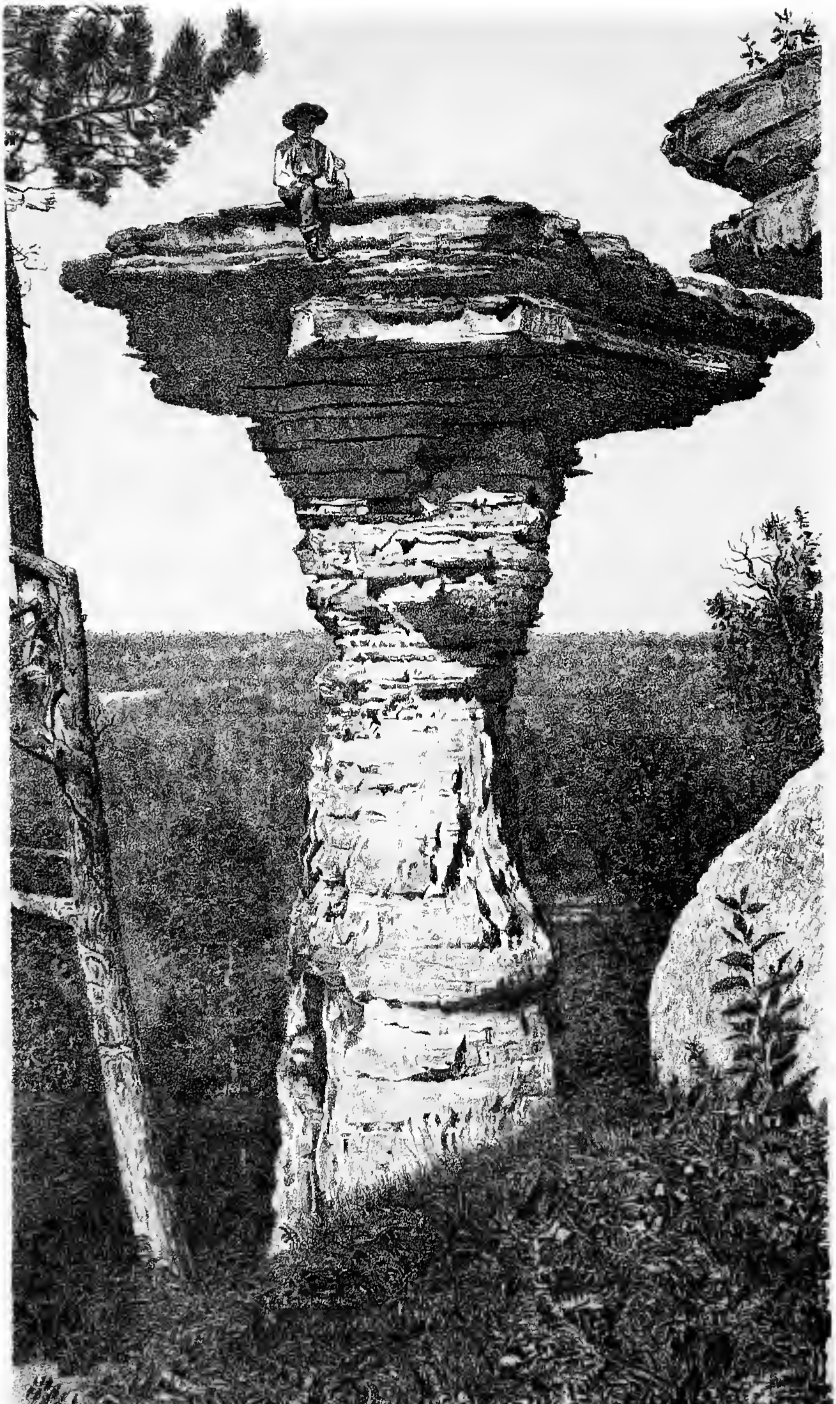
PLATE I



The Milwaukee Litho & Engr Co. H.H.Bennett, Photo.

POTSDAM SANDSTONE,

Stand Rock, Dalles of the Wisconsin.

GEOLOGY

OF

WISCONSIN.

SURVEY OF 1873-1877.

VOLUME II.

PART I. HISTORICAL.
II. EASTERN WISCONSIN.
III. CENTRAL WISCONSIN.
IV. LEAD REGION.

ACCOMPANIED BY AN

ATLAS OF MAPS.

PUBLISHED UNDER THE DIRECTION OF THE

CHIEF GEOLOGIST,

BY THE

COMMISSIONERS OF PUBLIC PRINTING

IN ACCORDANCE WITH LEGISLATIVE ENACTMENT.

1877.

David Atwood, Madison,
stereotyper and printer.

Seifert, Gügler & Co., Milwaukee,
lithographers.

To His Excellency, the Hon. Harrison Ludington,

Governor of Wisconsin.

Sir: — It affords me great pleasure to submit the following contribution toward the final report of the Geological Survey of Wisconsin, begun in the year 1873, and still in progress. The manuscript for the remaining volumes is in part prepared, but the completion of certain portions is dependent upon field work now being prosecuted, and must await its conclusion. An earnest effort will be made to complete the series at as early a date as the proper execution of the work will permit.

Most respectfully, your obedient servant,

T. C. CHAMBERLIN,

Chief Geologist.

Beloit, *August 8, 1877.*

PREFACE.

THE LAW, under whose authority the reports of the Geological Survey are being published, determines the character of one volume, which, from its nature, will most appropriately form the initial volume of the completed series. But as it involves general conclusions that can only be arrived at after the completion of field work, its appearance must be delayed until that work is accomplished. It was not deemed advisable on this account, however, to defer the publication of such portions as could be finished, and the present volume, although nominally the second of the series, appears first in the order of time.

Although its size has been expanded beyond what was originally intended, and a large portion of its matter printed in a smaller type than is desirable, it has been found impossible to include all the material that has been gathered relating to the regions reported upon, and a considerable amount of manuscript relating to each of the districts has been necessarily omitted, and other portions condensed to an undesirable brevity. It is believed, however, that, notwithstanding this, a creditable degree of thoroughness and fullness has been attained, and that, by the assistance of the ample maps and profiles that accompany the volume, an adequate knowledge of the structure of any locality may be obtained.

The law authorizing the survey requires the construction of a single map upon which shall be represented all the geological formations of the state. A map based upon a scale of fifteen miles to the inch, is the smallest upon which this can be successfully accomplished, and this fact has determined the form and dimensions of the accompanying atlas, whose sheets have the size requisite for such a map. A scale of three miles to the inch is the least that is at all adequate to the proper representation of the detailed mapping of the formations, and this scale has been uniformly adopted for the more elaborate geological maps. It was found that the surface of the state, on this scale, was readily and economically divisible into rectangles of the size indicated, and these constitute the Area maps of the atlas. Seven of these cover the territory reported upon in this volume. At least an equal number will be required for the regions yet to be reported upon, and these will be numbered consecutively with those now published, so that the whole series, when complete, may form a single portfolio. The contour lines of the topographical maps of the Lead region required the still larger scale of one inch to the mile, and five plates are devoted to them.

It may be unnecessary to state that the construction of an ordinary surface map is no proper part of the work of a geological survey, and the geological corps cannot justly be held responsible for errors of a merely geographical nature. When it is considered that the original provisions of the law required the examination of more than 13,000 square miles each year, it will be evident that no work of that kind was contemplated. But a correct geographical map is highly important to accuracy in the delineation of the formations sketched upon it, and hence the corps have labored under some annoying difficulties growing out of the inaccuracies of the original government surveys, and of the maps in common use. To overcome these difficulties, so far as possible, the Area maps have been built up, township by township, from the notes of the original linear survey of the government, and comparisons instituted with state, county, township and special maps, and with the observations of the geological corps. The townships and sections should be, setting aside the convergence of the meridians and the trivial effects of sphericity, perfect squares, and cover the state with a symmetrical network of lines, but it will be observed that there are marked departures from this form in some cases, due to errors in the linear survey, and an effort has been made, by carefully representing these on the maps, to restore the natural features to their true form and position.

The areas mapped as Wet Lands are essentially those given on the government plats as marshes, but that term is not now properly applicable to a considerable portion of the surfaces so designated, since most of them are so firm that they may be readily traversed by teams, and some are even cultivated with success in all except very wet seasons, and are, indeed, among the most valuable lands of the state. In the great majority of cases, except where they are fluviatile meadows, they represent extinct lakes, and hence their historical and geological significance is important.

The survey has been put under great obligations by the kindness of citizens and corporations in rendering valuable aid in various ways in the prosecution of the work. In addition to the more specific acknowledgments that have been made in connection with the annual reports and in other appropriate ways, the corps desire to tender this general expression of their appreciation of the numerous courtesies of which they have been the recipients.

It is due also to those whose results do not appear in an individualized form, to call attention to the analytical work of Prof. W. W. Daniells, of the State University; of Mr. Gustavus Bode, of Milwaukee; and of Mr. E. T. Sweet, recently of Madison; to the paleontological identifications of Prof. R. P. Whitfield, of New York, and to the drafting of Prof. W. J. L. Nicodemus and Mr. A. D. Conover, of the State University.

An expression of indebtedness is also due Prof. R. P. Whitfield, Hon. Geo. H. Paul, Prof. A. Salisbury, G. D. Swezey, J. H. Chamberlin and C. S. Bacon, for reading portions of the proof on subjects with which they are especially familiar.

The provision which has been made by the commissioners of public printing for the publication of the work has proved wise and judicious, as well as highly economical.

The mechanical execution of the work is the best witness that can be offered as to the skill and faithfulness with which the printers and lithographers have performed their respective tasks. The execution of large geological maps is confessedly a work of much difficulty, and great credit is due the lithographers for the obliging and liberal manner in which they have performed their work. In several instances they have exceeded the requirements of their contract.

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ACCOMPANYING THIS VOLUME.

NOTE. — As maps will accompany the other volumes of this report, it has been thought best to arrange and number the whole series as one set, for convenience of reference and binding, and hence the accompanying atlas begins with Plate III.

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REPORT ON THE LEAD REGION.

PART I.

HISTORICAL.

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PREFATORY NOTE.

The administration of the survey, at its commencement, was placed in the charge of the late lamented Dr. I. A. Lapham, who brought to the work the fruits of a large experience, and the acquisitions of years of industrious observation upon the geology and natural history of the state. Under his able management, the survey continued the first and the greater portion of the second year. Annual reports for each of these years were duly submitted by him, but were not published. He was succeeded as chief geologist in February, 1875, by Dr. O. W. Wight, who held the position one year, and who presented a report for that year, which was likewise not published. In February, 1876, the direction of the survey was placed in charge of the writer. Subsequently, provision was made, by enactment of the legislature, for the preparation and publication of the final report of the survey, and the foregoing annual reports were placed "in the hands of the chief geologist to be used in the preparation of his final report." Under these circumstances, it has seemed to me the part of justice to publish, as nearly intact as possible, the reports prepared by my predecessors. Certain portions of a report of progress, however, necessarily relate to the administration of the survey, and to other matters of transient interest which have little subsequent importance, and would be inappropriate in a report of this character, and hence there arose a necessity for the revision of these reports for this volume. This, to me a very delicate duty, it was presumed would be esteemed a favor by those most intimately concerned in their publication, and it was freely proffered them. The revisal of the reports of Dr. Lapham was very kindly undertaken by his son, Mr. S. G. Lapham, and they appear as they left his hands, with a few trivial changes made at his request. It should be considered by all, that these annual reports made thus early in the history of the work, and merely intended to show the progress and results of the survey, in accordance with legal requirement, cannot do full justice to their distinguished author, but it is hoped that they will *indicate* the work accomplished under his administration, and if there be anything meritorious in the final results of the survey, a just and generous public will award a due measure of honor to the hand that organized and gave it direction at its inception.

The like comity in relation to the revision of the report of 1875, extended to Dr. Wight, was declined, except the privilege of reading the proofs, but he has been kind enough to assure me that nothing has been omitted from his report that it is desirable to retain.

The revision of all these reports has been closely confined to the elimination of administrative and duplicate portions, and *everything of a geological nature has been retained*, even though it were only provisional in character, and this has been done to the exclusion of portions of my own and of my associates' manuscript. While publishing thus fully and scrupulously the reports of my predecessors, it is but just to myself to disclaim any responsibility for the views presented.

Since these reports, besides being themselves the earlier annals of the survey, contain historical sketches, they are grouped together to form the opening historical section of the volume.

The annual report for 1876, submitted by the writer, was promptly published, and hence no part of it will find a place in this volume.

The annual reports of the assistant geologists, being their own independent productions, were placed in their hands, and will be found incorporated in their reports upon the districts assigned them.

T. C. C.

BELOIT, *August 6, 1877.*

WISCONSIN GEOLOGICAL SURVEY.

REPORT OF PROGRESS AND RESULTS,

FOR THE YEAR 1873.

BY I. A. LAPHAM.

As required by the act "to provide for a complete geological survey of Wisconsin," approved March 19, 1873, I now have the honor to report the progress made, and the results attained during the first year of the survey, and also to lay before you the maps, profiles and drawings necessary to exemplify the same. The law reads as follows:

AN ACT to provide for a complete Geological Survey of Wisconsin.

The people of the State of Wisconsin, represented in Senate and Assembly do enact as follows.

SECTION 1. The governor is hereby required to appoint, by and with the advice and consent of the senate, a chief geologist, who shall be a person of known integrity, thorough practical and scientific knowledge of the sciences of geology and mineralogy, and, upon recommendation of said chief geologist, the governor shall appoint one or more assistants, not exceeding in number four, one of whom shall be a skillful analytical chemist and assayer; the said chief geologist and his assistants to constitute a geological corps, whose duty it shall be to make a thorough and complete geological, mineralogical and agricultural survey of the state, and topographical surveys of such portions as may be deemed by the corps to need them for the thorough completion of the work: *Provided,* That if the appointment of chief geologist be made during the recess of the senate, such appointment may be confirmed at the next session thereof.

SECTION 2. The survey shall have for its objects:

1st. An examination of the geological structure of the state, including the dip, number, magnitude, order and relative position of the various strata; their richness in minerals, metallic ores, clays, mineral waters, fertilizers, building stones and other useful materials, the value of such materials for economic purposes, and their accessibility for mining and manufacture.

2d. Accurate chemical analyses and assays of the various ores, clays, peats, marls, building stones, etc., discovered by the state.

3d. A careful topographical survey of the lead region, for the purpose of ascertaining as far as possible, the amount of denudation, and the exact position of the mining ground at each locality; also careful barometrical observations on the relative elevation and depression of various parts of the state.

4th. An examination of soils and subsoils, and observations upon the animal and vegetable productions of the state, with reference to its agricultural interests.

SECTION 3. It shall be the duty of said geological corps, in the progress of the examinations hereby directed, to collect such specimens of rocks, ores, fossils, minerals, etc., as may be necessary to exemplify the geology of the state. Sets of these specimens shall be deposited with the Wisconsin Academy of Sciences, Arts and Letters, and the State University, and with each one of the incorporated colleges of the state, and with each of the normal schools: *provided*, application be made to the chief geologist before the commencement of field work.

SECTION 4. It shall be the duty of the chief geologist and his assistants, on or before the first Monday in January in each year during the continuation of the survey, to make to the governor a report of the progress and results of the survey, accompanied by such maps, profiles and drawings as may be necessary to exemplify the same, which reports the governor shall lay before the legislature.

SECTION 5. As soon as the progress of the survey will permit, the chief geologist shall begin, and on completion of the survey, shall complete a final report, including the results of the entire survey, accompanied by such drawings and topographical maps as may be necessary to illustrate the same, and by a single geographical map showing by colors and other appropriate means the stratification of rocks, the localities of the beds of mineral deposits, and the character and extent of the different formations.

SECTION 6. To carry into effect the provisions of this act, the sum of thirteen thousand dollars for each year, until the completion of said survey, is hereby appropriated to be drawn from the treasury on warrants from the governor, as needed; which shall be in full for all expenditures except printing of reports. The salary of the chief geologist, and the salaries of the assistant geologists shall be fixed by the governor, and shall be for services actually performed, and time actually spent in the work. The balance of the sum hereinbefore appropriated shall be used in such manner as shall best promote the purposes of this act.

SECTION 7. The survey shall commence by the first of June next, or as soon thereafter as practicable, beginning with the counties of Ashland and Douglas, and the entire survey shall be completed within four years from and after its commencement.

Approved March 19, 1873.

ORGANIZATION OF THE GEOLOGICAL CORPS. — Governor C. C. Washburn, by commission dated the tenth day of April, 1873, appointed the undersigned chief geologist under the provisions of this law.

On the twenty-ninth day of the same month, Prof. Roland D. Irving, A. M., E. M., Prof. T. C. Chamberlin, A. M., and Mr. Moses Strong, A. M., were upon the recommendation of the chief geologist appointed as assistants in the survey. Prof. W. W. Daniells, M. S., was also engaged to make such chemical examinations and analyses of ores and minerals as might be needed for the survey. By an arrangement with the Regents of the State University, Prof. Daniells is to have the use of the apparatus belonging to the Institution without additional expense.

These gentlemen had, by previous study and training, qualified themselves for the special work required. Their elaborate reports herewith submitted will show that they have faithfully, efficiently, and satisfactorily performed the several duties assigned them; though the time between the close of the field operations and the day on which their reports must be submitted to the Governor is not sufficient to enable them to do that full justice to their work that could be desired.

The assistants were each directed to organize a party adequate to the special work required; to supply themselves with the necessary instruments and outfit; to give their attention to all facts throwing light upon any of the special matters required to be considered by the law authorizing the survey; and, as it is obviously impossible, as well as unnecessary to visit every square mile in the country they were directed to so plan their routes as to be able to examine the localities of greatest importance to the material interests of the state; and at the close of the fieldwork, to prepare, as soon as possible, a detailed report of the results of their work with the necessary maps, profiles and drawings. Each party was supplied with skeleton maps, traced from the township plats of the government land surveys, upon which was laid down, from time to time, such additional information as could be obtained. These plats, it is well known represent "townships" six miles square, divided into thirty-six "sections" of one mile square, upon a scale of two inches to one mile, which is sufficiently large to represent all but the minutest details of the geological survey. Among the instruments brought into requisition by the several parties were the aneroid barometer, miners' compass, odometer, clinometer, pocket level, tape lines, etc.

Prof. Irving's Party. — It was deemed advisable to assign to Prof. Irving of the State University, Madison, the duty of beginning the survey, by an examination of the Iron and Copper Ranges of Ashland and Douglas counties; and efforts were made to have the work begun as soon after the first day of June as possible. His party, consisting of Prof. R. D. Irving, Mr. Frank B. Jenney, Mr. Edmund T. Sweet, and Mr. James Munro, with a guide and a cook, though much delayed by ice in Lake Superior, were able to reach Ashland, and to commence the field-work of the Wisconsin Geological Survey on Monday the second day of June, A. D. 1873.

In addition to the general instructions detailed above, Prof. Irving was requested to give attention to the question of the age of the red sandstone and accompanying shale of the counties to be examined; whether the Archæan rocks are of different ages; and to the disturbances of the strata in the vicinity of the metal-bearing ranges, involving important questions regarding the proper system of mining.

His report, herewith submitted, will be found to contain ample details of the beds of silicious magnetic iron ores forming what is known as the Penokee Iron Range, with numerous analyses of the ores, including all information necessary for a proper understanding of the extent and value of these important ore beds. Other details brought forward in this report, showing what had previously been done in exploring this interesting region; its topography, surface, general, special and economical geology; its agricultural features, timber, etc., will be found equally interesting and valuable. These explorations, made so early in the season, were not accomplished without the patient endurance of much suffering and hardship, arising from the clouds of musquitoes, and from unfavorable weather.

Prof. Irving also made a partial examination of the iron ore beds at and near the Black River Falls, in Jackson county.

Prof. Chamberlin's Party. — To Prof. Chamberlin was assigned the duty of surveying that portion of the state lying immediately west of the line of outcrop of the Niagara or Clinton group of rocks, from the south line of the state through the counties of Walworth, Jefferson, Dodge, Fond du Lac, Calumet and Outgamie to the southern limits of the crystalline Archæan rocks in Shawano county; and upon his return route, to examine the outcrops of the lower strata lying west of that line. He would thus be led to examine the important iron beds, now so extensively mined at Iron Ridge, the artesian wells from which water flows so abundantly at Fond du Lac and elsewhere, and the highly interesting localities of quartzite in Dodge and Jefferson counties. He would also be in the midst of some of the most striking features of the glacial and modified "drift," with their "potash kettles," gravel hills and parallel ridges.

On the twenty-third day of June, work was commenced by this party under the immediate direction of Prof. Chamberlin, aided during portions of the time by Messrs. L. C. Wooster, F. H. King, N. D. Wright, Samuel Shaw and G. L. Merriman.

They reached Keshena, in Shawano county, early in September, and returned to Beloit by the last of that month. Some further explora tions were afterwards made by Prof. Chamberlin in person, as mentioned in his report.

In Prof. Chamberlin's report will be found much interesting and valuable information, stated in plain language, relating to the topography of the district examined by him; the drainage and water power; the distribution of vegetation, of marshes, of lands covered with oak, maple or pine forests, with a map showing the boundaries of these several divisions; the outlines of the several rock formations; the phenomena of the drift; the nature of artesian wells, and various matters coming under the head of economical geology. Special attention was, very properly, given to the subject of our peat deposits, which will increase in importance from year to year, as the forests disappear, and the cost of fuel becomes thereby increased.

These, and the various other matters of much practical utility presented in this report, will be read with much interest by the people of the state.

MR. STRONG'S PARTY. — Special provision having been made for a careful topographical survey of the lead region, for the purpose of showing the denudation of the superior strata that so evidently has occurred, and the exact position of the mining ground at each locality, with reference to the particular rock-formation in which it is found, it was deemed advisable to assign one of the three surveying parties expressly to this work. Accordingly Mr. Strong, having made suitable preparations, commenced that work on the fifth day of June.

For the purpose of securing the most general and complete view of the whole lead region during the first year of the survey, Mr. Strong was directed to give his attention to two lines, the one east and west, the other north and south through the middle of the district. This would lead him to construct a geological section from the Mississippi river eastward to Dane and Green counties, and another northward from the state line of Illinois, to the iron ores and quartzites of Richland and Sauk counties. This party consisted of Mr. Moses Strong, Mr. A. D. Conover, and Mr. J. W. T. Crawford. Mr. Strong's previous training and skill acquired in the best scientific schools in this country and in Germany, and in the business of a mining engineer, enabled him to perform, with full satisfaction, the duties thus assigned to him.

Special attention was to be given to the collection of all facts bearing upon the method by which the lead, zinc, and copper, were deposited in the veins or crevices; whether by deposition from above, injection from below, or by gradual infiltration from the inclosing rocks; these questions being deemed of the greatest theoretical and practical importance as showing the probable extent of these ores below the limits of present explorations. Also to ascertain whether there have been disturbances of the strata, centers of elevation, etc., questions of importance with regard to the downward continuance of the veins, and the proper method of drainage.

Mr. Strong's report will be found to contain much that is new and valuable in regard to this important and very interesting district. The local details, showing the present condition of the mines, and their capabilities of future production, cannot fail to be of great benefit to the state by making known in a reliable form the advantages that might be attained by a more vigorous prosecution of mining operations at many of the localities described.

The extent, physical characteristics, mineral contents, and other important particulars of each rock-formation occurring in the district examined, are clearly stated. The discovery of fossils in the Lower Magnesian limestone shows that animal life was not entirely destroyed during the epoch of the deposition of this great member of the Lower Silurian series of rocks, and places it more directly in unison with the Galena (or Lead-bearing) limestone from which it is only separated by a comparatively thin layer of sandstone — the St. Peters. It thus being shown to have one more character in common with that rock, we may expect to find still more common features, such as the occurrence of crevices, openings, and the ores of lead, zinc, and copper. Important facts are brought forward, bearing upon this question of the occurrence of metallic ores of economical value, in the Lower Magnesian limestone.

Quarries of brown sandstone equal in beauty and value, and possessing in many respects the same qualities, with that so much admired from Lake Superior, are first publicly noticed in this report.

Prominence is also very properly given to the layers of carbonaceous shale, containing from fifteen to forty-five per cent. of bituminous matter, which may, at some future time, be utilized in some way. It was found that this shale occupies a position between the Blue limestone below, and the Galena limestone above; and it thus becomes a ready means of determining the exact position of the mining grounds, with reference to the geological formations. We have here probable evidence of a considerable period of time during which vegetable life — perhaps in the form of sea weeds — predominated, and which may be regarded as an incipient effort towards the state of things that long ages afterwards supplied coal and oil to the world.

The history of former efforts in the production of copper at Mineral Point will be found interesting, and may lead to renewed efforts in that direction.

With regard to the zinc ores — consisting of the sulphuret (sphalerite or blende) and the carbonate (Smithsonite, or dry-bone) often, though improperly, called calamine, a term rightfully belonging to the silicious oxide, that probably does not occur in the lead region — full details will be found in Mr. Strong's report, showing the wonderful increase of production within the past two or three years. We have here a case where an ore, supposed for a long time to be worthless, is suddenly invested with great value; and owners of abandoned mines, find themselves in the possession of unexpected wealth. It is to be regretted that the want of a cheap fuel in the lead region prevents the smelting of these ores within our own state. The construction of a railroad from Milwaukee directly to the source of supply of these zinc ores, by cheapening the cost of transportation, might render the manufacture of spelter and zinc-white, a business of profit on the shores of Lake Michigan.

It is proper here to call attention to the fact that Wisconsin lead is known in the arts as soft lead, in contra-distinction from hard lead, so called, that comes from the far west. The latter kind, separated mostly from the silver lead ores, is supposed to contain other metals as impurities; while the former is free from all deleterious substances. Doubtless the poisonous quality of some lead pipes used for the conveyance of water may arise from the presence of arsenic, or other impurities from which our lead is free.

The very extended series of barometrical observations for altitude, made by Mr. Strong and his party, will have special value in the mining region, not only at present but for all future time.

Another highly important subject, the diminution of the flow of water from springs, and in the rivers and smaller streams is very properly presented, and many new facts mentioned. Although this falling off of the amount of water may be an advantage in working the lead, zinc and copper mines, allowing the miner to penetrate to greater depths before the steam pump or the tunnel must be resorted to, yet in view of other vital interests, this drying up of the living waters is to be deemed a disaster, which it should be the business of a wise and prudent government to check. Within the life-time of an individual, perhaps the change is not sufficient to be of much consequence; but within the life of the state, it will become a matter deserving the most serious attention.

It is perhaps to be regretted, that the necessity of extending the geological survey over the whole state, with an area of fifty-six thousand square miles, renders it impossible to make such special surveys of each mining district as are wanted for the practical purposes of the miner, and seem to be expected in some localities. Such working plans can only be made by the mining companies, and landed proprietors. Had this work been undertaken for each mining neighborhood, there would have been but little time or means left for the prosecution of the survey in other portions of the state.

It is deemed to be the proper business of the state survey to ascertain the dip, number, magnitude, and relative position of the various rock-strata; and, in the lead region especially, to make a careful topographical survey for the purpose of ascertaining as far as possible the amount of denudation, and the exact position of the mining ground at each locality. The miner is thus supplied with correct and tangible information to guide him in conducting his operations in prospecting for new ranges, by showing which are the mineral-bearing rocks, with their locality, dip, and thickness. This must be done, not only for the mining region proper, but for the whole state.

It is the proper business of the miner, at the expense of the owners, and not of the geologist at the public expense, to search with pick in hand, within the limits thus defined, for mineral ranges, sinking shafts here and there until he meets with success. It then, and not until then, becomes the business of the mining engineer to make those minute and detailed investigations and surveys that are needed in the preparation of working plans, maps and profiles, showing the most proper and economical method of working the mines so discovered. Such survey and map should show the exact extent, location, and dip of the several veins, with their crossings; the present condition of the works; the proper system of drainage; the depth to which the veins may be supposed to extend; the contour of the ground; and many other items, varying, of course, with the peculiarities of each location.

Such surveys and plans are necessary for the proper working of any mines, as has often been found at great cost; but they do not come within the requirements of the law authorizing and defining the present geological survey of Wisconsin. Should such surveys ever be undertaken by the state, the work now being done by Mr. Strong, will be a necessary preparation for their proper execution.

To indicate what is required by owners of mining property in the lead region. Mr. Strong has prepared a map of the Blue Mounds in Dane and Iowa counties, with the Brigham mines, showing the geological formations in colors, in the usual method, and also the topography by contour lines, and the depth at which each rock would be reached from any point. With the accompanying explanations it will be found that this kind of map shows a very considerable amount of special information needed for practical purposes, and for deciding many important questions in regard to the proper working of the mines.

To Mr. James Wilson, Jr., of Cassville, the survey is indebted for a traced copy of his detailed and very valuable working map of the Muscalunge diggings in Grant county, showing in full detail the exact location, direction, and extent of all the drifts, adits, and shafts, with the depth of the principal shafts, and the local names by which they are known. This map will be of general interest as showing the intricate and complicated nature of these drifts in the lead region. It could only be constructed from surveys made at different times during the history of mining operations; for many of these drifts and shafts, having been abandoned, are now obstructed with rubbish or filled with water. To explore and survey them at this time would require a heavy outlay in clearing these passages; an outlay which would scarcely be justified, except for the purposes of the owner in recommencing the work of mining.

The experience gained during the past year will perhaps enable us to do a greater amount of work hereafter. Much of the detailed information collected does not properly come into a report intended more especially to show the progress of the work, and to give early notice of important discoveries. Our note books will again be called into service in the preparation of the final report, intended to embrace the whole subject.

Practical Importance of Geological Knowledge. — The propriety of a more general diffusion of accurate knowledge of the simplest facts and deductions in modern geological science is evinced by the very positive assurances of numerous letter writers that coal is found — having been dug out by badgers, or otherwise exposed — in this state, which is well known to be entirely underlaid by strata of date much older than the coal-formation. We found one party diligently boring into a stratum of soft green shale, just like — as he informed us — the clay under which coal is found in Ohio and Pennsylvania. The slightest examination of the fossils found in this shale sufficed to show that it belonged to the Silurian age, and was deposited long before those peculiar conditions were brought into existence, which gave origin to the coal. We had here a practical illustration of the importance of the study of paleontology, the index, by means of which any given formation wherever found, can at once be referred to its proper position in the geological series, and thus lead with unerring certainty to inferences of the greatest practical importance.

Other parties were found sinking shafts, or digging wells under the direction of "spiritual mediums," or of persons skilled with the divining rod. Such persons can seldom be convinced of the futility of their labor by an appeal to the fossils.

MR. EDGERTON'S SURVEY. — Mr. B. H. Edgerton, engineer, having been commissioned by the Milwaukee and Northern Railroad Company to survey the northern extension of their road from Green Bay, an arrangement was made with him to report the results of such observations as he might be able to make, that would forward the objects of the geological survey. The line run was from near Green Bay, in ranges 19 and 20, very directly north to the Menomonee river, which it crossed at the head of the Big Quinnesec Falls. The list of elevations furnished by him shows the height of the ground above the level of Lake Michigan at the crossing of every section line, and the level of the surface of the water in the rivers over which the line was run. These latter are as follows:

	Sec.	T.	R.	Elevation above	
				Lake Michigan.	The Sea.
			East.	*Feet.*	*Feet.*
Little Suamico	26	26	19	144	722
Pensaukee river	35	27	19	128	706
North branch of Pensaukee	23	27	19	139	717
Oconto, above the falls	25	28	19	132	710
Little river	1	28	19	164	742
North branch of Little river	24	29	19	180	758
Little Peshtigo	36	30	19	157	735
Little Peshtigo lake	25	30	19	157	735
A small lake on	24	30	19	159	737
A creek (first sandstone found)	31	31	19	135	713
Beaver creek, on	13	31	19	139	717
Peshtigo river	26	32	19	162	740
Middle inlet	18	33	20	192	770
North branch	5	33	20	211	789
Wausaukan river	21	34	20	242	820
Pike river	15	35	20	309	887
Peminee-Bon-Won river	33	37	20	415	993
North branch of same	10	37	20	438	1,016
Menomonee river	7	38	20	472	1,050
Highest ground (2 miles south of river)	18	38	20	571	1,149

No indications of the existence of workable beds or veins of iron ore were observed upon this route; if any exist they are further to the north and west.

Mr. Edgerton reports as follows: "The geological formation of the country traversed I found to be much the same as indicated on your map, except that I did not succeed is discovering any evidence of the belt marked thereon as the St. Peters sandstone. The first cropping out of the rock which we found is at the Oconto Falls, in section 25, town 28, range 19 east, where the Magnesian limestone makes its appearance in the banks of the river and adjacent bluffs. The perpendicular fall here is about twenty-two feet, and the rapids which succeed make the whole fall of the river about sixty feet.

"We first discovered the Potsdam sandstone in section 34, town 31, range 19, where the bed and banks of a small creek are of this formation. It is a dark-colored loose stone, too soft to serve any useful purpose. At the falls of the Peshtigo river, in section 24, town 32, range 19, this sandstone is of a firmer and finer texture, and may be found useful as a building material. It has also a sharp grit, and close grain, that renders it serviceable for grindstones, and I was told that at an early day it was used for sharpening edged tools.

"In section 36, town 33, range 19, granite first shows itself, and with other metamorphic rocks, crops out from time to time until we reach the Menomonee river. It is a very abundant material at Pike river, in sections 15 and 16, town 35, range 20, and forms the bed and banks of the river at the falls. In section 34, town 37, range 20, trap rocks[1] are found interspersed with the granite, along the banks of the Peminee-Bon-Won, but after leaving that stream until we reach the north branch in section 3 of the same township, no rocks appear on the surface except granite. At the crossing of the North Branch, trap rocks again make their appearance and are frequently seen in alternation with the granite, until we reach the crossing of the Menomonee river on section 7, town 38, range 20, at the head of the Big Quinnesec Falls; at which point the rocks are mostly granite, but a small area at the top is composed of trap mingled with some talcose rocks.

"The granite of this region is mostly schistose in character and is frequently coarse and soft, so as to be of little use as a building material. It often abounds in seams, filled with feldspar, and other substances; and quite frequently these seams cross each other at acute angles.

"From the Peshtigo river I went westward as far as Thunder Lake, in section 15, town 32, range 18, and first discovered the granite in this direction near the line between ranges 18 and 19, and at the point between sections 13 and 18.

"At Keshena in town 27, range 15, or a little northwest from the village, the same rocks appear; and I judge that the line between the sandstone and granite follows about a northeasterly course to the Menomonee river, in town 36, range 21 east."

[1] These and the following rocks spoken of as trappean are metamorphic

Topographical Survey. — Much of the success of any geological survey depends upon the accurate measurement of the elevation of the country above some well known datum plane. For all such determinations in Wisconsin the level of Lake Michigan forms a convenient base from which to measure. The elevation of this lake above the sea was long ago determined, by the topographer of the early Michigan geological survey, under the direction of the lamented Dr. Douglas Houghton, to be 578 feet. Probably the first spirit level brought to Wisconsin was that of the late Hon. Byron Kilbourn, who in March, 1836, established the zero, at the lake level, to which all subsequent work of street grading, sewers, and the water-works of Milwaukee has been referred. It was also from this now well established datum plane that the surveys of the Milwaukee & Mississippi, the La Crosse & Milwaukee, and the Milwaukee & Horicon railroads were commenced; and it is to this zero therefore, that all work of the present geological survey will be referred.

