gravels of Illinois and Iowa (Lafayette) has been only interpreted on the erronious assumption that they are marine. The great amount of dissection of its surface and the advance stage of the channels in their relation to the structure of the rocks (cf. p.) leads the writer to think that it should be placed farther back than the Tertiary and perhaps as far as the close of the Comanchian (1).

Tertiary Erosion. A relative uplift of the peneplain inaugerated a new cycle of erosion on a southwardly inclined surface with its dainage lines approximatly those of today. When the streams began to intrench themselves they were upon the uniform Trenton limestone; as their channels were cut though, or their headwaters receeded into this, the soft St. Peters sandstone was disclosed filling the ancient Ordovician valleys but barely covering the intervening divides. It was only natural that those valleys should be in large part reexcavated both by the mig-

(1) Bain, Bull.294, p.15, cites Kümmel and Hershey.

ration of streams down the contact and by the advantage of those upon the soft formation as is the case in regions of inclined rocks. By this is explained the large size of the Barwig Basin (Pre-glacial Topography sheet) as compared with the narrow valley which formed its outlet; this basin must have been in danger of capture by the branch of Sugar River to the southwest which had reexcavated the Ordovician channel, thus ressurecting the buried topography. The same explanation is also thought to apply to certain of the features of the Middleton valley to the north as will be explained on p. .

The effect of the slight tilting of the strata described in Chapter I is thus largely obscured by the phenomenon just described but a close inspection shows a striking relation of the main valleys to the gentle synclinal depressinons shown on the Structure Sheet. This is considered as due to migration of the streams down the dip rather than to a consequent relation to deformation, a hypothesis which is supported by the greater development of tributaries on the north side where the dip is more gentle.

Pre-glacial Surface. Pursuing methods simalar to those outlined in the writers thesis on the district southeast of Madison the map (Historical Geology---Pre-glacial Topography) has been drawn on which it has been sought to represent the topography brought about by this Tertiary erosion period. In this work it has been assumed that the present surface is in most parts a close key to the pre-glacial one for wells on the uplands show that barring moraines, the mantle of drift is very uniform generally running close to 30 feet. A few wells in Barwig Basin are probably incorrect as the drillers and diggers do not seem to have recognized the St. Peters sandstone as rock; otherwise the records are fairly reliable but an error of any single one would not influence the map to any considerable extent.

Naturally it is only the rock surface which can be represented since the pre-glacial soil cannot be distinguised even where preserved beneath the drift. The rariety of glacial striae shows that ice erosion did but little work upon this surface but as will be explained on p. we here have to deal with considerable erosion by the waters derived from the melting of the ice.

Development of Valleys. It would appear from this map that erosion had produced a topography identical with that of the Driftless Area to the west today. Technically it was post mature with no considerable part of the peneplain left but the Middleton valley at the north must have had a more youthfull appearance for it was then nearly twice as deep as now. The high range of hills south of this valley (on the west line of Middleton township) approximated in elevation to the peneplain, and lay as they lie today, at the junction of three drainage basins---the Wisconsin to the northwest, the Yahara to the east, and the Sugar to the south, the divides radiating at nearly equal angles. It was fixing the pre-glacial location of that between the first named basins that has in the past offered most difficulty (1).

Middleton Valley. The course of the Middleton valley appears to have been fixed upon the north side of a low anticlinal interruption of the southerly inclination of the strata; this fact is especially clear at the Cross Plains end where it turns northwest along the strike of a low dome on the south. The great depth and ruggedness of this valley compared with that to the south at Verona is attributable to the fact that it had benn cut through into the weak formations below the Lower Magnesian limestone thus facilitating sapping and headwater recession.

The location of the divide between the preglacial streams which eroded this valley may be made on the following grounds:

Course on main valleys.

Location of narrowest point.

Course of tributary valleys.

Location of the divide on the uplands.

A critical inspection shows that this valley is a union of two, or more strictly four, separte ones which meet at a considerable angle near the west line of Middleton township (see figs. on p. . This is confirmed by the narrowness of both branches at this point as well as by the divergance of the tributary valleys. The course of the larger ones, especially that to the northeast, would be inconsidtant with the mature drainage system of the Driftless Area if, as was formerly supposed, the valley in which Lake Mendota is situated, once drained westward by this course. The location of the old divide (which in most cases in also the present one) as shown on the map of the pre-glacial topography may be followed from the north to the narrows at the western isolated hill but on the south its course is less definite. From the high hills along this divide it is very apparent that the hill summits are all very much lower to the east and southwest.

The figures on p. show a suggested hypothesis explaining the isolation of the two hills in the valley. It rests upon the observed increase in thickness of the St. Peters sandstone between them. The north fork of the pre-glacial Pheasant Branch is thought to have reached this ancient Ordovician valley first (cf. Historical Geology sheet) possibley because of a higher grade. It naturally proceeded to reexcavate it and thus the tributaries met around the eastern hill and finially tapped the two forks of

Black Earth Creek, doing the same for the western emminence. The exact correlation of the valleys southeast of the latter is open to question; the evidence rather favors the view shown on the map, that they belonged to the western system. This hypothesis also explains the close approach of the valley to tht high hills to the south. Thus it was that this col was readilly cut down through the thin (about 50 feet) Lower Magnesian limestone into the weak formations below. It had this great advantage over the Verona depression and appears to have been the lowest point on the divide for 20 miles in either direction.

Summary. We may therefore picture to ourselves the appearance of the area at the close of the Tertiary erosion period as much like that of the Driftless Area of today---low rounded hills past mature in development near the main channels to the south but often rugged with towers and cliffs where the sandstone outcropped, with valleys constricted among the smooth limestone hills but more open in sandstone districts. The Middleton valley along had bold bluffs with limestone bluffs with limestone crags rising above long taluses below. It was over such a country that the glaciers of the Pleistocene had to pass in their southwesterly course and here it was that the last or Wisconsin ice sheet, pressing farther than any of its predecessors, found its energy exhausted and could go no farther.

Pleistocene.

Earlier Glaciation. Little is known of the earlier ice invasions; their deposits have either been buried by the Wisconsin drift or swept away by erosion. The time since the second or Kansan epoch is estimated by the best authorities (1) to have been 16 times as great as from the climax of the Wisconsin to the present---amply sufficent for considerable erosion both of the older drift and the underlyin rock. As a matter of fact, the only pre-Wisconsin drift that can be distinguished within the area is two or three scattered boulders south of the railway west of Verona. It is possible, however, that

(1) Chamberlin and Salisbury, Text Book of Geology, Vol. III, p. ,refer to work of

all of the country near Nine Mound Prarie to the north may have been glaciated as it is difficult to distinguish older drift from outwash when exposures are poor; no erratics were found by the writer.

Reversal of Drainage. The first effect of each ice sheet advancing from the east was naturally to dam up the lower Yaharah valley and reverse its drainage thus causing a large lake which sought for its outlet the lowest break in the divide to the west. This lowest point(or points) was furnished by either the Middleton or Verona cols, more probably the former. As this condition of affairs must inevitably have recurred several times and lasted for a considerable period, at each advance of the ice, it would be strange if the escaping waters did not erode the col or cols to a large extent. On the other hand the prevalence of high cols in this region along the divide, shows that the outlet must have been nearly or quite as low as the present heights at the old divide or it would not have been chosen by the stream. During the long inter-glacial epochs, however, the drainage must have resumed in the main its former

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course obstructed more or less by the drift, which was thus largely eroded before the advent of the last ice sheet.

Wisconsin Epoch. During the advance of the vigorous Wisconsin glacier, its drainage must have been by this western outlet although less in volume than during the time of retreat when melting exceeded advance.

Johnstown Stage. When the ice reached its maximum extent its fron halted for a longer period than at any time during either its advance or retreat, for no over-ridden moraines nor recessional deposits compare in magnitude with the great outer or Johnstown Moraine. Where best developed, this is the most striking feature of the uplands of the area: a huge ridge 50 feet or more in heigth, almost continiously forest clad, composed on the surface almost entirely of erratic boulders but below of gravel and till, and rising abruptly above an ill defined outwash apron on the west but sloping away more gradually although interrupted by many kettles and minor ridges. to the rolling uplands to the east. In general it is located upon or slightly beyond, the crest of a rock ridge but in its fairly regular southeasterly course it crosses five large valleys (see maps). At the far northwest corner of the map it is represented by rough mounds and ridges of stratified material upon which part of the village of Cross Plains is situated. Rising to the summit of the hills to the east, it shrinks to a mere ridge of boulders sometimes only two or three feet in heigth which is situated just south of the crest of the pre-glacial divide. In the Middleton valley into which the ridge descends with a slight westward turn, the moraine is very indistinct and grades into the Upper Gravel Terrace of outwash which will be presently described. Upon the upland to the south to which the moraine rises in a manner indicating a farther extension of the ice in the valley than elsewhere, its best development is reached as was described above while in the southern valleys the ridge structure is less distinct although there is sharper differenciation from the outwash than at the north.