Since 1836, the level of Lake Michigan has varied, from 4 feet above this datum, in July, 1838, to 1.65 below in March, 1848, showing a total change of 5.65 feet; the mean being about one foot above the established zero.

These fluctuations have long been known to result from various causes, among them the effect of winds and storms; the annual change of the seasons producing high and low water, as in ordinary rivers; the variations, during different years, or series of years, as to wetness or dryness; and finally a regular (though very small) lunar tide, corresponding with that of the ocean.

Railroad Elevations. — In the prosecution of any topographical as well as of any other survey of the state, it is apparent that advantage should be taken of any work already done by others; and with this view, efforts have been made to secure, as far as can now be done the results of the several railroad surveys within the state, and the following list of stations, with their elevation above Lake Michigan and the sea will show what progress has been made in this direction.

Every railroad station, the elevation of which is here given, becomes a bench mark from which our barometrical measurements of the relative elevation and depression of various parts of the state, as well as all future surveys can be made, with definite knowledge of the absolute height above Lake Michigan and above the sea level.

The level of Lake Michigan, thus definitely made known, will be found a convenient datum plane to which all future railroad surveys may be referred; this can be done without the use of negative quantities, for no part of Wisconsin lies below that level. After the publication of the following list, it will not be difficult to connect any future survey with this, now well established datum plane, and thus aid directly in the development of the physical geography and topography of the state.

ELEVATION OF RAILROAD STATIONS.

Stations.	County.	Elevation above	
		Lake Michigan.	The Sea.
Ableman	Sauk	301	879
Ackerville	Washington	480	1053
Afton	Rock	180	758
Allen's Grove	Walworth	293	871
Amherst	Portage	466	1044
Amherst Junction	Portage	553	1131
Appleton	Outagamie (C. & N. W.)	128	706
Appleton	Outagamie (M. & N.)	145	723
Arena	Iowa	154	732
Arlington	Columbia	426	1004
Auburndale	Wood	645	1223
Augusta	Eau Claire	395	973
Avoca	Iowa	117	695
Baldwin	St. Croix	560	1138
Balch's Ranch	Wood	389	967
Bangor	La Crosse	174	752
Baraboo	Sauk	284	862
Barton	Washington	320	898
Beaver	Juneau	379	957
Beaver Dam	Dodge	340	918
Bearse Marsh	Wood	409	987
Belgium	Ozaukee	153	731
Beloit	Rock	163	741
Bellville	Jefferson	248	826
Berlin	Green Lake	184	762
Black Earth	Dane	232	810
Black River	Jackson	302	880
Black River Falls	Jackson	231	800
Blooms	Sauk	304	882
Blue River	Grant	85	608
Boardman	St. Croix	379	957
Boscobel	Grant	89	667
Branch-Zalesburg	Manitowoc	158	736
Brandon	Fond du Lac	421	1000
Bridgeport	Crawford	47	625
Bristol	Kenosha	191	769
Brodhead	Green	220	798
Brookfield Junction	Waukesha	246	824
Brooklyn	Green	400	978
Brown Deer	Milwaukee	85	663
Burlington	Racine	203	781
Burnett Junction	Dodge	299	877
Cambria	Columbia	284	862
Camp Douglas Junction	Juneau	356	934
Cato	Manitowoc	246	824
Calamine	La Fayette	234	812
Calvary	Fond du Lac	362	940
Cedarburg	Ozaukee	191	709

ELEVATION OF RAILROAD STATIONS—*continued.*

STATIONS.	COUNTY.	ELEVATION ABOVE Lake Michigan.	ELEVATION ABOVE The Sea.
Cedar Creek, Ackerville	Washington	480	1058
Cedar Grove	Sheboygan	114	692
Centralia	Wood	431	1009
Chelsea	Chippewa	945	1523
Chilton	Calumet	269	846
Clinton Junction	Rock	363	941
Clyman	Dodge	330	908
Colby	Chippewa	775	1353
Columbus	Columbia	256	834
County Line	Milwaukee	117	695
Cross Plains	Dane	280	858
Dane	Dane	481	1059
Darien	Walworth	367	945
Darlington	La Fayette	224	802
Deanville	Dane	305	873
Decca	Sheboygan	179	757
De Forest	Dane	341	919
Delavan	Walworth	356	934
Depere	Brown	9	587
Dexterville	Wood	417	995
Dillman	Milwaukee	107	685
Dodgeville	Iowa	691	1269
Dorchester	Chippewa	838	1416
Dover	Racine	234	812
Dreuckers	Ozaukee	154	732
Dundas	Calumet	160	738
Doyles — Otsego	Columbia	360	933
Devils Lake	Sauk	390	968
Eagle	Waukesha	365	943
Eagle Junction	Waukesha	360	938
East Madison	Dane	268	846
Eau Claire	Eau Claire	266	844
Edgerton	Rock	242	820
Ehlers Crossing	Ozaukee	93	671
Eldorado	Sheboygan	297	875
Elkhart Lake	Sheboygan	362	940
Elkhorn	Walworth	413	991
Elk Mound	Dunn	351	929
Elm Grove	Waukesha	170	748
Elm Grove	Waukesha	166	744
Elroy	Juneau	388	966
Evansville	Rock	325	903
Fairchild	Eau Claire	487	1065
Fall Creek	Eau Claire	357	868
Fall River	Columbia	290	935
Fayette	Walworth	283	861
Fond du Lac	Fond du Lac	168	746
Footville	Rock	238	816
Forest House	Waukesha	240	818
Forest Junction	Calumet	250	828
Fort Atkinson	Jefferson	220	798
Fort Howard	Brown	6	584
Fox Lake Junction	Dodge	305	883
Fox River	Kenosha	200	778
Franksville	Racine	150	728
Fredonia	Ozaukee	206	784
Genesee	Waukesha	325	903

Elevation of Railroad Stations — *continued.*

Stations.	County.	Elevation Above Lake Michigan.	Elevation Above The Sea.
Geneva	Walworth	274	852
Genoa	Walworth	264	842
Germantown	Washington	285	863
Giffords	Waukesha	297	895
Gills Landing	Waupaca	183	761
Gleason	Monroe	353	931
Glenbeulah	Sheboygan	289	867
Glendale	Monroe	419	997
Good Hope	Milwaukee	112	690
Grafton	Ozaukee	170	748
Grand Rapids	Wood	448	926
Granville	Milwaukee	168	746
Gratiot	La Fayette	205	783
Green Bay	Brown	6	584
Green Bay Jct. (Merrillan)	Jackson	365	943
Greenfield	Monroe	471	1048
Green Lake	Green Lake	235	813
Greenleaf	Brown	141	719
Hammond	St. Croix	525	1108
Hanover Junction	Rock	209	787
Hartford	Washington	408	986
Hartland	Waukesha	333	911
Hartman	Columbia	210	798
Hayton	Calumet	240	818
Hersey	St. Croix	588	1166
Herseyville	Monroe	190	768
Hilbert	Calumet	250	828
Hitchcock	Monroe	364	942
Horicon Junction	Dodge	306	884
Hubbelton	Jefferson	211	789
Hudson	St. Croix	128	706
Hulls Crossing	Sheboygan	354	932
Humbird	Clark	418	996
Humboldt Junction	Milwaukee	61	639
Iron Ridge	Dodge	345	923
Janesville	Rock	240	818
Jefferson	Jefferson	221	799
Johnson Creek	Jefferson	193	771
Juda	Green	243	821
Juneau	Dodge	335	913
Junction City	Portage	572	1150
Kansasville	Racine	240	818
Kaukauna	Outagamie	80	658
Kenosha	Kenosha	40	618
Kenosha Junction	Kenosha	101	679
Kiel	Calumet	333	911
Kilbourn City	Columbia	315	893
Kinnickinnic	Milwaukee	10	588
Kirkwood	Sauk	286	864
Knapp	Dunn	349	927
Knowlton	Marathon	547	1125
Koshkonong	Rock	249	827
La Crosse	La Crosse	70	648
La Fayette	Monroe	303	881
Lake	Milwaukee	154	732
Lake Side	Waukesha	292	870
Lamartine	Fond du Lac	250	828

ELEVATION OF RAILROAD STATIONS—*continued.*

STATIONS.	COUNTY.	ELEVATION ABOVE Lake Michigan.	ELEVATION ABOVE The Sea.
Latham	Calumet	143	721
La Salle	Sauk	320	898
Ledgeville	Brown	96	674
Lemonweir	Juneau	316	894
Le Roy	Monroe	375	953
Lewiston	Columbia	231	809
Lima	Rock	310	888
Linden	Juneau	320	898
Lindwerrn	Milwaukee	56	634
Little Chute	Outagamie	144	722
Lisbon	Juneau	315	893
Lone Rock	Richland	126	704
Lodi	Columbia	271	849
Lowell	Dodge	247	825
Lowerys	Monroe	389	967
Lyons	Walworth	222	800
Madison, east	Dane	268	846
Madison	Dane	275	853
Magnolia	Rock	340	918
Manawa	Waupaca	246	824
Manitowoc	Manitowoc	7	585
Manville	Marathon	713	1291
Marshall	Dane	286	864
Mauston	Juneau	309	887
Mazomanie	Dane	195	773
McFarland	Dane	289	867
Medford	Chippewa	842	1420
Medina	Outagamie	192	770
Menasha	Winnebago	177	755
Menomonie	Dunn	306	884
Merrillan	Jackson	365	943
Merrimac	Sauk	219	797
Mequon	Ozaukee	92	670
Middleton	Dane	347	925
Mill Creek	Wood	514	1092
Milton	Rock	293	871
Milton Junction	Rock	299	877
Milwaukee	Milwaukee	5	583
Mineral Point	Iowa	357	935
Minnesota Junction	Dodge	348	926
Monroe	Green	492	870
Morrison	Dane	387	965
Muscoda	Grant	109	687
Nashotah	Waukesha	350	928
Neenah	Winnebago	170	748
Nepeuskin (Rush Lake Junction)	Winnebago	263	841
New Holstein	Calumet	351	929
New Richmond	St. Croix	411	989
Northport	Waupaca	182	760
North Prairie	Waukesha	363	941
North Wisconsin Junction	St. Croix	295	872
Norway	Monroe	407	985
Oak Creek	Milwaukee	86	664
Oakfield	Fond du Lac	310	888
Oakwood	Milwaukee	105	685
Oconomowoc	Waukesha	283	861
Ogdensburg	Waupaca	292	870

Elevation of Railroad Stations—*continued.*

Stations.	Counties.	Elevation Above Lake Michigan.	Elevation Above The Sea.
Okee	Columbia	220	798
Oostburg	Ozaukee	102	680
Orange	Juneau	327	905
Oregon	Dane	365	943
Orford	Rock	313	891
Oshkosh	Winnebago	170	748
Otsego	Columbia	360	938
Pacific	Columbia	205	783
Palmyra	Jefferson	260	838
Pardeeville	Columbia	232	810
Penokee Gap	Ashland	713	1291
Pewaukee	Waukesha	263	841
Pine Lake	Waukesha	350	928
Pleasant Prairie	Kenosha	119	697
Plover	Portage	504	1082
Plymouth	Sheboygan	262	840
Portage	Columbia	232	810
Port Edwards	Wood	388	966
Port Washington	Ozaukee	87	665
Prairie du Chien	Crawford	41	619
Princeton	Green Lake	188	766
Rablin	Wood	428	1006
Racine (C. & N. W.)	Racine	40	618
Racine Junction	Racine	43	621
Racine (W. U.)	Racine	5	583
Randolph	Columbia	378	956
Random Lake	Sheboygan	295	873
Readstown	Vernon	155	733
Reedsburg	Sauk	300	878
Reeds Corners	Fond du Lac	407	985
Reedville	Manitowoc	242	820
Remington	Wood	403	981
Richfield	Washington	381	959
Rio	Columbia	352	930
Ripon	Fond du Lac	352	930
Riverside	La Fayette	208	786
Roberts	St. Croix	462	1040
Rockland	Brown	61	639
Rolling Prairie	Dodge	363	941
Rosendale	Fond du Lac	313	891
Rosendale (west)	Fond du Lac	304	882
Royalton	Waupaca	259	837
Rubicon	Dodge	440	1018
Rudds	Jackson	403	981
Rudolph	Wood	562	1140
Rush Lake Junction	Winnebago	263	841
Rusk	Dunn	331	909
Salem	La Crosse	171	749
Salem	Kenosha	198	776
Sanderson	Dane	275	853
Saukville	Ozaukee	181	759
Scandinavia	Waupaca	365	943
Schleisingerville	Washington	474	1052
Schwartzburg Junction	Milwaukee	66	644
Scranton	Jackson	386	964
Sheboygan	Sheboygan	7	585
Sheboygan Falls	Sheboygan	85	663

ELEVATION OF RAILROAD STATIONS — *continued.*

STATIONS.	COUNTIES.	ELEVATION ABOVE Lake Michigan.	ELEVATION ABOVE The Sea.
Sherwood	Calumet	253	831
Shopiere	Rock	366	944
Sparta	Monroe	215	793
Spencer	Marathon	730	1308
Spring Creek	Calumet	248	826
Springfield	Walworth	270	848
Spring Green	Sauk	144	722
State Line	Racine, C. & N. W.	90	668
State Line	Racine, C., M. & St. P.	90	668
State Line	La Fayette	475	1053
St. Cloud	Sheboygan	349	927
Stevens Point	Portage	508	1086
St. Francis	Milwaukee	65	643
Stoughton	Dane	279	857
Summitt	Fond du Lac	398	976
Sun Prairie	Dane	356	934
Syene	Dane	320	908
Taycheedah	Fond du Lac	173	751
Thienville	Ozaukee	88	666
Tomah	Monroe	383	961
Troy Center	Walworth	295	873
Truesdell	Kenosha	101	679
Tunnel City (Greenfield)	Monroe	483	1061
Turtle Creek	Rock	273	851
Ullao	Ozaukee,	117	695
Union Grove	Racine	182	760
Union Center	Juneau	366	944
Valley Junction, Wis. Valley R. R. & W. W. R. R.	Monroe	354	932
Waldo	Sheboygan	254	832
Waterloo	Jefferson	241	819
Watertown Junction	Jefferson	243	821
Warren	Monroe	448	1026
Waukau	Winnebago	474	1052
Waukesha	Waukesha	225	803
Waunakee	Dane	345	923
Waupaca	Waupaca	314	892
Waupun	Dodge	314	892
Wausau	Marathon	643	1221
Wauwatosa	Milwaukee	73	651
Wauzeka	Crawford	60	638
Weedens Crossing	Sheboygan	115	693
Westboro	Chippewa	923	1501
West Madison	Dane	275	853
Western Union Junction	Racine	144	722
Westport	Dane	359	917
Weyauwega	Waupaca	183	761
White Fish Bay	Milwaukee	73	651
Whitewater	Walworth	241	819
Wilson	St. Croix	518	1096
Wilson	Sheboygan	102	780
Wilton	Monroe	414	992
Windsor	Dane	304	882
Windsor	Racine	179	757
Winona Junction	La Crosse	86	664
Wonewoc	Juneau	333	911
Woodland	Dodge	373	951

ELEVATION OF RAILROAD STATIONS—*continued.*

Stations.	Counties.	Elevation above Lake Michigan.	Elevation above The Sea.
Woodman	Grant	73	651
Woodworth	Kenosha	170	748
Worcester	Chippewa	1038	1616
Wright's	Jackson	353	931
Wrightstown	Crawford	48	626
Wyocena	Columbia	249	827
Zalesburg	Manitowoc	158	736

ELEVATION OF LAKES IN WISCONSIN.

Beaver Dam pond	Dodge	282	860
Bonner's Lake	Racine	200	778
Cranberry	Jefferson	269	847
Crooked	Waukesha	288	866
Devils	Sauk	390	968
Duck	Walworth	270	848
Elkhart (Station)	Sheboygan	362	940
Fox (Junction Station)	Dodge	305	883
Fifth	Dane	324	902
Geneva (R. R. Bridge)	Walworth	300	878
Green Lake Station	Green Lake	235	813
Haymarsh	Polk	620	1198
Holdens	Walworth	325	903
Horicon	Dodge	277	855
Keesus	Waukesha	376	954
Kegonsa (1st)	Dane	260	762
Koshkonong	Jefferson	184	851
La Belle	Waukesha	273	838
Lac Vieux Desert	Oconto	951	1529
Long	Bayfield	739	1317
Mendota (4th)	Dane	270	848
Michigan	Milwaukee	....	578
Monona (3d)	Dane	262	840
Mud	Dane	328	906
Muskego	Waukesha	191	769
Nagowicka	Waukesha	304	882
Nashotah, upper	Waukesha	290	868
Nemahbin	Waukesha	289	867
Oconomowoc	Waukesha	282	860
Pewaukee	Waukesha	263	841
Pike	Washington	416	994
Powers	Kenosha	260	838
Pucawa	Green Lake	206	784
Random	Sheboygan	295	873
Rush	Winnebago	263	841
Shawano	Shawano	221	799
Silver	Waukesha	278	856
Spring	Columbia	205	783
Superior	Ashland	22	600
Trout	Lincoln	961	1539
Twin	Fond du Lac	450	1028
Waubesa (2d)	Dane	261	839
Wind	Racine	190	768
Winnebago	Winnebago	162	740

ELEVATION OF SUMMITS, MOUNDS, HIGHLANDS, ETC.

	Elevation above	
	Lake Michigan.	The Sea.
State Line of Illinois—		
On the line between Ranges 18 and 19 (Genoa)	262	840
" " C. & N. W. R. R. (Sharon)	349	927
" " C., M. & St. P	90	668
Near Warren, Ill	475	1053
Head of Montreal river (Owen)	1150	1728
St. Croix and Brulé Portage (Owen)	674	1252
Mount Trempealeau (Owen)	607	1185
Maiden's Rock (Owen)	443	1021
West Blue Mound (Whitney)	1151	1729
East Blue Mound (Whitney)	1000	1578
Platte Mound (at base 553)	703	1281
Sinsinewa Mound (base 366)	591	1169
Sinsinewa Mound College	462	1040
Penokee Gap	713	1291
Government Hill (Waukesha Co.)	669	1247
Lapham's Peak (Washington Co.)	824	1402
Elephants Back (Kilbourn City	555	1133
Buena Vista, Sec. 23, T. 22, R. 9 E	605	1183

GOVERNMENT SURVEYS.—It is very generally known that the admirable system of surveys into townships, six miles square and sections of one mile square, with their boundary lines running due north and south and due east and west, adopted for the survey of the government lands of the United States, though exceedingly well adapted to the purposes for which it was chiefly intended, that of disposing of these lands, is altogether too crude and inaccurate for any scientific purpose. There are offsets occasioned by the spheroidal shape of the earth, that could not be avoided, but there are also many other irregularities arising from various causes which prevent the construction, from these surveys alone, of an accurate map of the state. Among these causes may be mentioned the necessity, often occurring, for making surveys of public lands to meet the wants of settlement and improvement before the principal or governing lines can be run. Some townships have been resurveyed in a neighboring state, revealing gross irregularities, only to be accounted for by a want of honesty on the part of the surveyor; how many similar cases exist in Wisconsin can only be known when the country becomes fully occupied, and the lines of the public survey retraced.

While some tiers of sections are double the usual width [1] others are

[1] In range 9, towns 21 to 30, inclusive.

contracted to a quarter of their proper size[1]. Some section lines instead of running due east and west, or due north and south, are found to make considerable angles with these cardinal directions. Almost every section, when accurately remeasured, is found to show either an excess or a deficiency of the normal quantity of six hundred and forty acres. Railroad engineers discover these inaccuracies while running their lines with the theodolite, and connecting them with the section lines. One who, under instructions, followed a section line over a level country, was afterwards censured for the curves he had introduced at almost every mile of the road, where only a straight-line was intended.

On the official plats of the surveys of the public lands, now deposited in the office of the secretary of state, at Madison, we often find the north line of a township varying considerably from the true east and west direction; while the south boundary of the next township (which is the same line) shows no such variation[2]. Again, the east line of one plat differs from the west line of the next in the same manner. In all such cases there are no means, short of actual resurvey, of determining which is correct, nor what changes are required in the form of the subdivisions, or the direction of their boundary lines, to make them conform to these unexplained irregularities.

If we plat one of the banks of the Mississippi or Menomonee rivers by the Wisconsin surveys, and the other, upon the same map, from those of Iowa and Minnesota, or of Michigan, we shall find that these rivers have in some places a wonderful breadth, while at others the two banks will be brought so near together as to leave scarcely room for a trout brook.

Considerable progress has already been made in an attempt to trace all these irregularities; to show the offsets upon the correction lines, and to construct a diagram or skeleton map which shall correctly represent the surface of the state. This work must be done before any correct map of the state can be made. Such maps are found to be matters of necessity in all civilized countries; large amounts of money and many years of labor having been expended to secure this object in Great Britain, France, and many other countries.

The proper corrections to be made in the lines of the public land surveys can only be ascertained and applied after a complete geodetic survey shall be made, such as is now being prosecuted by the general government, under the direction of the coast survey and of the engineer department. Such survey contemplates the accurate determination of the latitude and longitude of numerous prominent points

[1] In town 16, range 1 to 11 east. [2] Notably townships 1 and 2 in range 9 east.

which are to be connected, and made the basis of a system of triangulation, covering all the ground to be surveyed.

The engineer department of the United States army have in charge the survey of the lakes, which reaches into this state along the shores of Lake Superior, Lake Michigan and Green Bay, and also other military and geographical surveys in the west. The work of the lake survey will be available, so far as it goes, for the purposes of the state survey, and it is exceedingly desirable that it should be extended so as to embrace a larger portion of the interior. At my suggestion Gen. Humphrey, chief of engineers, has authorized the determination of the position of points on the base line of the land survey (the southern boundary of the state) and others on the fourth principal meridian, and on the "correction lines;" these being the governing lines of the public land surveys, their exact determination becomes of the greatest importance. Should the congressional appropriation for these objects be continued, other work of the same kind will be done.

If such a survey could be extended over the state of Wisconsin, and properly connected with the land surveys, it would accomplish all that could be desired in this direction. It was found that congress, while making provision for extending the coast survey across the continent, so as to form a geodetic connection between the Atlantic and Pacific coasts, required also the determination of points in each state in the Union, which shall make requisite provision for its own topographical and geological surveys. Under this authority, the officers of the coast survey have already taken observations for determining the position of Madison and La Crosse, and arrangements have been made for the further prosecution of the work, which will be in charge of Prof. J. E. Davies, of the University of Wisconsin. In addition to the general benefits of that survey, it will be the means of training a number of young men in the methods of this important kind of work, thus making it the source of educational advantages.

Other important surveys have been made by the general government within our state. Among them, perhaps the most valuable are those made a few years ago under the direction of Gen. G. K. Warren, of several of the larger rivers, including the Mississippi so far as it forms our western boundary, and portions of the St. Croix, Chippewa, Black, Wisconsin and Fox rivers. Of these, maps were constructed on a scale of two inches to one mile (same as the plats of the government land surveys), showing not only the margins of the rivers, with the islands and sand bars, but also the boundaries of the bottom lands and the position of the adjacent bluffs. Copies of these detailed and costly maps have been furnished for the use of the state survey, and add very materially to our knowledge of the minute topography of the state. They will also soon become still more valuable as a means of showing what changes are annually taking place along the course of these important rivers.

With the public land surveys, thus tested and corrected, together with the railroad surveys, and the barometrical measurements of heights by the geological survey, we shall have abundant material for the construction of a very full and correct topograpical map of the state.

It is therefore to be hoped that means will not be withheld for the vigorous prosecution of these important surveys on the part of the United States government. All such work is of the greatest practical importance in the more correct determination of the boundaries of real estate, thus, perhaps, preventing future litigation, neighborhood quarrels, and uncertainty as to the ownership of property.

MINERALS. — The following enumeration of the mineral species heretofore found in Wisconsin, has been made up from observation, and from various sources of information; and though it is, doubtless, far from complete, either in the number of species existing in the state, or in the enumeration of localities, it will serve as a beginning towards the more complete mineralogical survey contemplated.

CATALOGUE OF MINERALS.[1]

I. NATIVE ELEMENTS.

Gold. — Gold is said to have been found in several places in the northern part of the state.

Silver. — Native silver is found associated with copper in boulders of the drift, having been transported from the copper veins of Lake Superior. It is said to occur in veins on the Montreal river; and, associated with lead, in Ashland county.

Copper. — Copper has been found in limited quantities in regular veins on the Montreal river and at several other places in Ashland and Douglas counties. In the form of drift boulders it is often found, especially in the eastern half of the state; the masses vary from a few ounces to several hundred pounds; the largest, found near Hustisford in Dodge county, had a weight of 487 pounds.

Iron. — Meteoric iron has been found in Washington county on the farm of Louis Korb, in masses varying from 8 to 62 pounds. They are, apparently, all fragments of one meteorite which must have exploded when very near the surface of the ground. It has been analyzed and described, and samples sent to collectors under the name of the "Wisconsin Meteorite." The presence of nickel, and peculiar Widmannstätthian figures leave no doubt of the meteoric origin of this iron.

Native Sulphur. — Sulphur, resulting from the decomposition of marcasite, has been found in the lead mines at Mineral Point, Shullsburg, etc.

Graphite (Plumbago, Black Lead). — Graphite is said to have been found in the northern portion of the state.

[1] A list of all the minerals known *at the close of* the survey to occur in the state will be given in another volume of the report.

II. Sulphids, Arsenids, etc.

Galenite (Sulphuret of Lead). — Extensively mined in the southwestern counties of the state. Occurs in small quantities in many other localities.

Sphalerite (Blende, Black Jack). — Abundant and now extensively mined in the lead region.

Chalcocite (Sulphuret of Copper). — At Mineral Point, and other places.

Niccolite (Arsenical Nickel). — Found in very small quantities in Douglas county, 1873.

Pyrite (Cubical Iron Pyrites). — At Mineral Point, etc.

Chalcopyrite (Copper Ore). — At Mineral Point, Mt. Sterling and other places, but not in workable quantity.

Marcasite (Iron Pyrites, Mundig). — With ores of lead and zinc in the lead region; masses in drift clay near Lake Michigan, and elsewhere.

Tetrahedrite (Gray Copper Ore).— Left Hand River, Douglas county. (Owen.)

III. Oxygen Compounds.

Cuprite (Red Copper Ore). — Left Hand River, Douglas county. (Dana.)

Water. Natural waters in the Archæan and Sandstone regions are usually soft and nearly pure; in other portions of the state, hard, or containing lime and magnesia from the limestones. At Sparta, Waukesha, etc., the water of certain springs and wells is found to possess medicinal virtues. At Fond du Lac, Sparta and Watertown, the iron tubes through which the water flows become highly magnetic.

Hematite (Red and Specular Iron Ore). — Iron Ridge, Hartford, Depere, etc., in small grain; flax seed ore. Used with Lake Superior ores at Milwaukee and other places. Penokee Iron Range, Ashland county, Wood county, etc.

Menaccanite (Titanic Iron Ore). — In small quantities near Baraboo, Sauk county. In trap rocks, Lake Superior. (Owen.)

Magnetite (Magnetic Iron Ore).—Penokee Iron Range, Ashland county, in great abundance; also at Black River Falls, Jackson county, and other places. It is found in the form of sand on the shores of the great lakes.

Limonite (Brown Iron Ore). — Ironton, Sauk county, supplying an iron furnace. In less quantities at various places, resulting from the decomposition of marcasite. Bog ore in Wood county and elsewhere.

Wad (Oxide of Manganese).—In small quantities in the lead region, and other places; also the variety asbolite or earthy cobalt.

Quartz. — Crystalized quartz is found in various places. In the form of grains it constitutes the sandstones, often pure and white. Its varieties, amethyst, carnelian, jasper, chert, etc., are often found. Quartzite occurs in extensive ridges among the Archæan rocks.

Amphibole (Hornblende, etc.).—Abundant in the Archæan rocks. Variety, tremolite at Lac de Flambeau. (Norwood.)

Garnet. — Lac de Flambeau river, four miles above the mouth, and other places in Archæan rocks. (Norwood.)

Epidote.—Associated with copper ores in Ashland and Douglas counties.

Phlogopite (Rhombic Mica).—On the Eau Claire river, four miles above the falls, in large plates. (Dr. Littel.)

Wernerite (Scapolite). — Twin Falls, of the Menomonee River of Green Bay. (Foster & Whitney.)

Labradorite. — An ingredient of trap-rocks; upper rapids of the Bois Brulè river of Lake Superior. (Owen.)

Albite (White Feldspar). — Common in boulders of Archæan rocks.

Orthoclase (Potash Feldspar). — Common in Archæan rocks. By decomposition forms Kaolin (Potter's Clay).

Tourmaline. — Outlet of Lac de Flambeau. (Schoolcraft.)

Cyanite (Kyanite). — Lac de Flambeau. (Dr. Norwood.)

Laumonite. — Copper veins on the Montreal river. (J. P. Hodges.)

Chrysocolla (Silicious Oxide of Copper). — Wisconsin, with carbonate of copper. (Dana.)

Prehnite. — Accompanying copper ores, Lake Superior.

Talc. — Ableman, Sauk county, in quartzite.

Glauconite (?) (Green Sand). — Forming layers in the Potsdam and Upper sandstone Madison, Janesville and numerous other places.

Sapronite (Thalite, Owen). — Black river (of Lake Superior). Three miles above Kettle river.

Kaolinite. — Grand Rapids, Wood county. Potter's clay at Menasha and elsewhere. Brick clay at Milwaukee, Watertown, Port Washington, Sheboygan, etc., making brick of a light cream color. Pipestone (Catlinite) in Barron county on lands belonging to the Cornell University. There are also clays so largely consisting of silex in minute grains as to be useful as polishing powders.

Apatite (Phosphate of Lime). — In the Potsdam sandstone and in Galena limestone the fossil Lingulæ are composed of phosphate of lime.

Barite (Sulphate of Barites. Heavy Spar). — Abundant in the lead region; Mineral Point, Shullsburg, etc.

Celestite (Sulphate of Strontia). — In drift clay filling a crevice in limestone, Wauwatosa near Milwaukee.

Anglesite (Sulphate of Lead). — In small crystals, lining cavities in galenite at Mineral Point.

Leadhillite. — At Mineral Point. (Owen.)

Gypsum. — At Sturgeon Bay. Also among the lead mines.

Melanterite (Sulphate of Iron, Copperas). — In the lead mines, formed by the decomposition of marcasite (iron pyrites).

Calcite (Calcareous Spar, Tiff). — Common in the lead region. Fine crystals (scalene dodecahedrons) at Shullsburg. Coarse stalactites in Cleveland's Cave, Dane county. Tufa deposited from springs incrusting moss, leaves, sticks, etc., at numerous places. Travertine (called marble) in Sauk and Richland counties. Hydraulic limestone has been found in some localities.

Dolomite. — Most of the limestones of Wisconsin contain magnesia, and are properly dolomites.

Siderite (Carbonate of Iron). — Penokee Iron Range, Ashland county; rare.

Smithsonite (Carbonate of Zinc, Dry Bone). — At Mineral Point, and other places in the lead region. Extensively mined for the manufacture of zinc.

Cerussite (Carbonate of Lead, White Lead ore). — At Mineral Point, Blue Mounds and elsewhere in the lead region.

Hydrozincite (Calamine, Zinc bloom). — At Linden in a concretionary fibrous crust on Smithsonite (Whitney).

Malachite (Green Carbonate of Copper). — In minute quantities in connection with other copper ores, Mineral Point, etc.

Azurite (Blue Carbonate of Copper). — At Mineral Point; Left Hand river, in minute quantities.

IV. Hydrocarbon Compounds.

Petroleum. — Some layers of rock in the lead region are highly bituminous, burning with a flame when heated.

Asphaltum. — Some small cavities in the Devonian limestone near Milwaukee, and also east of Fond du Lac, contain mineral tar.

Peat is found underlying very many of the bogs and swamps; sufficient to be of economic value whenever the forests are destroyed and coal becomes scarce.

The following species have been found in the mining region of Lake Superior, in Michigan, and may therefore be found in similar localities in Wisconsin:

Donieykite (Arsenical Copper).	Datolite.
Algodonite (Arsenical Copper).	Pectolite.
Whitneyite (Arsenical Copper).	Chlorastrolite.
Argentite (Sulphuret of Silver).	Apophyllite.
Bornite (Purple Copper ore).	Natrolite.
Covellite (Indigo Copper).	Analcite.
Cerargyrite (Horn Silver).	Chabazite.
Fluorite (Fluor Spar).	Harmotome.
Melaconite (Black Oxide of Copper).	Stilbite.
Gothite (Oxide of Iron and water).	Heulandite.
Manganite (Gray Oxide of Manganese).	Serpentine.
Wollastonite (Tabular Spar).	Genthite.
Pyroxene.	Delessite.
Pseudomalachite.	

MINERAL WATERS. — Mineral waters being included among the numerous objects to be investigated by the survey, a beginning has been made in the collection of facts and information in regard to them, and arrangements made by which it is hoped that all desirable information will be at hand, ready for the final report.

Mr. Gustavus Bode, of the firm of J. H. Tesch & Co., Milwaukee, having already analyzed a number of these waters, arrangements were made with him to furnish corrected copies of his work for the use of the survey, and to make such further analyses as should be deemed advisable.

The accompanying table will show in the most compact and convenient form the chemical composition of twenty-three of the waters of our springs, wells, rivers, and lakes:

ANALYSES OF THE WATERS OF WISCONSIN.

SUBSTANCES IN 1,000 PARTS.	Richmond's Spring, Whitewater.	Market Square, Milwaukee.	Eureka Spring, Milwaukee.	Well at Waterloo.	W. Rahn's Artesian Well, Manitowoc.	Oakton Spring, Pewaukee.	Siloam Spring, Milwaukee.	Schweickhardt's Spr. Wauwatosa.	Lowe's Springs, Palmyra.	Spring at East Troy.	Mineral Rock Spring, Waukesha.	Nemahbin Mineral Spring, Delafield.
Lime	.....	0.274	0.229	0.319	0.844	.....	0.126	0.115	0.127	0.119	0.099	0.117
Magnesia	.....	0.172	0.086	0.201	0.275	.....	0.064	0.073	0.049	0.066	0.067	0.045
Soda	.....	0.209	1.508	0.399	0.278	.....	0.043	0.011	0.032	0.011	0.022	0.029
Potash	.....	0.014	.....	0.066	0.007	.....	.....	.....	.....	.....	.....	.....
Lithia	.....	.....	.....	0.006	.....	.....	.....	.....	.....	.....	.....	.....
S. Ox. of Iron	.....	.....	.....	.....	.....	.....	.....	0.005	.....	.....	.....	0.001
Alumina	.....	.....	0.187	.....	.....	.....	.....	.....	.....	.....	.....	0.002
Silica	.....	0.041	0.123	0.024	0.020	.....	0.010	0.035	0.020	0.024	0.019	0.018
Sulphur. Acid	.....	0.113	0.146	0.138	1.492	.....	0.022	0.006	0.012	0.011	0.010	0.011
Nitric Acid	.....	.....	.....	0.409	.....	.....	.....	.....	.....	.....	.....	.....
Chlorine	.....	0.274	2.034	0.657	0.196	.....	0.010	0.003	0.014	0.004	0.003	0.012
Carbon. Acid	.....	0.370	0.328	0.253	0.190	.....	0.176	0.177	0.163	0.166	0.160	0.151
Org. matter	.....	.....	.....	.....	.....	.....	.....	trace	.....	.....	trace	.....
Combined as follows:												
Chl. sodium	0.015	0.432	3.353	0.417	.....	0.003	0.016	0.004	0.023	0.007	0.005	0.019
potassium	.....	0.026	.....	0.126	0.013	.....	.....	.....	.....	.....	.....	.....
lithium	.....	.....	.....	0.022	.....	.....	.....	.....	.....	.....	.....	.....
calcium	0.032	.....	.....	0.514	0.384	.....	.....	.....	.....	.....	.....	.....
Sulph. Soda	0.004	0.030	0.260	.....	0.638	0.011	0.050	0.010	0.021	0.019	0.017	0.019
potash	0.014	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
lime	.....	0.164	.....	.....	0.991	.....	.....	.....	.....	.....	.....	.....
magnesia	.....	.....	.....	0.205	0.824	.....	.....	.....	.....	.....	.....	.....
Nitrate soda	.....	.....	.....	0.643	.....	.....	.....	.....	.....	.....	.....	.....
Bicarb. soda	0.038	0.044	0.130	.....	.....	0.006	0.016	0.009	0.023	.....	0.022	0.021
lime	0.452	0.369	0.409	0.240	0.432	0.249	0.225	0.205	0.227	0.212	0.176	0.209
magnesia	0.328	0.361	0.180	0.281	.....	0.218	0.135	0.154	0.103	0.138	0.140	0.095
iron	0.012	.....	.....	.....	.....	0.010	.....	0.007	.....	.....	.....	0.001
Silica	0.022	0.041	0.123	9.024	0.020	0.013	0.010	0.035	0,020	0.024	0.019	0.018
Alumina	trace	.....	0.188	.....	.....	0.003	.....	.....	.....	.....	.....	0.002
Org. matter	0.043	.....	.....	.....	.....	0.004	.....	trace	.....	.....	trace	.....
Total	0.960	1.467	4.643	2.472	3.302	0.507	0.452	0.424	0.417	0.400	0.379	0.384

ANALYSES OF THE WATERS OF WISCONSIN — *continued.*

SUBSTANCES, IN 1000 PARTS.	Bethesda Spring, Waukesha.*	Magnetic Well, Watertown.	Artesian Well, Madison.	Lethean Spring, Waukesha.	Dousman's Trout Spr'gs, Waterville.	Hacket's Spring, Hale's Corners.	Milwaukee River, above the dam.	Wild's Artesian Well, Fond du Lac.	Harriman's Min. Spring, Appleton.	Lake Michigan, at Milwaukee.	Artesian Well, Court House Square, Sparta.*
Lime	0.096	0.108	0.082	0.099	0.101	0.079	0.067	0.063	0.034	0.048	0.043
Magnesia	0.059	0.060	0.059	0.050	0.039	0.050	0.049	0.040	0.027	0.017	0.018
Soda	0.024	0.012	0.037	0.028	0.025	0.015	0.005	0.061	0.043	0.002	0.005
Potash	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Lithia	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Sesqui Ox. of Iron	.....	0.002	0.006	0.002	.....	0.004	.....	.....	0.002	.....	0.005
Alumina	.....	0.002	.....	0.002	.....	0.002	.....	.....	.....	.....	.....
Silica	0.014	0.017	0.026	0.014	0.016	0.016	0.055	0.013	0.015	0.016	0.013
Sulphuric Acid	0.009	0.023	0.016	0.009	0.009	0.010	0.009	0.049	0.013	0.005	0.028
Nitric Acid	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Chlorine	0.008	0.002	0.007	0.007	0.011	0.002	0.002	0.045	0.004	0.003	0.007
Carbonic Acid	0.149	0.147	0.147	0.133	0.129	0.139	0.103	0.090	0.095	0.053	0.037
Organic Matter	.....	.....	.....	.....	.....	.....	trace	.....	0.011	.....	.....
Combined as follows:											
Chloride of Sodium	0.013	0.004	0.012	0.012	0.018	0.004	0.004	0.074	0.006	0.006	0.009
potassium	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
lithium	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
calcium	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.005
Sulphate of Soda	0.015	0.024	0.027	0.016	0.017	0.019	0.007	0.073	0.023	.....	.....
potash	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
lime	.....	0.013	.....	.....	.....	.....	0.009	0.010	.....	0.009	.....
magnesia	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.042
Nitrate of soda	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Bicarbon'e of Soda	0.020	.....	0.035	0.023	0.018	0.008	.....	.....	0.052	.....	.....
lime	0.171	0.183	0.145	0.170	0.179	0.151	0.112	0.105	0.076	0.079	0.072
magnesia	0.125	0.126	0.124	0.106	0.081	0.111	0.103	0.083	0.056	0.035	0.008
iron	.....	0.004	0.010	0.002	.....	0.006	.....	.....	0.003	.....	0.006
Silica	0.014	0.017	0.026	0.014	0.016	0.015	0.055	0.012	0.015	0.016	0.013
Alumina	.....	0.002	.....	0.002	.....	0.002	.....	.....	.....	.....	.....
Organic Matter	.....	.....	.....	.....	.....	.....	trace	.....	0.011	.....	.....
Total	0.358	0.373	0.379	0.345	0.329	0.316	0.290	0.357	0.242	0.145	0.155

Though we have none that can properly be classed as "salt water," nearly every one contains a small quantity of chloride of sodium (common salt), varying from a mere trace up to 0.423; the mean (omitting No. 3 as exceptional) being 0.052. It is believed that no salt bearing strata exist among the rocks of Wisconsin, and consequently that the production of salt can never become one of the resources of our people.

A few only of these waters contain potash in small quantities, in

* A more complete analysis of the water of the Bethesda spring will be found in the report on Eastern Wisconsin, and of the Sparta well in the report of Mr. Strong in a subsequent volume.

combination with chlorine. Epsom salt (sulphate of magnesia) is found only in two; sulphate of lime is equally rare, being only found in two cases. The very small amount of alumina is remarkable, where there is so much clay in the soil. The occurrence of chloride of lithium * and nitrate of soda is also an interesting variation in the composition of these waters, being only found in the well at Waterloo. Possibly the proximity of this locality to the quartzite (and perhaps other Archæan rocks) may have something to do with this variation.

The absence of nitrogen, ammonia, the bromides, iodides, etc., will be remarked by persons familiar with the composition of mineral waters.

In seeking for the cause of this unusual absence of mineral matter in our spring waters, we must remember that the geological history of Wisconsin differs essentially from that of other countries. A large proportion of the state is underlaid by rocks of Archæan age, an age the furtherest remote from the present, while the remainder is almost exclusively occupied by Silurian rocks, they being the oldest of the fossil bearing series. It thus appears that during all the ages of the Carboniferous, Permian, Jurassic, Triassic, Cretaceous and Tertiary periods, Wisconsin continued to be dry land, subject to the abrading and purifying action of rains and frost. This is still further attested by the wonderful amount of denudation our strata have sustained, and which it is made the duty of the survey to investigate. While the Alleghany and Rocky mountains were being uplifted from the depths of the sea, Wisconsin stood firm, always above its waters, always contributing of her substance for the accumulation of the sedimentary rocks of the adjoining states — contributions which she still continues to make.

During all these vast periods, each occupying an incalculable length of time, rains have continued to fall, the waters have continued to percolate through the soil and porous rocks, dissolving and carrying away all soluble substances. It is not therefore wonderful that by this time the waters of the state have an unusual degree of purity. Waters percolating through our limestones and sandstones can now absorb but small amounts of earthy or alkaline salts.

The waters now examined are chiefly from the southern and southeastern portions of the state, where the several magnesian limestones prevail; and hence they contain, as before stated, as chief ingredients, the carbonates of lime and magnesia, resulting directly from the de-

* By a typographical error, the quantity of lithium in the Waterloo water has been overstated; it is correctly given in the table above.

composition (aided by free carbonic acid) of these magnesian limestones. Whether the Archæan rocks further north will afford waters of a different class, as seems probable, remains to be determined in the further progress of the survey.

Waters percolating through the drift that so completely covers and conceals the rocks, are also found to contain chiefly lime and magnesia with smaller quantities of soda, chlorine, iron, etc. These elements are most usually combined with carbonic acid, and are the product of the solution of magnesian limestone almost everywhere existing in the form of boulders, gravel, or calcareous sand. If we take a limestone pebble from one of these springs, it will usually be found soft and much decayed upon the surface by the action of the waters, and it would be wonderful indeed if such waters should not contain lime, or if such rocks should not, in the course of ages, be dissolved and carried away. As the carbonate of magnesia is always associated with the carbonate of lime in the rocks, so it is in the mineral waters. In general, the waters are found to partake of the character of the rocks and soils through or over which they percolate or run.

The figures in this table show the number of parts in one thousand parts (by weight) of the water, which consist of solid matter that remains when the water is evaporated. If we do not care to consider minute differences arising from changes of temperature, and the specific gravity of the water, we have only to multiply the figures in this table by seven, to find the number of grains in one pint; this product being multiplied by eight will show the number of grains in a gallon. The table shows, without any change of the figures, the number of ounces in a cubic foot of the water.

This decimal system of stating the results of chemical analyses is adopted in all cases except in regard to mineral waters, where we often find only the number of grains in a pint, a quart, or a gallon. Americans were the first to adopt in currency and coinage this simple, convenient, easily comprehended and labor-saving system, and we should not be the last to apply it in other cases. Its benefits are international. If we give the number of grains of solid matter in a gallon of water, we use a language understood, perhaps, at home, but not anywhere else; but if we say there are so many parts in every thousand parts of water, we state a fact in a manner that is understood in every part of the world. There will be ten grains in every thousand grains; ten pounds in every thousand pounds; ten grams in every thousand grams; and the Frenchman, or the men of any other nation, will not have to search the encyclopedia to find the value of a grain or the size of a gallon in Wisconsin. No matter what the system of weights and measures may be in any other country, the decimal system is the same in all. The general tendency of our times is towards simplicity and international uniformity, especially in coinage, weights and measures, and hence the adoption of the decimal system should be encouraged in all proper ways.

Many of these waters, as well as many others not included in the table, are now known from the best of all tests, actual experience, to possess valuable remedial qualities, and they are annually resorted to by great numbers of invalids, who, with judicious treatment, are almost always benefited.

These analyses were all made by Mr. Bode, except No. 1, Richmond's, at Whitewater, made in 1873, by Dr. J. E. Garner, of Milwaukee, and No. 6, the Oakton Spring, at Pewaukee, made in 1872, by Dr. J. V. Z. Blaney, of Chicago.

Comparing these results with the analyses of other mineral waters, we are at once impressed with the small amount of mineral matter our waters are found to contain, only four having more than one part in one thousand; the average of twenty-two (No. 3 being omitted as exceptional) showing a mean of 0.657, or about two-thirds of one part only, in one thousand.

The slightest inspection of the table will show that the carbonates of lime and magnesia constitute the most prominent and important ingredients of these waters. These, with the carbonate of soda, present in many of them, bring the mineral waters of the state into the class of alkaline waters, and they are arranged in the table in accordance with the relative quantity of these salts, those having the most being placed before those having less. The average in the whole number (twenty-three) is 0.365, or a little more than one-third of one part in a thousand, and more than half of the total average total quantity of solid matter in these waters.

The purgative salts (sulphates of soda and magnesia) are found only in very small quantities, except in one case; the mean of nineteen waters (No. 5 omitted) being only 0.023.

Of the twenty-three waters, ten only, or less than half, contain iron, varying from 0.001 to 0.012, the mean being 0.006. This quantity, though apparently so small, seems to have very useful medicinal effects, and it suffices to discolor objects over which the waters run. Iron rust is deposited so freely from the waters of the several artesian wells at Sparta, that they are not used for cooking or for washing purposes.

Rain-Fall. — It is solely to the clouds that we are indebted for the supply of water, in the form of rain, hail and snow, to all our lakes, rivers, springs and wells. The underground rivers reaching from the Rocky mountains, or the highlands of Dakota, exist only in the imagination. Heavy or continuous rains cause the water to rise in the non-flowing artesian wells, in the same manner and for the same reason that the water in lakes, rivers and ordinary wells rise under the same circumstances. In dry weather, or during continued cold weather, when the falling water ceases to penetrate the soil, the reverse takes place, the waters of lakes, rivers and non-flowing artesian wells fall below their average height. Springs are subject to the same variation to a considerable degree; it is only those that have their sources at considerable distances that show but little or no variation during the changing seasons.

The mean monthly and annual amount of rain-fall, at any given locality is, therefore, an item of great importance that will often be needed in the prosecution of the survey, and hence I contribute the following table, the result of many years of patient labor. It will thus be made accessible to engineers, agriculturists and meteorologists, who will often have occasion to use it.

The table shows the monthly and yearly amount of rain and melted snow at Milwaukee, latitude 43° 3′ N., longitude 87° 56′ W. The observations for the years 1843–48 were made by E. S. Marsh, M. D.; for 1855–59 and for 1872–73, by Mr. Charles Winkler; for all the other years by I. A. Lapham.

TABLE OF RAIN-FALL AT MILWAUKEE.

MONTHS.	1841.	1843.	1844.	1845.	1846.	1847.	1848.	1849.	1850.
January	0.80	....	1.67	1.30	1.92	1.06	**0.91**	1.20	0.75
February	**0.33**	....	**0.35**	1.73	0.80	1.25	1.12	**0.37**	0.38
March	2.26	....	1.66	1.35	1.24	1.40	1.94	2.31	2.85
April	1.47	....	3.15	1.15	**5.33**	2.12	1.20	3.24	2.24
May	1.78	....	4.20	0.78	1.33	3.53	3.60	4.08	**0.28**
June	6.13	....	**5.34**	3.22	4.05	1.75	4.33	3.73	1.98
July	3.72	0.86	5.05	3.81	3.18	1.43	2.70	2.36	1.99
August	3.85	3.37	3.85	0.80	0.90	1.42	**5.10**	3.54	**9.03**
September	**7.02**	1.57	0.99	**4.92**	3.27	2.35	2.73	1.25	1.73
October	1.23	1.29	1.74	0.93	**0.30**	**0.83**	3.50	3.07	1.00
November	1.70	2.79	1.46	**0.24**	1.68	**4.37**	2.50	**5.00**	2.80
December	4.03	0.85	3.04	0.31	1.26	0.94	3.89	0.94	1.43
Winter	....	....	2.87	6.07	3.03	3.57	2.97	5.46	**2.02**
Spring	5.51	....	9.01	**3.28**	7.90	7.05	6.74	9.63	5.37
Summer	13.70	....	**14.24**	7.83	8.13	**4.60**	12.13	9.63	13.00
Autumn	9.95	5.65	4.19	6.09	5.25	7.55	8.73	9.32	5.53
Year	34.32	....	32.50	**20.54**	25.26	22.45	33.52	31.09	26.41

TABLE OF RAIN-FALL AT MILWAUKEE — *continued.*

MONTHS.	1851.	1852.	1854.	1855.	1856.	1857.	1858.	1859.	1860.
January....	0.89	1.13	....	4.05	2.00	**0.10**	2.15	1.10	0.53
February ..	2.51	1.00	.. ....	**1.20**	1.00	1.85	**1.46**	1.20	1.40
March	**0.37**	4.56	1.33	1.86	**0.15**	1.20	2.11	4.42	**0.33**
April	1.47	2.64	2.07	1.80	3.10	3.69	5.15	**4.57**	**0.33**
May.......	**6.85**	1.95	3.73	1.45	3.04	**4.60**	**8.51**	3.62	1.34
June.......	4.43	2.46	5.76	3.68	4.13	3.41	4.08	3.97	**4.15**
July.......	3.37	3.27	**6.15**	5.56	2.26	3.14	3.86	2.08	1.95
August	3.15	**0.58**	0.97	3.09	0.91	3.01	2.15	**0.27**	2.80
September .	2.92	2.30	2.81	**6.88**	2.70	2.73	3.92	2.35	2.50
October....	1.32	**4.87**	3.60	2.01	2.48	3.96	4.59	1.52	2.09
November..	2.08	2.72	**0.43**	1.85	**4.42**	1.50	4.95	3.12	2.61
December..	1.04	1.85	2.03	2.61	2.83	1.70	1.93	0.64	1.99
Winter	4.83	3.17	....	7.28	5.61	4.78	5.31	4.23	2.57
Spring.....	8.69	9.15	7.13	5.11	6.29	9.49	**15.77**	12.61	4.00
Summer ...	10.95	6.31	12.88	12.33	7.30	9.56	10.09	6.32	8.90
Autumn ...	6.32	9.89	6.84	10.74	9.60	8.19	**13.46**	6.99	7.20
Year.......	30.40	29.33	....	36.04	29.02	30.89	**44.86**	28.86	24.02

MONTHS.	1861.	1862.	1863.	1864.	1865.	1866,	1867.	1868.	1869.
January....	2.15	3.41	3.33	2.15	0.22	2.58	2.61	1.29	2.51
February...	3.34	**0.48**	1.85	0.42	3.58	1.64	2.13	0.92	2.76
March	1.53	2.10	2.48	2.52	3.89	1.50	1.81	4.59	1.17
April	3.65	**5.34**	1.04	3.01	1.96	3.04	1.73	2.97	3.90
May.......	4.32	5.11	5.21	2.74	1.11	2.06	**4.39**	2.05	4.77
June.......	1.80	3.86	**0.79**	**0.15**	3.57	4.83	2.04	**5.78**	**7.67**
July	**4.87**	4.09	2.41	**7.07**	1.78	2.73	2.60	3.73	2.76
August....	2.21	2.94	2.62	0.61	4.34	3.95	2.01	1.85	3.70
September..	3.39	5.03	1.02	2.93	**4.67**	4.55	1.46	**0.90**	1.97
October	**1.48**	3.26	2.97	1.63	4.13	2.76	**0.80**	1.18	**0.46**
November..	1.59	1.28	3.15	2.61	**0.31**	1.32	1.53	3.23	3.35
December..	1.55	1.37	**4.57**	1.99	0.52	3.00	1.51	0.88	2.79
Winter.....	7 48	5.44	6.55	7.14	5.79	4.74	**7.74**	3.72	6.15
Spring.....	9.50	12.55	8.73	8.27	6.96	6.60	7.93	9.61	9.84
Summer....	8.88	10.89	5.82	7.83	9.69	11.51	6.65	11.36	14.13
Autumn....	6.46	9.57	7.50	7.17	9.11	8.63	**3.79**	5.31	5.78
Year.......	31.88	38.27	31.80	27.33	30.08	33.96	24.62	29.37	37.81

TABLE OF RAIN-FALL AT MILWAUKEE—*continued.*

MONTHS.	1870.	1871.	1872.	1873.	No. of Years.	Mean.
January	2.37	3.14	0.57	2.39	29	1.73
February	1.32	1.32	**0.36**	1.50	29	1.36
March	**5.01**	2.75	0.80	1.48	30	2.10
April	**0.51**	**3.30**	2.50	2.70	30	2.68
May	0.63	2.24	3.10	4.89	30	3.24
June	2.62	3.03	4.42	3.40	30	3.69
July	4.64	1.84	1.93	1.82	31	3.20
August	2.69	3.77	2.64	**5.26**	31	2.82
September	2.10	**0.60**	**8.87**	2.57	31	3.07
October	1.99	2.72	0.82	2.12	31	2.15
November	0.94	2.40	1.80	**1.40**	31	2.31
December	1.79	2.03	1.00	2.81	31	1.91
Winter	6.48	6.25	2.96	4.89	....	5.00
Spring	6.15	8.29	6.40	9.07	....	8.02
Summer	9.95	8.64	8.99	10.48	....	9.71
Autumn	5.03	5.72	11.49	6.09	....	7.53
Year	26.61	29.14	28.81	32.34	....	30.27

This table shows that the rain in Wisconsin is generally very well distributed through the several months, seasons and years; the general average for thirty-one years being 30.27 inches, varying from 20.54 in 1845, to 44.86 in 1858; the greatest amount in any one month was 9.03 inches in August, 1850, and the least 0.10 in January, 1857. The most rain upon an average falls in June; the least in February; the three months of summer have been supplied, upon the average, with the most rain, the three months of winter, the least; while the spring months have a little more than those of autumn.

During nearly half the years covered by the table the rain-fall differed but little from the general mean; while nine were considerably in excess, and eight were supplied with less than 28 inches.

From the published results of observations collected by the Smithsonian Institution, it appears that the average rain-fall at about twenty stations in Wisconsin, or on its immediate border, was about three inches more than at Milwaukee.

The annual supply of falling water, as shown by this table, is equivalent to a sheet of water two and three-fourths feet deep, spread evenly and uniformly over the whole area of the state. The most careful investigations have shown that this is sufficient to account for the outflow of all our lakes, rivers and springs; the total quantity thus carried away being, in our climate, found equivalent to only about one-fourth of the total rain-fall. The remainder is evaporated, and thus returned to the atmosphere, either directly from the surface, or after having performed service in the growth of plants. The quantity of water absorbed by the roots of plants, with its mineral contents, and then evaporated from the leaves, is enormous.

Rain water soon penetrates the soil and finds its way through crevices and pores of the more solid rock strata, down to very considerable depths, dissolving such substances as are soluble and carrying them to distant places. It is here we must look for the origin of all mineral waters, and for the cause of a large share of the denudation which in the lapse of many ages has become so very considerable.

Knowing this annual quantity of water-supply and outflow, with the amount of mineral matter it carries, we lack only a knowledge of the amount of matter mechanically suspended in running water, derived from the loose soil and from abraded rocks, to be able to calculate the time required for the excavation of any given valley whose dimensions are known.

The gradual decay and wearing away of rocks is not confined to the limestones and softer rocks, but includes many of the older and harder kinds, especially such as contain feldspar and similar minerals. Rocks are always penetrated with water and they hold in their pores an average of five or six per cent. by weight; a hundred pounds being capable of absorbing five or six pounds of water. As the clouds afford a constant supply which is continually removed in underground currents, springs and rivers, carrying with it the mineral matter taken up, we have a perpetually recurring cause of geological change. During the progress of water through the different rocks, meeting with different chemical elements, many chemical changes probably occur in the substances taken up, and it is only the final result of all these changes that we find in the mineral spring as it appears at the surface. Any considerable change of the course of the water among the rocks would, therefore, lead to changes in the composition or combination of ingredients it contains.

Water when pure has but little power to dissolve mineral matters, but when combined with carbonic acid, this dissolving power is very much increased. When waters holding these substances reach the open air they give off the excess of carbonic acid, and hence, by losing a portion of their dissolving power, become unable to hold them, and they are deposited forming a coating to sticks and stones over which they may run.

If this deposit consists chiefly of lime, and accumulates with considerable rapidity, such springs are known as petrifying springs, or lime springs, of which we have many examples. The deposit often forms considerable conical mounds surrounding the spring; and moss, leaves, shells, sticks, etc., are often incrusted in such manner as to preserve beautifully their peculiar markings.

In many cases the oxide of iron is thus thrown down, discoloring everything over which the water runs. The quantity of iron thus deposited does not depend so much upon the absolute quantity of iron in the composition of the water as upon the feebleness with which it is held in solution. Such springs are called chalybeate, or iron springs.

Sulphuretted hydrogen, which gives the sulphur taste and odor to many springs, is supposed to result from the decomposition of organic (animal or vegetable) matter — mostly of vegetable origin. Such springs are called sulphur springs, and we have several examples in the state.

The rock strata are clearly shown, by the evidence of marine fossil shells and corals, to have been originally deposited in the waters of an ancient sea, from which they have been elevated to form our present continent; and it is not, therefore, wonderful that they should yield to the percolating waters those elements which we find in mineral waters. The supply might be supposed to diminish as ages pass by, but never to become exhausted.

All natural waters may be regarded as "mineral waters" — for none are absolutely pure. Indeed it is probable that *pure* water, such as can only be obtained by careful distillation, would not sustain either animal or vegetable life. Even rain water is found to contain minute quantities of salt, of ammonia, soda, lime, and organic matter, with traces of many other substances. It is mainly from the mineral matters dissolved in water that plants derive their solid materials constituting the ash. The silica, though small in amount in water, is of great importance to the growth of plants, especially the grasses, including the cereals, etc.; all our waters contain silica.

Springs, whose sources are near the surface, are apt to contain matters resulting from the decay of organic matter, and other deleterious material. Those which come from greater depths, and have passed over greater distance, are supposed to be of greatest value; the organic matter having been absorbed in passing through the soil and rocks. Such springs usually assume a temperature showing little change from winter to summer, and which correspond, with the mean annual temperature of the place.

Several of these waters, notably those of Fond du Lac, Sparta, and Watertown, are known as magnetic; the iron tubes through which they flow, possessing the magnetic property in a high degree. Whether this magnetic quality has any medicinal value remains yet to be determined. A French savan has endeavored to demonstrate that the medicinal value of mineral waters is mainly due to their electrical condition; and the subject is well worthy of investigation by those most interested in it; and those who have the opportunity.

There are, in this state, many other springs and wells, not included in the table above, that have been brought to the notice of the public for their medicinal virtues; among them the following, all at Waukesha: Hygiene, Mount Horeb, Barstows, White Rock, and Fountain Springs.

Progress has been made towards the compilation of a list of all the more important springs, including those noted as petrifying (lime), chalybeate, sulphur springs, etc., and also such as are of sufficient capacity to supply ponds for the artificial rearing of fish.

The investigation of mineral waters cannot be said to be complete without a determination of the gaseous matters they contain, for these may materially modify the medicinal or other effects of the solid ingredients. This can only be done at the spring, with water taken at the moment it reaches the open air.

Relation of the Geological Survey to Agriculture. — The law providing for a geological survey of the state of Wisconsin, includes also, and very properly, provision for some work for the special interest of agriculture; it being now generally known and admitted that these two subjects are so intimately related, that whatever is done to increase our knowledge of the local and special geology of any district tends, at the same time, to promote the interest of the farmer cultivating land in the same district. The underlying rocks are examined as to their chemical composition, and surface arrangement or geographical extent; they are the sources from whence is derived the very soil into which the farmer annually intrusts his seed. Their dip, order of succession, depth beneath the surface, their porous or impervious nature; these are the data for deciding about artesian or other wells, often the only resource for a permanent supply of water for farm purposes; and as the forests become reduced in extent, the necessity for such wells will be gradually increased. The drift phenomena, gleaned from an extended and careful study of the loose materials covering and concealing the more solid rocks, left here by the glaciers of the ice period, the study of which is so interesting to the practical and speculative geologist, have been the means of diffusing and spreading the soil over the rocky surface, commingling and mixing the various clays, sands, and pebbles, derived from the disintegration of the rocks, in such manner as to render them the best suited for the growth of vegetation. The mineral and other native resources are discovered and made known; they are the material for various manufactures, and their development creates a home market — the best of all markets — for farm products; thus deciding the great question, now so much agitated, relating to cheap transportation, by avoiding the necessity of any transportation of these products.

The barometrical measurements of the heights and depressions, required of the survey, will show in many cases the sources of water supply upon which we are dependent for this life-giving element. These are taken as data in the topographical survey, which is to show the general contour of the ground, the extent, elevation, and slope of drainage basins, or river valleys; the amount and value of water power afforded by these rivers; the proportion of timbered, open, and prairie land; the uplands, the swamps, and marshes; all such detailed information is of importance to various interests, and especially to the agriculturist. The geodetic survey, which has, through the instrumentality of the geological survey, been extended into Wisconsin by the general government, will also aid in the development of the topographical features of the state, and will show with greater accuracy the exact position of the principal lines of the government surveys, from which are derived and established the boundaries of farm lands, thus often preventing litigation and neighborhood quarrels.

It is further made the duty of the survey to search for and properly examine all mineral fertilizers that may exist in the state; to analyze the clays, peats, marls and other natural products useful, either in maintaining the richness of the soil or of restoring it when exhausted by the injudicious management of ignorant and selfish men. The soils and subsoils are to be made subjects of study, and observations are to be made upon the animal and vegetable products with reference to their agricultural interest. Specimens are to be collected exemplifying the geology of the state, which are to be deposited with the various institutions of education, from which the youth of our state may hereafter acquire that more definite knowledge of our local geology which will enable them to prosecute their future labors in farming with greater advantage both to themselves and to the country.

It is now very generally admitted that the chemical analysis of soils does not lead to all of the beneficial results that were formerly anticipated from this source. The healthy growth of farm crops is dependent upon too many varying conditions, besides the mere quantity of plant-food that may exist in the soil, to enable the chemist to detect the cause of any given failure, by soil analysis. It was once supposed that we had only to analyze a soil before and after a crop has been taken from it, to detect the substances that had been abstracted, and thus indicate what should be artificially supplied to stimulate the growth of the next crop; but such is the minuteness of the quantity of plant-food compared with the mass of the soil, that chemical science has not yet, except to a limited extent, been able to accomplish this task. Consequently no general effort will be made to analyze the soils of the state; but if any are found, that, from any special peculiarity or other reason, seem to require it, such analysis will be made.

Geology is now very properly included among the studies to be pursued in agricultural colleges, with a view to its special advantages in the proper cultivation of the soil — a cultivation which shall, without the least diminution of its annual product, perpetually maintain its fertility. Every farmer should know whether his land is underlaid by rocks whose disintegration is beneficial or otherwise; whether these rocks are of the granitic kinds, or whether they consist of sandstone, limestone or shales. He should also be able to determine the nature of the pebbles, small and large, abounding in his fields, the gradual decay of which, from year to year by reason of exposure to weather changes — frost, rain, sunshine and alternate exposure to heat and cold — will add useful or useless, or even deleterious qualities to the soil. Limestone pebbles especially, by their gradual disintegration, are of the greatest value by restoring fertilizing substances to the soil that would otherwise soon be exhausted by continual cropping. If these pebbles are of such quality as to be thus beneficial, the land possesses additional value; if otherwise, a larger annual expense for fertilizers will be required. The system of farm management, suited to the one case, would require modification for the other. Hence it is sufficiently apparent that some knowledge of geology is quite essential to the intelligent farmer, and that it is wise to include it in a course of studies to be pursued in our agricultural colleges.

The several reports to be made to the governor annually in January, though chiefly intended to make known the progress and results of each year's work, will be found to contain much that is of interest to the farmer. The publication and general distribution of reports of geological surveys always prove beneficial, by calling public attention, in an official and reliable manner, to the resources and advantages of the district surveyed, for the agricultural, manufacturing and other interests.

LIST OF MAPS

Accompanying the First Annual Report of the Wisconsin Geological Survey, 1873.

A map of the state (published by Silas Chapman) on a scale of six miles to an inch, showing in colors the boundaries and extent of the several rock formations so far as is known up to the end of the year 1873. On four sheets.

A map of the Muscalonge diggings in Grant county, on a scale three chains (198 feet) to an inch.

A map of Ashland county and another of Douglas county, on a scale of two miles to one inch, showing the geological features and mineral ranges in those counties; also a map of the Apostle Islands; to accompany the report of Prof. R. D. Irving.

A map in two sheets on a scale of two miles to an inch, showing the geology and topography of the region surveyed by Prof. T. C. Chamberlin, from the state line in Walworth and Rock counties to Keshena, in Shawano county. Also two maps, on a scale of six miles to an inch (based upon Mr. Chapman's map); one showing the distribution of vegetaticn, etc., the other representing the areas occupied by the different kinds of soil in the same region. These maps accompany the report of Prof. Chamberlin.

Geological Map of the Lead Region (in part) on six sheets, to wit:

1st. Ranges two and three east from three miles south of the state line to Mineral Point, being townships No. one, two, three and four, in those ranges.

2d. Townships four and five in ranges one to six west, inclusive.

3d. Townships four and five in ranges one to five east, inclusive.

4th. Ranges two and three east, in townships five to nine, inclusive.

5th. Ranges two and three east, in townships ten, eleven, twelve and thirteen.

6th. Ranges five and six east, from township five to the Wisconsin river in township nine.

Topographical Map of the Lead Region (in part) on two sheets, to wit:

1st. Ranges two and three east, in townships one to six, inclusive.

2d. Townships four and five in range one east, and ranges one to six west, inclusive.

These maps are all upon a scale of one mile to an inch.

A geological, topographical and subterranean map of the Blue Mounds and the Brigham Lead Mines, on a scale of one to twenty thousand.

All these maps in the lead region accompany the report of Mr. Moses Strong.

All of which is respectfully submitted.

I. A. LAPHAM,
Chief Geologist.

MILWAUKEE, *January, 1874.*

PLATE. IA.

The Milwaukee Litho & Engr. Co.

POTSDAM SANDSTONE,

Showing False Bedding, Dalles of the Wisconsin.

REPORT OF PROGRESS AND RESULTS,

FOR THE YEAR 1874.

BY I. A. LAPHAM.

During the past year the same parties have been in the field as in the preceding year, and in addition a party under the charge of Maj. T. B. Brooks, late of the Michigan Geological Survey, as will be mentioned in a subsequent part of this report. I am glad to be able to state that the survey is progressing with reasonable rapidity; the amount of work done being considerably in excess of that of 1873.

The first annual report of progress and results of the survey was deposited in the office of the governor on the first Monday in January, 1874, with ample maps and illustrations, accompanied by the reports of the several assistants. It was found impracticable to complete the reports of explorations made by the several parties in 1873, in as full detail as is desirable, in time to be presented to the governor on the day required by law. They were accordingly presented in an unfinished condition, with the expectation that additional matter could be annexed when prepared. By a law, approved March 4th, 1874, it was provided that the manuscript report of the geological survey then made, with the maps and drawings, should be bound and preserved in the vaults of the office of the secretary of state at Madison; hence all such additional matter is necessarily excluded, and is herewith submitted in the form of supplementary reports.

For greater convenience in binding and in future publication, it was decided to make all sections, drawings, and maps, so far as was practicable upon sheets of uniform size; and rules were adopted to secure uniformity in respect to the position of maps and profiles upon the sheets.

Tracings from the township plats of the government land survey were furnished to the several parties as needed; and as before, they were greatly assisted by the published maps of the several counties.

These are especially valuable as showing the location of the public roads, usually from actual survey.

The specimens collected during the year, for study and comparison, with the duplicates intended for the Academy of Sciences, University, colleges, and normal schools, now amount to a very considerable number, requiring much room and involving some expense for their storage and proper arrangement for convenient reference in making up the reports.

Nearly five hundred townships (about one-third of the total area of the state) have now been examined, with more or less minuteness, by the several parties, as follows:

By Prof. Irving in 1873,	45	townships.
1874,	98	"
By Prof. Chamberlin in 1873,	75	"
1874,	130	"
By Mr. Strong in 1873,	50	"
1874,	66	"
By Maj. Brooks in 1874,	17	"
By Mr. Ives in 1874,	7	"

Several of the aneroid barometers purchased for the survey, having been found to be imperfect and useless, others of better quality, which have proved quite satisfactory, were obtained directly from the makers in London, England.

Prof. R. D. Irving's Party. — Prof. Irving was directed to make such explorations and surveys as would enable him to construct a geological map and section along a line extending from the south part of Dane county, northward, through portions of Columbia, Adams, and Wood counties, to Grand Rapids, and thence up the Wisconsin river to Wausau; the breadth occupied to embrace two or three ranges of townships; thence along the southern boundary of the Archæan rocks in Wood, Clark, and Jackson counties, he was to extend his work westward to the Black River Falls; the details of this important locality having been previously examined by him. This route would enable him to determine many important questions, in a portion of the state heretofore but little known geologically; especially in regard to the quartzites, conglomerates, and other rocks of the Baraboo river; the sandy region north of Portage; the kaolin beds; the Mosinee hills; and the reported localities of iron ores. As the iron ores of Lake Superior and the Menomonee region extend through considerable distances, it was hoped that there might be a similar range of ore beds extending eastward from Black River Falls; a very important question that might be determined, by the explorations thus to be made.