<u>Lakes</u>. Apparently the only lake dammed up at

the Johnstown stage of the ice front (see map on Historical Geology sheet) was in Secs. 24 and 25, Cross Plains but its great hiegth above the outlets to both north and south, make it questionable if there could ever have been a sufficent supply of water to cause it to overflow. No outlet channel can be distinguished to the north although there is a well defined outwash plain through which a stream has eroded a channel near its descent into the Middleton valley (see map). It is evident that at one time the ice crossed this valley head and deposited the boulder ridge which is seen on the west side of the present basin which was enclosed by the moraine when the ice retreated to form a more even front. Owing to the removal of stones from the fields the exact limit of this extra morainic drift could not be traced; it is apparently not very extensive. The presence of an apron of outwash upon the east shows that much water must have entered this basin in glacial times;;whetther or not the present underground drainage (see p.) was then open is impossible to say but it probably was not.

Drainage Lines. The chief points of escape for the waters derived from the melting of the ice at the Johnstown stage are shown on the map above refered to. In both of the main valleys the ice front was far west of the old col which must therefore have been buried by groun moraine. In the Middleton valley a valley train of coarse limestone pebbles with scattered boulders and now covered with clay was laid down by the overloaded stream; it has been termed by the writer the Upper Gravel Terrace. The simalar deposit in the Verona outlet is less well marked (cf. p.   ). As these main outlets, not to mention the valleys northeast of Cross Plains, drew water from far back under the ice, other exits must necessarily have been of minor importance, barring the possibility of considerable streams on the surface of the glacier which was probably covered with melted out englacial drift. However, the drainage of six square miles or more must have flowed out largly at the Cave outlet (Sec. 6, Verona) and to a less extent farther north (cf. last page). The consideration of this outlet is closely connected with the question of the outlet of the pre-glacial valley (Barwig Basin) which now drains into the cave (cf. p.). We may dismiss at once the possibility that this was also an enclosed basin during Tertiary times and the most natural exit would have been through the present col and along the narrow valley below to the Sugar River. The only alternative is to assume an outlet to the Morse's Pond valley to the east through a pronounced ridge which appears to have a rock core. It was the former route which was followed by the glacial waters and ithe steep sides of the valley together with the presence of gravel and boulders high up on thems shows that considerable erosion was accomplised by the stream, a fact which is supported by the lack of harmony of the ravine with the open limestone slopes above. The presence of tributaries in the rock flat to the east with its thin covering of extra morainic drift goes against this view, however, and it may well be that the broader valley above is a ressurected Ordovician surface (cf. p.). Below where these phenomena are seen the waters were closely crowded to the moraine and a marked amount of erosion may be distinguished.

Valley Aggradation. When the valleys leading directly away from the ice front were filled with glacial debris the water must have backed up in their branches forming lakes. A notable instance is the upper course of the Sugar in the far southwestern corner of the area as are also the north flowing valleys near Cross Plains. As a natural consequence, these tributary streams filled the lakes in large measure and aggraded their channels to the level of the Upper Gravel Terrace. In some cases the filling was not completed and small drained areas (in part possibly due only to settling) still survive, examples on which may be seen southeast of Cross Plains although unfortunatly the best are not on the present map. The fact that more do not exist shows that the process of aggradation was largely completed before the close of the Johnstown stage and the erosion of the Upper Terrace, although in parts of several valleys it is still in progress. The material is generally not acessable but is apparently largely soil and some fine chert gravel.

Strictly these deposits should not have been mapped as outwash but as they are genetically dependant upon and grade into the latter they have been.

Intermediate Stage. After the abandonment of the Johnstown Moraine by the ice, the excess of melting over advance was such as to cause the front to retreat so continually that it was only at scattered points that any moraines were deposited. A lake appears to have been enclosed in Sec. 10, Verona; its sediments consist largely of gravel and sand terraces which all rise to about the same heigth. All the strata exposed were flat laying with occasionally boulders and clayey layers, while the whole is overlain by boulder clay. The depressions like that containing Morse's Pond were probably caused by the melting of ice blocks. On the whole the lake features of these deposits are not very prominant and indeed it is difficult to see why the water should have chosen this high outlet rather than the low one to the east. It has not therefore been mapped as a lake bed. Another interesting feature which is probably connected with thes basin is the gravel terrace along the northwestern side of the valley to the northeast; at one point it is fronted with a short one on the opposite side. They are composed of very coarse limestone cobble stones with little sand and a thin boulder clay mantle. The close association and apparent gradation of these features with and into terminal morainic deposits has led to their being mapped as the same. An alternative view would be to regard them as remnants of an eroded gravel terrace leading to the supposed lake basin.

Milton Stage. The next important halt of the glacial border is recorded in the massive and rugged moraine two mile south of the village on Middleton which is correlated with an early stage of the Milton Moraine, so prominent a mile or so to the east of the area (1); this stage is represented on the Historical Geology sheet. This assumption of an east and west border along a lobe in the Middleton valley was due to the greater protection from melting offered by that depression. South of this moraine, which is almost entirely composed of sand and gravel with the usual boulder clay mantle, is a gravel terrace of questionable interpretation.

(1) Stromme, thesis.

It was probably deposited like that mentioned in the consideration of the Johnstown stage lakes (p.) in the edge of a body of standing water which drained out through the high col on Sec. 27, Middleton as represented on the map. This assumption is strengthened by the eroded valley though the gravel terrace north of Morse's Pond but the exact shore lines of the lake could not be determined. The position of the western edge of this lobe appears to have varied considerably as the moraine is there very discontinious. The water escaping from the part north of the Middleton valley eroded the col on Sec. 6, Middleton to a considerable depth; no solid rock is now seen in its bottom but the steep sides are out of harmony with the valley to east and west. The permanent reversal of drainage through this col has also eroded it to a depth of about five feet throughout half its length in very recent times.

Erosion of Gravel Terrace. In the Verona valley the gravel terrace of the earlier stage of the ice front was only slightly eroded and a tributary (see map) entered from the north inside the moraine to make up for the cessation of the Cave outlet. The Milton Moraine east of the area raised the divide to 1000 feet A.T. thus closing this outlet permanently. On the other hand, the waters were so cleared by this time in the Middleton valley that the Lower Gravel Terrace was eroded out of the Upper to a maximum depth of about 20 feet decreasing to nothing near the western isolated hill. The gravel terraces west of the eastern hill and of the moraine near Middleton (see map, p.), are of questionable interpretation; the former may have been a portion of an earlier outwash terrace but is more likely an interlobate deposit while the latter seems to be an outwash apron of the poorly marked moraine which raised the divide to its present elevation (928' A.T.). It gives the impression of a delta but no lake basin can be made out to the west.

Middleton Sub-stage. The last mentioned moraine is a product of a later sub-stage of the Milton, which is well recorded in the ridges of sand and gravel west of the village of Middleton. At this time a small la e was probably dammed up to the southwest.

Pheasant Branch Substage. A still farther retreat of the ice front brought it into a more regular position just east of the area. This inclosed the basin of Lake Middleton as will be explained at greater length in Chapter IV. Several smaller depressions were also formed south of the main portion of the outwash apron while the settling basin of Lake Middleton must have cleared the waters so that they could readilly erode the outwash plains to the west. However, no higher stages than those which have persisted into recent times could be distinguished on either Mud or Middleton lakes. The drainage relations of this stage are also shown on the Historical Geology sheet where Lake Middleton is represented as somewhat higher and less filled with sediment.

Readjustment of Streams. Following upon the lowering of Black Earth Creek by the erosion of the Lower Gravel Terrace, its tributaried proceeded to adjust themselves to the lower base level and so cut broad trenches in the Upper Terrace. In one case (S.E. 1/4, Sec.11, Cross Plains) the stream appears to have flowed in meanders which are now entrenched.