Before commencing the field-work of the season, Prof. Irving prepared the supplementary report herewith submitted, embracing details of results attained in 1873, which, for want of time could not, as before stated, be included in his general report for that year, now deposited in the office of the secretary of state. This supplementary report, covering seventy-four pages of manuscript, with several maps, diagrams and sections, will be found to contain much additional matter relating to the geology of Douglas, Bayfield and Ashland counties.

The rocks in this part of the state are referred to five different periods, as follows:

1st. Laurentian — Granite, etc.
2d. Huronian — Iron-bearing series.
3d. Copper-bearing rocks.
4th. Potsdam sandstone.
5th. Quaternary — Drift, etc.

Many facts and arguments are adduced to show that this is the proper order of arrangement, and ample details are given, so that geologists may judge of the correctness of these views.

Prof. Irving has been able to show the existence of a synclinal axis extending in a southwesterly direction, through these counties, being the westward inland extension of the great trough between Keweenaw Point and Isle Royale, occupied mostly by the waters of Lake Superior. We thus have a more clear understanding of the different directions assumed by the dip of the rocks at different localities, and are brought to a knowledge of one of those grand movements in the remote past, by which the solid rocks have been folded, contorted, and lifted to their present complicated positions. To understand these ancient disturbances of the strata is not only a matter of interest in speculative geology, but is also one of the greatest practical importance to the miner and to all having occasion to deal with these rocks.

It will be seen that the Copper-bearing rocks are Pre-Silurian, though not as old as the Huronian. Prof. Irving's conclusions on this point are that:

1st. "The beds of the Copper-bearing series and those of the Huronian were once spread horizontally over one another, including the whole series of tilted sandstone on the Montreal river; they were disturbed by the same force, and received their present tilted positions at the same time, as evinced by the entire conformability of the two series.

2d. "The horizontal sandstones of the Apostle Islands, and the west end of Lake Superior, were laid down subsequent to this tilting, and also to an immense amount of erosion; and the sandstones of eastern Lake Superior were formed at the same time. These points are proved by (1) the occurrence of horizontal sandstones in immediate proximity to tilted sandstones and traps, in Ashland county; (2) the occurrence of the same in the Apostle Islands, within but a few miles of the tilted beds of the Montreal; (3) the actual contact of the horizontal sandstones with the melaphyrs of the Copper-bearing series in Douglas county; and (4) similar and additional facts observed by Messrs. Brooks and Pumpelly in the upper peninsula of Michigan.

3d. "That hence the Copper-bearing rocks should rather be classed with the Archæan than with the Silurian rocks."

Under the head of "Economic Geology," Prof. Irving discusses the questions regarding the probable existence of copper, silver, etc., with an account of the attempts heretofore made in mining for these metals.

Accompanying this supplementary report, Prof. Irving has furnished for preservation, a transcript of notes made by him in 1873, on the iron ores and iron mounds at and near Black River Falls, in Jackson county, with the analyses of the ores, so far as they have been finished; these are to be used in compiling a final report, when the survey in that neighborhood is completed. From these notes it appears that there are no less than nine different beds of iron ore interlaminated with slates, crossing the river at various points, within a distance of less than two miles, and that there are seven prominent mounds, consisting chiefly, or largely of iron ores, with slates and quartz. Several analyses already completed, indicate 26 to 32 per cent. of metallic iron, associated chiefly with silica. The slates are supposed to be of Huronian age, resting upon gneissoid granite below, and covered unconformably by the Potsdam sandstone.

There are indications of a great lapse of time, and of very considerable erosion after these slates were hardened into rock and elevated to their present position, but before the deposition of the Potsdam sands. Specimens were obtained near the mouth of Snow creek, showing the junction of the sandstone with the Huronian slaty ore, in a very interesting manner; some of the horizontal and some of the inclined layers being seen in the same hand specimen.

These notes are accompanied by a map showing the occurrence of the mounds, and another showing the position of the iron beds along the river above the falls, with diagrams illustrating the same.

Prof. Irving's party took the field in the latter part of April, and continued until the portion of the appropriation allotted to this service was exhausted in September. Some work had previously been done near Madison. The services of Mr. E. T. Sweet were again secured, and proved to be altogether satisfactory. On the 26th of June the party had reached Lodi, and soon after, Portage, where Prof. James H. Eaton, of Beloit, joined it in the explorations of the quartzites of Columbia county. He continued with the party until near the close of the season. At Grand Rapids the party had an interview with Prof. Davenport Fisher, of the Naval School at Annapolis, who had made and furnished to the survey an analysis of the kaolin of that place. In September Prof. Irving and Mr. Strong met in Jackson county, and by conference, were enabled to determine some results beneficial to the survey.

Reference to the report of Prof. Irving, herewith submitted, will show the progress he has made, and the results, so far as they have been worked up, at the present time. In this report will be found much detailed information of local interest and importance, regarding the dip, thickness and economic value of the several rocks, and its publication cannot but be useful to the citizens of the state as well as to the scientific geologist. With the aid of the map and sections, all these details may be clearly understood, even by persons not familiar with the science of geology generally.

The interesting fact is pointed out that the boundaries of the prairies, as laid down upon the government plats, correspond, in a general way, with the boundaries of the geological formations — another instance of the bearing one study may have upon another. The nature of the soil, derived directly from the rocks, has much to do with the distribution of trees and other plants over the earth's surface, and hence we find the native flora considerably modified by the rocks of the several geological districts.

The artesian well at the state house, Madison, disclosed the Archæan character of the rock immediately below the Potsdam at that place, and gives probability to the suggestion that our whole state is underlaid by these rocks at no great depth.

REGISTER OF THE ARTESIAN WELL IN THE CAPITOL PARK, MADISON.

Above level of the Ocean.		Thickness.	Depth from Surface.	Above level of Lake Michigan.
	SOIL.			
926	Top of well	....	....	348
918	Soil and clay	8	8	340
	DRIFT.			
858	Sand and boulders	60	68	280
846	Gravel	12	80	268
829	Clay and laminated rock	17	97	251
824	Grayish-brown rock (boulder?)	5	102	246
804	Indurated clay (quite compact)	20	122	226
800	Rock (boulder?)	4	126	222
	POTSDAM SANDSTONE.*			
745	Sandstone gravel, quite loose, white and yellow, no cement or coherence	55	181	167
671	Loose, white, uncemented sand, with layers of yellow sand	74	255	93
661	Bottom of tubing	10	265	83
166	White sandrock, grains sharp, but always somewhat rounded, with occasional layers of grayish color, the whole cemented sufficiently to preserve the sides of the well. Sample from 700 feet below surface showed under microscope very much rounded grains of limpid quartz, some perfectly pure, some stained in spots with oxide of iron	495	760	—412
131	White quartz sandrock of finer grain, mixed with a substance resembling porcelain	35	795	—447
122	Red clay-like powder, very slightly gritty, under highest power appears to be mostly very fine quartz sand.	9	804	—456
120½	Coarse, dark, reddish-brown powder, mostly very much rounded quartz grains, but mingled with some dark, opaque grains also rounded, belonging therefore with the mechanical rocks	1½	805½	—457½
	ARCHÆAN.			
98	Dark grayish mixed rock, very hard to drill, coming up in quite large fragments all angular; carries patches of a greenish cleavable mineral; sp. gr. of rock, 2.76; hardness, 5; fuses at about 3 to a black bead. The included mineral (prehnite) is cleavable and semi-translucent, and fusible at 3.5 to 4 to a white enamel.	22½	828	—480
89	Crystalline rocks (work suspended)	187	1015	—667

The numerous artesian wells, though not always successful in affording water, show very important results in regard to the rock strata far beneath the surface. The recent discovery of native copper and silver in the well at Kilbourn City, at the depth of 516 feet,

* Possibly this should stand next before the gravel, depth 80 feet.

must be deemed one of no inconsiderable interest, being the first indication of the existence of these metals (uncombined) in the central or southern part of the state. Whether they exist at this place in quantity sufficient to be profitably mined can only be determined by sinking a shaft to the depth indicated. The copper-bearing rock was exceedingly hard, and had a depth of eighteen feet. Until we know the dip of this rock, it will be impossible to ascertain its real thickness; if the stratum lies horizontally (which is not very probable), it has a thickness of eighteen feet; if it has a dip of 45° or more, its thickness is only thirteen feet or less. It is not improbable that when the proper trend of these rocks can be found, a search in the right places may lead to further discoveries of importance. The top of this well is 347 feet above Lake Michigan; Archæan rocks were reached at 118 feet below; total depth of the well (December, 1874) 840 feet.

One of the first results of Prof. Irving's survey of Dane county was the identification of a hitherto unrecognized layer of sandstone, far down in what has been classed as Lower Magnesian limestone; to this, in accordance with the custom of geologists, he has given the local name of "Madison Sandstone." It is much used in and about Madison as a building stone. That portion of the Calciferous or Lower Magnesian limestone series lying below the Madison Sandstone, and down to the Potsdam, forms the immediate shore of Lake Mendota (4th lake), and has with much propriety been named the "Mendota Limestone" in the report. This explains some anamolous sections heretofore made, and introduces two new names into the local geological nomenclature.

We thus find additional resemblance between the formations in Wisconsin and those in Missouri, where Prof. G. C. Swallow long ago recognized, and arranged under the head of "Calciferous sandstone or Magnesian limestone series," seven different members, which may now be parallelized with our strata as follows:

MISSOURI.	WISCONSIN.
First Limestone, 190 feet.	Buff Limestone, 50 feet.
Saccharoidal Sandstone, 125 feet.	St. Peters Sandstone, 100 feet.
Second Limestone, 230 feet.	Main Beds, 80 feet.
Second Sandstone, 70 feet.	Wanting.
Third Limestone, 350 feet.	Wanting.
Third Sandstone, 50 feet.	Madison Sandstone, 35 feet.
Fourth Limestone, 300 feet.	Mendota Limestone, 30 feet.
Potsdam Sandstone.	Potsdam Sandstone.

Prof. T. C. Chamberlin's Party.—Before entering upon the field work, Prof. Chamberlin completed his report of the work done in

1873, by sending a supplementary report, which, as above explained, could not be prepared in time to be bound with the matter previously reported by him. This supplementary matter is therefore herewith submitted, and will be restored to its proper place in the preparation of the final report, as contemplated by section five of the law authorizing the survey.

In this report will be found many details with respect to the Lower Magnesian limestone, as it occurs in the northeastern part of the state, showing much the same general characteristics as in the southwestern counties. It is interesting to note the occurrence of a considerable fault in the strata in the town of Ellington (T. 22, R. 16 E.), such dislocations being rare in Wisconsin. To this we may attribute some very marked peculiarities in the hydrography of that vicinity.

Wherever mining has been prosecuted in search of gold, silver, copper, etc., examination of the rocks gave little indication of the presence of these metals; and it has very often been the business of the survey to discourage the search for ores in places where they are not to be found. Copper-mining at Berlin and gold-mining at Winneconne are among the projects thus discouraged.

The quartzites of Portland, Dodge county, and some new localities discovered in adjacent portions of Jefferson county, are fully described. Several other outcrops of Archæan rocks are described — as at Berlin, Mukwa and Keshena.

The important subject of artesian wells is also fully discussed in this report, giving many details that will be of great value in the future operations of well-digging.

It was deemed most conducive to the public interest to direct Prof. Chamberlin to continue his survey from Beloit along and near the south line of the state to Lake Michigan, and thence northward between his line of operations in 1873 and the shore of the lake. Though much covered with drift, it was hoped that a sufficient number of outcrops of rock could be found to reveal the general geological character of this district, and perhaps develop some new and interesting facts in regard to this portion of the state. Funds were supplied him for expenses of the field-work on the first of May, and the work commenced soon afterwards. By the last of August this party was able to reach the extremity of the peninsula between Lake Michigan and Green Bay, at "Death's Door," and to commence the return trip, in which some points of special interest were reëxamined, and many new localities visited. Active duties in the field were brought to a close in October. The services of Messrs. L. C. Wooster, G. D. Swezey, and J. H. Chamberlin were secured during portions of the season;

and Mr. F. H. King was engaged to continue his observations upon animal and vegetable life, such as are required by the provisions of the law authorizing the survey. Two thousand five hundred miles of travel with a team; seven thousand specimens of rocks, fossils, and minerals collected; these are justly deemed a good season's work.

Prof. Chamberlin's report of his operations during the year 1874 will be found to contain ample details of the geology of the district assigned to him. These will settle many questions as to the non-occurrence of coal and other useful minerals, which are dependent upon the kind of rock found. The difficulty of determining the proper order of succession of the various strata, with their general dip and strike in a region where outcrops can be only here and there examined, is very great. Hence, perhaps there may still remain some important questions for future investigation; but sufficient has been ascertained, it is believed, to answer all the general objects and purposes of this survey.

Attention is called, in this report, to the great valley diverging from the west shore of Lake Michigan towards the southwest, well marked by the waters of Green Bay, Lake Winnebago and the valley of Rock river; the rock ridge bordering this great ancient valley on the east; the very remarkable drift ridge, locally known as the potash kettles, extending from the south line of the state to the peninsula of Green Bay; the several systems of parallel drift ridges, some of them sharp and narrow, called hog's backs; and the more level districts along the immediate shore of the lake.

A very important and interesting deduction made by Prof. Chamberlin, as a result of his explorations, is the fiord character of the peninsula of Green Bay; this being the result of intense glacial action, perhaps near the close of the great ice period. The glacier seems to have been concentrated upon Lake Superior by the converging shore lines, and passing southward to Green Bay, was thence diverted towards the southeast, plowing six or more great furrows, which are now indicated by bays on both sides of the peninsula. These valleys, or fiords, are continuous across this narrow neck of land, and may be traced on the charts of the lake survey upon the bottom of Lake Michigan, for a distance of twelve or fourteen miles.

If the peninsula north of Sturgeon Bay was ever covered with drift, it has been entirely removed, perhaps by the abrading action of waves at a time when Lake Michigan stood at a much higher level than now; the rock surface being now covered only with a thin layer of soil, destitute of drift material.

Some very remarkable facts relating to the course of streams are referred to as indicating changes that have taken place in the condition of the land in remote times.

The drainage is shown to be a proper medium between the slow-flowing streams and swamps of a flat country, requiring artificial drainage, and the rapid currents of highly inclined lands, causing extensive erosions and the loss of the more fertile portions of the soil.

Attention is given to the fact that large areas represented as marsh on the government plats are now dry and arable; that many of the streams have disappeared and become mere periodical runs; and that the volume of running water has been considerably reduced; facts undoubtedly due to the removal of the forests and the cultivation of the soil.

Prof. Chamberlin, with the active and intelligent aid of Mr. Swezey, enters with much detail into the important subject of the distribution of plants over the surface of the state, and accompanies his report with a map representing, as well as can be done, the principal facts as observed and recorded during the progress of the survey. Plants are arranged into fifteen different classes or groups, each of which occupies certain localities to the exclusion of the others, and each indicating some peculiarity of soil, geological formation, or climate.

Under the head of Surface Geology will be found many important facts in regard to the soil and subsoils, of which he distinguishes eight different kinds, each with its peculiar qualities and value. One of these — the calcareous sandy soil, found near Elkhart lake — consists mainly of small crystals of dolomite or magnesian limestone, which, while having the appearance of being sandy and unpromising, is found to possess great fertility.

The measurements along the west shore of Lake Michigan, intended to show the progress that lake is making in wearing away its banks, are not only of interest and importance at the present time, but will possess value to those who shall come after us for many years in the distant future. They show a mean annual abrasion in Racine county of 3.33 feet; and in Milwaukee county of 2.77 feet. The rapidity of geological changes, made under our own eyes, is prominently exhibited in the fact above mentioned of a ravine having been formed near Racine within the past twenty-eight years, which is half a mile in length, one hundred and twenty feet wide and forty feet deep.

The ample topographical details, including lists of elevations, will have their use in all future projects for the construction of canals, railroads, and for many other practical and useful purposes.

Section two of the act to provide for the geological survey, among other objects and duties, very properly requires observations to be made upon the animal and vegetable productions of the state, with reference to its agricultural interests. This duty has been assigned to Mr. F. H. King, under the direction of Prof. T. C. Chamberlin, one of the assistants in the survey. Though this work is incomplete, it is deemed best to present herewith, for preservation and future use the two reports now prepared by Mr. King, which will be found to contain brief notes of very numerous and important observations made by him during the years 1873 and 1874, relating to the birds and to the Lepidopterous insects of the state.

The notes upon the birds relate chiefly to their food, as ascertained by an examination of the contents of the stomach of the several species; this becomes important by showing whether they destroy our insect enemies or friends. It is only by such observations, made by persons who find pleasure in the pursuit, and who are to be relied upon for care and accuracy, that the truths of natural history can be ascertained and recorded. One hundred and two species of Wisconsin birds are mentioned, and facts of greater or less importance are recorded in regard to them. Fifty-four species of insects, injurious to one hundred and twenty-six species of plants, and seven species whose habits are such as to be deemed beneficial, are included in this report.

Mr. King's notes are to be preserved for use in making up a more general and complete work upon the animal and vegetable productions of the state, which will embrace also such further observations as may hereafter be made during the continuance of the survey.

Mr. Moses Strong's Party. — As early in the season of 1874 as the weather became suitable for active operations in the field, Mr. Strong, with the aid of Mr. George Haven as an assistant, and John Cain as teamster, resumed the work of surveying those portions of the lead region not covered by him in 1873. The preceding winter had been spent in preparing plats and collecting such information of the country to be examined, as would facilitate the field-work of the season. The southern and eastern portions of the lead region were first surveyed, including the whole of Green county; and, after completing a few townships in the northeastern part of Iowa county, he proceeded in August to carry out that portion of his instructions that contemplated the extension of his survey northward, through Richland, Vernon and Monroe counties to the southern limits of the Archæan rocks in Jackson county. The northern portion of the lead region, and the much broken district extending from the great east and west watershed to the Wisconsin river, were next examined in detail.

He was thus fortunately able to accomplish the whole of the work assigned to him at the beginning of the season, and to prepare his second annual report, with the necessary maps, sections and diagrams, within the time prescribed by law.

The work of the past season is so intimately connected with that of the previous year, that it was deemed best to include the whole in one report; accordingly this has been done by Mr. Strong, so that the accompanying report gives one connected and comprehensive view of his work, and its results up to the present time.

In this report will be found full details with respect to the district thus surveyed, arranged under the following heads:

Previous publications and surveys;
Topographical and geological maps and sections;
Barometrical observations;
Physical geography, and surface geology;
The several rock formations; being the
Potsdam sandstone,
Lower Magnesian limestone,
St. Peters sandstone,
Buff and Blue (Trenton) limestone,
Galena limestone, and
Cincinnati group,

All considered with respect to their geographical boundaries, lithological character, ores, minerals and paleontology;

The origin of river valleys;
Explanation of mining terms;
Present condition of the mines;
Statistics of lead, zinc and copper production;
Explorations north of the Wisconsin river, and
Prehistoric mounds of the lead region.

Topographical maps accompany this report, embracing the entire lead region, on a scale of one mile to an inch, which is sufficient to exhibit, by contour lines fifty feet apart (vertically), the elevation of every point above the level of the sea. These maps also show the position of the public roads. Such maps have special value not only in respect to future railroad surveys, showing at once the practicability or impracticability of any contemplated route, and thus save the time and expense of a very large amount of preliminary surveys, but are, obviously, of great importance to the mining interest, as indicating the proper system of drainage, location of "levels," etc. Geological maps are also furnished, constructed upon the same scale, showing the position of the several rock formations, by which the relation of any particular quarter section of land to these formations can be seen, and its value with respect to mining prospects at once ascertained. The information from which these maps were constructed has been collected with great care, involving an immense number of barometrical observations, and a great many miles travel.

From information contained in these two series of maps, it is easy to construct geological sections on any desired line. Those prepared by Mr. Strong, and accompanying his report, have been selected with a view of showing the "dip, number, magnitude, order and relative position of the various strata," as well as the amount of denudation to which the country has been subjected. The amount of denudation thus shown, seems wonderful, but is accounted for when we consider the immense time during which the rocks have been exposed to the abrading influences; being no less than the time occupied by the formation of the Devonian, Carboniferous, and all subsequently deposited rocks.

The regularity and simplicity of the geological features of the lead region are quite remarkable; there being no sudden breaks or "faults" in the strata, no upheavals to any considerable extent; no intrusive rocks, breaking through the different formations; and the veins from which ores are extracted do not penetrate the strata below the horizon of the St. Peters sandstone.

The origin and nature of springs are not well understood, many crude notions being commonly entertained in regard to them; hence Mr. Strong has, very properly, adduced the facts to show that the springs near the top of the Blue Mounds have an abundant source of supply, even in the small area of the mound above.

Though the lead region is supposed to have been exempt from the influence of the glaciers which have distributed so much drift material over adjacent districts, there are some facts still requiring explanation, particularly the one first noticed by Prof. Whitney, of the occurrence of blocks of St. Peters sandstone resting upon formations of later age. The boundary of the glacial drift through Green county has now been accurately traced. The occurrence of drift material in the valleys of the Mississippi and lower Wisconsin is rightly attributed to river transportation from above.

With respect to the several geological formations, much information is given in detail, systematically arranged, and not before published.

Mr. Strong's survey, and the experience of the past twelve years have given additional proof of the correctness of the views of Prof. J. D. Whitney, as set forth in his report, published in 1861. Among the most important of these views are the following:

That the lead crevices, with their mineral contents, are not true veins extending indefinitely downwards, but partake of the nature of shrinkage cracks or joints, such as may be seen in almost all limestone quarries.

That though the mineral grounds have considerable lateral extent, they reach only a short distance downwards.

That the filling of the crevices with mineral matter was not from below by volcanic heat, but from above, and by precipitation from a solution.

Much doubt and uncertainty still exist as to the origin of the metallic sulphurets, and as to the time when, and the special conditions under which they were introduced into these crevice joints. The occurence of a similar lead region in southeastern Missouri, and of another in the southwest part of the same state; the first in the Lower Magnesian limestone, the last in rocks of the Subcarboniferous age, would seem to indicate either that these conditions were repeated at three different times, or that they were brought about at a time subsequent to the deposition of the Subcarboniferous limestones.

Attention is directed to the fact that the valley of Sugar river, which constitutes the eastern boundary of the lead region, is much broader and deeper in proportion to the amount of water at present flowing in that stream than is usual; and hence the inference that at some time in the remote past, a large river found its channel along the course of the present Sugar river. With a breadth of stream of only about one hundred feet, it has a valley as broad as that of the Mississippi. In the future progress of the survey, additional light may be thrown upon this subject.

The information contained in this report with respect to the present condition of the mines will have a practical value, and will contribute much towards directing the attention of capital and enterprise to that important industrial interest in our state.

The following table shows the amount of lead and zinc produced for the years named:

Years.	Lead.	Zinc.	
	Galenite, Pounds.	Smithsonite, Pounds.	Blende, Pounds.
1860	....	320,000	....
1861	....	266,000	....
1862	17,037,912	....	....
1863	15,105,577	1,120,000	....
1864	13,014,201	3,173,333	....
1865	14,337,895	4,198,200	....
1866	14,029,192	7,373,333	....
1867	13,820,784	5,181,445	841,310
1868	13,869,619	4,302,383	3,078,435
1869	13,426,721	4,547,971	6,252,420
1870	13,754,159	4,429,585	7,414,022
1871	13,484,210	16,618,160	9,303,625
1872	11,622,668	27,021,388	16,256,970
1873	9,919,734	18,528,906	15,074,664
Total	163,422,672	97,080,704	58,221,446

It will be seen from the above that while the production of lead ore has been diminishing, during the past three or four years, that of zinc ores is rapidly increasing.

The explorations made north of the Wisconsin river, and outside of the lead region proper, were necessarily of a more general character, and the facts collected are represented upon maps on a much smaller scale. Those made in 1874 were confined chiefly to a single range (range two west) of townships, so that the entire extent of the Paleozoic rocks could be explored within the time and means applicable to this portion of the work. The most northern outlier of the St. Peters sandstone was found in the south part of township twelve; and the last occurrence of limestone (Lower Magnesian) in this range is on sections 10 and 15 in township seventeen.

Here are found those high, continuous dividing ridges forming serious obstacles to railroad construction, and from which fine views of the surrounding valleys may be seen.

The search for oil at "Oil City" resulted only in a fine flowing artesian well whose waters may be found to possess medicinal virtues, and a knowledge of the strata below, down to the Archæan rocks. Here the Potsdam sandstone has the unusual thickness of 844 feet.

These explorations, being in a line nearly parallel with the Mississippi river, will form a convenient base for the surveys to be made in 1875, between that line and the river.

The ancient artificial mounds, especially those of imitative forms, found within the district surveyed by Mr. Strong, have received a share of his attention. They were built in prehistoric times, by an extinct race of people, whose existence here is believed to have been with that of the Mastodon. They thus form the connecting coeval link between the geologist and antiquary; the duties of the one cease, while those of the other commence with the epoch of the mound builders.

SURVEYS IN OCONTO COUNTY, BY MAJOR T. B. BROOKS. — Maj. Brooks, late of the geological survey of the state of Michigan, undertook to trace the Iron-bearing, and other rocks found on the east side of the Menomonee river of Green Bay, above Sturgeon Falls, across that river into Wisconsin, and to ascertain as far as was practicable their southern and western boundaries, where they are succeeded by granitic rocks. Special search was to be made with the aid of the "mining compass" and otherwise, for iron ores, but the money applicable to this survey not being adequate to the sinking of experimental pits, shafts, or drifts, such work was necessarily left to private enterprise, guided by the results of such survey as he should be able to make. A suit of specimens was to be collected and forwarded to the chief geologist, with a full report in detail, illustrated by the necessary maps, sections and diagrams. All chemical analyses were to be made by Prof. Daniells, of Madison.

Maj. Brooks commenced active operations in the woods with ample assistance and supplies, on the 10th of August, and the work was continued fifty-six days. The weather, with slight exceptions, proved favorable; and the report of results will show that each person engaged must have done his whole duty. His camps were moved along the course of the river, from which he extended his observations south to the outcrops of the granite, and west, as far as the "Great Swamp," in range 17 E., town 40 N. He was thus able, though not without much exposure and difficulty, to accomplish all the objects proposed, and in a satisfactory manner.

It is gratifying to know that his report, now being prepared, will show that the Iron range extends across the Menomonee into Wisconsin, and that there is a strong probability that it will hereafter be found to contain, within this state, workable beds of ore.

The rocks examined, as in other portions of the Archæan regions, were found to be quite local in extent, and often gradually passing, by insensible degrees, from one to another, rendering it very difficult, if not impossible, to distinguish the different kinds, and to classify them under appropriate names. Efforts have been made to overcome this difficulty by chemical analysis, and also by microscopic examination of very thin sections, prepared with great care and skill. In this way it is sometimes found that rocks, having the same general appearance to the eye, are made up by the aggregation of very different minerals. The specimens of rocks and minerals sent in were collected and transported with very considerable labor. They are all numbered, and the exact locality from which they were obtained properly designated. They will be of much use in the further prosecution of the survey, and will, at its close, be distributed to the institutions entitled to receive them in accordance with the law.

One of the most serious difficulties met with by Maj. Brooks and his party, and which materially retarded the progress of his work, arose from the gross inaccuracies of the government surveys in that part of the state, and the careless and insufficient manner in which the lines and corners were established. Lakes were found having but little resemblance to their representation upon the plats; streams are made to run where none exist; swamps are laid down where excellent pine-lands yield an abundance of lumber; when a tract of land is "entered," the purchaser may find his quantity or number of acres deficient, or largely in excess. It is matter of common remark among woodsmen in this region, that the Wisconsin surveys are much less reliable than those of Michigan on the opposite side of the river. Under these circumstances, it may be a question whether it is not the duty of the government to resurvey in a more thorough and accurate manner, the public lands in this region of the country before they become of so much value as to lead to endless trouble in attempting to retrace the section lines.

It is much to be regretted that the several stations of the United States lake survey were not connected with the lines of the public land survey. This would have afforded many points for correcting the maps projected from the land surveys alone.

At the suggestion of the geological survey, Gen. A. A. Humphrys, Chief of Engineers, directed that the latitude and longitude of certain points upon the fourth principal meridian, the base, and the correction lines, be ascertained with the utmost exactness. These, being the governing lines of the land surveys, are most important; and it is, therefore, extremely desirable that their exact position should be ascertained.

As the first fruit of this application, the following determinations were furnished to the survey by Gen. C. B. Comstock, on the 17th of July, 1874:

1. Intersection of the fourth principal meridian with the state line between Illinois and Wisconsin, lat. 42° 30′ 26.1″; long. 90° 25′ 33.6″.

2. First section corner of the Wisconsin survey on the state line *west* of the fourth principal meridian, lat. 42° 30′ 26.4″; long. 90° 26′ 44.2″.

3. Southeast corner of section 13, township 18, range 1 west, lat. 44° 1′ 49.6″; long. 90° 25′ 56″.

4. Northeast corner of section 1, township 18, range 1 west, lat. 44° 4′ 26.6″; long. 90° 25′ 56.7″.

5. Southeast corner of section 31, township 21, range 3 east, lat. 44° 14′ 57.3″; long. 90° 10′ 45.8″.

6. Southwest corner of section 31, township 21, range 3 east, lat. 44° 14′ 57.2″; long. 90° 11′ 48.9″.

Points Nos. 5 and 6 are on the correction line between townships 20 and 21, near Balch's Ranch, on the Wisconsin Valley Railroad.

On the correction line between townships 30 and 31, range 19 west, east of the St. Croix river.

7. Southeast corner of section 34, township 31, range 19 west, lat. 45° 7′ 21.8″; long. 92° 41′ 24.6″.

8. Southwest corner of section 33, township 31, range 19 west, lat. 45° 7′ 22.1″; long. 92° 43′ 52.1″.

The following local bearings were determined:

1. The state line between Illinois and Wisconsin, from its intersection with the fourth principal meridian, bears W. 16′ 17″ N. to point No. 2 above.

2. The fourth principal meridian, from the southeast corner of section 13, township 18, range 1 west, bears N. 11′ 10″ W. to point No. 4 above.

3. The correction line between townships 20 and 21, from the southeast corner of section 31, township 21, range 3 east, bears W. 5′ 18″ S. to point No. 6 above.

4. The correction line between townships 30 and 31, from the southeast corner of section 34, bears W. 10′ 20″ N. to point No. 8 above.

In accordance with an act of congress, and upon application from the state geological survey, as explained in my last report, the superintendent of the coast survey has made arrangements for the prosecution, with suitable instruments, of geodetic surveys within this state. These will consist of the determination, by the accurate methods of that survey, of the geographical position of certain prominent points, and the measurement of a base line, from which, by a connected system of triangles, with sides ten to twenty or more miles in length, an amount of exact knowledge of the geographical and topographical features of the state will be acquired, sufficient for the projection of a correct map. These surveys when completed and properly connected with the lines of the land survey will leave nothing to be desired.

The work of the past season has been the determination of the latitude and longitude of Madison and La Crosse, and reconnoissance necessary for the selection of suitable triangulation stations, along the valley of the Wisconsin river from Prairie du Chien to Kilbourn City. This important survey is very properly placed in the hands of

Dr. John E. Davies, of the State University, and affords excellent opportunities for giving instruction in the several branches of knowledge required for such work.

Mr. Frank Ives, having spent much time in the valley of the Bois Brulé river, Douglas county, with his attention upon the geological features, was requested to make a report of the results of his observations for the use of the geological survey. A copy of this report is herewith submitted. It will be found to contain much local information of considerable importance, which could not otherwise have been obtained except at a very considerable expense, owing to the wildness and unsettled condition of the country.

The position of many of the rapids, falls, and lake-like expansions of the river is here first ascertained; the location of several, before unknown, outcrops of the Lake Superior sandstone, and the discovery of a range of possibly mineral-bearing trap rocks, in the south part of township 43, range 10 west, are among the items of importance in this report. Some remarkable drift ridges, extending across the valley, seem to indicate several successive stages in the decay of the ancient glaciers, each leaving traces of its work in the form of ridges, resembling, in many respects, the "terminal moraines" of the modern glaciers of the Alps. Above this most ancient or boulder drift, Mr. Ives recognizes two distinct epochs; one represented by the sand and fine gravel of the so called barrens; the other by the red, marly clay, so well known on the borders of Lake Superior.

His observations upon the soil, climate and mineral productions, seem to be judicious and well worthy of the consideration of all who are interested in that portion of our state.

Mr. Gustavus Bode of Milwaukee has furnished the survey with the analysis of ten springs and wells, made during the past year, thus affording additional knowledge of the character of the natural waters of the state. Of these, eight have the bicarbonates of lime and magnesia as their chief ingredients, supplied directly from the magnesian limestones abounding, not only in the solid rock, but in the gravel and boulders of the drift. The other two indicate the presence of sulphuric acid, arising probably from the decomposition of iron sulphurets, by which these salts have been converted into sulphates of lime and magnesia. They also contain the sulphate of soda. If these waters could be examined as they first issue from the ground, they would, doubtless, show the presence of gaseous matter giving them qualities not indicated by the analysis of the solid substances obtained by evaporation. Several springs and wells are known to be highly impregnated with sulphuretted hydrogen, and, doubtless, we have many waters whose medicinal qualities are of great value, but not yet known and appreciated.

It will be seen that the work of the several parties has been so distributed over the state as to give the most general and correct view of the several rock-formations, and prepare the way for greater progress during the remainder of the time allotted to the survey. The most recent rocks — the Drift, Devonian and Upper Silurian came under the special consideration of Prof. Chamberlin; the Lower Silurian of the Lead region and the country immediately north of it were investigated by Mr. Strong; while the more ancient (Archæan) has chiefly received the attention of Prof. Irving and Maj. Brooks.

The chemical analyses needed for the survey have been, as heretofore, under the direction of Prof. W. W. Daniells, of the State University, who has made a great number of full analyses, and numerous examinations, with a view to the determination of the value of certain mineral products.

General Geological Map. — With this report is presented a copy of Mr. Chapman's sectional map of the state, on a scale of six miles to an inch, upon which is represented the geological features so far as they are known up to the date of this report.

LIST OF MAPS AND SECTIONS ACCOMPANYING THIS REPORT.

I. Prof. Irving's Supplementary Report, 1873.

I. General Map of Northern Wisconsin. Plate 4.
II. Topographical and Outline Map of the Apostle Islands. Plate 5.
III. Additional map for Plate 1 — Ashland county.
IV. Map of the Ashland Mining Company's Location. Plate 8.
V. Showing the occurrence of the Iron Mounds, in the vicinity of Black River Falls. Plate 6.
VI. Showing the Formations in detail along Black river, above the falls. Plate 7.

II. Prof. Irving's Report, 1874.

VII. Map of Townships 5, 6, 7 and 8, in Ranges 8, 9, 10 and 11.
VIII. Map of T. 9, 10, 11 and 12, R. 8, 9, 10 and 11.
IX. Map of T. 13, 14, 15 and 16, R. 8, 9, 10 and 11.
X. Map of T. 17, 18, 19 and 20, R. 8, 9, 10 and 11.
X. (2) Map of T. 21, 22, 23 and 24, R, 7, 8, 9 and 10 E.
X. (3) Map of T. 25, 26, 27, 28 and 29, R. 5, 6, 7 and 8 E.
X. (4) Map of T. 21, 22, 23 and 24, R. 3, 4, 5 and 6 E.
X. (5) Map of T. 21, 22, 23 and 24, R. 1, 2, 3 and 4 W.
XI. Sections in central Dane county. Plate 2.
XII. Grouped sections in Dane county. (Double sheet.) Plates 3 and 4.
XIII. Sections in Dane and Columbia counties.

III. Prof. Chamberlin's Report, 1874.

XIV. Geological Map, T. 1, 2, 3 and 4, R. 17, 18, 19 and 20.
XV. Geological Map, T. 1, 2, 3 and 4, R. 21, 22 and 23.
XVI. Geological Map, T. 5, 6, 7 and 8, R. 19, 20, 21, 22 and 23.
XVII. Topographical Map of Milwaukee county.
XVIII. Geological Map, T. 9, 10, 11 and 12, R. 19, 20, 21 and 22.
XIX. " " T. 13, 14, 15 and 16, R. 20, 21, 22 and 23.
XX. " " T. 17, 18, 19 and 20, R. 21, 22, 23, 24 and 25.
XXI. " " T. 21, 22, 23 and 24, R. 23, 24 and 25.
XXII. " " T. 21, 22, 23 and 24, R. 19, 20, 21 and 22.
XXIII. " " T. 25, 26, 27 and 28, R. 23, 24, 25, 26 and 27.
XXIV. Profile of Drift Formations.
XXV. Map of Subsoils.
XXVI. Map of Post Tertiary and Recent Formations.

IV. Mr. Strong's Report, 1874.

XXVII. Geological Map, T. 1 and 2, R. 2 and 3 W.
XXVIII. Topographical Map, T. 1 and 2, R. 2, 3 and 4 W.
XXIX. Geological Map, T. 1 and 2, R. 1 E. and 1 W.
XXX. Topographical Map, T. 1 and 2, R. 1 E. and 1 W.
XXXI. Geological Map, T. 1 and 2, R. 4 and 5 E.
XXXII. Topographical Map, T. 1 and 2, R. 4 and 5 E.
XXXIII. Geological Map, T. 1 and 2, R. 6 and 7 E.
XXXIV. Topographical Map, T. 1 and 2, R. 6 and 7 E.
XXXV. Geological Map, T. 1 and 2, R. 8 and 9 E.
XXXVI. Topographical Map, T. 1 and 2, R. 8 and 9 E.
XXXVII. Geological Map, T. 1, R. 4, 5 and 6 W., and T. 2, R. 4 W.
XXXVIII. Topographical Map, T. 3, R. 4, 5 and 6 W.
XXXIX. Geological Map, T. 3, R. 1, 2 and 3 W. and R. 1 E.
XL. Topographical Map, T. 3, R. 1, 2 and 3 W. and R. 1 E.
XLI. Geological Map, T. 3, R. 4 and 5 E.
XLII. Topographical Map, T. 3 and 4, R. 4 and 5 E.
XLIII. Geological Map, T. 3 and 4, R. 6 and 7, E.
XLIV. Topogrophical Map, T. 3 and 4, R. 6 and 7 E.
XLV. Geological Map, T. 3 and 4, R. 8 and 9 E.
XLVI. Topographical Map, T. 3 and 4, R. 8 and 9 E.
XLVII. Geological Map, T. 6, R. 6 W.
XLVIII. " " T. 6 and 7, R. 4 and 5 W.
XLIX. " " T. 6 and 7, R. 2 and 3 W.
L. " " T. 6 and 7, R. 1 W. and 1 E.
LI. " " T. 6, 7 and 8, R. 4 E.
LII. " " T. 8, R. 1, 2 and 3 W. and R. 1 E.
LIII. " " T. 8 to 22, R. 2 W.
LIV. Profiles (double sheet).
LIV. (2) Ancient Mounds.
LV. General Geological Map of the State, in four sheets.

Additions.

XXIV. (2) Geological Profiles.
XXVI. (2) Map of Vegetation.
XXVI. (3) Topographical Map.

LIST OF PAPERS ACCOMPANYING THIS REPORT.

R. D. Irving's Supplementary Report.
R. D. Irving's Transcript of notes relating to Black River Falls.
R. D. Irving's Report, 1874.
T. C. Chamberlin's Supplementary Report.
T. C. Chamberlin's Report, 1874.
F. H. King's Report on Birds.
F. H. King's Report on Insects.
Moses Strong's Report, 1874.
Frank Ives' Report, Douglas County.
J. H. Eaton's Report, Quaternary of Central Wisconsin.

REPORT OF PROGRESS AND RESULTS,

FOR THE YEAR 1875.[1]

BY O. W. WIGHT.

In compliance with a requirement of the act "to provide for a complete Geological Survey of Wisconsin," approved March 19, 1873, I have the honor to report the progress made during the third year of the survey.

Brief History of Previous Geological Surveys in Wisconsin.—The first geological survey undertaken by the government of the United States was instituted by the appointment of G. W. Featherstonhaugh, Esq., by the war department, with instructions to make a reconnoissance "of the elevated region lying between the Missouri river and the Red river, known under the designation of the Ozark mountains." It was in the early part of the year 1834. In the winter of 1834–35, that gentleman visited the lead mines of Missouri and made a perfectly worthless report. The next year Mr. Featherstonhaugh was employed by the government under the title of United States Geologist to explore the region between the St. Peters river and the Missouri, and to make a general reconnoissance of the northwest. He referred the whole series of Lower Silurian rocks in the lead region of Wisconsin and up the river to the falls of St. Anthony and

[1] The fullest opportunity has been offered the author of this report to revise it for this volume, but not having been accepted, the delicate duty has devolved upon very unwilling hands. Certain portions of an annual report necessarily refer to matters of transient importance and are of little subsequent value. Such portions of this report have been omitted, viz.: A financial statement, a business account of the work in Oconto county, and an outline of the work remaining to be done. The law authorizing the survey, which has been previously given, and the reports of assistants prepared by themselves, are also omitted, as in the case of the reports of 1873 and 1874. I have deemed myself under obligations to publish everything of a geological nature, even where dissenting from the views presented. T. C. C.

beyond to the carboniferous limestone. It is hardly possible to conceive of a graver blunder, or an exhibition of profounder ignorance in the domain of practical geology.

A resolution of February 6, 1839, adopted by the house of representatives, reads as follows: "That the President of the United States be requested to be caused to be prepared, and presented to the next congress, at an early day, a plan for the sale of the public mineral lands, having reference as well to the amount of revenue to be derived from them, and their value as public property, as to the equitable claims of individuals upon them; and that he, at the same time, communicate to congress all the information in possession of the treasury department relative to their location, value, productiveness, and occupancy; and that he cause such further information to be collected, and surveys to be made, as may be necessary for these purposes." In pursuance of this resolution, the commissioner of the general land office appointed Dr. D. D. Owen to take charge of a geological survey of the Upper Mississippi lead region. Dr. Owen began his work, with 139 assistants, in September, 1839, and finished it the same autumn. His report, accompanied by maps, drawings of fossils, sections, etc., was transmitted to the land office, April 2, 1840. It was printed without the maps in June of the same year.

The senate ordered it reprinted, with the maps and drawings, in 1844. Dr. Owen's report contains the first scientific description of the lead region of Wisconsin. With a few mistakes, easily made in a hasty survey, without skilled assistants, the report determines the geological structure of the southwestern part of the state.

The general government authorized a geological survey of the Chippewa land district in 1847, and Dr. Owen was very fortunately selected to take charge of it. His preliminary report was furnished to the treasury department in April, 1848. His final report was published, with a general geological map, including the whole state of Wisconsin, in 1851. It is a monument of Dr. Owen's industry and scientific knowledge. Professor J. D. Whitney, a most competent witness, truly says, speaking of his previous report, "There were probably few, if any, persons in the country, at that early period of our geological culture, who could have executed the survey with the ability and energy which were displayed by this gentleman."

The legislature of Wisconsin passed an act, approved March 25, 1853, under which Mr. Daniels was appointed State Geologist. His report, about fifty pages in length, bears no date, but was printed in 1854. It repeats the views of Dr. Owen and is mostly confined to the lead region. About a year afterwards, Mr. Daniels was removed, and

Dr. J. G. Percival was appointed in his place, August 12, 1854. He held the office till his death at Hazel Green, May 2, 1856. Dr. Percival was in the field two seasons. His first report, of 100 pages, was published under his own supervision. He left a second report nearly complete, which was subsequently published in 1856. His work was mostly confined to the lead region, but the second season he made a "reconnoissance of the state for the purpose of forming a general idea of the geological arrangement." At once scientist and poet, morbid and eccentric, Dr. Percival made accurate original geological observations, but refused to hold intercourse with others from whom he might have received important information and valuable aid.

In March, 1857, the Wisconsin legislature passed an act providing, that "James Hall, of Albany, N. Y., and Ezra S. Carr, and Edward Daniels, of Wisconsin, are hereby designated and appointed commissioners to make a geological, mineralogical, and agricultural survey of this state, embracing a scientific and descriptive survey of the rocks, fossils and minerals of the state; full and complete assays of the ores and minerals, also of the soils and subsoils, with classification and description of the same and their adaptation to particular crops, and the best methods of preserving and increasing their fertility. They shall also make a full collection of the rocks, ores and minerals, and whatever illustrates the economic geology of the state, and deposit the same in the rooms of the State University, or such other place as may be provided for the same, constituting a museum of practical and scientific geology. Said commissioners shall also make full collections of soils, native fertilizers, cultivated and other useful plants, constituting a museum of practical and scientific geology, and deposit the same as aforesaid." The act also provided that "the sum of six thousand dollars per annum, for the term of six years, is hereby appropriated, to be drawn from the treasury quarterly on warrant of the governor, and paid to persons entitled to receive the same; which sum shall be in full for salaries of commissioners, assistants, rent of room, and all other expenses incident to said survey, exclusive of printing the annual reports of said commissioners."

The survey thus authorized was not begun until the following year, 1858. In that year Prof. Hall and Dr. Carr employed, at their own expense, Col. Charles Whittlesey, to explore the country between the Menomonee and Oconto rivers, "as a preliminary to more extended surveys to the northward." In the spring of 1859, they made an engagement with Prof. Whitney to make a careful survey of the lead region. Prof. Whitney having been employed as chemist and mineralogist in the Iowa survey, had become, to a certain extent, familiar with the upper Mississippi lead region. The Wisconsin legislature passed an act, approved by Gov. Randall, April 2, 1860, authorizing the governor to use that portion of the fund accruing under the law of 1857, from the signing of the act until the organization of the survey in 1858, to the payment of Prof. Whitney and Col. Whittlesey, and also making Prof. Hall principal of the geological commission. Col. Whittlesey explored the country, and commenced a report on the iron region of Lake Superior. Prof. Whitney completed his surveys, maps and reports of the lead region. An act was passed, approved April 15, 1861, authorizing and directing the governor of the state "to purchase of Prof. James Hall one thousand copies of the first volume of his Geological Report of Wisconsin, confined mainly to the lead region, with the details of the geology, mineralogy, and mining thereof; and to contain between four and five hundred pages. The said volume shall embrace a chapter on the general geology of the state, and its relation to the surrounding states, and shall be the same size, and in all respects as to type, paper and binding, equal to the Iowa Geological Report, with all necessary maps and illustrations; provided, that the said one thousand copies, delivered at the capitol in the city of Madison, shall not cost more than three dollars each." In 1862, the said first volume of Prof. Hall's report was published in accordance with the specifications of the law. Prof. Whitney's report of the lead region occupies three-fourths of the volume. Both Hall and Whitney are masters in this field of science, and the work of both was well done.

The next year the legislature, under the pressure and excitement of the war, repealed the law authorizing the geological survey of the state. Whereupon, Dr. Carr and Mr. Daniels abandoned the field. Not so Prof. Hall. He had a contract, under seal, with the governor, according to the provisions of the law, and claimed that the legislature could not annul it. He continued his labor, and completed that portion of his work which had been assigned to him in its division among the three commissioners. The second volume of his report has been ready for publication more than a dozen years. Prof. Hall has made repeated applications to the legislature of Wisconsin for compensation, but in vain. We are informed that he has brought suit against the state, through ex-Chief Justice Dixon, for two thousand dollars (a year's salary, under his contract), with accrued interest amounting to as much more. The second volume of his report, in manuscript, has in the intervening time been a loss to science and a loss to the economic geology of Wisconsin. It contains, we are informed, the report of Col. Whittlesey on the iron region in the northern part of the state.

"Descriptions of new species of fossils," made by Prof. Hall, accompanying his report of progress to Gov. Randall, in December, 1860, were subsequently embodied in the first volume of his report, published in 1862.

The report of John Murrish, as commissioner of the survey of the lead district, made to Gov. Lucius Fairchild, and submitted with the governor's message in 1871, contains many useful, practical suggestions by an experienced miner and intelligent man. Whilst this report does not, in our judgment, successfully combat the scientific conclusions of Prof. Whitney, it exhibits comprehensive views, and gives valuable hints to explorers for mineral deposits. Doubtless, if the labors of experienced miners, like Mr. Murrish, and the labors of purely scientific geologists could be combined, better practical results might be obtained.

Under the provisions of the present law, the geological corps was organized by the appointment of I. A. Lapham as chief geologist, and Prof. R. D. Irving, Prof. T. C. Chamberlin and Mr. Moses Strong as assistants. The commission of the first, issued by Gov. C. C. Washburn, was dated April 10, 1873. The commissions of the assistants were dated April 30, 1873.

For an account of work accomplished by this corps during the years 1873 and 1874, the undersigned has the honor to refer your excellency to the brief reports of progress made by the chief at the close of those years, and the accompanying voluminous reports made by his assistants, together with maps, profiles, tables, etc.

The commission of the undersigned bears date February 16, 1875. His predecessor was appointed by Gov. Washburn, in the spring of 1873, after the adjournment of the legislature. His name was not sent to the senate for confirmation during the session of the subsequent legislature. It was therefore decided (so the undersigned is informed) by the judiciary committee of the senate, in the early part of the session of the last legislature, that the office of chief geologist was vacant. His Excellency, Gov. Wm. R. Taylor, did the undersigned the honor to send in his name to the senate, and the senate confirmed the appointment with singular unanimity.

The assistant geologists, following a rule of courtesy under such circumstances, offered to surrender their commissions. The newly appointed chief requested them to withdraw their resignations, and to continue their work. With this request they cheerfully complied.

The resignation of Prof. Daniells, however, as chemist to the survey, was accepted after due deliberation, and the undersigned appointed in his place Mr. Gustavus Bode, of Milwaukee, whose acknowledged eminence in his scientific speciality was a guaranty of peculiar fitness for the work entrusted to his care and skill.

Mr. E. T. Sweet, who had been connected with the survey from the beginning, a trained geological observer, an experienced practical chemist, was employed in a general way, to be transferred from one field party to another, or to be detailed to the laboratory of the State University for special analytical work.

Mr. Sweet has shown himself very efficient in connection with Prof. Irving's party, in connection with the party of the chief geologist in making an extensive reconnoissance of the northern portion of the state, and in the labor of the laboratory.

Mr. Charles E. Wright, of Marquette, L. S., Michigan, a partner as mining engineer and iron expert of Maj. T. B. Brooks, with whom he was engaged on the geological survey of the upper peninsula of Michigan, was employed during two months in making explorations at Penokee Gap, on the Chippewa, Wisconsin, Pelican and Wolf rivers, under the personal supervision of the undersigned. His experience among crystalline rocks, his knowledge of the Laurentian and Huronian formations, and his skill in detecting under the microscope the difference between crystallization by igneous action and metamorphosis, made his services of especial value in a reconnoissance of the Archæan region of Wisconsin.

Reconnoissance Made in the Northern Part of the State under the Personal Direction of the Chief Geologist, During the Latter Portion of the Season of 1875.— About the middle of August the state geologist began an extensive reconnoissance of the northern portion of Wisconsin, for the general purpose of ascertaining the nature and amount of work to be done to complete the survey in 1876. The reports of the surveys made by Dr. Owen and by Messrs. Foster and Whitney, were carefully studied and extensive notes taken, for the purpose of having a sort of geological guide book of the region, and for the purpose of avoiding an unnecessary repetition of work already performed and recorded. Maps, camping materials, supplies, instruments, etc., were collected beforehand, and all preparations made for moving as rapidly as possible, and covering the greatest amount of territory in a given time.

Mr. E. T. Sweet, a seasoned explorer, a good geological observer, a hardy and enthusiastic worker, who had had experience in the northern wilderness of Wisconsin, was detailed from the field party of Prof. Irving, to accompany the chief geologist during the whole trip.

Charles E. Wright, E. M., of Marquette, Michigan, a highly educated lithologist and mining engineer, who had had many years of experience among the crystalline rocks of the upper peninsula of Michigan, was engaged to meet the party at Ashland on the first of September, and to continue with it till the close of the reconnoissance.

For the details of the work accomplished, your excellency is referred to the reports, maps and sections of Mr. Sweet and Mr. Wright, which are herewith submitted.

Among the objects designated in advance to be accomplished by the reconnoisance, were to observe the trap dykes (the Copper-bearing rocks of Mr. Sweet's report) crossing the St. Croix river, and to ascertain their direction; to study the relation of these same dykes to the Potsdam sandstone and to the Lake Superior red sandstone; to collect facts bearing upon the relative age of the Potsdam sandstone and the Lake Superior sandstone; to investigate the relations of the copper-bearing conglomerate to the older and the more recent formations; to make a more careful and accurate geological section of Penokee mountain; to determine the general direction of that range, and the probable locality where it crosses the St. Croix river; to find, by long journeys northward and southward on the Chippewa, Black, Wisconsin and Wolf rivers, boundary points between the Huronian and Laurentian formations; to discover indications of mineral deposits; and to collect information in regard to roads, bridle paths, trails, and streams navigable for canoes, in order to enable the chief geologist to give intelligent directions for conducting the survey in detail next season, with economy and efficiency.

The numerous trap dykes crossing the St. Croix river were found to run in a general east-northeast and west-southwest direction, nearly parallel to each other.

There are three trap ridges between Osceola Mills and the village of St. Croix Falls; whether these dykes, so called, are of the same age, is a problem to be solved by future examinations.

Whether they are igneous in origin, or whether a portion of them are of igneous origin and another portion are not, can only be determined by a more careful examination of their crystalline structure under the microscope. The Canadian geologists have made out, on the northern shore of Lake Superior, several systems of trap dykes, evidently of different eruptive periods; but the geological character of the region on the southern shore of the lake is so different in many respects from that of the opposite shore, that no trustworthy argument can be drawn from analogy. It is sufficient to remark here provisionally, that the apparent common lithological character and the same general trend of the trap ridges crossing the St. Croix river would point to the same geological era.

A somewhat careful examination at St. Croix Falls enabled the exploring party to determine that the Potsdam sandstone was deposited in the ancient Silurian sea at a period subsequent to the formation of the trap, whatever may have been its origin. The beds of the Potsdam sandstone are horizontal over the uneven and tilted surface of the underlying igneous or crystalline rocks.

Almost in contact with the trap, the sandstone contains numerous well preserved organic remains. Three miles north of Osceola Mills, a ledge of sandstone was found lying horizontal, unconformably on the more ancient formation. These facts incontestably prove, that this particular trap dyke was not erupted or upheaved through a superincumbent layer of sandstone.

At Kettle river rapids was first found, in ascending the river, a red sandstone, having all the lithological characteristics of the Lake Superior red sandstone, in talus along the shore. The water in the river was extremely low, so that unusual opportunity was afforded for observation. The slabs and fragments of the red sandstone were sharply angular, showing that they were *in situ* or not far away. In the bank, forty or fifty feet higher, was a fine exposure of Potsdam sandstone in a massive ledge.

The party had neither the time nor the means at its disposal to make an excavation to ascertain by definite observation whether the Superior red sandstone existed in true formation beneath the Potsdam. Such a fact, definitely settled by a competent observer, would be strong evidence that the former is, at least in part, older than the latter.

At "Pine Island," in the same rapids, the Superior red sandstone was found in ledge, bearing abundant angular fragments of the adjacent trap, forming a brecciated conglomerate that is evidently kindred to the conglomerate that extends from Keweenaw Point, in Michigan, along the northern base of the Porcupine and Penokee mountains, west southwestward, till it is lost beneath the heavy drift of northwestern Wisconsin. Everywhere this conglomerate is formed by fragments of the more elevated Huronian or trap ridges, carried down by the action of the elements and imbedded in the Superior red sandstone. The ledge of conglomerate under consideration was found to be lower than the horizon of the neighboring Potsdam. Placing the conglomerate and the Superior red sandstone in the same geological category, this fact goes far to strengthen, if not confirm, the conjecture, advanced in the preceding paragraph.

Another fact has considerable bearing upon the same point. The Superior red sandstone, wherever it borders on the trap ridges, shows that it has been tilted, broken up or crushed. It therefore appears, that the trap, whether erupted, or upheaved convulsively or slowly, encountered this formation in its ascent. On the contrary, as we have already seen, the Potsdam exhibits undisturbed horizontal bedding on the trap. One of two things necessarily follows: either the Superior red sandstone is older than the Potsdam, or the trap rocks, wherever they occur in conjunction with the Superior red sandstone, are younger than where they occur in conjunction with the Potsdam. The evidence is not conclusive, but it is strongly corroborative.

Again, it is known that the Superior red sandstone has a much greater thickness than the Potsdam. In the region of Montreal river, its thickness has been computed at five thousand feet. By trigonometrical calculation, Mr. Sweet has found its thickness to be about four thousand feet on the upper St. Croix. The Potsdam in Wisconsin is not over nine hundred feet thick.

Now it is evident that the Superior red sandstone must have been much longer in forming than the Potsdam. As the former does not belong to a later period, a portion of it must certainly antedate the latter.

Awaiting then, a longer and more careful study and more extensive and accurate collection of facts, it may be conjectured that the lower and thicker portion of the Superior red sandstone is synchronous with and the equivalent of the Acadian epoch of Dawson, in the Canadian survey, while the upper and thinner portion is synchronous with, and the equivalent of the Potsdam sandstone of the New York geologists, which is represented over a wide area of Wisconsin. The argument from paleontology has no bearing on this difficult question. The red sandstone of the Lake Superior region is without organic remains. The Potsdam of Wisconsin, while it is rich in fossils, contains no species that is identical with any species in the Potsdam of New York. The epoch of the formation is determined solely on stratigraphical grounds, by its relation to the underlying Archæan, and to the overlying Calciferous of the Canadian group, or the Lower Magnesian limestone.

The journey from the head of St. Croix river to Bayfield confirmed previous information, that the country is covered with drift to such an extent as to make satisfactory geological exploration an impossibility. There is not an outcrop of rocks for fifty miles. Most of the region is destitute of living springs and streams. Numerous depressions in the drift are partly filled with water, forming lakelets without inlet or outlet. Some of these little lakes are large enough to be kept pure by the action of the winds and waves. The soil is sandy and barren, supporting only a stinted growth of "jack" pines and "scrub oaks." Fire has killed the timber over wide areas, on which grass was growing, exhibiting before our eyes nature's simple method of converting woodland into prairie. The reverse process is just as simple. When prairies are no longer swept over by fire, timber springs up, reconverting prairie into woodland. Grass, with fire as an ally, can beat timber. Timber can beat grass when it has no fire to fight.

The same kind of "Jack" pine barrens, interspersed with prairie, extends from a short distance above St. Croix Falls to the basin of Lake Superior. Along the streams, on the "bottom" lands, there is a heavy growth of timber, including white pine, oak, poplar, and maple. Towards the sources of the streams flowing into the St. Croix from the Wisconsin side, are many fine forests, supplying vast quantities of lumber. In the basin of Lake Superior, the soil is fertile, supporting great forests of Norway pine, some white pine, hemlock, maple, etc. The agricultural capabilities of the St. Croix valley are not very great. The farmer could look to the basin of Lake Superior much more hopefully for a reward of industry and enterprise.

A new geological "section" of the Penokee range was made by the party at Penokee Gap, along Bad river, where the Wisconsin Central railroad crosses. For a clear description of the structure of this Huronian formation, your excellency is referred to the special report of Charles E. Wright and the accompanying chart.

In the most conclusive manner, the unconformabitity of the overlying northward dipping Huronian, to the underlying southward dipping Laurentian, is made out.

The undersigned is less reserved than Mr. Wright in expressing an opinion as to the value of the iron deposit in the Penokee range. Careful chemical analyses of good specimens of magnetic ore show that it is very rich in metallic iron, that it is free from titanic acid, that it contains very little phosphorus, that silica is not sufficiently abundant to seriously interfere with its reduction in the furnace.

Well selected specimens have shown from sixty to sixty-eight per cent. of iron, of fine quality. To scientists it is not necessary to state that the richest possible iron ore is a pure magnetite which yields seventy-two and forty-one hundredths per cent. of metal. It is simply a popular delusion that there are ores rich enough to yield seventy-five, eighty or eighty-five per cent. of iron.

It is an important fact, that Mr. Wright found, by microscopic examination, the crystalline structure of the Penokee rocks, to be metamorphic and not igneous. His authority on this point is conclusive.

Whether the Huronian formation of the Penokee mountain extends westward to the St. Croix river, is a question of great interest, both in the scientific and economic geology of Wisconsin. Awaiting deductions from more detailed examination to be made by the survey in 1876, the undersigned may here give the arguments in favor of such a conclusion, taken from the report of Mr. Sweet, who has had more experience in this part of the state than any other member of the geological corps:

"I. The westward extension, and occurrence on the St. Croix river, of all the formations in their regular order, except the horizontal sandstone formed north of the Penokee range, is a strong argument from analogy. We can not expect to find as well defined ridges nor as high ranges near the St. Croix as there are in the eastern part of Ashland county, for the dip of all the formations gradually decreases towards the west. The dip of the Huronian schists at the gorge at Tyler's Fork is 75° to the northwest. At Penokee Gap it is 66°, and at a point near Atkins Lake only 45° in the same direction. The conglomerates and sandstones, which have nearly a vertical dip to the northwest at the mouth of the Montreal river, and the mouth of Tyler's Fork, have but a slight dip on the St. Croix river. At Lehigh's on Bad river, the southward dipping sandstones have a dip of 38° to the southeast; at Wilton's the dip is 25°; at the St. Croix only 14° to the southeast.

"II. If the Iron-bearing belt extends westward as far as the St. Croix, it doubtless follows the southern boundary of the Cupriferous formation. It would, therefore, intersect the river some distance below the mouth of Snake river. Then in the neighborhood of a line drawn from Snake river to Penokee Gap, one would expect to find indications of the formation."

Iron ore is reported, by explorers, to have been found in place, at several localities in the vicinity of this line.

Explorers report it from near the southern end of Long Lake, from section 18, town 43, range 9 west, and from the northern part of Burnett county. Near the mouth of Wood river, on section 19, town 38, range 19 west, are found on the original survey plat the signs used to indicate rocks *in situ*, and the words "iron ore."

"III. The occurrence of small angular boulders of magnetic rock and iron ore, in the drift at numerous localities in Polk and Burnett counties," is another strong argument.

"IV. In Michigan and in all regions where magnetic iron ore is found, much reliance in exploring is placed upon magnetic surveys. Valuable mines have been discovered by noting the abnormal deflections of a delicate magnetic needle in passing along at right angles to the trend of formations. This method often succeeds, when the dip compass fails. Although magnetic surveys have not been made in the region under consideration, lineal surveys have, and the variation at several points of each section recorded upon the township plats.

"In the townships through which the Huronian belt would be expected to pass, the difference between the maximum and minimum deflection to the east is much greater than in townships known to be distant from magnetic influences.

"For instance, township 37, range 20 west, the difference is 5° 39′, and township 36, range 20 west, the difference is 5° 30′. Numerous other instances might be mentioned. The fluctuations of the needle from a fixed point under ordinary circumstances, is not usually over one to two degrees."

It is only necessary to add here that the explorations in the Penokee range for the discovery of iron ore would, in the judgment of the undersigned, be more likely to prove successful, if they were confined to boring with the diamond drill into the northern brow of the mountain at right angles to the dip of the rocks of which the formation is composed. The better ores are softer; therefore have undergone more denudation than the harder ores; consequently the former are buried under surface debris, whilst the latter are exhibited in outcrop. By traversing the magnetic schists with the diamond drill, the quality of the borings can be constantly tested, and the true horizon of valuable ores can be accurately ascertained.

The long journeys down the Chippewa river, from the crossing of the Central railroad to Eau Claire, up the Wisconsin river from Wausau to the mouth of the Pelican, up the Pelican to its source, and down the Wolf from a short distance above Post Lake to Shawano, were fertile in negative results, but afforded too few data to determine with any degree of accuracy, boundaries between the Huronian and the Laurentian formations in the wild Archæan region of the state. Apparently the Chippewa river traverses an area of Laurentian till it touches the Potsdam sandstone in its southeastward course. A Huronian range is known to enter the state from the Michigan side, at and above the mouth of Pine river on the Menomonee, and to extend westward. At Post Lake dam, on the Wolf river, highly crystalline hornblende rocks were examined, which, with other indications, led to the conjecture, that the Menomonee Huronian range crosses in that region. Similar indications were found on Pelican river, and to the northwest of Pelican Lake.

The "Greenstone group" found between Jenny and Grandfather Bull Falls on the Wisconsin river, the quartzite near Wausau, and the silicious rock of Marshall hill, evidently Huronian, give additional points for determining the general direction of the Menomonee range. The southwestern termination of it, where it disappears under the Potsdam, would seem to be at Black River Falls. Between this range and the Penokee mountain range there is probably a nearly continuous area of Laurentian. And between the Menomonee Huronian range and the irregular line of the northern edge of the Potsdam there is a continuous Laurentian belt.

The geographical boundaries of these formations can only be determined by more detailed explorations.

It is a matter of great practical importance to trace the outlines of the Huronian and Laurentian formations in the Archæan region of the state, for, judging from results obtained from the adjacent region of the Upper Peninsula of Michigan where exactly the same formations exist, the Laurentian rocks contain no useful minerals, while the Huronian areas promise an abundance of iron, if not more precious metals.

HAMILTON OR ~~LOWER HELDERBERG?~~—There is a region of Wisconsin, on the shore of Lake Michigan, beginning in the city of Milwaukee, extending northward to the vicinity of the county line of Ozaukee, running inland half a dozen miles, shaped something like a segment of a circle, which has been placed by geologists in the Upper Helderberg epoch, and has been called by one scientist in connection with the present survey of the state, the Hamilton formation.

The undersigned, soon after he began studying the geology of Wisconsin, was led to doubt whether the region in question belongs to the Devonian age, as it must, if it is either Upper Helderberg or Hamilton. The proper place for a full discussion of the subject will be in the final report, after the geological survey of the state is completed. Yet it may not be out of place to give here, briefly as may be consistent with clearness, the reasons which have forced the present head of the survey to conclude, against his predecessors, against his associates, that the limited area under consideration is Lower Helderberg, and consequently belongs to the Upper Silurian and not to the Devonian age.

In North American Geology, following the nomenclature of Prof. Dana and the New York geologists, the proper place of the Lower

Helderberg is above the Salina and below the Oriskany. Of course, its stratigraphical relations vary in localities. The normal underlying formations will be wanting where, during one or more preceding epochs, emergence of the land had taken place and, consequently, the ancient ocean, having receded, was not there busy with its work of rock-making.

For the same reason, in many localities, the normally overlying series are entirely wanting. The Lower Helderberg, like the rocks of any other period, are entirely wanting, where the dry land had appeared before that particular epoch. Over a large area of Wisconsin, for example, there are no rocks above the Archæan, for the simple reason that this area has been an emerged portion of the continent since the primeval ocean first deposited the Laurentian and Huronian formations. Nowhere in the state do we find rocks of the Mammalian, Reptilian, or Carboniferous ages, because during all these long divisions of geological time, Wisconsin has been dry land. In other places on the globe, the seas have continued their labor of rock-making, but here the continent was finished long ago. In places portions of the continent have been upheaved during one or more periods, and then for a season submerged again by faster or slower subsidence. During the period of emergence, rock-making has ceased; with resubmergence rock-making has gone on again. Thus epochs are wanting here and there, and the geologist has dynamical problems to solve more difficult than problems of lithology.

The Lower Helderberg epoch takes its name from the Helderberg mountains in the state of New York, where the formation is complete. Beginning from below, its subdivisions are: (1) The Tentaculite or Water-lime group; (2) The Pentamerus limestone; (3) The Catskill or Delthyris shaly limestone; (4) The Encrinal limestone, and (5) The Upper Pentamerus limestone.

In this connection, it is necessary to consider more particularly the lowest, or Water-lime division. In fact, the different subdivisions observed in the Helderberg mountains, scarcely appear outside of New York state. All of them but the Water-lime group disappear, even in New York, westward of Ontario county. "This group," says Mr. Vanuxem, in the New York state survey, "takes its name from its earthy drab colored limestone, from which all the water-lime in the district south of the Erie canal, with one exception, is manufactured. It consists generally of dark blue limestone, and usually of two layers of drab or water-lime stone; the two always separated by an intervening mass of blue. The group is well defined, and is readily recognized in this state and in Pennsylvania, by its mineral nature, its fossils in particular, and by its position." Mr. Vanuxem traced it in that early date to Fort Plain, Cherry Valley, Richford Springs, various points in Oneida county, Onondaga Valley, Syracuse, Auburn and Cayuga Bridge. It must not be forgotten, however, as Sir Wm. E. Logan points out (Geology of Canada, p. 363), that Mr. Vanuxem confounded this group, in part, with the upper portions of the underlying gypsiferous series, which it closely resembles in lithological character.

The Lower Helderberg formation extends over a wide region of North America. Becrafts mountain and Mount Rob, near the city of Hudson, are isolated monuments of this geological epoch. The formation extends, in a broken way, through Connecticut, Massachusetts, New Hampshire, Maine, New Brunswick and Nova Scotia. According to Sir Wm. E. Logan, there are outliers of Lower Helderberg at Point Gaspe and near Montreal, at St. Helens Island, at Round Island, at Isle Bizard, at cuttings for the Grand Trunk Railway, between Point Claire and St. Anne. The distinguished chief of the Canadian survey justly remarks (Geology of Canada, p. 358): "From these scattering outlying patches, it would appear that a considerable area in the Champlain and St. Lawrence valleys was once continuously covered with rocks of the Lower Helderberg group; while from the unconformable relation of these to the formations on which they repose, it is evident that, prior to the Lower Helderberg period, the older fossiliferous strata had suffered a great amount of denudation."

This group extends along the Apalachian mountains southward, through southeastern New York, New Jersey, Pennsylvania, Maryland and Virginia. The formation is thicker on the Potomac river than on the Hudson. It thins out to the westward in the southern as well as in the northern portion of the range.

The Water-lime division of the Lower Helderberg enters Canada opposite to Buffalo, and according to Sir Wm. E. Logan, "can be traced pretty continuously, in a band varying from twenty to forty-five feet in thickness."