Subsequent branching of these streams has produced a fairly mature system of smooth, clay floored valleys throughout the Upper Terrace and its allied formations. In what part the clay is original upon the eroded surface, due to slumping, or to alluvial filling has not been determined as the problem is one of great difficulty. Certain evidences will be presented in the next chapter whick seem to imply that it is in large measure an eolian deposit formed either from englacial drift melted out of the ice, or frm the rearrangement of the same material after its deposition by the ice and before vegetation became abundant. If the winds had been very active in this work we would expect to find a simalar loess like mantle far beyond the limits of glaciation. As a matter of fact there are certain anolous clay patches upon the sandstone in the township of Springdale but the presence of cherts in some as well as their dense character suggests strongly that they are residuals of the Trenton limestone. More detailed study is necessary before a conclusion can be reached.

Recent.

The post-glacial changes in the topography of the area may be summarized as settling and local induration of the glacial deposits, lake extinction, and erosion and aggradation by streams.

The settling of the glacial deposits subsequent to the retreat of the ice is a matter not yet fully worked out. Some of the open, clay floored valleys may be due in large part to such an agency accentuated by erosion for just such action may be seen in the recent alluvium of Pheasant Branch (cf. p.). It is certain that much of the undulation and many of the smaller depresssions of the outwash plains are due to this cause alone. The matter is again referred to in the following chapter.

The subject of lake extinction is treated also in the next chapter on Extinct Lake Middleton and Hydrology.

Except for a continuation of the process of stream readjustment to the Lower Gravel Terrace as described on p. , and the erosion of the valley of Pheasant Branch as treated in the following chapter, the erosion by streams has been small since glacial times. In many places along the Middleton valley and to a less extent on the rollin hills to the south, gullies have been cut to a depth of nearly 30 feet largely in the last 60 years. They are grassed over in their upper portions but below the break through the sod erosion is more rapid; it is thought that this sodded part represents the state before the cultivation of the soil for all this destruction is due to the removal of the forests and to careless cultivation.

The material removed is deposited as soon as the grade becomes less or the water can spread. Such deposits have been mapped as alluvium but their exact discrimination is impossible. A notable alluvial fan is that of Pheasant Branch just east of th area and described in the next chapter; along all of the course of the stream there is a flood plain composed of sand and gravel in course of transportation to this fan. There are also several smaller fans along the south side of the Middleton valley which are composed of very coarse gravel. The valley at the mouth of the Cave is known to contain more than seven feet of black soil (cf. p.) of which it is stated by Mr. John Drager that five feet has been deposited in the last quarter of a century.

CHAPTER IV.

Extinct Lake Middleton.

Location. The bed and outlet of Extinct Lake Middleton are situated on Sections 1 to 4, and 10 to 12, Middleton township and project slightly into Section 34, Springfield as shown on the accompanying maps. As there seen the lake was during its period of maximum extent, about one and a half miles in diameter with fairly regular shores and the slight maximum depth of 10 or 12 feet in Sec. 3. Its overflow, at least during its later stages, was, and the drainage of the present basin is, to the east by a small creek known as Pheasant Branch which flows into the far western end of Lake Mendota. This stream now drains about 15 square miles of the country to the west.. Because this basin illustrated several principles of physiography it has received more attention in the present report than its size would otherwise warrent.

Beaches. In and west of the village of Middleton, the railway and road have well nigh obliterated the beach lines of this lake and it is not until the old shore turns north away from them that it becomes at all plainly visable. Following along the eastern edge of some indistinctly morainic topography, in which some slight cliffs were once cut by the waves, a break is reached whose bottom, at an altitude of 927 feet A.T., is fully two feet below the average elevation of the beach lines. Here then must be an old outlet to the west, a fact which is attested by the steep cut bank on its north side. Going on to the north of this outlet the evidencies of the former activity of the waters become far more striking in the form of a wave cut cliff which at one point appears to have been cut in sandstone although subsequent slumping has buried the soft rock, while along portions of this abandoned shore many boulders occur forming the boulder line so characteristic of modern beaches in this vicinity. Other relics of the lake are seen in obscure spits at two points. North of the town line in Springfield, deposits of alluvium from two streams have obscured the shore line; farther east, however, a strongly marked cliff rises sharply above the marshy lowland

and finially runs out into the sharp point in Sec. 2, Middleton. At this spot the activity of the waves was at a maximum and the cliff and boulder line can hardly escape attention. East of the headland no remarkable features are found until the little point a quarter of a mile north of Pheasant Branch is reached; here is found (sketck ,p.) the northern end of a barrier which lies off the older shore and is sharply cut in two by the stream valley. From here on a uniform low cliff extends to the village of Middleton.

Basin Floor. The floor of the lake basin is nearly plane with very insignificant undulations and inclines gently towards the northwest. Its soil is sandy near the old shore line while farther out especially to the west and north there is marly clay and some peat. Both near the western outlet and the road bridge some boulders were found and others may exist. Previos to the settlement of the country the larger part of the basin was marshy as is shown on the key map on p. . This map is adapted from the State Survey atlas and is probably extremely inaccurate in the limits it puts to the marsh. Around th edges elms and oaks had begum to creep in and larg parts were probably willow grown. Now ditches, only a portion of which are shown on the map, serve to lead off the water. Going eastward it is not easy to say where the natural stream valley begins but no natural tributaries are found more than a quarter of a mile west of the road brodge while the stream profile shows a marked change of grade near that point.

Outlet. The uppermost tributaries are smooth in outline and grassed over down to an elevation od about 8 feet above the stream below which sharp gullies appear. At the bridge and several points just below, a marked terrace appears at about the same level but here nearly 15 feet above the stream. The cross sections (p.) show such a terrace remnant as does the contour sketch ( ); the latter also shows a portion of an adandoned channel upon it. Below the broad example at the crossing of the old shore line these remnants of a higher flood plain are somewhat less common but near the rapisa over the boulders of the moraine (cite of old mill dam?) there is apparently a broad meander some 8 feet above the stream on the south shore while the village of Pheasant Branch stands upon a still higher flat. Slight evidences of the terrace stand at a lower elevation here than up stream and all cannot be correlated with any exactness. The surfaces of the terrace are, however, usually not strictly flats but were originally rough from the accumulation of sand around trees etc., or have been altered by settling, dunes, alluvial fans, and gulleying. A feature of uncertain interpretation is the upper flat and the rounded valleys in which the entire steep sided valley and many of its tributaries are sunk. The cross sections (p.) illutrate some of its characters. It is covered (cf. p.) with a reddish clay layer continious with that of the outwash plain above.

Deposits. The various deposits exposed along the valley of Pheasant Branch are described in the table of stratagraphic sectionc on p. . They are predominantly sand and gravel with a clay covering which contains very few boulders except near the rapids in the moraine. Between the shore line and the road bribge it is lacking but to the west it reappeard with a bluish color and thickens radiply upstream. Its upper foot or two contains numcrous small shells and it is frequently ferruginous with iron concretions around plant roots or again is semi-indurated or exhibits a jointed structure. A. local exception to the clay is a five foot bed of cross bedded sand and clay with layers dipping east (on map). The clay east of the old shore is reddish in color, often partially indurated with iron, and is sandy or contains lenses of sand near its lower boundary. The sand and gravel are found by means of well borings to have a thichness of over ~~200~~ 60 feet. Cross bedding, lumps of clay, iron concretions, and peculiar wavy beds (fig. p.) are common features.

History---glacial. Having now treated the major features of the bed of Extinct Lake Middleton we will turn to its history as interpreted from them. The large valley in which it is situated (see Pre-glacial Topography map) was the confluence of several eastward flowing streams in Tertiary times just as it is today. As the last ice sheet of the Pleistocene retreated its front halted for a sort time (Middleton Sub-stage) and deposited the poorly defined moraine and outwash to the west (Sec.10, cf.p.) and in so doing raised the col to probably 980 feet above tide, that being higher than any point in the valley to the west. Retreating still farther east, another halt ensued near Pheasant Branch village thus enclosing a deep basin under the site of Lake Middleton (Pheasant Branch Substage shownon lastmap of Historical Geology sheet). Into this depression the sand and clay laden streams from the glacier poured forming the beginnings of the lake. Finially however, the basin was filled up nearly to the present level before the ice retreated farther. At times doubtless, ice bergs broke away from the glacier and carried out the boulders now seen in the finer material. The anomalous lens of cross bedded sand and clay (p.) may have been deposited in a pit left by the melting of a berg, and the action of the post-glacial lake lake may have filled many more.