Although this language was used in the Canadian report of 1863, yet strangely enough, Mr. Newberry, in the recent Ohio report, says that the Water-lime group "had not been recognized beyond the limits of New York previous to 1869." In that year Mr. Newberry discovered the Water-lime subdivision of the Lower Helderberg on the islands in the upper end of Lake Erie, and on the adjacent shore. "Since our first identification of the Water-lime," he says (Geological Survey of Ohio, p. 137), "we have traced it over a very large area within this state, and have learned to recognize it almost at a glance by its prevailing lithological characters. We have also obtained its characteristic fossils from hundreds of localities. The result of our investigation has been to show, that the Water-lime, judged by the area it occupies, with its outcrops, is, in Ohio, the most important of all the Silurian strata. It underlies a broad belt of country on either side of the Cincinnati axis, from the lake shore to Hardin county. There the two belts coalesce, and the Water-lime stretches entirely over the arch, forming the surface rock for nearly a hundred miles east and west. Further south the margin of the Water-lime sweeps around the blue limestone area, exterior to and parallel with that of the Niagara.

"South of the national road, and east of the anticlinal axis, the Water-lime forms a constantly narrowing belt, which passes through the counties of Madison, Fayette, Highland and Adams, to the Ohio. In parts of Adams and Highland it forms a feather edge on the flanks of the Cincinnati arch, beyond which the Huron shales rest directly on the Niagara. This shows that the sea in which the Water-lime was deposited reached but part way up the slope of the old Silurian island."

The same formation extends westward into Indiana. In western Tennessee it has been recognized in Stewart, Benton, Decatur, Hardin and Henry counties.

Worthen, in the Illinois reports, refers to the Lower Helderberg epoch a silicious limestone directly overlying the Cincinnati, with no intervention of the Niagara limestone. "No beds of undoubted Niagara age," says Mr. Worthen (Illinois Reports, vol. I., p. 127), "were ever deposited in southern Illinois, but in their place these silicious limestones, representing in part the age of the Lower Helderberg limestones, and, in part, the Oriskany sandstone of the New York series, were deposited, resting directly upon the Cincinnati group of the Lower Silurian." "Again," says Mr. Worthen, giving an account of the geology of Union county (Illinois Report, vol. III., p. 36), "the Lower Helderberg formation is similar in its appearance here to the outcrops of it, already described in the foregoing report on Alexander county, and it may be described as a thinly bedded, grayish colored, close-textured, silicious and cherty limestone, sometimes argillaceous and shaly, and again so flinty that it is difficult to say whether the flint or the limestone predominates." The flinty character of this formation at certain localities in New York was fully described by Mr. Vanuxem.

Following the Lower Helderberg northwestward from Buffalo, through Canada, we find rocks with the same lithological characters at the junction of Lake Huron and Lake Michigan, occupying the entire island of Bois Blanc, occupying most of the small peninsula west of St. Martin's Bay, and skirting the Straits of Mackinac along the northern shore of the southern peninsula of Michigan. It overlies the Salina formation, and, consequently, is in the exact stratigraphical place of the Lower Helderberg. Speaking of these same rocks, Dr. Rominger says (Geological Survey of Michigan, vol. I., p. 28, of his division of the subject), "Taking into consideration the stratigraphical sequence, surmounted above by well characterized Upper Helderberg strata, underlaid below by beds of perfect lithological resemblance to the Onondaga salt group, we may safely take the intermediate beds as contemporaneous with the Lower Helderberg group."

Now the formation, under discussion in the state of Wisconsin, has, so far as the underlying strata are concerned, the same stratigraphical relations as the Water-lime subdivision of the Lower Helderberg in New York, Canada, the Appalachian region (and westward to the Mississippi river), and on the islands and adjacent shores of Mackinac straits. The Salina or Onondaga salt group underlies it here as elsewhere.[1]

As an exception to the general statement, if Mr. Worthen is correct, not only the Salina, but other formations are wanting below the Water-lime in southern Illinois, down to the Cincinnati limestone. But in this limited region of Wisconsin, the underlying Salina is present, and crops out all around the Water-lime in a narrow circular rim.[2] The ancient Silurian sea slowly receded from the Archæan peninsula in northern central Wisconsin, with its outlying islands and reefs, depositing in turn the Potsdam sandstone, the Calciferous or Lower Magnesian limestone, the St. Peters sandstone, the Trenton limestone, the Galena limestone, the Clinton and Niagara groups, the Salina, and, finally, at the last point of emergence, the Water-lime base of the Lower Helderberg.

There is a stronger argument from stratigraphy than that of the normal relations of the Salina and the Water-lime.

If the formation in question is Hamilton, then the absence of the intermediate strata must be accounted for, and reconciled to the facts of local, as well as North American geology. Between the Salina

[1] Recent investigation has shown that the rocks here called Salina are themselves probably the Lower Helderberg. T. C. C.

[2] On the maps published previous to the more careful investigations of the present survey, the formation was represented as here stated, but upon confessedly imperfect evidence. It is now shown that this mapping was unwarranted. T. C. C.

and the Hamilton, there are the epochs of the Lower Helderberg and the Oriskany in the Upper Silurian age and the Cauda-galli, Schoharie, Corniferous, and Marcellus epochs in the Lower Devonian age.

During all that long period, therefore, while the ancient sea was depositing, under different conditions, these half dozen formations, the little semi-circular patch of Wisconsin, under discussion, must have been dry land, with the Salina for surface rock, and then must have become submerged long enough for the deposition of the Devonian Hamilton, again to be emerged at the close of that epoch, and remain dry land to the present hour. And this submergence must have been just far enough, according to such a hypothesis, to leave at every point on its margin a semi-circular rim of Salina. It would be impossible to harmonize a supposition of this kind with the known facts of rock-strueture of surrounding regions, or to make it consistent with the recognized laws of dynamical geology. It is much more rational to suppose that the land was slowly rising; that, consequently, the Silurian sea was slowly receding; that the last edge to emerge was the region in question; that during its own epoch the Salina was deposited; that, emergence still slowly going on, the Water-lime of the Lower Helderberg, being next in order of time, was laid down over a narrower area, after which the ocean disappeared from our shores, leaving the territory where Wisconsin now is, henceforth a part of the abiding continent.

The paleontological indications for determining the age of the formation are far less satisfactory than the stratigraphical. There is no doubt that these rocks are of the same epoch as those mapped by Mr. Rominger in the Michigan survey at the Straits of Mackinac as Helderberg. He says (p. 28, Paleozoic rocks), speaking of the paleontological evidence: "Leperditia alta and Spirifer modestus are known as Lower Helderberg species. On such a meagre representation of such a rich fauna, I would hesitate to base conclusions regarding the age of the formation." Yet, as already stated above, he concludes from stratigraphy that the rocks are Lower Helderberg. The undersigned, while investigating the lithological and stratigraphical characters and relations of the formation, has left mainly to others an examination of its fossils. *Orthis plicata*, *Avicula rugosa* and *Tentaculites*, designated by Mr. Vanuxem as characteristic of the Water-lime group, have been found by the chief geologist at Humbolt Falls. *Leperditia alta*, a still more important characteristic fossil, has also been found.

The most satisfactory paleontological evidence of this formation is *Eurypterus remipes*, which has not been discovered in the region.

It is only fair to state that Prof. Chamberlin, of the survey, has designated from this region *Ichthyolites*, *Strophodonta demissa*, *Atrypa occidentalis*, *Spiriferina zigzag*, casts of dermal tubercles of fish, and other organic remains, which he regards as characteristic of the Hamilton epoch; yet he marks a large percentage of these specimens as questionable, and does not take into account fossils that are clearly of the Water-lime period.[1] The paleontological question can only be settled by a more careful and ample collection of organic remains than has hitherto been made, which shall be submitted to Mr. Billings, Mr. Meek, or some other great authority in this difficult branch of science, who can judge with ample knowledge and without prejudice.

While acknowledging that paleontological evidence is of the highest value, and is of itself sufficient to settle the age of a formation, when unmistakable and clear, yet we are reminded that the fauna of Paleozoic time in the northwest differs greatly from the fauna of the same time in the east. For example, the Potsdam of Wisconsin, as said above, does not contain a single species identical with any species found in the same formation in New York. It is necessary to rely on the stratigraphical relations for determining its age.

The lithological evidence, which, ordinarily, is of the least value, and is often of no value at all, may, in this case, be regarded as of considerable importance. Prof. Dana's brief description of the Water-lime as "a drab colored or bluish impure limestone, in thin layers," is everywhere characteristic of this formation. Its lithological character does not essentially change in different regions, which ordinarily makes lithological evidence in geological questions so unreliable.

The undersigned, coming to the conclusion, mainly on stratigraph-

[1] This remark was probably not intended to convey the full significance which its language might seem to imply, but as it has been retained, it becomes necessary to state that it was evidently made under a misapprehension of the character of the fossils in question. At Dr. Wight's request, I furnished him with a box of fossils collected from the formation, but as they had not then received systematic investigation, a portion of the labels were prudentially marked with an interrogation point in accordance with the habit of conscientious investigators, but there were a sufficient number not so marked to demonstrate the Hamilton age of the deposit. There were no fossils characteristic of the Water-lime period contained in my collection, and it is safe to say that none exist in the formation. *The entire collection of the survey*, which is ample for the determination of the age of the rock, has been submitted to Prof. R. P. Whitfield, a most eminent authority, who pronounces the fauna distinctively Hamilton, and fully substantiates the correctness of my position. See page 397. The question of the hydraulic properties of the rock, which is independent of its age, first received my attention about one year previous, and would have been discussed in my annual report for that year, but for the delay in the analysis of specimens sent to the chemist of the survey for that purpose, June 12, 1874.
T. C. C.

ical evidence, that the formation under consideration is the Water-lime group of the Lower Helderberg, predicted from the lithological characters of the rock, that the region would prove rich in hydraulic cement. He did not then know that any discovery of the valuable commercial properties of the rock had been made. An analysis of specimens furnished Prof. Gustavus Bode, chemist of the survey, confirmed the conclusion and the prediction. The state of Wisconsin may be congratulated in a discovery that will add greatly to her resources, to her industry and to her commerce.

In the meantime, Mr. D. J. Whittemore, E. C., chief engineer of the Chicago, Milwaukee and St. Paul Railway, a well known Wisconsin scientist, had made a long series of careful experiments to test the commercial value of the cement rock found in the Water-lime formation under consideration. He has demonstrated that it produces a cement of better quality, consequently of higher value, than any cement now produced, either in America or Europe, except the Portland.

The following resumé of the results of his experiments has been kindly furnished by Mr. Whittemore himself:

MILWAUKEE, *December 23, 1875.*

DR. O. W. WIGHT, *State Geologist of Wisconsin:*

MY DEAR SIR: In compliance with your request, I herewith make a condensed statement of the principal results attained in my experimental inquiry as to the value of hydraulic cement, made from the recently discovered stone deposit in the vicinity of Washington street bridge, near this city.

For the purpose of comparison, I selected from very many samples of commercial cements those that, after a few days' trial, gave indications of good quality; therefore, you will bear in mind, that the average strength of the commercial cement experimented upon by me, is considerably above the general average of the cements in our market. In both manipulation and testing, I availed myself of every experiment that I could well devise to secure uniform treatment throughout my inquiry.

I converted the natural Milwaukee stone into a cement by the usual method of calcination and grinding, and experimented upon the product from single stones separately; also upon the mixed products of two stones selected from widely separated localities of the ledge, each submitted to varied degrees of torrification in the preparation, and all gave very similar results. This determines quite conclusively that within the limits hereinafter mentioned the deposit has a uniform character, a matter of much importance in determining its value.

My experimental tests were directed to determining the following features, viz.:

1st. To ascertain the tensile strength in pounds per square inch of mortar, composed of equal weights of cement and sand, at the age of ninety days, the last eighty-nine in water.

2d. To ascertain the breaking strength of mortars of cement mixed with definite portions of sand, moulded into bars one inch square, and resting on supports three inches apart, and broken by application of weight in the middle. Age of mortars one hundred days, the last ninety-nine in water.

3d. To ascertain the crushing strength in pounds per square inch of mortars of cement, mixed with definite portions of sand, at the age of ninety days, the last eighty-nine in water.

4th. To ascertain the adhesive strength, in pounds per square inch of mortars composed of equal parts of cement and sand, to common brick, at the expiration of seventy days.

The following table is a compilation of the average of all of my determinations, and is derived from over fifteen hundred individual tests:

	Tensile Strength.	Breaking Strength.		Crushing Strength.			Adhesive Strength.
Composition of Mortars.	1 to 1 by Weight.	2 Cement and 1 Sand.	1 Cement and 2 Sand.	1 Cement and 1 Sand.	1 Cement and 2 Sand.	1 Cement and 3 Sand.	1 Cement and 1 Sand.
Average of Milwaukee Cement.......	290	124	69	2.365	1,451	1,107	75½
Average of Commercial Cement.......	192	80	44	1,477	799	488	45½

The strengths of the commercial cements are derived from the average of many tests of the number of brands represented below.

For tensile strength, 14 brands of cement.

For breaking strength, 6 brands of cement.

For crushing strength, 11 brands of cement.

For adhesive strength, 9 brands of cement.

I desire to state that the *average* results attained by the Milwaukee product exceeded the maximum attained by the best of the commercial cements.

I have now under examination the product from a section of the Milwaukee ledge extending from the surface to a depth of thirteen feet, running through eleven layers, and its strength compares very favorably with the former determinations of the Milwaukee cement.

The rock from which the cement, experimented upon, was made, was selected from the banks and bed of Milwaukee river, between the west line of the east half of northwest quarter of section No. 5, town 7 north, range No. 22 east, and the east and west quarter line of section No. 4, same town and range.

Yours Truly, D. J. Whittemore, C. E.

Artesian Wells. — As an addition to accounts of artesian wells given in previous reports, the survey is indebted to the General Manager's office of the Chicago, Milwaukee & St. Paul Railway, for the following:

Milwaukee, *July 6, 1875.*

Dr. O. W. Wight, *State Geologist,*

Sir: I send you below an account of the different strata found in putting down three artesian wells on our lines in this state. Yours Truly, John C. Gault.

ARTESIAN WELL AT MILWAUKEE.	*Feet.*
Earth	170
Lime rock	267
Shale	165
Second Limestone	253
Sandstone full of water	193
Total depth	1048

AT WESTERN UNION JUNCTION.	*Feet.*
Earth	147
Lime rock	233
Shale	200
Lime rock	285
Sandstone	[1] 100
Sandy lime	141
Struck St. Peters Sandstone	[2] 1106
Depth of well	[3] 1263

AT MADISON.	*Feet.*
Earth	75
Sandstone	525
Shale	4
Second Sandstone	18[illegible]
Trap rock	5
Total depth	795

Water does not rise above surface of ground, but it supplies a large pump, without any apparent loss of volume.

Mineral Springs. — In addition to the analysis of Wisconsin spring waters given in previous reports of the survey, two are especially noteworthy.

Prof. C. F. Chandler, Ph. D., Chemist to the New York School of Mines, gives the following analysis of the water of the Beloit Iodo-Magnesian springs:

	Grains in 1 gallon.
Chloride of Sodium	0.3362
Bromide of Sodium	trace.
Iodide of Sodium	0.0049
Bi-carbonate of Soda	0.1406
Bi-carbonate of Magnesia	12.2803
Bi-carbonate of Lime	14.5196
Bi-carbonate of Iron	0.0396
Sulphate of Lime	0.1326
Sulphate of Potash	0.3123
Phosphate of Soda	0.0104
Alumina	0.0590
Silica	0.7581
Organic Matter	trace.
Total per U. S. gallon of 231 cubic inches	28.5936

Prof. Gustavus Bode, Chemist to the Wisconsin Geological Survey, gives the following analysis of the water of a very remarkable artesian well at Sheboygan:

[1] Struck small flow.

[2] Found 15 feet limestone in the sandstone.

[3] Sandstone again to bottom mixed with red rock.

One gallon, U. S. measure, contains: —

	Grains.
Total quantity of Salts	657.8833
Consisting of:	
Bi-carbonate of Lime	1.4945
Bi-carbonate of Magnesia	0.3782
Chloride of Sodium	367.6470
Chloride of Potassium	9.9064
Chloride of Lithium	0.0244
Bromide of Sodium	1.0553
Iodide of Sodium	0.0232
Sulphate of Magnesia	89.3340
Sulphate of Lime	76.1463
Chloride of Calcium	109.2998
Sulphate of Iron	0.7442
Alumina	1.0980
Silica	0.7320

Acknowledgments. — The State Geologist has to thank in this formal manner, the officers of the Chicago, Milwaukee and St. Paul Railway, the officers of the Wisconsin Central Railway, the officers of the Wisconsin Valley Railway, the officers of the Chippewa Falls and Western Railway, the officers of the West Wisconsin and the North Wisconsin Railway, the officers of the Green Bay and Minnesota Railway, for free transportation of men and materials in behalf of the survey. The Wisconsin Central and North Wisconsin have even put trains at the disposal of the chief geologist, free of cost, in order to facilitate and expediate his work. Such generous liberality cannot be too highly praised. Acknowledgments are also due to Captain Knapp, in command of a steamboat on the St. Croix river, not only for free transportation of the party of reconnoissance, but for services in procuring proper boats for ascending the river above the falls. Captain Vaughan, of Ashland, also laid the survey under especial obligations for putting his tug boat at the disposal of the undersigned and his party. Hotel keepers everywhere in the state have shown their substantial good will to the survey, by keeping men who were working in the field at reduced rates. The American Express Company, through the friendliness of its general manager in this state, Mr. Antisdel, has carried packages for the survey free of cost.

In these various ways large expenditures of money have been saved to the state, and the chief geologist has been enabled to accomplish much more than would otherwise have been possible. The people all over the commonwealth have expressed, both verbally and by letter, great interest in the survey, and are looking forward with hopefulness of results to the time when its final reports shall be published.

O. W. WIGHT, A. M., M. D.,
Chief Geologist.

Milwaukee, *December 30, 1875.*

PLATE, II

The Milwaukee Litho & Engr. Co.

LUCAS POINT, GREEN LAKE,

Showing junction of Potsdam Sandstone and Lower Magnesian Limestone.

PART II.

GEOLOGY

OF

EASTERN WISCONSIN.

BY T. C. CHAMBERLIN.

ACKNOWLEDGMENTS.

It is fitting that I should acknowledge in a preëminent degree my obligations to the lamented Dr. Lapham, under whose direction as chief geologist the earlier part of the field work, which forms the basis of this report, was performed. In addition to the inestimable value of such direction to a young geologist, there was ever at my disposal and furnished to my needs, a large fund of information concerning local formations and the unwritten history of previous investigations. While nothing will be found reported without specific mention that has not been a matter of personal observation, it is impossible to discern in how far that observation has been enriched by such assistance.

My acknowledgments are also due to those who have been associated with me as assistants during the progress of the work. Of these especial mention is to be made of the accurate and efficient aid of Mr. L. C. Wooster, who assisted in the field work of each season; of Mr. F. H. King, who sustained that relation with equal acceptance during two seasons, and of Mr. G. D. Swezey, whose botanical observations are especially to be noted. Efficient assistance was also rendered for shorter periods and special service by Messrs. N. D. Wright, Samuel Shaw, S. E. Lathrop, G. L. Merriman, J. H. Chamberlin, and W. C. Stevens, and in office work by W. F. Brown, I. M. Buell, C. S. Bacon, C. S. Douglas, and others. To Prof. R. P. Whitfield I am also indebted for valuable suggestions in relation to paleontological questions.

For the innumerable courtesies that have been received from citizens in the prosecution of the work, and that in many instances have been of the utmost value, I desire to express my most sincere thanks. It would be exceedingly gratifying to me to be able to make specific mention of these favors, and such acknowledgment has been made so far as possible in the manuscript annual reports, but the list has now swollen to such dimensions as to preclude its publication here. A very just legal acknowledgment has been made in the provision of the law of publication and distribution, which entitles all who have assisted in the prosecution of the survey to a full set of the reports, and the fulfillment of that provision will give me the utmost pleasure.

EXTENT OF THE DISTRICT.

The district described in the following chapters consists of the counties of Rock, Jefferson, Dodge, Green Lake, except that portion lying on the left bank of the Fox river, Winnebago, Outagamie, that portion of Waupaca which lies on the left bank of the Wolf river; those portions of Shawano and Oconto occupied by Paleozoic rocks, and all the counties lying east of these, consisting of Door, Kewaunee, Brown, Calumet, Manitowoc, Sheboygan, Fond du Lac, Washington, Ozaukee, Milwaukee, Waukesha, Walworth, Racine and Kenosha. It constitutes a belt averaging about sixty-five miles in width and more than one hundred and eighty in length, the extreme width being eighty-one miles, and the extreme length a little over two hundred. It includes nearly twelve thousand square miles. The area lies throughout its entire extent, adjacent to Lake Michigan, and might appropriately be termed the Lake Border Region, were it not that it includes so large an area whose drainage is tributary to the Mississippi.

PLATE, II

The Milwaukee Litho & Engr. Co.

PREVIOUS PUBLICATIONS RELATING TO THE REGION.

The following is a list of all publications relating in any specific way to the region, that have come to my knowledge. And as the nature and limits of this report preclude, for the most part, specific reference to the contents of these publications, either in commendation or criticism, it is hoped that this mention will be accepted as an acknowledgment of the credit due their authors:

Report of a Geological Reconnoissance, made in 1835, from the Seat of Government, by Green Bay, in the Wisconsin Territory, to the Couteau de Prairie. By George W. Featherstonhaugh, Washington. 1836. 8 vo., pp. 168.

On the Existence of certain Lacustrine Deposits, in the vicinity of the Great Lakes, usually confounded with the Drift. By I. A. Lapham. Am. Jour. of Science, 2d Series, vol. 3, p. 90. 1847.

On the Geology of the Southeast Portion of Wisconsin, not heretofore surveyed. By I. A. Lapham. Included in Foster and Whitney's Report on the Geology of the Lake Superior Land District. Part 2d, pp. 167, *et seq*. Washington. 1852.

Geological Formations of Wisconsin. By I. A. Lapham. Transactions of Wisconsin State Agricultural Society. Vol. 2d. 1851, pp. 122, *et seq*.

A Geological Map of Wisconsin. By I. A. Lapham. 1855.

Report of a Geological Survey of Wisconsin, Iowa and Minnesota, and a portion of Nebraska. By D. D. Owen. Philadelphia. 1852. The chapters relating to this district are by Col. Whittlesey.

Annual Report of the Geological Survey of Wisconsin. By James G. Percival. Madison. 1855. Ditto, 1856.

Annual Report of the Geological Survey of Wisconsin. By Edward Daniels. Madison. 1857.

Report of Progress, on behalf of the Geological Commission of Wisconsin. By James Hall. Executive Message and Documents. 1859.

Descriptions of New Species of Fossils from the Northwestern States. By J. H. McChesney. Chicago. 1859.

On Drift Cavities, or Potash Kettles of Wisconsin. By Chas. Whittlesey. Proceedings American Association for the Advancement of Science. Vol. 13. p. 297. Springfield. 1860.

Report of the Superintendent of the Geological Survey of Wisconsin. By James Hall. January 1, 1861. Executive Message and Documents.

Report of the Geological Survey of Wisconsin. Vol. 1. By James Hall. Madison. January, 1862.

On the Fresh Water Glacial Drift of the Northwestern States. By Charles Whittlesey. Smithsonian Contributions to Knowledge. Washington. December, 1866.

Geological Survey of Wisconsin. 1859-1863. Paleontology. By James Hall.

Relations of the Niagara Group. By James Hall. Report of Regents of University of New York.

On Western Boulder Drift. By E. Andrews. American Journal of Science. Part 2. Vol. 48. 1869.

A New Geological Map of Wisconsin. By I. A. Lapham. Milwaukee. 1869.

The Glacial Features of Green Bay, of Lake Michigan, with some Observations on a Probable Former Outlet of Lake Superior. By N. H. Winchell. American Journal of Sciences and Arts. Vol. 2. July, 1871.

United States Engineers Reports on the Surveys of Fox and Rock Rivers.

Geological Report of Michigan. 1869-73. Dr. Rominger on Paleozoic Formations.

Catalogue of Plants Found in the Vicinity of Milwaukee. By I. A. Lapham. 1838. 12 mo. pp. 23.

On the Plants of Wisconsin. By I. A. Lapham. Proceedings American Association for Advancement of Science. Vol. 2. 1850. pp. 19. Also published in Transactions of Wisconsin State Agricultural Society. Vol. 2. 1852, pp. 375, *et seq.*

Notes on the Woods of Wisconsin. By P. R. Hoy. Transactions Wisconsin State Agricultural Society. Vol. 2. 1852, pp. 419, *et seq.*

The Grasses of Wisconsin and the Adjacent States. By I. A. Lapham. Transactions Wisconsin State Agricultural Society. Vol. 3. pp. 397, *et seq.*

The Forest Trees of Wisconsin. By I. A. Lapham. Transactions Wisconsin State Agricultural Society. Vol. 4, pp. 195, *et seq.*

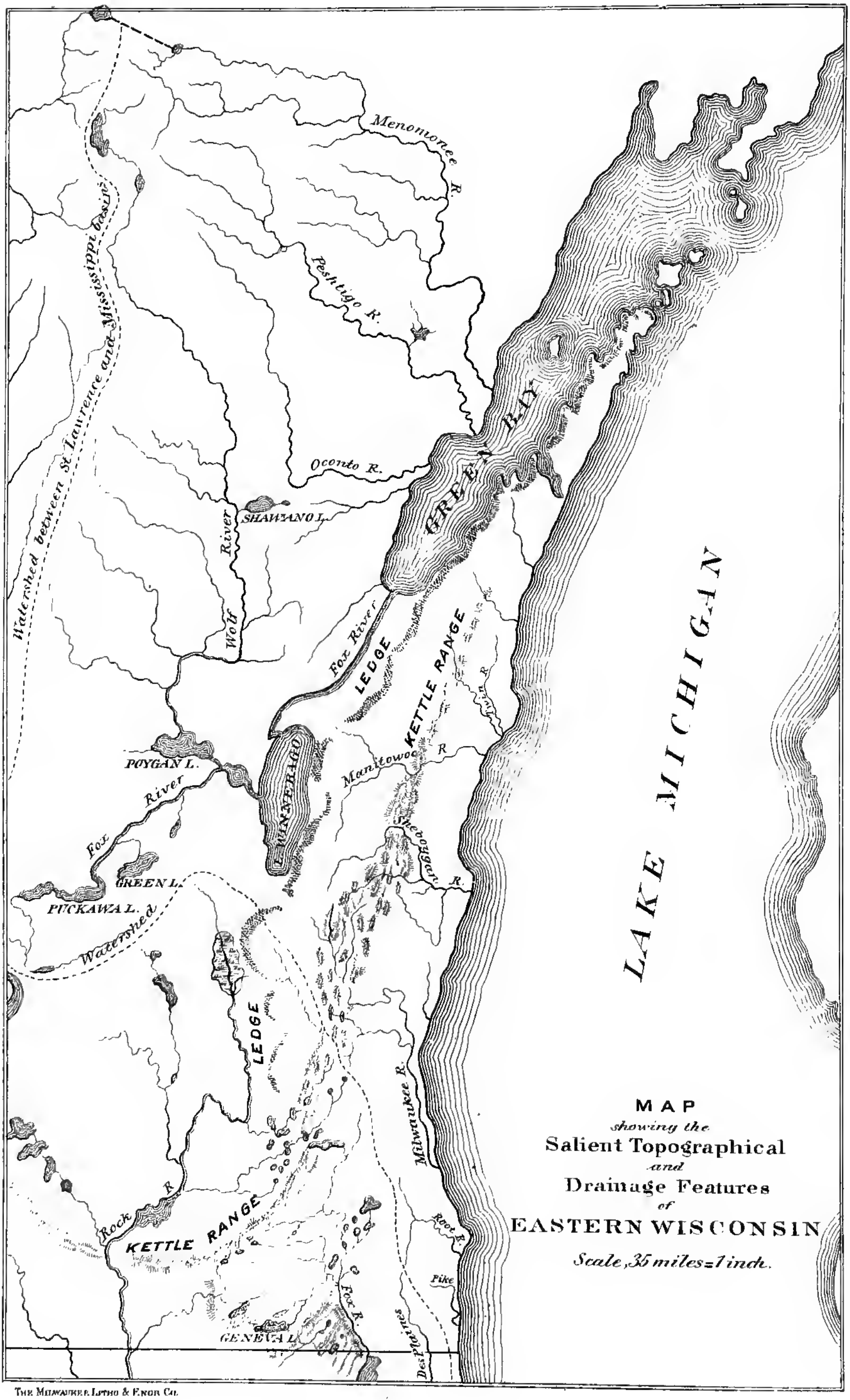
Additions to the Flora of Wisconsin. Transactions Wisconsin State Agricultural Society. Vol. 5. 1858, p. 417. Also vol. 6, 1860, p. 258.

Map of Wisconsin, Illustrating Distribution of Timber, etc. By J. W. Hoyt. Transactions Wisconsin State Agricultural Society, 1860.

Fauna of Wisconsin. By I. A. Lapham. Transactions Wisconsin State Agricultural Society. Vol. 2. 1852, pp. 237, *et seq.*

Notes on the Ornithology of Wisconsin. By P. R. Hoy. Transactions State Agricultural Society. Vol. 2, 1854, p. 341. Also, the same, with additions in Proceedings Academy Natural Sciences. Philadelphia. Vol. 6. pp. 304, 381, 425. 1854.

Quadrupeds of Illinois, Wisconsin, etc. By Robert Kennicott. Patent Office Reports. 1856, p. 52.



The Milwaukee Litho & Engr Co.

GEOLOGY OF EASTERN WISCONSIN.

CHAPTER I.

TOPOGRAPHY.

When Eastern Wisconsin first emerged from the ocean, it doubtless presented an essentially plane surface, having a slight inclination to the east and southeast. The irregularities which it now presents are due to subsequent changes, the results of three classes of agents, acting at different times and under different conditions.

1. During the long ages between the emergence of the land and the drift period, the streams were cutting their beds deeper and deeper into the rock, and rendering the former level surface more and more irregular. The softer rocks were more readily eroded than the harder ones, and this helped to increase the unevenness. There was a tendency of the streams, as far as the slope favored, to follow the less resisting belts of soft rock, and as these run in a northerly and southerly direction in this region, the main streams had that direction. The little streams gathered into the larger ones in a manner not unlike that by which the branches of a tree are united into the trunk. The unevenness of surface produced by erosion of this nature possesses a certain kind of system and symmetry readily recognizable. As this erosion occupied the time preceding the Glacial period, we may conveniently designate the features produced by it *Pre-Glacial.*

We have the best example of this kind of surface configuration in the Lead region, over which the drift forces did not act, and which has not been resubmerged, so that we have the results of this class of action pure and simple. As we proceed eastward into the region of drift action in the central part of the state, these features are modified more and more by the results of glacial action, until in eastern Wisconsin they become wholly obscured, except in their grander outlines.

2. The modifications of the surface constituting this first class of topographical features were produced by running water, those of *the second class*, which were produced next in order of time, were formed by ice in the form of glaciers, it is confidently believed, and by the agencies brought into action through their melting. The work of the ice was two-fold: first, in the leveling of the surface by planing down the hills and filling up the valleys; and second, in the creation of a new uneven surface, by heaping up in an irregular and promiscuous manner the clay, sand, gravel and bowlders it had formed, thus giving the surface a new aspect.

Among the features produced by the action of the ice, are parallel ridges sometimes miles in length, having the same direction as the ice movement, hills of rounded flowing contour sometimes having a linear arrangement in the direction of glacial progress, mounds and hummocks of drift promiscuously arranged on an otherwise plane surface, oval domes of rock (roches moutonées), sharp gravel ridges, often having a tortuous serpentine course, transverse to the drift movement, peculiar depressions known as "kettles," and half submerged rock gorges, known as fiords, all of which will be considered more fully in describing the minor topographical features of the region, and in discussing the Quaternary formations.

The melting of the ice mass gave rise to swollen lakes and flooded rivers, which eroded at some points and filled up at others, and so still farther modified the face of the country. All these peculiarities, being the result, directly or indirectly, of the ice action, may be denominated *Glacial features.*

3. Subsequent to the Glacial period, the wearing action of the streams was resumed, but under somewhat new conditions. In addition to this, there occurred a depression of the land toward the north of several hundred feet, attended by an increased volume of water in the lakes, by which nearly one-half of the district was submerged. The advancing waters of this period leveled down many of the surface irregularities, and while the land was submerged the "red clay" was deposited which still further leveled the surface. After the land arose again from the water, the streams resumed their cutting, and as the clay was soft, they rapidly eroded deep, wide gorges, leaving abrupt terraces on either side. The results of the these agencies produced peculiarities in the surface contour that may, following out our plan, be called *Post-Glacial features.*

To the three agencies, lake action, ice and running water, assisted slightly by winds, the topographical peculiarities of the district are chiefly due. There is no evidence of violent eruptions, upheavals or outbursts. There was indeed the gradual elevation and depression of the surface and probably some little flexure of the crust, and there are at two or three points, indications of faulting; but in general, the region has been free from violent agitation, and owes none of its salient topographical features to such causes.

Having thus briefly considered the *general methods* by which the present aspect of the country was produced, we may now more satisfactorily examine its *special features*, and if the reader will have recourse to Plate IV of this volume, and, for minor details, to the accompanying atlas, it will relieve us mutually of the wearisomeness of mere elementary geographical details, while it contributes to a clearer and more vivid understanding of the subject.

No part of Wisconsin can properly be said to be mountainous, nor does it, over any considerable area, sink to a dead level. It presents the golden mean in a gently undulating diversified surface, readily traversible in all directions by the various highways of communication. The eastern district under consideration contains the more level portions of the state, but presents at the same time much of diversity and many most interesting topographical features.

Setting aside minor details, the state presents *two general slopes*, a short, abrupt declivity northward to Lake Superior, and a long, gentler incline southward. Through the center of this southward slope there extends a moderate elevation — a low anticlinal axis — giving a southeasterly and southwesterly inclination to the strata on either side. The district under consideration is wholly confined to the southeasterly slope.

The symmetry and simplicity of this system is however traversed in a peculiar manner by *a diagonal valley* occupied by Green Bay and the Fox and Wisconsin rivers. This feature of the general surface of the state enters, in an interesting way, into the topography of our district, and from its commercial importance demands attention. This valley, including its extension into Michigan, is occupied by the waters of Green Bay for about one hundred miles, with an average breadth of about twelve miles. The bay projects into Wisconsin about seventy miles beyond Porte des Morts at the extremity of the peninsula, and about forty-five miles beyond the mouth of the Menomonee river, which forms the state boundary.

This valley is abruptly limited on the east side by precipitous rocky cliffs rising from 100 to 200 feet above the Bay. From the crest of these cliffs, the land slopes toward Lake Michigan. On the opposite or west side of the valley, the surface rises very gradually for 20 to 30 miles, beyond which the slope becomes somewhat steeper. The Bay has a trend of about S. 35° W. Following up the valley in this direction, it presents the same characteristics, bounded by an abrupt wall of rock on the east, and gently sloping upward to the west. It rises somewhat rapidly, so that when Lake Winnebago is reached, an elevation of 169½ feet, canal survey, or 162 feet, railroad survey, has been attained. This lake strikingly resembles Green Bay in the nature of its eastern and western shores. Its trend, however, is nearly due north and south, and if we follow on in this new direction, the valley leads up over the watershed between the Mississippi and St. Lawrence basins, into the valley of Rock river. This extension of the Green Bay valley will be noticed farther on.

For the present, however, we are considering the diagonal valley — the topographical and drainage basin — which has its extension in the valley of the Upper Fox river. Like the preceding, this portion of the valley has its more abrupt slope on the south side, but this is far less conspicuous than before, nor do we find the same broad, level tract on the opposite side. These differences are due partly to the fact that the valley, in this portion, *crosses* the geological formations obliquely, whereas, in the lower portion, *it followed their trend*, and partly to the fact that here the drift movement was across the valley from eastward to westward to a considerable extent. This valley undoubtedly had an existence before the glacial epoch, and during that period it was probably more filled than eroded.

The Fox river, in this portion of its course, has a much less rapid descent than between Lake Winnebago and Green Bay, a circumstance greatly favoring its improvement and navigation. The Upper Fox descends 40 feet in an air-line distance of about 60 miles, or a little more than 100 miles along its meanderings, while the Lower Fox descends 162 (169½) feet in half that distance.

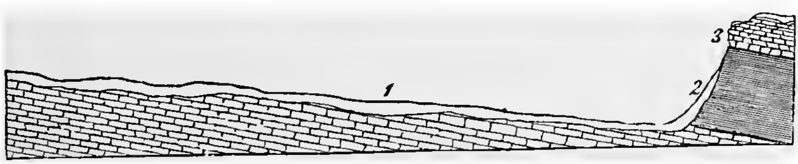
The valley leading south from Lake Winnebago, which has been alluded to as an extension of the Green Bay valley, and, as will hereafter be seen, is in many respects entitled to be so considered, rises 140 feet in 15 miles. These facts, supported as they are by many others of similar import, show that the diagonal valley under consideration is not a fanciful conception, but a well characterized, if not obvious, fact.

The commercial importance of this valley in presenting suitable conditions for the establishment of water communication between the Mississippi and the great lakes, has awakened a deep interest among leading citizens of this and adjoining states, and public attention has been so thoroughly turned toward it, and the prospect of realization is so good, and so immediate, that so far as the people of the state are concerned, it would need little discussion here, even if the limits of my field comprehended its entire extent and brought the whole of the subject under consideration. But it deserves to be here recorded for the information and guidance of capitalists abroad, that for a moderate expenditure this remarkable natural feature can be made to yield an important avenue of transportation.

In this connection the attention of capitalists is invited to the facts given subsequently in relation to *the water power* of the Lower Fox river, bearing in mind that grain bearing vessels will offer return transportation at the most reasonable rates, thus placing manufacturing establishments in the most advantageous relation to the thousands of miles of rich territory along the Mississippi and its tributaries, and the still other thousands of miles of shore line around the great lakes. The enterprise for the improvement of this channel of communication, under the auspices of the general government, is already (1876) far advanced.

It has been already remarked that the valley from Green Bay to Lake Winnebago is exceedingly abrupt on the east, and very slightly ascending on the west. The persistence of this peculiarity for so great a distance points to some *general cause.* This is readily found in the nature of the rock from which the valley was eroded. The strata in this portion of the state dip to the eastward. Three groups of beds are concerned in the formation of the valley. The uppermost one, which forms the cliffs on the east side, consists of hard, thick-bedded magnesian limestone, belonging to the Niagara period. Beneath this lies a series of clays, soft shales, and limestones, very easily eroded by water, forming the Cincinnati group, and below this again is a hard, thick-bedded dolomite, known as Galena limestone, which forms the bottom of the valley and its western slope, as shown in the accompanying figure:

Fig. 1.



1. Galena limestone. 2. Cincinnati shale. 3. Niagara limestone. 1—2. Green Bay valley.

It becomes evident enough then, from these facts and from an inspection of the valley, that it was formed by the wearing away of the softer strata, leaving the harder ones above projecting in mural cliffs. This eroding action is still going on, and to some extent is greatly facilitated by numerous springs that issue from the upper surface of the clay and shale, keeping them soft and assisting in wearing them down. The dip of the rocks tended to keep the stream hard against the soft stratum, and so hastened its removal.

There is abundant reason for believing that this process had far advanced before the glacial period, and had already formed so considerable a valley as to influence the glacial movement. During the latter part of that period, at least, the ice mass moved southward *up* the valley, modifying its sides and polishing its rock bottom in the most beautiful manner. Subsequently the valley was partially filled with red clay, without however affecting its general features. The stratigraphical relations of this valley are then most conspicuous. If, keeping this prominently in mind, we follow up the valley, we are led southward from Lake Winnebago to what was formerly Lake Horicon, now drained to a marsh, where the head waters of the Rock river gather together and flow southward to the Mississippi. We have then crossed the watershed between the great St. Lawrence and Mississippi basins; and yet on the very divide itself we find the peculiar character of the valley still conspicuous. The watershed in the trough of the valley is, in round numbers, 200 feet above Lake Michigan, while on either side the surface rises to more than twice that elevation.

The Horicon basin is only a repetition of that of Lake Winnebago, overlooked by the same line of cliffs on the east, and scarcely confined by the gentle rise on the west. Descending *the Rock river valley*, these features are still discernible, but become more and more obscured by the heavy drift accumulation of this region, until in the southern tier of counties they are almost entirely concealed by a great drift ridge, a glacial moraine, hereafter to be described, which stretches entirely across the valley and, combined with other elements, gives it a new character. The river has removed from the eastern side of the valley to a more central position, and from it there arise diversified undulating slopes on either side.

The course of the Rock river through this valley is interesting and for convenience may here be considered, in lieu of its appropriate place. From Horicon marsh southward, it follows, as closely as the drift accumulations will permit, the ledge of Niagara limestone above mentioned until about opposite Oconomowoc, when it turns abruptly and flows to the northwest, until it reaches Watertown, where it bends again suddenly to the southward and follows this course, bearing westward, till it leaves the state. The sigmoid flexure thus formed is apparently due to drift accumulations. Were these removed, there is little doubt that the stream would follow its course along the strike of the formations, at least as far as the moraine in Walworth county. Beyond that point the drift is so deep as to preclude any knowledge of the configuration of the rock surface.

It is interesting to notice that this river, which has been following the trend of a soft, easily eroded formation — the Cincinnati shale — from which it is now forced by drift, passes across the Galena and Trenton limestones and makes its bed in *the next lower soft formation*, the friable St. Peters sandstone, which it follows, until it leaves the state.

Considering the Rock river valley as an extension of that of Green Bay, the two forming one great excavated trough, the *elevations* it attains become matters of much geological and commercial importance. At the north, it finds in Green Bay the level of Lake Michigan and, as has been previously remarked, rises somewhat rapidly about 170 feet to Lake Winnebago. Throughout the length of that lake, a distance of thirty miles, it is essentially level. From its southern extremity, the valley again rises about 140 feet to the watershed, making its greatest elevation a little over 300 feet.[1] The former Lake Horicon was 285 feet above Lake Michigan. From this point a gentle declivity brings the valley down to 150 feet, at Beloit, on the state line. It continues its moderate descent till it joins the Mississippi, where it is about 50 feet below Lake Michigan. This Illinois extension of the valley differs, however, somewhat widely in geological and topographical features from the portion in Wisconsin.

The commercial importance of the foregoing facts is very considerable as now realized, but is far greater in its future possibilities. It furnishes important facilities for both land and water communication. The sagacious proprietors of the Chicago & Northwestern Railway early perceived this and located nearly 200 miles of their road in this valley, thus securing an easy grade along a line of important towns, supported by an exceedingly rich agricultural region, and possessing some of the finest water powers of the interior.

Water communication is utilized to some extent, but the great possibilities in this direction lie yet undeveloped. In the year 1866, a survey of this valley from Fond du Lac to the Mississippi was authorized by the general government and executed by Col. James Worrall, under the direction of Gen. J. H. Wilson, having for its object the determination of the practicability of establishing a capacious

[1] All elevations in this report, unless otherwise designated, signify altitude above Lake Michigan, which, awaiting more accurate measurements, is considered 578 feet above the ocean.

channel of water communication between the Mississippi and the northern lakes. Important facts developed by that survey may be found in Ex. Doc. No. 15, of the House of Representatives, 40th Congress, and should not be forgotten by an enterprising people.

Returning from this digression, it is to be remarked that the *diagonal valley* previously described, and this Rock river, Green Bay valley, unite at the north and join the great depression occupied by *Lake Michigan.* The bed of this great lake is excavated chiefly from the soft rocks of the Devonian age, and has its axis parallel to the strike of the formations. The western edge of the lake rests upon the Niagara dolomites, but the dip of the formation is greater than the slope of the lake bed, so that this formation is probably overlaid near the western edge of the lake by the upper formations.

This great submerged valley possesses one of the main features that characterize the Green Bay valley, that of having a more abrupt slope on the east. At least this is true of the northern portion according to the lake survey charts, for which I am indebted to the kindness of Gen. C. B. Comstock. This, however, is not a conspicuous fact, and the eastern shore is far from being precipitous. The eastern line of Wisconsin would, if traced on the bottom of Lake Michigan, *lie almost wholly below the sea level.* The extent to which Lake Michigan occupies the territory of the state and its nearly constant level, make its surface our most convenient datum plane in giving elevations and discussing topographical features. The elevation of the surface of the lake above the sea level, that has been adopted in the progress of the survey, is 578 feet. In the report of the survey of Rock river, 576 feet is given, and Gen. Comstock informs me that the lake survey use at present 581 feet above mean tide at New York. The series of levels, now being run, will, when completed, give for the first time an accurate determination of the level of the great lakes.

The erosion of the great valleys we have now considered left of necessity adjacent *slopes* and *dividing ridges.* North of the Fox river a very large area is included in a southerly and southeasertly incline, the drainage of which is tributary to that river. This is indicated clearly by the general course of the Wolf, Oconto, Peshtigo and Menomonee rivers and their branches. On the west side of Rock river there is a similar slope tributary to it. But the most conspicuous elevation in the district is the extensive ridge that lies immediately east of the valleys of Green Bay and Rock river, and which has already been cursorily mentioned in the descriptions of those valleys.

A glance at the course of the rivers of this region shows that the summit of this elevation is immediately adjacent to the valleys mentioned. Its average elevation above Lake Michigan varies from about 400 feet, in the south and central portions, to 200 feet, at the north, while isolated points considerably exceed these figures. From this crest the surface slopes eastward to Lake Michigan, and onward under its waters down to and below the sea level. With an unessential exception, this slope is everywhere underlaid by the Niagara limestone, to the dip of which, and the softness of the underlying shale, the ridge owes its origin. Indeed, the ridge is simply the projecting edge of the inclined Niagara strata. At the south, where this eastward slope enters the state from Illinois, it is about forty miles wide. It retains this amplitude for upwards of 100 miles, extending in an almost due north course, beyond which it curves more rapidly to the eastward, and gradually narrows till the limiting waters of Lake Michigan and Green Bay on either side meet and mingle through Porte des Morts. But in fact it does not end here. As a submerged ridge it extends onward to Michigan, its crest appearing as a line of islands, stretching across to the peninsula east of Big Bay de Noquet, which presents similar features due to the same cause.

Without destroying the truth of what has been said of this eastward sloping rock-ridge, the region presents a secondary topographical feature of no insignificant importance.

It consists of a line of immense *drift hills*, superimposed upon the terrane just described, and known as the *Potash Kettle, or Pots and Kettles Range.* As the term "Potash" has now no special significance, it will be dropped from this report. At the south these drift hills rest directly upon the summit of the rock-ridge, their added height reaching an altitude of from 400 to 800 feet above Lake Michigan. To the northward, however, the drift moraine has a somewhat more easterly trend than its indurated companion, and creeps down the eastern slope of the latter, until it ends in Kewaunee county, midway between the shore of Lake Michigan and the rock-crest that overlooks Green Bay. This modifies, somewhat, the simplicity of contour that would otherwise be presented, but owing to the great irregularity of the drift accumulation, the streams find their way across it, and the drainage system of Lake Michigan is not essentially affected by it. In Walworth county a branch from this drift ridge extends westward, crossing the Rock river, beyond which it curves to the northward, and passes beyond the limits of my district. The effect of this upon the features of the Rock river valley has already been noted.

These then are the *salient topographical features* of the district, the great Lake Michigan basin, the Green Bay valley, with its twofold extension in the Upper Fox and Wisconsin river valleys, and in the Rock river basin, and their attending slopes and ridges.

If we descend to *minor features*, a large number of most interesting phenomena will be presented. As these, however, are chiefly due to erosion and to drift accumulations, they may most intelligently be considered in connection with the drainage system and the glacial formations.

Elevations. The following elevations constitute a more specific class of topographical data. They will be of great value in making estimates for Artesian wells, a subject which possesses very great importance in this region, and in locating preliminary lines of railroad, in which respect they have already proved serviceable, and in various other ways. The elevations of railroad stations, and in many cases of intermediate points on the line, are those furnished me by Dr. Lapham, from the railroad surveys. To the same source, also, I am indebted for the altitudes of the Oconomowoc lakes, and some other points. The elevations along the line of the proposed Chicago and Midland railroad are from the survey of Mr. F. J. Starin, who kindly placed the profiles at my service, which have proved of much use in other ways. Elevations on the Peshtigo river were generously furnished by Mr. Paul Wood, civil engineer of the Peshtigo Company. A few have also been taken from other trustworthy sources. These being the results of actual leveling, by competent engineers, are a very close approximation to the actual elevations. The remainder are the results of observations with aneroid barometers, and are liable to more considerable errors, because the nature of the instrument does not permit so great precision, and more especially because of the fluctuations of the atmosphere, for which, in a series of observations made in connection with and subordinate to geological field work, it is impossible to make altogether accurate corrections. A very large number of observations were made which are not thought worthy of publication, because changes in the weather and other circumstances rendered them unreliable, and in using those given it will be judicious to leave a liberal margin for variation due to changes in the pressure of the atmosphere, which could not be detected. The laborious work of reducing the barometrical observations was chiefly performed by Messrs, L. C. Wooster, G. D. Swezey, J. H. Chamberlin and C. S. Bacon. The elevations for Milwaukee county are the results of a special and very full series of observations made by Chas. Lapham, which the importance of that region, as a railroad center, seemed to warrant.

LIST OF ELEVATIONS ABOVE LAKE MICHIGAN.

(For the elevation above the ocean, add 578 feet.)

	Feet.
Ahnapee. T. 25, R. 25 E.	
Sec. 5, S. W. qr.,	60
Bank S. of Ahnapee,	60
Three miles S. W. of Ahnapee,	122
Angelica. T. 26, R. 18 E.	
Sec. 33,	285
Ashford. T. 13, R. 18 E.	
Sec. 2, N. Line,	441
2, average,	516
3, R. R. cut,	459
11, N. E. qr.,	498
13, center,	466
23, Elmore Village,	421
23, Surface of Kettle Formation,	444
24, W. side river,	322
Auburn. T. 13, R. 19 E.	
Sec. 8, center N. hf.,	490
New Cassel bridge,	438
New Cassel depot,	466
Sec. 30, Five Points,	468
30, R. R. crossing,	409
32, S. E. qr., Milwaukee river,	376
Avon. T. 1, R. 10 E.	
Sec. 5, N. E. qr.,	272
5, S. E. qr., stream,	192
9, S. W. qr.,	320
13,	327
13, Bottom of Galena,	330
18, S. E. corner,	318
22, S. W. qr.,	245
25, S. W. qr., slough,	171
Aztalan. T. 7, R. 14 E.	
Sec. 7, S. W. qr.,	251
17, Village,	276
18, N. E. qr.,	297
18, Marsh,	252
20, S. E. qr., river bank,	226
20, S. E. qr., water level,	210
Barton. (See *Kewaskum.*)	
Beaver Dam. T. 11, R. 14 E.	
Sec. 2, near mid. W. line,	277
2, center S. E. qr., creek,	268
3, N. E. qr.,	327
Beaver Dam Lake,	282
Sec. 7, S. W. qr., marsh,	284
8, near center N. W. qr.,	300
10, N. W. qr., ridge,	320
Beaver Dam. T. 12, R. 14 E.	
Beaver Dam Station,	340
Sec. 34, mid. S. E. qr., R. R.,	317
Belgium. T. 12, R. 22 E.	
Sec. 2, N. line,	145
3, S. line,	145
10, N. line,	145
10, S. line,	152
15, N. line,	152
22, N. line,	153
28, N. line,	156
33, N. line, Deckers,	154
Bellevue. T. 23, R. 21 E.	
Sec. 15, mid. W. line,	136
20, S. E. qr., stream,	28
Beloit. T. 1, R. 12 E.	
Sec. 3, S. W. qr. of S. W. qr.,	196
6, near center W. line,	200
6, S. W. corner, hill,	309
10, E. line N. E. qr.,	152
10, N. E. qr.,	180
10, near center,	273
10, S. E. qr.,	200
10, S. line, S. E. qr.,	302
17, near center,	314
17, N. W. qr.,	228
18, S. E. corner,	225
18, S. line, hill,	260
19, center W. hf.,	264
26, N. W. qr.,	193
27, near center,	197
28, mid. S. line,	251
28, Hyde's place,	233
28, Summit, Hyde's,	275
29, N. E. qr., creek,	189
30, S. E. corner,	167
31, center, creek,	144
33, mid. W. line,	210
34, N. W. qr., Hanchett's quarry,	213
34, S. E. qr. of N. W. qr.,	201
34, mid. W. line,	236
35, S. E. qr.,	161
36, near center S. E. qr.,	176
S. line College Campus,	192
Iodo-Magnesian springs,	177
Bloomfield. T. 1, R. 18 E.	
Sec. 6, N. hf.,	345
35, N. E. qr.,	254
35, S. E. qr.,	264
Genoa Station,	264
Bradford. T. 2, R. 14 E.	
Hill W. of Fairchild,	325
Brighton. T. 2, R. 20 E.	
Sec. 18, N. hf.,	250
Brillion. T. 20, R. 20 E.	
Sec. 6, N. E. corner,	175
6, mid. S. line S. E. qr.,	211
7, Forrest Junction,	250
15, near mid. W. line,	255
16, near mid. S. line	249
18, near mid. N. line,	250
18, near mid. S. line,	267
19, mid. S. line S. W. qr.,	250
22, mid. W. line N. W. qr.,	250
23, near S. W. corner,	229
25, W. line,	248
26, mid. N. line N. W. qr.,	227
30, mid. W. hf.,	230
31, mid. W. hf.,	238
Bristol. T. 1, R. 21 E.	
Sec. 5, Branch of Eau Pleine,	149
Bristol station,	191
Sec. 8, N. W. qr.,	214
9, center, river,	147
9, W. line,	154
Woodworth station,	170
Sec. 12, center,	128

List of Elevations above Lake Michigan — *continued.*

Location	*Feet.*
Bristol. T. 1, R. 21 E. — (con.)	
Sec. 19, N. W. qr.,	230
Brookfield. T. 7, R. 20 E.	
Sec. 7, N. W. qr.,	233
9, N. W. qr.,	431
11, N. E. qr.,	219
Forrest House station,	240
Brookfield Junc.,	246
Elm Grove station,	170
Burnett. T. 12, R. 15 E.	
Burnett Junc.,	299
Lake Horicon,	277
Burlington. T. 2, R. 19 E.	
Sec. 5, N. E. qr.,	199
Burlington station,	206
Sec. 4, mid. N. line N. E. qr.,	179
5, mid. S. line,	210
6, mid. W. line,	230
7,	263
8, mid. S. line,	223
17, lake,	200
Calamus. T. 11, R. 13 E.	
Sec. 6, mid. N. line N. E. qr.,	366
7, mid. S. hf.,	361
Loss Lake,	291
Sec. 18, center N. hf.,	400
18, center,	394
18, near center,	306
19, near center N. line,	277
19, S. W. qr.,	276
23, N. E. qr., stream,	258
27, N. E. qr.,	305
27, center E. hf., swamp,	270
31, N. W. corner,	265
31, S. W. corner, marsh,	239
34, N. W. qr.,	266
35, S. W. qr.,	297
35, S. W. qr., ridge,	318
Caledonia. T. 4, R. 22 E.	
Sec. 5, Root river,	81
5, near S. line,	122
8, mid. S. line,	141
17, mid. S. line,	152
20, mid. S. line S. E. qr.,	161
Franksville station,	150
Sec. 31, center,	169
33, S. W. qr., railroad,	111
34, E. hf.,	90
35, E. hf., valley,	54
—— T. 4, R. 23, E.	
Sec. 6, S. line,	110
7, S. line,	80
18, S. line,	70
19, center,	80
20, S. line,	60
27, N. E. qr.,	18
29, S. line,	60
Calumet. T. 17, R. 19 E.	
Sec. 26, mid. N. line,	381
28, near W. line, stream,	335
35, N. W. qr.,	410
Cato. T. 19, R. 22 E.	
Sec. 1, near mid. E. line,	215
1, center Kettle Range,	245
1, near mid. W. line,	274

Location	*Feet.*
Cato. T. 19, R. 22 E. — (con.)	
Sec. 2, near mid. W. line,	255
2, mid. N. line S. E. qr.,	280
Cato Corners, hill,	301
Sec. 3, S. W. qr., stream.	223
3, near mid. W. line,	246
4, near mid. W. line,	288
5, near mid. W. line,	263
5, S. W. qr. of N. E. qr.,	263
5, N. W. qr. of N. E. qr.,	277
6, S. E. qr. top of quarry,	346
6, near mid. W. line,	275
27, N. E. qr. Lower Cato Falls,	255
28, Clark's mills, river,	159
32, mid. E. hf.,	277
35, N. W. corner,	269
35, center N. E. qr., Kettles,	259
Carlton. T. 22, R. 24 E.	
Sec. 6, E. Twin river	80
6, S. E. qr., Michicott river,	76
20, mid. S. line,	131
28, N. E. corner,	71
31, mid. S. line, creek,	30
33, S. line, Michicott river	24
Casco. T. 24, R. 23 E.	
Casco village	157
Stream E. of Casco,	128
Sec. 7, Cowles' creek,	186
9,	183
13, mid. W. hf., hill,	235
14, E. line, N. E. qr.,	95
14, near middle,	165
14, S. E. corner,	123
14, S. W. qr., W. side hill,	230
14, S. W. qr., high ridge,	252
15, S. E. qr., stream,	183
16, average level,	220
17, level of upland	219
Cedarburg. T. 10, R. 21 E.	
Sec. 4, N. E. qr. of N. W. qr.,	296
4, mid S. line, N. W. qr.,	332
Mud lake,	294
Sec. 6, S. W. corner,	352
8, N. W. corner	308
Grafton above dam,	163
Grafton station,	170
Sec. 26, mid. W. hf.,	180
26, mid. E. line,	193
33, mid. E. line	240
33, mid. S. line,	222
Cedarburg station	191
Cedar creek at R. R. bridge,	177
Sec. 35, center W. hf.,	168
35, N. W. qr.,	167
35, S. E. qr.,	118
Center. T. 3, R. 11 E.	
Sec. 9, stream and marsh,	293
16, N. E. qr.,	363
16, center,	364
20, N. W. qr.,	400
21, center N. W. qr.,	389
32, N. E. qr.,	354
33, N. W. corner,	339
Footville station,	238

List of Elevations above Lake Michigan — *continued.*

	Feet.
Centerville. T. 17, R. 23 E.	
Sec. 3, mid. N. line	64
3, creek,	47
10, near mid. N. line,	63
15, N. W. corner,	66
15, Fish creek,	30
21, N. E. corner,	60
28, N. E. corner,	67
28, center E. line,	53
33, N. E. corner,	61
Charlestown. T. 18, R. 20 E.	
Chilton station,	269
Sec. 20, Hayton station,	249
Hayton village, stream,	227
Sec. 22, E. line (est.),	242
Chilton. T. 18, R. 19 E.	
Sec. 13, general level,	336
26, N. W. qr. (est.),	398
27, mid. N. W. qr. (est.),	392
28, N. E. qr. (est.), stream	669
Claybanks. T. 26, R. 26 E.	
Sec. 29, N. E. qr., top of terrace,	87
29, N. E. qr., bottom of terrace,	12
Clinton. T. 1, R. 14 E.	
Sec. 2, E. hf.,	370
2, S. W. qr.,	352
9, center,	373
10, N. W. qr.,	362
17, Clinton Junction,	364
18, N. E. qr.,	338
Clyman. T. 10, R. 15 E.	
Sec. 6, N. W. qr., creek	227
18, mid. E. line. marsh,	231
20, near N. W. corner,	258
20, center, N. E. qr. of N. E. qr.	277
28, Clyman station,	330
Cold Spring. T. 5, R. 15 E.	
Three-qr. miles S. of Hebron,	296
Bark river marsh,	223
Cold Spring village,	226
Cold Spring mill pond,	212
Concord. T. 7, R. 16 E.	
Concord village,	287
Sec. 30,	324
Cooperstown. T. 21, R. 22 E.	
Sec. 1, S. W. qr.,	219
11, mid. S. line, stream,	184
23, mid. S. line,	240
24, mid. N. hf.,	172
25, N. E. qr., bottom of ledge,	69
35, mid. S. line, outcrop,	266
Dale. T. 21, R. 15 E.	
Medina station,	192
Darien. T. 2, R. 15 E.	
Sec. 24, S. W. qr., hill	398
28, S. E. qr.,	363
28, Darien station,	367
31, mid. E. line,	290
31, S. W. corner,	341
33, W. line,	290
Delafield. T. 7, R. 18 E.	
Lakeside Station,	292
Pine Lake Station,	350
Nagowicka Lake,	304
Pewaukee,	263
Delavan. T. 2, R. 16 E.	
Sec. 2, S. E. qr.,	383
3, S. E. corner,	385
9, S. line,	375
10, W. line,	390
17, E. hf.,	356
17, Delavan Station,	342
19, N. W. qr.,	327
24, hill,	571
De Pere. T. 33, R. 21 E.	
Sec. 26, center N. hf.,	245
28, ledge,	114
33,	213
Dover. T. 3, R. 20.	
Sec. 13, mid N. line,	261
17, N. W. qr.,	253
Eagle Lake,	223
Sec. 25, S. hf.,	263
Kansasville Station,	240
Sec. 28,	217
Dover Station,	234
Sec. 33, N. E. qr.,	230
Eagle. T. 5, R. 17 E.	
Sec. 12, near mid. N. line,	355
14, near N. E. corner,	363
14, N. E. qr.,	370
19, S. E. qr.,	292
19, mid. W. line,	266
20, S. E. qr.,	324
21, E. hf.,	355
22, mid. W. hf., Eagle,	365
22, N. E. qr.,	359
East Troy. T. 4, R. 18 E.	
Honey Creek, S. of village,	239
Eaton. T. 18, R. 21 E.	
Sec. 18, S. E. qr.,	221
19, S. E. qr.,	295
32, N. W. qr.,	276
Eden. T. 14, R. 18 E.	
Sec. 6, N. W. corner,	433
22, center,	463
22, S. line,	489
24, S. W. qr.,	472
25, N. hf., creek,	404
25, N. W. qr.,	515
27, N. E. qr., river,	434
27, S. E. qr.,	432
27. N. line N. E. qr.,	415
Egg Harbor. T. 29, R. 26 E.	
1 mile S. of Egg Harbor,	180
Sec. 22, N. W. qr.,	154
27, N. W. corner,	172
27, W. hf.,	150
27, S. W. qr.,	137
34, N. W. corner, swamp,	139
Egg Harbor. T. 30, R. 27 E.	
Sec. 29, N. E. qr.,	180
Elba. T. 10, R. 13 E.	
Sec. 1, mid. S. line,	249
6, S. W. corner, Crawfish,	235
Elba R. R. crossing,	251
Sec. 16, N. line N. E. qr.,	294
16, S. E. qr. R. R.,	258
Danville,	289
Sec. 25, S. W. qr.,	219

LIST OF ELEVATIONS ABOVE LAKE MICHIGAN — *continued.*

	Feet.
Elba. T. 10, R. 13 E. — (con.)	
Sec. 27, N. E. qr., Crawfish,	232
28, S. W. qr.,	257
30, Crawfish,	251
31, N. W. qr.,	277
Emmet. T. 9, R. 15 E.	
Sec. 5, mid. E. line,	302
20, S. E. qr., quarry,	282
32, R. R.,	243
Rock river N. of Watertown,	211
Empire. T. 15, R. 18 E.	
Sec. 4, S. E. corner,	399
12, N. W. qr., lowland,	368
Erin. T. 9, R. 18 E.	
Sec. 1, S. W. qr. of S. E. qr.,	668
1, S. E. qr., hill,	674
14, S. W. corner,	517
14, Lapham's peak,	824
Farmington. T. 7, R. 15 E.	
Johnson's Creek station,	193
Sec 28, N. E. qr.,	260
Farmington. T. 12, R. 20 E.	
Sec. 6, S. W. qr., stream,	362
6, near N. W. qr.,	439
9, near N. E. corner,	254
21, N. E. corner,	230
27, mid. S. line,	315
30, W. line,	411
33, N. W. corner,	277
Forrest. T. 15, R. 19 E.	
Sec. 7, E. hf, Sheboygan river,	356
9, S. W. qr.,	410
9, S. E. corner, stream,	360
13, center N. E. qr.,	498
13, E. line N. E. qr.,	497
14, near E. line,	445
14, center,	428
16, N. E. qr.,	389
24, center N. hf.,	424
25, S. W. qr., stream,	451
36, center N. W. qr.,	515
Forrestville. T. 26, R. 25 E.	
Sec. 17, mid. E. line S. W. qr.,	170
30, N. E. qr., river,	3
32, mid. E. line (?)	119
Fox Lake. T. 13, R. 13 E.	
Emily Lake,	312
Sec. 4, mid. N. line,	377
4, mid. S. line,	346
5, mid. N. line,	382
5, N. W. qr.,	412
17, S. E. qr.,	293
31, N. W. qr. of N. W. qr.,	377
31, mid. W. line N. W. qr.,	383
31, S. W. qr.,	381
Franklin. T. 5, R. 21 E.	
Sec. 3, N. line N. E. qr.,	153
3, angle, Loomis rd., E. of riv.,	133
3, Root river, Loomis rd.,	118
3, W. line N. E. qr.,	130
3, W. line S. W. qr.,	190
4, N. W. corner,	130
5, N. W. corner,	205
5, N. line, angle of rd.,	230
6, N. line, on rd.,	235

	Feet.
Franklin. T. 5, R. 21 E. — (con.)	
Franklin Village (hotel),	218
Sec. 6, E. of center, on rd.,	250
7, N. line,	210
7, S. line N. W. qr., road,	220
7, N. W. qr., brook,	183
8, near N. W. cor., road,	200
8, N. line, R. R. grade,	183
8, W. line S. W. qr., road,	226
8, center S. W. qr.,	215
8, mid. W. line S. E. qr.,	199
8, N. W. qr., angle of roads,	196
8, Lake,	172
9, mid. N. line N. E. qr.,	206
9, mid. N. line,	212
9, mid. N. line N. W. qr.,	215
9, N. W. corner,	194
9, N. line S. W. qr.,	212
9, center S. W. qr.,	216
9, mid. W. line N. E. qr.,	217
10, mid. N. line N. E. qr.,	120
10, N. line, Root river	113
10, mid. N. line,	134
10, mid. N. line N. W. qr.,	155
10, N. W. corner,	180
10, mid. W. line N. W. qr.,	173
10, mid. W. line,	185
10, mid. W. line S. W. qr.,	190
11, mid. N. line N. E. qr.,	155
11, mid. N. line,	140
11, mid. N. line N. W. qr.,	125
11, N. W. corner,	125
12, mid. N. line N. E. qr.,	183
12, mid. N. line,	158
12, mid. N. line N. W. qr.,	180
12, mid. N. line W. hf. N. W. qr.,	190
12, N. W. corner,	178
13, mid. N. line N. E. qr.,	138
13, mid. N. line,	138
13, mid. N. line N. W. qr.,	158
13, N. W. corner,	147
14, mid. N. line N. E. qr.,	137
14, mid. N. line,	136
14, mid. N. line N. W. qr.,	154
14, mid. N. line W. hf. N. W. qr.,	165
14, N. W. corner,	138
15, N. line, Root river,	105
15, mid. N. line,	157
15, mid. N. line N. W. qr.,	182
15, mid. N. line W. hf. N. W. qr..	141
15, N. W. corner,	167
15, mid. W. line,	185
15, mid. W. line S. W. qr.,	200
16, mid. N. line N. E. qr.,	188
16, mid. N. line,	176
16, mid. N. line N. W. qr.,	175
16, N. W. corner,	197
17, mid. N. line,	200
17, jct. Loomis & Franklin rds.,	215
17, S. line N. E. qr.,	210
18, N. line, R. R. grade,	215
18, N. W. corner,	223
18, W. line N. W. qr. R. R.,	205
20, N. line, Loomis road,	220
20, W. line, Loomis road,	206

List of Elevations above Lake Michigan — *continued.*

Location	*Feet.*
Franklin. T. 5, R. 21 E. — (con.)	
Sec. 22, mid. W. line S. W. qr.,	182
22, N. W. corner,	175
22, W. line near N. W. cor.,	170
22, mid. W. line N. W. qr.,	175
22, mid. W. line,	168
25, mid. N. line N. E. qr.,	132
25, mid. N. line,	153
25, mid. N. line N. W. qr.,	132
25, N. W. corner,	163
26, mid. N. line N. E. qr.,	190
26, mid. N. line,	157
26, mid. N. line N. W. qr.,	138
26, N. W. corner,	130
27, N. line, Root river,	96
27, mid. N. line,	110
27, mid. N. line N. W. qr.,	112
27, N. W. corner,	146
27, mid. W. line N. W. qr.,	122
27, mid. W. line,	103
27, mid. W. line S. W. qr.,	114
28, N. W. corner,	190
29, mid. W. line N. W. qr.,	190
29, N. W. corner,	195
30, mid. N. line N. E. qr.,	196
30, mid. N. line,	218
34, mid. N. line N. E. qr.,	100
34, N. line, Root river,	92
34, mid. N. line,	106
34, N. W. corner,	105
35, mid. N. line N. E. qr.,	148
35, mid. N. line,	126
35, mid. N. line N. W. qr.,	110
35, N. W. corner,	100
36, mid. N. line N. E. qr.,	158
36, mid. N. line,	140
36, mid. N. line N. W. qr.,	113
36, N. W. corner,	130
Franklin. T. 20, R. 22 E.	
Sec. 1, S. W. corner,	277
1, S. W. qr.,	335
2, highest pt. of Kettle range,	303
4, S. W. qr.,	300
19, mid. W. line,	311
31, S. E. corner,	297
31, mid. S. line, high ridge,	320
Franklin. T. 22, R. 23 E.	
Sec. 11, N. W. qr.,	168
15, center N. E. qr.,	286
22, S. line S. E. qr.,	112
34, N. W. corner, creek,	90
34, S. W. corner,	92
34, S. E. qr., creek,	62
Fredonia. T. 12, R. 21 E.	
Sec. 1, N. E. corner,	279
12, S. E. corner,	202
22,	303
25, S. E. corner	229
28, Waubakee village,	194
29, Quarry on N. side river,	197
33, Milwaukee River,	169
35, S. line S. W. qr., R. R.,	228
Fredonia Station,	206
Fulton. T. 4, R. 12 E.	
Newville Bridge,	208
Fulton. T. 4, R. 12 E. — (con.)	
Edgerton Station,	242
Sec. 3, center N. line,	251
4, center N. hf.,	232
5, center S. line,	273
5, S. line S. E. qr.,	284
6, N. W. qr.,	240
10, S. W. qr.,	219
Geneva. T. 2, R. 17 E.	
Sec. 2, S. E. qr.,	436
5, S. hf.,	445
6, mid. E. line,	415
6, Elkhorn Station,	415
9, center E. hf.,	402
9, mid. E. line, R. R.,	406
9, N. W. qr.,	418
10, mid. E. line,	400
10, near center,	423
10, W. hf.,	415
13, N. W. corner,	337
14, near center,	342
23, S. hf.,	277
25, W. line,	333
34, mid. E. line,	345
36, Geneva Station,	300
Lake Geneva,	282
Genesee. T. 6, R. 18 E.	
Genesee Station,	325
Saysville Mill Pond,	232
Sec. 13, N. line,	327
14, S. W. qr.,	313
15, mid. S. line,	329
21, N. E. qr., creek,	315
21, mid. S. line,	331
21, hill,	350
25, mid. N. E. qr.,	228
25, center S. W. qr.,	225
29, S. E. corner,	359
31, North Prairie Station	363
35, mid. S. line N. W. qr.,	367
Germantown. T. 9, R. 20 E.	
Sec. 5, N. line, R. R.,	278
6, N. E. qr.,	289
9, N. line, R. R.,	313
10, N. W. corner,	276
10, center S. hf.,	297
15, S. E. qr., Menomonee River,	273
16, W. line, R. R.,	298
17, mid. line, R. R.,	318
17, W. line, R. R.,	328
18, W. line, R. R.,	360
21, N. line, R. R.,	286
22, W. line, R. R.,	273
22, center,	275
23, N. W. qr., R. R..	301
23, W. line, R. R.,	295
23, mid. S. line, R. R.,	293
25, S. line, R. R.,	248
25, W. line, R. R.,	278
26, S. E. qr.,	313
28, mid. N. line,	286
30, mid. E. line, S. E. qr.,	276
32, N. W. corner,	296
32, center,	284
35, S. W. corner,	319

LIST OF ELEVATIONS ABOVE LALE MICHIGAN — *continued.*

Germantown. T. 9, R. 20 E. —(con.)