During its later stages, however, the water must have been too shallow to float any considerable ice fragments. Most of the minor undulations as suggested on p. are probably due simply to settling of the sediments. The finer material, the clay, was naturally deposited farthest away from the ice and less sediment of all sizes was deposied away from a direct line to the western outlet thus explaining the northwesterly inclination of the basin floor. The form of the outwash plain to the east (see Madison Quarrange) indicates that most of it was deosited by a stream which left the ice south of the road due east on Middleton. As Mud Lake to the west was probably never over a foot lower and the grade of Black Earth Creek is low, the western outlet was not cut down.

<u>Cause of Drainage</u>. For how long after the retreat of the ice from the moraine its drainage still continued to flow to the west by the old route cannot be determined, but it was probably a considerable time before the present drainage of Lake Mendota to the sotheast was opened. Upon the withdrawal

of the supply of water from the east, Lake Middleton must have diminished in size assuming a level of about 929 feet above tide and thus continuing to flow through the western outlet. That it persisted for a very long time after the close of the glacial epoch is evident from the shell bearing clays and the freshness of the beaches the like of which no ice-dammed lake has left.

It now remains to be seen why the eastern outlet became established and drained the lake, a question which hinges lasgely on the interpretation of the upper terrace or rounded valley in which the steep sided gulley and some of its tributaries are sunk. Two main hypotheses may be advanced depending upon whetther we regard this terrace as (1) original, or (2) secondary, and under each the steep graded eastern outlet may be supposed to be (a) original, or (b) due to piracy.

Simalar clay floored valleys exist to the south both along the road and railway and have been mapped the same on the plate (p.   ). Although they present the outline of fairly mature (cf. p.   ) erosion valleys, there are no alluvial fans of magnitude comparable with the volume of material which would have been removed were they wholly the product of erosion. However, the village of Pheasant Branch (p.) stands upon a thin soiled sandy flat which is thought to represent a remnant of just such a fan which has elsewhere been eroded away. Moreover, the clay covering is the same as is found elsewhere upon all the drift (cf.p.) ahich is usually supposed to have been deposited during the retreat of the ice either directly or by the sluggish waters. As many objections may be raised to this older view of its origin, it appears far more likely that it is an eolian deposit formed during the erosion of the t terrace and before vegetation covered the drift. The writer therefore beleives that the upper terrace is partly due to erosion along an older depression and that it was largely formed before the advent of the protective covering of vegetation. As its development is no greater along the Branch than in the valleys to the south it is not necessary to assume that the lake originally had an eastern outlet. Indeed it appears from the evidencied cited above (p.) that the drainage of even the eastern part of the lake took place at a comparatively recent date. The increase in drainage area from some 200 acres to 15 square miles brought about by the piracy of the stream flowing upon the terrace with the fall of 80 feet in less than three quarters of a mile, is beleived to account for the different shape of the inner valley. The other outlet could not cut down for as stated before (p.) it had a fall of but a single foot to Mud Lake on the west. If the map in the State Survey atlas (cf. p.) is correct, it was still marshy as late as 1850.

So far had the process of extinction gone before the coming of the white men, that the valley head had advanced almost half a mile into the lake bed and sent out many tributaries, while large trees had grown up on the drained portions. The Branch had even begun to meander and broaden its valley while a few duned were being formed of sand blown up from the flood plain: an equilibrium had been reached.

Recent Changes. When the surrounding country was settled, however, the cutting of the forests and the ploughing of the fields increased the run off enormously. Ditches also led the upland streams direct to the Branch which was thus rejuvenated although made less constant in its flow. In sixty years its valley has been deepened from 5 to 15 feet and the older flood plain largely swept away and many tributaries begun or revived. The ditches (which have not yet entirely succeeded in draining the lake bed) have been largely eroded. Fully half of the material removed, which exceeds 10 million cubic yards, has been carried away in this short time and added to the great alluvial fan north of the village of Pheasant Branch. This fan is almost entirely clear sand and at the normal stage of the water the stream entirely disappears into it through about 10 or 15 feet of sand which overlies peat below.

Summary. It is therefore concluded that Extinct Lake Middleton was a survival of a nearly filled glacial lake; that only a western outlet existed upon the retreat of the ice; that the basin was later tapped by the piracy of the head of Pheasant Branch with its steeper grade; that this drained the lke and the erosion cycle had reached an equilitrium long ago; that this was disturbed by the destruction of the forests by white men intoducing the cycle of erosion which is now in progress.

Lake Middleton beds.

Numbers refer to map.

(1) East of bridge on N. bank in sand pit.

Number		Feet
VI	Dune (?) sand........................	0.5
V	Black sandy soil......................	0.5
IV	Horizontally bedded white sand.............	3
III	Thin, cross bedded white sand with some pebbles.......................	3
II	Horizontally bedded white sand with spots of clay, pebbles surrounded by clay, iron stains and concretions..................	2
I	Horizontally bedded yellow sand...........	1
		13.0

(2) At outlet the red clay begins to the east; below is nothing but clean sand with a little gravel.

100 yards east, S. side.

IV	Soil..................................	1
III	Grayish sandy clay.....................	2
II	Ferruginous clay and sand with a few pebbles; indurated into "hard pan".................	1
I	Horizontally bedded sand with red specks; not well exposed but extends to bottom of valley with some gravel being redder than beneath the lake.........................	30
		34

200 yards E. on N. side.

IV	Soil..................................	1.5
III	Semi-indurated grayish clay with a little sand and some iron stains......................	5

Number		Feet
II	Same as III but with lenses and pockets of sand....................................	1
I	White to buff sand with red stains along bedding planes; probably extends to bottom of valley; exposed..........................	1.5
		9.0

(4) West of bridge, N. side. On the south are several medium sized boulders.

III	Black sandy soil............................	0.5
II	Undulating layers of clay and sand (sketch on p.); blocks of grayish clay end sharply or interleave with white sand and so on. These phenomena may be connected with slumping at some stage of their formation.........	1 to2
I	Pure white sand, very fine grained, with some clay and a few pebbles and iron concretions; base is coss bedded; shows undulating layers much like those of II......................	5
		7.0

(5) S. side

IV	Thin soil; grayish white clay carrying numerous snail shells.........................	2
III	Thin bedded gray clay; few small pebbles; iron concretions around roots; cleaves with a good set of rectangular joints............	1.5
II	Thin, horizontally bedded pebbly sand with iron concretions; truncated I.............	1
I	Pebbly, cross bedded sand (dip W.).........	2.5
		7.0

100 yards W. on N. side.

Number		Feet
IVI	Grayish clay with thin soil................	1
II	Coss bedded sand; below interlamminated with clay; dips <u>east</u>............................	5
I	Grayish clay with interbedded sand lamminae	2
		8

(6) Forks of stream in eroded ditches.

Grayish to bluish or red clay; upper two feet shell bearing; locally semi indurated forming ferruginous shale or pebbles in the stream bottom; has no

joints visable..............................7

West of here is a sandy terrace with many large boulders on top of it.

CHAPTER V.

Hydrology.

The following account of the hydrology of the area is a brief ones as no detailed ivestigation was made of anthing except the cave. The following subjedts will be considered: lakes and ponds, streams, sink holes and caves, underground water, and springs.

Lakes and Ponds. The district is poor in lakes, the only one existing in historic times, Mud Lake which still appears on many maps, is now filled with vegetation since the great drougth of the '90s (1). In the last few years, however, the renewed rainfall has made it a very wet marsh it now being the resort of many hundreds of water fowel driven from the lakes near Madison. A raised beach is found some three to four feet above the present level. The lowering of the water is due in part to the downcutting of the outlet but more largely to deforesation and consequent extinction of feeding springs, as the drainage area is small. The "false hook" shown on p.   is composed of large boulders and gravel and its heigth above the raised beach refers its

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(1) Thwaites, thesis.

formation to ice action rather than to shore drift. The consequences of deforestation and cultivation have also extinguished three ponds south of Middleton village. Morse's Pond in the south centeral part of the area is remarkable both for its freedom from rushes and from raised beaches; it is probably rather deep. A few smaller ponds complete the list, but the clay soil enables the construction of many artificial ones; the largest of the last class is the Cross Plains mill pond.

Streams. The drainage basins of the area are essentially those of Tertiary times as outlined in Chapter IV, p. . The only changes of magnitude are the shifting of the divide in the Middleton valley three miles to the east, the damming of the valley east of the Johnstown Moraine in two places (cf. p.), and the formation of the enclosed basin south of Morse's Pond.

No permanent streams of any size are found within the area. The largest, Sugar River, is never over ten feet across and occupies a small meandering trench in its alluvial plain (cf. p.); it is partly spring fed. A branch was formerly dammed near the spring on Sec. 6, Verona but is not now used. Pheasant Branch (see Chapter IV) flows constantly but is smaller than when it turned a grist mill at the village of the same name east of the area. Black Earth Creek, which formerly drained Mud Lake, is now dry early in the spring and steam has long been the chief power at the Cross Plains mill which uses it. The dam backs up the water to such an extent that the trench which it has cut in the Lower Gravel Terrace (cf. p.) in post glacial times, is entirely obliterated.

Sink Holes and Caves. The most striking features of the underground drainage of the area are the various sink holes which drain large inclosed areas. The largest of these is the famous Richardson's Cave or "Great Cave of Dane County" which takes the drainage of six square miles; a more detailed account of it follows on p. . (see also figure on p.). It is in the upper part of the Lower Magnesian limestone, and even if only a part of the numerous reports of cave holes found in wells are true, and there seems little reason to doubt the qualitative correctness on most, the entire formation is riddled with such channels. Occasionally they outcrop in ledges as in the col in Sec.6, Middleton. When filled they are spoken of as "mud holes" or less often as "gravel below the rock" (Well 88, Middleton 29). For the most part they do not seem to carry much water probably because of this glacial filling. A sink hole (fig. p.) drains about 250 acres of Sec. 24, Cross Plains into a crevice in the St. Peters sandstone; judging from a neighboring well record the limestone is not far below and contains openings. A smaller hole was pointed out to the writer in the bottom of the gulley in Sec.15, Verona. These enclosed basins are due to glacial action for it may be seen that the size and extent of the caves precludes their post-glacial origin.

Underground Water The sedimentary rocks and glacial deposits of the area are so pourous that they contain large amounts of water. The majority of the wells on the uplands are in the Lower Magnesiand while those of the valleys are in the drift, the gravels of the outwash plains being favorite sources at a slight depth in spite of the obvious danger of contamination. If it were known to drillers, the clean white sandstone of the Madison could be reached south of the Middleton valley at a depth of not over 200 feet as may be seen by a comparison of the topographic map and structure sheet.

The source of the ground water is ver local as the deep seated artesian circulation of the Potsdam sandstone is not reached, although cave water may well come some distance and still be contaminated. The disposal of the water of the large cave could not be traced; if it were salted it might be, but if it soon enters the sanstone (see structure sections) it might take over a year to reach the large spring 6600 feet to the southwest! If the flow is largely in openings the time would be much less and owing to the reprehensable practice of throwing dead animals into the cave, it may constitute a grave menace to the surrounding country. Barring this danger, the general character of the ground water is good and not essentially different from the

Madison city water. The village of Middleton is now instaling a water supply system.

Springs. Springs are rare being now found only along the Middleton and Sugar valleys. When the country was forst settled, however, there were many more which have since gone dry. Those in the northern valley near Cross Plains issue from the base of the Upper Gravel Terrace and are apparently underflow from the tributary valleys to the south. Along the Sugar River and its branches they appear either in the limestone or near its summit below the porous St. Peters sandstone. The greatest seepage is along the east side of the valley in Secs. 6 and 7, Verona. Springs such as described are essentially surface phenomena of the underground circulation. therefore in the present state of enlightenment concerning water contamination, the exploitation of a spring for drinking water cannot be considered a legitimate business.

Richardson's Cave. Richardson's Cave or the "Great Cave of Dane County" (for reference see p.) is located on the N.E. 1/4, Sec.5, Verona. The mouth of the cave is situated at the eastern extremity of a low limestone ridge projecting into a flat plain from the inner side of the Johnstown Moraine. It is the terminus of a gulley which is the course of a intermittant stream draining approximatly six square miles to the north.

Exterior Features. The cave, however, both owing to its natural limitations and to the fact that the enterances soon clog with driftwood, is not sufficient to take all of the drainage of the region now that it is under cultivation. In times of exceptional rainfall, there is found at the mouth a lake of some five feet in depth, which discharges through a col to the southwest into a stream leading to the sugar River. That this often occurs and is reducing the elevation of the divide, is evident from the well-marked gulley thereseen.

The actual mouth is of considerable size, although now choked with driftwood and fallen blocks, being a chamber of some 50 feet in depth, 25 feet in width, and 10 feet in heigth. At the far south end (see sketch, p.) of this is a small opening through which the writer and his party entered; a few feet to the north a larger one appears, while farther on and just ouside is again a small apcture--- others are very likely concealed by debris. In addition to the horizontal openins or drifts, there are several sink holes, the two largest of which form branches of the meandering gulley and are shown on the sketch. All are filled with rubbish and seem impracticable of exploration.

The rock exposed at the enterance is a rather massive phase of the Lower Magnesian limestone. It is stated to have been once burned for lime but no trace could be seen of a kiln and little of excavations. Near the top of the exposure which is badly weathered, there appear traces of a brecciated structure, unerlain by a foot or more of red and white chert containing some chert-limestone breccia. Below no structural features were noted. The attitude of the beds is that of a low anticline striking about N.70-E., and dipping a few degrees in both directions; this is probably only an irregularity of deposition, since joints are rare.

Interior. Immeadiately upon entering the southern drift, one finds it to be say three by three feet in size floored with loose angular fragments of rock probably derived from the roof as far in as it freezes. A smaller branch to the right appeared to communicate with the larger opening to the north, and was therefore not entered. After progressing some 75 feet, no more stones were found, but the floor was a hard, black soil, evidently the same as that exposed in the gulley ouside. Numerous puddles of water were found, and nearly every portion of the walls and roof was plastered woth mud and straw. We advanced about 450 feet along a crooked passage, turning several right angles usually to the right, and finding two open passages on that side. The first of these consisted of an enlarged joint, some 10 feet high, 2 feet or less wide, and 50 feet long; at the farther end it enlarged and divided into two neither of which was open to advance. In this gallery the mud was several feet higher than in the main drift and the limit of the last flood could be seen upon the walls. A few other joint openings of small size were seen a various points but they are rather uncommon.

It was in fact, seldom that one could stand upright, and then usually under a more or less circular opening in the roof which became smaller towards the top. The summits alone of these were free from mud and showed white or grayish limestone or chert. The largest of these openings was possibly four feet above the general ceiling; they were found to have no relation to the passage nor to the banks of mud on its floor.

Elsewhere the covering of mud and the weathered condition of the rock concealed its exact character but apparently it is all simply ordinary massive dolomite. In places veins and beds of quartz stood out and still more seldom the surface was fretted. Few rocks had fallen from the top while the depredations of former explorers have left nothing but remnants of the few stalactites none of which exceeded an inch and a half in diameter.

At a distance of approximatlt 450 feet (obtained by measuring the guide twine) from the enterance, the drift forked. Following the passage to the right we went through a larger drift around in a circle to the second opening mentioned above. All of this end of the cave had a greater heigth and a more irregular floor together with more small branches than that traversed up to the forks. We returned and tried one of these on the left and after passing through some very small openings found further progress barred by mud banks.

Returning to the forks we entered the other drift which showed less sign than any of the others of being a channel for the floods. Here was seen more clean rock, with irregular surface and a few small stalactites in process of formation although at no point was any large amount of water entering the cave. At about 50 feet or more along this passage there was a natural bridge, with an opening about a foot high below and a larger one over a sharp inverted V of mud above. A few feet beyond was another, but beyond this the tunnel became to small to admitt of free progress.

<u>Conclusions</u>. The sink holes at the mouth of the cave as well as the large amount of mud indicate that only a portion of the cave is now open. Although

the current enters with great force as evinced by the depth of the gulley at the mouth, the cave is obviously being rapidly filled up. Nevertheless, as recently as August, 1906 the entire lake at the mouth was seen to drain away over night and it may be that an equilibrium has now been established. Should the flow cease a swamp of some 10 acres would result unless the col had been eroded away or ditched or the flat had been aggraded to a higher level (cf. p.).

The relation of the cave to the pre-glacial topography as shown on the map, taken in connection with its size refer its origin to the early part of the Tertiary erosion period described on p. . Exactly why it escaped filling by the glacier is not evident but it was probably because of a dam of drift at the enterence which has since been removed.

General Conclusions.

It has been sought to demonstrate in the foregoing pages the following facts: that there is an unconformity at the top of the Lower Magnesain limestone and possibly at the summit of the overlying St. Peters sandstone; that the domed layers found in the former are in some way related to mud cracks or kindred phenomena of shallow water deposition; that the breccias, contorted beds and so on are either caused by the same action or are mere incidents of the settling, induration, or dolomitization of the formation; that succeeding the deposition of a great thickness of sediments above the highest now found, there was a period of slight deformation and a prolonged one of erosion which reduced the area to the condition of a peneplain at an unknown date; that a relative uplift of this surface inaugerated the formation of the present topography of the Driftless Area; that in this epoch the buried Ordovician valleys were largely reexcavated while one of them exerted a determining influence on the location of the col in the Middleton valley; that this valley and col were brought very low because cut into the soft Cambrian rocks; that during each ice epoch the eastern drainage was ponded and reversed through this oulet eroding it to an indeterminable extent; that the same occured to a less extent in the case of a col to the north; that the Wisconsin ice sheet advanced beyond the divide and deposited large moraines and outwash plains without obscuring the major outlines of the previos topography; that during its retreat several temporary lakes were formed and the outwash plains eroded into terraces; that two lakes, Mud and Middleton survived; that the former was extinguished largely by vegetation and spring dessication and the latter by the piracy of Pheasant B Branch on the east; that locally in other places post glacial erosion has been considerable especially since the settlement of the country and the increase of run off consequent on cultivation; that the "Great Cave of Dand County" does exist and before the recent filling with mud, must have been of considerable size, being only one of alarge system of passages throughout the entire Lower Magnesian limestone.

FINIS.

APPENDIX---TABLES OF DATA.

I Table of Outcrops.

The columns are: section, serial number on map, elevation of top, formation, and remarks.# refers to Table III.

II Table of Well Records.

The columns are: section, serial number on map, elevation of ground, depth to rock or total depth, elevation of rock or of bottom when not reaching rock in which case it is underlined, grade of reliability from A to D, and remarks.

III Sections of Exposures.

Arranged by serial numbers

Bibliography of general references.

Outcrops.

MIDDLETON

S.	No.	Elev.	F. Ref.		Remarks
3	45	940	Gms		Qr.; slumped yellow ss.
4	26	1000	Olm		Disint. ls. by road under cemetary.
	46	1015	Olm		Old qr.
	47	1020	Olm		Sandy, weath. ls.
6	24		Olm		Ls. in gutter.
	25		Osp		Yellow ss in pit; iron conc.
	48		Olm		White ls & chert; caves; folded layers (sketches p); ledges & qr.
7	41	940	Gms	≠	Soft yellow or white ss; non-calc.
	43	1008	Olm	≠	Thich-b. white ls.
8	27	1100	Olm		Ledges of sil. ls.
		987	Gms		White ss.; case-h.; east end of hill
10	12	1020	Olm		Qr.; ss. in road.
	44	1000	Olm		Prospect in disint. ls.
11	19	1000	Olm Gms		Geol. of Wis. II, p.603.; contact at elev. 970, floor of qr., 952; Findlay thesis.
	62	980	Olm		Road; below 15' clay & sand.
	63	960	Gms		Road, E. side; buff disint. ss.
15	44		Olm		Qr. 8' face see Sec. 10.
16	17		Olm Gms		Sandy, weath. conglomerate of small, flat ls. pebbles; unconformable upon thin-b. ls.; buff and white ss. below 978.
17	18		Olm Gms	≠	Gulley. Contact 980
	28		Osp		Large cliffs of yellow ss.; cross-b.
	49		Olm		White ls. in road.

18	29	1200	Ot	
			Osp #	
	50	1140	Ot	disnt., buff to white ls.
	51	1130	Osp	massive buff vine gr. ss
	56		Olm	white ls.
	163	1020	Osp	ss ledges
	164	1000	Olm	sil. ls.; near top?
24	16	1040	Olm	which disint. ls. in road
25	32	1060	Olm	qr.; cherty ls.
26	14	1110	Ot	white ls.
27	13		Ot #	
31	90	1080	Ot-Osp	cliffs of Osp S.W.
	94	980	Osp	
	99	1000	"	
	100	"	"	
	101	"	"	
	102	"	"	
	103	1020	"	
	104		Ot-Osp	
	105	1060	"	
	106	1040	"	
34	59	1090	Olm	hard white ls.; glacial striae.
35	15	1120	Ot	bufflls.
	20	1120	"	qr.; thin'b. buff ls.; fossils
	26	1120	"	
	33	1050	Olm	
	34	1060	"	white ls.; top oolitic & conc.
	38		Ot-Osp #	

VERONA.

2	36	1070	Ot	knowlls of frag. of Ot.
	37	1050	Osp	loose non-glacial sand in gulley.
4	6	1040	Olm	disint. ls.
5	7	1025	Olm	massiave to cong. or domed ls.
	8	"	"	cherty ls.; 6'; top thin-b.
	33		"	Cave see p. .
6	11	1120	Ot	disint. buff ls.
	91	1060	Ot-Osp	contact in road; ss. below.
	93	1000	Olm	ls. qr on knol & in spring.
	96	"	Osp	ss. ledges on ridges and knowls.
	143		Olm	white ls.
	144		Ot-Osp	qr. & ledges
	145		Osp	yellow ss. on hill
	146		"	" " along road
	147		"	ss. ledges
	148		Osp-Olm	ss. & cherty ls; spring.
	149		Olm	ls. ledges; stony soil.
7	68	945	Osp	cut in white & red ss.; cherts above
	80	940	Olm	cut in disint. cherty ls; also road
	81	980	Osp	ss. ledges.
	82	970	Osp-Olm	contact in road see map. p.
	83	974	Olm	Disint. ls.
	84	1040	Olm-Osp	ss. in road; ls in gulley to S.
	150		Osp	ss. ledges
	151			ss.?
	152		Olm	ls. ledges
	154		Osp	ss. frag.
8	107	1040	Olm	ls. along road
	108	1020	"	ls. in road.
	153		O"	ls. qr.
	155	1038	"	hard ls.
	156		Olm-Osp	chert overlain by cong.
9	5	1030	Olm	disint. ls. with oolitic chert.
	140		"	ls. ledge
	142		"	" "

10	57	1030	Osp	massive yellow case-h. ss. in qr.
	58	1050	"	same fretted; cliff.
14	61		?	Old prospects abandoned.
16	1		Olm	massive ls & domes see p. .
	2		"	chert ls.
	3		"	thin-b ls & chert
	4		"	cherty ls.
	14I			sink hole in bottom of gulley.
	158		Olm-Osp	incic. of cherty ss. & ls.
17	157	1028	Olm	cherty ls.
18	77	980	Osp	ss. in private road S. of field in woods.
	78	1030	Olm	indic. of ls. on same road in field
	79	935	"	ls. in 2 springs
21	159		"	qr. in ls.
	160		Olm-Osp	ss. & ls in road.
	166		Osp	ss. ledges
22	16I		Osp	red ss.
	162		?	white ss. or earthy ls.?
	165		?	chert; top of Olm?
CROSS PLAINS.				
1	23	1020	Olm	hard ls. with striae under gravel
2	2a	1000	"	white disint. ls.
	131	"	"	ledges; ss. below(Єms)
	130	940	Olm-Єms	ledge & qr.; ls. & cross-b. yellow ss.
	129	1000	Olm	qr.; massive ls.; dip. N.-70-W.
3	32	1000	Olm-Єms	brech. ls. above white conc. ss.
	109	952	"	contact; white cross-b ss.
	110	920	Єms	knob of yellow ss.
	127	938	Єms-Olm	ledge of white fretted ss.; ls.
	128	909	Єml	shaley red or green ls. in field

10	111	960?	Gms	ss. ridge.
	112	9I5	0lm-Gms	cherty ls. over yellow ss.; a slump fault.
	113	"	Gml-Gms	red to greenish shale overlain by thin-b. calc. ss.
	114		0lm-Gms	contact 975?; dip S.-70-W.
	115	985	Gms-Gml	contact
	116	975?	Gms	ledge os massive ss.; dips S.-30-W.
	117		0lm	ledge & qr.
	118	958	Gms	knowls of yellow conc. ss.
11	22			0lm-Gms-Gml; last by road.
	40		0lm	thin-b. white ls; earthy texture
	42	989	0lm-Gms	ls. ledges with shells; ss.below
	119		"	ss. at W. ; ls to E.; domes
	120	995	"	ledges of ls.
	121	985	"	
	122	990	0lm	
	123	975	Gms-0lm	contact
	124	980	0lm;	qr. shows domes see.p.
13	52	1110	0sp	ss. ledges.
	53		0lm	cliffs
	54		"	
	55		"	may be slumped
	56		"	
	125		"	
	126	1120	0lm-0sp	ls. in road; cliff of yellow ss.
	134	1140	0t-0sp	contact at brow of hill; iron layer.
24	131	1140	0t-0sp	sink hole; contact 1132; seep.
	132	1164	0t	
	133	1180	"	
	135	1122	0t-0sp-0lm	contacts 1122, 1095?
	136	1080	0lm	white ls in field
	138	1090	0sp-0lm	contact at turn of road
	139	1050	"	

25	85	1180	0t-0sp-0lm	0t to 1120
	86	1060	0lm	low rounded knowls
	87	1125	0t-0sp	contact; 20' of 0sp
	88		"	2 gullies exposing contact
36	80	1105	0t-0sp	contact at 1100
	92	1080	0lm	crystalline ls.
	95	1060	"	qr in same.

SPRINGDALE

1	64	935	0lm	spring
	97	1040	0lm	ledge of crystalline ls.
	98	"	"	" " " "
12	65	980	0lm	cherts in road
	66	990	0sp	knowls of yellow ss.
	67	990	0lm	ls. ledge
13	69	1000	0lm	indic. of ls.
	70	"	"	" " "
	71	990?	0lm-0sp	contact in road
	72	980	0lm	cherty ls.
	73	1000	0lm-0sp	contact; ls. to bottom of hill
	74	1020	0lm	incd. of ls.
	75	1040	0t-0sp-0lm	0t at corners cont. 1045; indc of 5' of ss.; then ls.
	76	950	0lm-0sp	contact; ls to bottom of hill

Well Records.

MIDDLETON.

1	22	950	40	910	A	ss.
	25	945	60	A885	A	
2	23	940	100	840	A	blue clay.
	24	950	40	910	A	
	26	940	100	840	A	blue clay; in Springfield
	27	947	207	740	A	clay 40'; sand below
	28	925	200	725	B	sand; Schröder
	29	925	200	725	B	"
4	49	960	100?	860-	C	
	50	980	70	910	B	
	51	975	140-	855?	D	
	52	960	70	890-	D	
5	53	1003	188	815	A	sand; blue clay; "soapstone at 75-80'; hard gravel; water at 120'
	57	1020	60	960	B	
6	30	1035	20	1005	B	ls.; gravel or sand above; cave at 975
	54	1080	60	1020	B	all 208; ls.
	55	1060	20	1040	B	
	56	1160	40	1120	B	
8	3	940	130	810	A	gravel or quicksand
	4	960	100	860	C	gravel
	58	940	120	820	C	sand & boulders
	95	940	80	860	A	
9	6	940	60	880	B	sand
	20	930	40	890	A	gravel
10	19	936	40	890	B	sand point
	48	936	46	890	B	sand point
11	16	930	100	830	B	Hotel; mud
	17	940	65	875	A	sand
	18	940	180	760	B	Teckam; yellow ss.

13	59	960	140	820	A	blue ss.
14	61	1000	190	810	C	
15	60	1000	30	870	B	Lüeboke
16	9	1060	120	940	D	
	66	1080	50	1030	C	Location indef.
17	1	960	3	957	B	"shell"
	2	1020	200?	820?	E	close to ledges
	89	1130	50	1080	B	
19	45	1160	35	1125	B	ss. above ls. with caves
	90	1100	90	1010	D	Bricked up; probably in ss.
	92	1140	60	1080	C	
	94	1083	33	1050	B	
20	87	1100	30	1070	A	"soapstone"
	91	1140	20	1120	B	
21	65	1085	50	1035	B	ls.
22	63	1060	190	870	A	
	64	1075	172	903	A	
	67	1060	35	1025	A	
	68	1065	40	1025	A	
23	62	1010	180	830	B	Loc. uncertain
25	38	1050	20	1030	A	ls.; near outcrop
	70	1080	28	1052	A	
26	41	1173	3	1170	B	Ort place
	69	1037	60-	980?	C	
27	79	1060	30	1030	C	
	80	1110	30	1080	C	
28	83	1080	40	1040	B	
	84	1130	10?	1120?	C	dug in rock

29	43	1140	35	1105	B	hard rock; red clay at 110'
	48	1090	25	1065	A	old caved in well; reddish clay 10'; red clay 2'; sandy gravel rest of way
	85	1078	28	1050	A	hard ls to 105; soapstone; cherty ls. to 115'
	86	1055	21	1034	A	
	88	1070	35?	1035?	C	blasted in rock; said to pass through gravel below; now filled.
30	44	1150	135	1015	A	dug 75' in sand; struck red clay; probably too low in Osp
	47	1125	75	1050	A	sand point; may be in soft ss.
	93	1150	90	1060	B	dug 90' in sand; rock below.
32	33	1040	14	1026	B	Krüger
	81	1040	20	1020	A	
	82	1055	35	1020	B	
33	31	1097	7	1090	C	
	32	1130	30	1100	B	cave at 82'?
34	39	1072	32	1040	A	cheese factory
	40	1075	30	1045	B	neighbor says 50
	78	1050	30	1020	B	
35	71	1050	28	1022	A	

VERONA

2	72	980	40	940	B	ls.
3	74	1025	45	980	B	
	75	1020	50?	970?	C	
	76	1015	70	945	B	
	77	1020	70	950	A	
4	21	1040	24	1016	A	John Drager
	37	1080	57	1023	A	hard ls.
5	11	1030	30	1000	C	boulder at 30'; said to be cased 100'
	34	1072	72	1000	A	

10	35	1000	18	982	A ss.
	73	1020	40	980	C dug 40'; rock below
11	42	985	60	925	C neighbor says about 40'
15	15	970	55	915	B
	36	980	40	940	C
16	10	1000	70?	930?	C dug 50'; rock in last 30'
	12	980	80?	900	C sand
22	13	1000	80	920	B gravel; claims deepest well in V.
	14	980	60	920	B gravel
CROSS PLAINS					
24	46	1140	20	1120	C Cleveland; mud hole or cave.

I3 Middleton 27.

Quarries owned by Emil Teckam. Identifications of fossils by Prof. Blackwelder; many are tentative.

UPPER QUARRY

Trenton limestone.

Nunber Feet

X Soil of angualar to rounded fragments of ls. with a few drift pebbles..................1

<u>Braciopoda</u>?

<u>Pelecepoda</u>: Vanuxemia??

IX Broken claycy ls..........................3

<u>Cephalapoda</u>: Cyrtoceras sp.

<u>Corals</u>: Streptelasma corniculum; S. profundum

VIII Buff to white, thin bedded ls., with a wavy shale parting at base........................4

<u>Braciopoda</u>: Strophomena cf. winchelli

<u>Cephalapoda</u>: Onoceras plebium??; Orthoceras sociale??

<u>Corals</u>: Streptelasma profunda.

<u>Gastropoda</u>: Bellerophon; Lophospira cf. humilis; L. cf. serrulata.

<u>Pelecepoda</u>: Ctenedonta gibberula?; Cypricardites cf. rectirostrus; Vanuxemia suberecta?

VII Blue ls.; weathers buff....................1.5

<u>Bryozoa</u>: undetermined.

<u>Corals</u>: Lichenaria.

<u>Gastropoda</u>: Lophospira sp.

VI White ls.; weathers buff; shale at base....2

<u>Braciopoda</u>:Strophomena winchelli (5 spec.)

<u>Bryozoa</u>: location?

<u>Cephalapoda</u>: Orthoceras anellum?; O. sociale?; O. sp.

<u>Corals</u>: Lichenaria (loc.?); Streptelasma profunda??

<u>Gastropoda</u>: Raphistoma.

<u>Vermes</u>: tubes of Scolithus??

Number Feet

V Same as VI with many lenses of fossils; limonite concretions after marcasite; calcite crystals; best stone in firm thick beds with shaley partings......................5
Braciopoda: Hebertella; Strophomena winchelli
Cephalapoda: Cyrtoceras sp.; Orthoceras sp.?
Corals: Streptelasma profunda; S. sp.
Gastropoda: Pleurotomaria nasoni? (loc.?)
Ostracoda: Leperditia sp. (loc. VI?)

IV Bluish rough surfaced layer................0.5
Corals: Streptelasma profunda (loc. V?)

III Same as V but more heavily bedded, rougher surfaced, and nearly barren...............4

II Blue shaley layer sometimes absent.........0.25
Braciopoda: Strophomena sp.
Cephalapoda: Orthoceras sp.

I Buff to white ls.; forms floor of quarry at elevation 1130; mostly unexposed..........3

LOWER QUARRY

VI Soil and disintegrated ls; top rather thick bedded and is continious with I above......7
Braciopoda: Strophomena winchelli.
Cephalapoda: Orthoceras planoconvexum?
Pelecepoda: Ctenodonta cf. ventricosa; Vanuxemia rotundata?
Trilobita: Isotelus?

V Irregularly bedded shaley grayish blue ls.; beds 1 to 2 inches; black markings.........2
Braciopoda: Orthis tricenaria; Strophomena winchelli
Bryozoa: moulds only.
Cephalapoda: Endoceras; Orthoceras sp. ((ringed).
Gastropoda: Bellerophon; Hormotoma gracilis; Lophospira sp.; Protowarthia cf. cancellata; Raphistoma sp.; Raphistomina sp.;

Number Feet

Tetranota bidorsata?
<u>Ostracoda</u>: Leperditia cf. fabulite
<u>Pelecepoda</u>: Ctenodonta alta?; C. gibberula??; Cypricardites?; Modiolospis sp?
<u>Pteropoda</u>: Hyolithus sp.
<u>Trilobita</u>: Isotelus?

IV Solid buff to white ls; often crowded with fossils; locally blue colored..............2
<u>Braciopoda</u>: Hebertella?
<u>Corals</u>: Streptelasma profunda
Pelecepoda: Cypricardites rotundatus (Vanuxemia dixonensis?)

III Hard, blue to buff ls; irregular fracture; rough surfaced..........................2

II Buff, rough surfaced ls with red shaley partings; grades to massive below..........4.5
<u>Cephalapoda</u>: Orthoceras sp.

I Massive buff ls.; bluish in middle of top layer which is 28 inches thick............4

45.75

The following are unlocated:
Upper quarry.
<u>Braciopoda</u>: Orthis tricenaria; Strophomena winchelli
<u>Cephalapoda</u>: Gonioceras occidentale; Orthoceras beloitense?; O. sociale.
<u>Gastropoda</u>: Lophospira sp.
<u>Pelecepoda</u>: Ambonychia sp.; Ctenodonta sp.
<u>Pteropoda</u>: Hyolithus
<u>Trilobita</u>: Ceraurus (hypostome of)?
Lower quarry.
<u>Pelecepoda</u>: Cyrtodonta billingsi?

The study was not sufficent to draw very definite conclusions; the molluskan aspect of the fauna and the limitation of Lichenaria to VII of the Upper Quarry are most to be noted.

18 Middleton 17.
Gulley south of Extinct Mud Lake. Contact base of Olm elevation 978.

Lower Magnesian limestone.

Number		Feet
XX	Massive white ls.; weathers sandy; base not seen	3
XIX	White to yellowish ls.; weathers to resemble sandstone; flow and plunge structure	3
XVIII	Unexposed	2
XVII	Thin bedded white ls.; dips W	1
XVI	Unexposed	2.5
XV	Disintigrated, thin bedded ls. with chert nodules; middle faily massive with a bed of such; top shows irregular bedding	7
XIV	Unexposed	3
XIII	Sandy ls. with chert nodules	2
XII	White chert	0.1
XI	Firm hard ls.; bedding thin and irregular with small knobs at top; in places cherty and br brecciated	2
X	Red to white chert	0.1
IX	Same as XI	8
VIII	White ls. with irregular surface	4
VII	Buff to white cherty ls; bedding thin and irregular; layers pinch out over the inclined sandstone beds below	3
VI	Greensand shale with a lens of oolite	0.3

Number		Feet
V	Weathered oolitic chert or white sandstone	0.3
IV	Greensand shale with red layers	0.1
III	Oolitic chert; top soft like sandstone	1
	Madison sandstone.	
II	Soft ss. with greensand and shale; top purer; layers form a small anticline	1
I	unexposed	3
-	Pure white ss and quartzite; middle 0.5' is cross bedded	2
		48.4

29 Middleton 18.
Trenton Limestone

Number		Feet
II	Soil; some disintegrated ls but usually gravely clay resting on solid rock..........................	4
I	Buff to white ls.; texture crystalline; beds 18 inches or more, averâgeing 3 to 8 inches; about a foot of ls below quarry floor; then white or ferruginous sandstone at elevation 1140.........	13

Fossils.
Identifications from Geology of Wisconsin, vol.II, p. 607.
Braciopoda: Strophomena sp.
Cephalapoda: Onoocras pandion; Orthoceras anellum
Corals: Petraria corniculum (Streptelasma?)
Gastropoda: Murchisonia bicinata; M. tricarinata; Pleurotomaria nasoni·; Raphistoma lenticulare; Trochonema umbilicata.
Pelecepoda: Vanuxemia ventricosus.

A structure section is also given from here to 0-43 (see p.); it does not agree very closely with the writers determinations, except that the thicknes of the St. Peters is about correct. Prof. C.C. Leith states that a few years ago he found a chert conglomerate at its base; this is not now visable. The St. Peters is highly charged with iron near its top but is pure below. Cross bedding and flow and plunge structure are seen on a large scale. In one place, on the east side of the spur east of the quarries, the weathered out iron concretions etc. are unusually fantastic like the bones of some animal.

38 Middleton 35.

Numerous excavations on a bold limestone bluff; see Stromme's thesis (p.) for exposures on eastern end.

Northern quarry.

Number	Trenton limestone.	Feet
V	Disintigrated ls. and soil such as covers all the top of the bluff; some fossils all poorly preserved........	8
IV	Thin, irregularly bedded buff to white limestone; fossiliferous and often very good specimens..........	2
III	Greensand parting............................	-
II	Thich bedded ls; few fossils...............	4
I	Sandy or crystalline thick bedded ls.; barren below is thiner bedded again...............	2

Elevation of base of section 1085, of sharp contact with sandstone (marked by iron concretions), 1075.

In southern quarry the rock is thinly bedded and barren.

Fossils.

Best specimens collected by O.U. Stromme.

Braciopoda: Orthis tricenaria; Rhynconella sp.
Bryazoa: at least two species but not identified.
Cephalapoda: Orthoceras sp.
Corals: Streptelasma sp.
Crinoidea: stems.
Gastropoda: Lophospira?; Raphistoma?; Tetranota??
Pelecepoda: Vanuxemia rotundata.
Trilobita: Isotelus?

43. Middleton 7.
Quarry at R.R. curve; shows contorted beds; see sketches on pp. .

Lower Magnesian Limestone

Number		Feet
VII	Disintigrated ls.	8
VI	Masive to thin bedded white hard ls.; many quartz and iron geodes.	26
V	Porous crystalline ls.; top shaley and possibly mud cracked; many crystals of limonite after marcasite.	2
IV	Thin bedded ls. and chert with domes.	3
III	Broken and brecciated ls. Mud cracks at top.	7
II	ThThin sandy parting.	-
I	Hard sandy ls.; rough surface.	2
		48.0

Elevation of base 960; at the cossing to the west, O-41, there is seen 20 feet of softish yellow to white, non-calcareous ss. with flow and plunge structure and medium to coarse grain. Elevation of base about 920

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