		Feet.
Sec. 35,	center S. W. qr.,	195
35,	near S. W. corner,	314
35,	mid. S. line S. W. qr.,	270
36,	S. line, R. R.,	198
36,	S. E. corner, R. R.,	193
36,	center S. W. qr.,	195

Gibson. T. 21, R. 23 E.

		Feet.
Sec. 1,	N. line N. E. qr.,	63
7,	mid. N. hf.,	96
9,	N. E. qr.,	160
21,	near S. W. corner,	174
24,	E. line S. E. qr.,	83
26,	S. W. qr., Jambo Creek,	49

Gillette. T. 28, R. 19 E.

		Feet.
Sec. 1,	Little River,	164
25,	Oconto River above the falls,	132

Grafton. T. 10, R. 22 E.

		Feet.
Sec. 5,	mid. N. hf.,	174
8,	S. line, R. R.,	117
9,	near center S. hf.,	111
19,	N. E. qr. of N. W. qr.,	211
20,	mid. N. hf., R. R.,	119
20,	mid. E line N. E. qr.,	150
20,	bank Lake Michigan,	119
20,	S. line, R. R.,	130
29,	S. line, R. R.,	96
32,	S. line, R. R.,	97

Granville. T. 8, R. 21 E.

		Feet.
Sec. 1,	mid. N. line,	68
1,	N. line, river	56
2,	N. line, Cedarburg P. Road,	68
2,	mid. N. line, R. R.,	83
2,	N. W. corner,	89
2,	S. E. qr. brook	74
3,	mid. N. line,	75
3,	N. W. corner,	87
4,	mid. N. line,	100
4,	N. W. corner,	143
5,	N. W. corner,	145
6,	mid. N. line,	190
6,	W. line, C.,M. & St. P. R. R.	190
6,	mid. W. line,	173
6,	N. line S. W. qr. R. R.	186
7,	N. line R. R.	169
7.	mid. N. line,	206
7,	N. W. corner,	169
8,	mid. N. line,	165
8,	W. line, Granville,	167
8,	mid. W. line,	184
9,	mid. N. line,	125
9,	N. W. corner,	179
10,	mid. N. line,	84
10,	mid. N. line, N. W. qr.	122
10,	N. W. corner,	98
10,	Whittaker's house,	103
11,	N. line R. R.	85
11,	mid. N. line,	79
11,	N. W. corner,	77
12,	N. line river,	54
12,	N. W. corner,	89
13,	N. W. corner,	123
13,	mid. W. line,	166
14,	mid. N. line,	99
14,	N. W. corner,	119

Granville. T. 8, R 21 E. — (con.)

		Feet.
Sec. 15,	N. line R. R.,	158
15,	N. W. corner,	185
16,	mid. N. line,	177
16,	N. W. corner,	175
17,	N. line R. R.,	142
17,	mid. N. line,	167
17,	N. W. corner,	213
19,	mid. N. line, N. E. qr.,	168
19,	mid. N. line,	180
19,	mid. W. line, N. E. qr.,	212
19,	center,	190
20,	N. E. corner, water in E. br.,	124
20,	mid. N. line, N. E. qr.,	160
20,	mid. N. line,	152
20,	N. W. corner,	215
21,	N. line, M. & St. P. R. R.	168
21,	mid. N. line,	188
21,	N. W. corner,	136
22,	mid. N. line,	180
22,	N. W. corner,	160
22,	center R. R.,	154
23,	mid. N. line,	115
23,	mid. N. line N. W. qr.,	145
23,	N. W. corner,	135
24,	mid. N. line E. qr. N. E. qr.	135
24,	mid. N. line, N. E. qr..	98
24,	N. line W. C. R. R.,	112
24,	N. W. corner,	131
24,	W. line R. R.,	138
24,	N. line S. E. qr. R. R.,	115
24,	mid. W. line S. W. qr.,	150
25,	N. W. corner,	109
25,	N. line R. R.,	93
25,	mid. W. line,	105
25,	N. line,	129
25,	N. line N. W. R. R.,	115
25,	mid. N. line,	111
25,	mid. N. line N. W. qr.,	102
26,	mid. N. line N. E. qr.,	129
26,	mid. N. line,	110
26,	W. line S. E. qr. R. R.,	107
27,	N. W. corner,	130
27,	mid. N. line N. E. qr.,	135
27,	mid. N. line W. hf. N. E. qr.	179
27,	mid. N. line,	154
27,	N. W. corner,	148
28,	mid. N. line, N. E. qr.,	177
28,	mid. N. line,	147
28,	N. W. corner,	161
29,	200 ft. W. N. E. corner,	175
29,	N. line, N. F. du Lac R'd,	121
29,	mid. N. line,	138
29,	N. W. corner,	152
30,	mid. N. line,	218
30,	mid. N. line N. W. qr.,	170
30,	N. W. corner,	145
30,	center,	170
31,	N. line, E. branch,	118
31,	mid. N. line,	150
31,	mid. N. line N. E. qr.,	130
31,	N. W. corner,	158
31,	center,	160
31,	mid. W. line S. E. qr.,	125
32,	mid. N. line,	162

LIST OF ELEVATIONS ABOVE LAKE MICHIGAN — *continued.*

Granville. T. 8, R. 21 E. — (con.)	*Feet.*
Sec. 33, mid. N. line,	134
33, mid. W. line,	160
33, center N. E. qr.,	154
34, mid. N. line N. E. qr.,	106
34, mid, N. line,	136
34, N. W. corner,	160
34, mid. W. line,	140
35, N. line R. R.,	94
35, mid. N. line,	97
35, N. W. corner,	97
36, N. line W. C. R. R.,	56
36, N. W. corner,	96
36, W. line R. R.,	93
36, mid. N. line W. hf. S. W. qr.	94
36, mid. N. line S. E. qr. R. R.,	58
36, S. E. qr., Schwartzburg St'n,	66
Green Bay. T. 24, R. 22 E	
Sec. 13. mid. S. line,	238
13, Outcrop,	80
22, W. hf., near Franken,	219
—— T. 25, R. 22 E.	
Whitney's Bluff,	91
Sec. 16, On bluff,	100
Greenbush. T. 15, R. 20 E.	
Glenbulah Station,	289
Sec. 4, center,	466
St. Cloud Station,	349
Sec. 6, N. E. corner,	323
8,	416
10, center,	289
35, mid. W. line, plateau,	408
36, center summit of ridge,	524
36, near center, road,	513
Greenbush hotel,	297
" stream,	283
Hill S. of Greenbush,	417
Greenfield. T. 6, R. 21 E.	
Sec. 1, mid. W. line,	62
2, W. line N. W. qr.,	82
2, mid. W. line,	94
3, W. line,	156
3, N. of center, creek,	124
3, N. line, Muckwonago road,	132
4, mid. N. line,	125
4, N. W. corner,	180
4, near center, Poplar creek,	136
4, center,	143
4, center S. W. qr.,	158
4, W. line,	173
5, mid. N. line,	219
5, N. W. corner,	155
6, mid. N. line,	154
6, N. W. corner,	178
6, mid. W. line N. W. qr.,	190
6, mid. W. line,	205
7, N. W. corner,	174
7, near N. W. cor., Root river,	169
7, mid. W. line N. W. qr.,	189
7, mid. W. line,	178
7, mid. W. line S. W. qr.,	178
7, mid. line S. E. qr.,	199
8, N. line, Muckwonago road,	212
8, mid. W. line N. E. qr.,	170
8, N. line S. E. qr.,	151

Greenfield. T. 5, R. 21 E. — (con.)	*Feet.*
Sec. 8, W. line S. E. qr. Muckw'go R.,	170
8, center N. W. qr., "	173
9, N. W. corner,	200
9, N. line S. E. qr.,	141
10, mid. N. line,	135
11, N. line N. E. qr. R. R.,	90
11, N. W. corner,	112
11, mid. W. line N. W. qr.,	127
11, mid. W. line,	102
11, mid. W. line S. W. qr.,	125
12, center,	84
12, S. W. qr., Janesville road,	54
13, mid. N. line N. E. qr.,	55
13, mid. N. line,	90
13, mid. N. line N. W. qr.,	106
13, mid. W. line N. W. qr.,	93
13, N. W. corner,	124
13, mid. W. line,	119
13, mid. W. line S. W. qr.,	146
13, S. line, Loomis road,	137
14, mid. N. line N. E. qr.,	137
14, mid. N. line,	158
14, mid. N. line N. W. qr.,	170
14, N. line R. R. grade,	146
14, N. W. corner,	140
14, mid. W. line,	192
14, W. line S. W. qr., Janesville R.	202
14, N. E. qr., Janesville road,	177
14, S. W. qr., Janesville road,	163
15, mid. N. line N. E. qr.,	170
15, mid. N. line W. hf. N. E. qr.,	183
15, mid. N. line,	175
15, mid. N, line N. W. qr.,	150
15, N. W. corner,	145
15, N. line N. W. qr., Brook,	140
16, mid. N. line N. E. qr.,	155
16, mid. N. line,	170
16, mid. N. line N. W. qr.,	200
16, W. line, Beloit road,	225
16, mid. W. line S. W. qr.,	183
16, mid. W. line S. E. qr.,	215
16, center,	209
16, mid. W. line N. E. qr.,	183
17, mid. N. line N. E. qr.,	210
17, center,	200
17, S. W. qr., angle Beloit road,	190
17, W. line, Beloit road,	180
18, N. line, Root river,	149
18, mid. N. line E. hf. N. W. qr.,	156
18, mid. N. line N. W. qr.,	161
18, N. W. corner,	193
18, mid. W. line N. W. qr.,	212
18, mid. W. line,	182
18, mid. W. line S. W. qr.,	212
18, mid. W. line S. hf. S. W. qr.,	236
19, N. line, Root river,	145
19, mid. N. line N. E. qr.,	170
19, mid. N. line,	230
19, mid. N. line N, W. qr.,	210
19, N. W. corner,	214
19, mid. W. line N. W. qr.,	244
19, mid. W. line,	255
19, W. line S. W. qr., Beloit road,	245
20, mid. N. line S. E. qr.,	178

List of Elevations above Lake Michigan — *continued.*

Greenfield. T. 6, R. 21 E. — (con.)	*Feet.*
Sec. 20, center,	159
20, mid. line, Root river,	143
21, mid. N. line N. E. qr.,	217
21, mid. N. line,	221
21, N. W. corner,	180
21, mid. W. line,	180
21, mid. N. line S. W. qr.,	210
21, center,	240
22, mid. N. line N. E. qr.,	174
22, N. line N.E. qr., R.R. bridge,	172
22, mid. N. line,	185
22, mid. N. line N. W. qr.,	199
22, N. W. corner,	188
22, mid. W. line,	220
22, W. line, Janesville road,	244
22, center S. W. qr., R. R.,	240
22, N. line S.W.qr., Janesville R.,	200
23, mid. N. line N. E. qr.,	179
23, mid. N. line,	165
23, mid. N. line N. W. qr.,	181
23, N. W. corner,	192
23, mid. W. line N. W. qr.,	187
23, mid. W. line,	180
23, mid. W. line S. W. qr.,	196
24, N. line, Loomis road,	137
24, N. W. corner,	137
24, mid. W. line S. W. qr.,	170
24, N. line, S. W. qr.,	122
24, W. line, N. E. qr., Loomis' Road,	117
26, N. line, Loomis' Road,	180
26, N. W. corner,	193
26, mid. W. line, N. hf. N. W. qr.,	232
26, mid. W. line, N. W. qr.,	220
26, mid. W. line,	227
26, mid. W. line, S. W. qr.,	223
26, center S. W. qr.,	210
26, center,	186
26, N. E. qr., brook,	160
27, N. W. qr., R. R. grade,	195
28, N. line N. E. qr., Janesville Road,	198
28, N. W. corner,	157
28, W. line S. W. qr., Root R.,	141
29, S. E. qr., Janesville road,	199
30, N. W. corner,	265
30, mid. W. line N. W. qr.,	254
30, mid. W. line	234
30, mid. W. line S. W. qr.,	229
31, N. W. corner,	223
31, center W. hf. N. W. qr.,	233
31, N. line S. W. qr., road	212
31, center brook,	192
31, mid. N. hf. S. E. qr.,	192
32, N. line N. E. qr., Janesville road,	224
32, Hale's Corners,	211
32, mid. W. line S. W. qr.,	195
33, N. line N. E. qr., Root R.	128
33, mid. N. line, R. R.,	133
33, mid. N. line N. W. qr.,	157
33, N. W. corner,	171
34, mid. N. line N. E. qr.	152
34, mid. N. line,	192

Greenfield. T. 6, R. 21 E. — (con.)	*Feet.*
Sec. 34, mid. N. line N. W. qr.,	180
34, N. W. corner,	156
34, near S. line, Loomis road,	153
35, N. line, Loomis road,	198
35, N. W. corner,	202
35, mid. W. line N. W. qr.,	152
35, N. W. qr., pond,	127
Harmony. T. 3, R. 13 E.	
Sec. 2, N. W. qr.,	344
Hartford. T. 10, R. 18 E.	
Hartford Station,	408
Sec. 1, near N. W. corner,	487
13, near S. E. corner, stream,	411
13, center, R. R.,	453
13, W. line, R. R.,	440
14, center, R. R.,	430
14, W. line, R. R.,	430
16, N. E. corner,	466
16, center E. hf.,	403
17, W. line, R. R.,	388
18, center, R. R.,	385
18, W. line, R. R.,	392
21, center, R. R.,	414
21, W. line, R. R.,	406
22, center, R. R.,	428
22, W. line, R. R.,	422
24, little W. of mid. of E. line,	740
25,	566
Hartland. T. 26, R. 17 E.	
Sec. 21, Hartland,	257
Hebron. T. 6, R. 15 E.	
Cushman's mill pond,	244
Herman. T. 16, R. 22 E.	
Sec. 11, N. E. corner,	235
12, mid. N. line, N. E. qr.,	128
13, mid. S. line,	121
26, near S. line, stream,	105
26, S. E. qr., stream,	147
Holland. T. 13, R. 22 E.	
Sec. 1, N. line R. R.,	97
12, N. line R. R.,	109
13, N. line R. R.,	102
16, S. E. qr., bridge,	133
24, N. line R. R.,	107
25, N. line R. R.,	103
26, Cedar Grove,	114
29, W. line N. W. qr.,	307
35, N. line R. R.,	144
36, center E. line,	48
Top of terrace above Amsterdam, R. 23,	47
Bottom of terrace above Amsterdam, R. 47,	5
Holland. T. 21, R. 20 E.	
Sec. 20, S. E. qr.,	233
20, S. W. qr.,	279
Jackson. T. 10, R. 20 E.	
Sec. 1, 30 rods W. of S. E. corner,	288
1, mid. S. line, creek,	282
1, valley of creek,	292
4, mid. S. line S. E. qr.,	292
6, center, R. R.,	386
6, N. line, R. R.,	379
7, N. E. qr.,	440

List of Elevations above Lake Michigan — *continued.*

	Feet.
Jackson. T. 10, R. 20 E. — (con.)	
Sec. 7, mid S. line S.W. qr., valley,	396
30, N. E. qr., Cedar creek,	275
31, mid. S. line,	319
32, S. E. qr., brook,	273
32, N. W. corner, R. R.,	276
32, mid. N. line N. W. qr.,	327
33, mid. N. line N. E. qr.,	340
34, N. W. corner,	300
34, S. W. corner,	273
36, S. E. qr.,	208
36, S. W. qr.,	334
Jacksonport. T. 29, R. 27 E.	
Ridge S. of Jacksonport,	42
Racine Limestone,	58
Coral beds hf. mile S. of Jacksonport,	20
Sec. 33, S. hf.	62
Janesville. T. 3, R. 12 E.	
Janesville Fair Grounds,	295
Janesville Station,	240
Jefferson. T. 6, R. 14 E.	
Jefferson station,	221
Rock river at Jefferson,	206
Mouth of Crawfish river,	200
Sec. 9, S. E. qr., stream,	242
12, N. E. qr., hill,	365
15, near center W. hf., stream,	227
17, N. E. qr.,	269
17. N. W. qr., quarry,	260
18, center W. hf., hill,	442
19, near N. W. corner,	315
Johnstown. T. 3, R. 14 E.	
Level of Rock Prairie,	316
Kewaskum. T. 12, R. 19 E.	
Sec. 5, N. line, R. R.,	398
12, mid. E. line,	409
20, mid. E. line, stream,	410
22, S. W. qr., R. R.,	354
22, mid. N. line,	409
28, near mid. N. line,	528
30, N. W. corner,	463
33, N. E. corner,	362
34, N. E. qr., R. R.,	363
35, R. R.,	370
Kewaunee. T. 23, R. 24 E.	
Sec. 5, N. W. qr., ledge,	145
14, Kewaunee river at bridge,	9
14, S. W. qr., junction of Upper Coral and Racine,	32
20, mid. N. line,	124
26, Est., general level,	124
30, mid. S. line	138
31, outcrop,	140
31, N. E. qr.,	134
Koshkonong. T. 5, R. 14 E.	
Fort Atkinson station,	249
Marsh below Fort Atkinson,	200
Lake Koshkonong,	(200) 184
Kump's quarry,	267
Sec. 23, center W. hf.,	257
27, S. W. qr.,	252
31, N. E. qr., quarry,	248
34, N. E. qr.,	298
32, center N. hf., valley,	252

	Feet.
Kossuth. T. 20, R. 23 E.	
Sec. 12, E. line, S. E. qr., river,	28
15, N. E. qr.,	124
26, S. E. corner,	109
36, S. E. qr.,	93
La Fayette. T. 3, R. 17 E.	
Sec. 8, near center, stream,	277
18, N. E. qr.,	317
19, N. E. qr.,	365
30, N. E. qr.,	437
31, N. E. qr.,	443
31, S. W. qr.,	438
La Grange. T. 4, R. 16 E.	
Sec. 1, nearly S. of hill,	365
Heart Prairie,	387
Lake. T. 6, R. 22 E.	
Sec. 7, mid. N. line,	60
7, mid. N. line, N. W. qr.,	79
7, mid. W. line,	78
7, mid. W. line, S. W. qr.,	50
7, mid. N. line, S. W. qr.,	87
7, W. of center,	64
7, N. of center,	80
7, center, N. E. qr.,	65
7, highest land in cemetery,	95
8, N. E. corner,	17
8, mid. S. line, S. E. qr.,	53
8, N. W. corner,	52
8, mid. N. W. line, N. W. qr.,	58
8, W. line, Kinnickinic,	10
8, mid. W. line,	30
8, mid. W. line, S. W. qr.,	50
9, mid. N. line, N. W. qr.,	35
9, N. W. qr., angle in road,	53
9, mid. line, road,	18
9, mid. line, road E. and W.,	38
9, S. E. qr.,	16
9, near E. line, S. E. qr., R. R.,	30
9, center S. E. qr.,	51
10, N. W. qr., bank of lake,	25
10. S, E. qr., bank of lake,	25
15, N. line, bank of lake,	40
15, N. line, N. W. qr., Chic. rd.	55
15, center,	75
15, Chicago road, N. of school house,	58
15, Chicago road, S. of school house,	75
15, S. E. qr., Deer creek, R. R.,	60
St. Francis R. R. station,	65
Sec. 16, mid. W. line, N. E. qr. of S. E. qr.,	57
17, N. W. corner,	57
18, mid. N. line, N. E. qr.,	78
18, mid. N. line,	82
18, N. line, N. W. qr., brook,	55
18, mid. N. line, N. W. qr.,	86
18, N. W. corner,	83
18, mid. W. line, N. W. qr.,	70
18, mid. W. line,	60
18, mid. W. line, S. W. qr.,	90
19, N. W. corner,	102
19, mid. W. line,	113
19, W. line, S. W. qr., creek,	100
19, mid. W. line, S. W. qr.,	125

List of Elevations above Lake Michigan — *continued.*

Lake. T. 6, R. 22 E. — (con.)	*Feet.*
Sec. 20, N. W. corner,	80
20, mid. N. line N. E. qr.,	109
20, mid. N. line,	105
20, N. line, railroad,	86
20, mid. W. line N. W. qr.,	79
20, mid. S. line S. W. qr.,	97
21, mid. N. line N. E. qr.,	72
21, mid. N. line,	78
21, mid. N. line N. W. qr.,	83
21, N. W. corner,	100
22, N. line, Chicago Road,	80
22, center N. E. qr., Chicago R'd,	82
22, mid. line, Chicago Road,	100
22, S. E. qr., Chicago Road,	90
23, N. line, bank of lake,	30
23, N. line, Lake Shore Road,	45
23, mid. N. line,	35
23, W. line S.W. qr., Chi. Road,	120
23, N. E. qr., Lake Shore Road,	115
23, N. line S. E. qr., Lake Sh. R'd,	75
24, mid. line, bank of lake,	60
25, N. line, bank of lake,	80
25, N. W. corner,	90
25, mid. W. line,	102
25, mid. line, bank of lake,	80
26, mid. N. line N. E. qr.,	87
26. mid. N. line,	130
26, N. line, railroad,	113
26, N. W. corner,	116
26, mid. W. line N. W. qr.,	89
27, N. line, Chicago Road,	124
27, mid. W. line,	122
27, N. W. corner,	83
27, mid. line, Chicago Road,	84
27, center S. E. qr.,	95
28, mid. N. line,	88
28, N. W. corner,	81
29, mid. N. line N. E. qr.,	74
29, mid. N. line,	82
29, N. line, railroad,	97
29, N. W. corner,	96
29, mid. W. line N. W. qr.,	118
29, mid. W. line,	111
29, mid. W. line S. W. qr.,	134
29, mid. S. line S. W. qr.,	137
30, mid. N. line N. E. qr.,	129
30, mid. N. line,	113
30, mid. N. line N. W. qr.,	127
30, N. W. corner,	136
30, mid. W. line N. W. qr.,	165
30, mid. W. line,	185
30, mid. W. line S. W. qr.,	178
31, N. W. corner,	180
31, mid. W. line N. W. qr.,	190
31, mid. W. line,	195
31, mid. W. line S. W. qr.,	175
32, N. line N. E. qr.,	122
32, mid. N. line,	139
32, N. line, railroad,	137
32, N. W. corner,	142
32, mid. S. line S. W. qr.,	154
33, mid. N. line N. E. qr.,	103
33, mid. N. line,	115
33, mid. N. line N. W. qr.,	102

Lake. T. 6, R. 22 E. — (con.)	*Feet*
Sec. 33, N. W. corner,	120
34, N. line N. E. qr., road,	98
34, mid. N. line,	90
35, N. line, railroad,	111
35, mid. N. line,	115
35, N. E. qr., angle Chi. Road,	108
36, N. line bank of lake,	90
36, mid. N. line W. hf, N. W. qr.,	110
36, N. W. corner,	93
Lake Mills. T. 7, R. 13 E.	
Sec. 1, W. hf.,	265
3, center N. E. qr.,	274
3, near center N. W. qr.,	327
3, mid, W. line N. W. qr.,	311
3, S. W. corner,	291
4, center N. W. qr.,	330
4, flat,	315
5, N. E. qr., hill,	370
6, S. W. qr.,	398
8, mid. S. line,	373
Koshkonong Creek at Kroughville,	257
Sec. 10, mid. W. line,	315
Lake Mills village,	260
Lake Mills village, N. W. part,	277
Rock Lake,	250
Sec. 18, mid. S. line,	345
19, S. W. qr., creek,	288
28, mid. S. line S. E. qr.,	278
31, S. W. qr., creek,	272
33, N. E. corner,	363
La Prairie. T. 2, R. 13 E.	
Sec. 13, mid. W. line,	271
16, mid. W. line,	242
Lima. T. 4, R. 14 E.	
Sec. 6, S. E. qr., marsh,	243
13, N. E. qr.,	307
14, S. E. qr.,	316
18, near mid. W. line,	248
21, S. E. corner,	301
22, Lima station,	310
23, mid. N. hf.,	305
23, W. line,	308
30, E. line,	311
Lima. T. 14, R. 22 E.	
Sec. 2, E. line S. E. qr., highland,	129
16, mid. E. line,	164
20, center S. E. qr.,	219
26, center N. hf.,	119
Hingham Mill Pond,	192
Lincoln. T. 25, R. 24 E.	
Sec. 19, S. line outcrop,	232
20, S. line S. W. qr.,	192
22, mid. S. line S. E. qr.,	197
23, mid. S. line S. W. qr. (est.),	168
26, swamp,	114
35, stream,	98
Linn. T. 1, R. 17 E.	
Sec. 5, Moorfield's lime kiln,	368
Geneva lake,	282
Little Suamico. T. 26, R. 19 E.	
Sec. 26,	144
Lowell. T. 10, R. 14 E.	
Sec. 6, S. W. qr.,	256

List of Elevations above Lake Michigan — *continued.*

	Feet.
Lowell. T. 10, R. 14 E. — (con.)	
Sec. 7, near center W. hf.,	236
15, Lowell Village, -	241
19, N. E. qr., -	245
30, center E. hf., R. R., -	240
30, near S. line S. E. qr., marsh,	216
Lowell Station, - -	247
Lowell. T. 11, R. 14 E.	
Sec. 26, S. E. qr., ridge, - -	300
30, near center W. hf.,	236
31, near center W. hf., -	266
36, mid. S. line S. E. qr., creek,	240
36, hill-top, -	305
Lynden. T. 14, R. 21 E.	
Sec. 1, mid. S. line S. E. qr., -	262
2, mid. S. line S. E. qr.,	264
3, mid. S. line, R. R.,	224
4, mid. S. line, valley, -	245
4, S. E. corner, Onion River, -	211
6, mid. S. line S. E. qr.,	299
26, near center,	492
27, mid. S. line, - -	352
28, mid. E. line S. E. qr., stream,	278
30, near mid. W. line,	433
30, S. line N. E. qr., stream,	305
35, N. E. corner, church,	316
35, N. line, R. R., -	307
Cascade River, below mill,	287
Lyons. T. 2, R. 18 E.	
Lyons Station, - - -	222
Sec. 1, center E. line, R. R., -	207
1, near mid. S. line,	291
1, S. W. qr.,	194
1, near S. W. corner,	339
2, S. W. corner, R. R.,	200
7, S. W. qr., -	273
8, mid. W. line, - -	285
9, N. E. qr., - - -	228
10, N. hf., - -	220
10, near center S. line, -	366
12, near east line,	355
12, S. E. qr., brook, -	218
23, mid. E. line, - -	321
23, mid. E. line, S. E. qr., -	355
28, S. line S. E. qr., -	319
Magnolia. T. 3, R. 10 E.	
Magnolia Station, -	340
Sec. 6, mid. W. line N. W. qr.,	354
6, mid. W. line, - -	285
6, S. W. qr., flat,	286
6, S. W. qr., - -	309
6, S. W. qr., Allen's Creek,	278
6, S. E. qr., -	360
7, S. E. qr., - -	433
7, S. E. qr., road, - -	323
7, S. E. qr., top of ledge,	450
9, N. W. qr., Allen's Creek, -	292
23, N. W. qr., -	339
26, S. W. qr.,	384
26, S. W. qr., summit, -	441
28, S. W. qr., -	339
34, N. W. qr., -	432
Manitowoc. T. 19, R. 24 E.	
City, S. W. corner, -	65
Station, - - -	7
Manitowoc. T. 19, R. 24 E. — (con.)	
Sec. 5, near W. line, -	79
6, center S. W. qr., -	69
7, N. W. qr., bridge,	43
17, N. W. cor., Little Man'woc,	15
17, S. W. qr., R. R., -	44
18, N. W. qr. S. E. qr., R. R.,	51
18, S. W. qr., R. R.,	60
19, N. W. qr., R. R., -	53
Manitowoc Rapids. T. 19, R. 23 E.	
Sec. 2, mid. S. line S. W. qr.,	136
3, near S. E. corner,	153
4, mid. E. line,	203
4, mid. S. line, highland,	213
4, mid. N. line, R. R.,	154
5, mid. E. line,	158
6, mid. E. line, -	173
10, near N. line S. E. qr.,	60
11, near N. line, -	124
12, near mid. W. line, -	75
12, mid. S. line S. W. qr.,	68
13, center N. W. qr., R. R.,	68
13, near S. E. corner, -	70
19, N. E. qr., top of Kettle's,	166
19, mid. N. W. qr., river,	108
22, N. line N. W. qr., -	140
24, mid. E. line N. E. qr., -	53
25, N. W. qr. of S. E. qr., R. R.,	53
32, center stream, -	142
34, mid. E. hf., N. shore Sil. L.	150
34, center S. E. qr., -	129
34, S. line S. E. qr.,	123
35, near center, -	111
Maple Grove. T. 20, R. 21 E.	
Reedsville Station,	242
Sec. 6,	328
6, S. W. corner, - -	329
7, Serpentine ridge, -	304
12, S. E. corner, -	247
29, mid. W. line S. W. qr.,	296
30, near mid. W. line,	276
32, near N. E. corner,	278
33, E. line,	276
34, E. line,	262
35, S. E. corner,	240
Maple Valley.	
Sec. 24, N. branch Little River, T. 29, R. 19 E., - - -	180
Sec. 24, Small Lake, T. 30, R. 19 E.,	159
25, Little Peshtigo Lake, -	157
Marshfield. T. 16, R. 19 E.	
Sec. 6, N. W. corner (est.), -	402
6, stream, - -	360
6, S. W. corner, -	406
6, S. E. corner, -	433
14, S. E. qr., Reichart Quarry,	357
16, S. line, Maria Hotel -	365
17, N line (est.), R. R.,	371
17, S. W. corner, hill, - -	442
20, near center, hill, -	450
24, S. E. qr., - -	424
25, N. line, - - -	420
30, S. W. qr., Steffer's quarry,	409
Calvary station, - -	363
St. Cloud station, -	349

LIST OF ELEVATIONS ABOVE LAKE MICHIGAN — *continued.*

Locality	Feet.
Memee. T. 17, R. 22 E.	
Sec. 1, mid. N. line, -	175
5, N. W. qr.,	348
8, N. W. corner, -	348
14, S. W. qr., river,	135
21, mid. N. line, - -	248
21, center, stream,	175
Menasha. T. 20, R. 17 E.	
Menasha station, - -	177
Menomonee. T. 8, R. 20 E.	
Sec. 2, N. E. qr., outcrop,	193
6, E. side N. E. qr., -	259
8, outcrop, -	290
8, S. line S. W. qr., hill, -	334
Menomonee Falls, - -	238–226
Sec. 17, center N. hf.,	314
19, N. E. qr., spring,	287
30, S. W. corner,	279
Mequon. T. 9, R. 21 E.	
Mequon station, -	92
Thiensville station, -	88
Sec. 1, mid. N. line N. E. qr.,	147
10, R. R., -	128
31, N. E. corner, valley,	154
31, N. W. corner,	252
32, N. line,	172
35, R. R., - - -	107
35, N. W. qr., R. R., -	97
—— T. 9, R. 22 E.	
Sec. 5, near N. E. corner, -	111
5, S. line, R. R., -	93
6, mid. N. line, river, -	83
8, S. line, R. R.,	98
17, S. line, R. R., -	94
20, mid. N. line, bank of lake,	110
20, N. W. corner, -	83
29, S. line, - -	112
32, S. line, -	76
Merton. T. 8, R. 18 E.	
Sec. 2, ⅛ mi. N. of Monches, -	369
Lake Kessus, -	376
North Lake, -	309
High land E. of Pine Lake,	384
High land W. of Pine Lake,	345
Ridge 1 mi. W. of Pine Lake,	359
Valley 1½ mi. W. of Pine Lake,	318
Metomen. T. 15, R. 14 E.	
Sec. 1, N. E. qr., River's quarry, -	350
Reed's Corners station, -	407
Brandon station, - -	421
Michicott. T. 20, R. 24 E.	
River at Michicott,	22
Sec. 4, S. W. qr., -	60
8, S. hf. of S. E. qr, T. 21,	126
9, E. hf. of N. E. qr., river,	11
22, N. W. qr., - -	53
32, S. W. qr., T. 21,	108
Milford. T. 8, R. 14, E.	
Hubbleton station, - -	211
Sec. 21, mid. N. line, - -	260
24, N. E. corner, - -	232
24, mid. S. line,	222
33, N. E. qr., quarry, -	284
36, center N. hf., -	295
—— T. 7, R. 14 E.	

Locality	Feet.
Milford. T. 7, R. 14 E. — (con.)	
Sec. 6, S. E. qr., outlet of lake,	228
6, S. E. qr., outcrop, -	252
Milton. T. 4, R. 13 E.	
Milton station, -	293
Milton Junction,	299
Ridge S. of Milton Junction,	318
Sec. 10, S. E. corner, -	216
22, center E. hf., hill, -	375
25, S. E. qr., -	307
26, S. E. qr.,	303
30, N. E. qr.,	289
30, N. W. qr., -	255
Milwaukee. T 8, R. 22 E.	
Sec. 4, N. line, bank of lake, -	87
4, mid. W. line, -	93
4, center,	88
5, mid. N. line,	76
5, N. W. corner, -	87
5, N. W. qr., Washington R'd,	78
5, N. line S. W. qr., "	85
5, mid. line R. R.,	84
6, mid. N. line, -	107
6, mid. N. line, N. W. qr.,	117
6, N. W. corner, -	127
7, mid. N. line, - -	103
7, N. W. corner, -	95
8, mid. N. line, -	93
8, N. W. corner, -	91
8, center N. E. qr., -	79
8, center, - - -	70
9, N. line R. R.,	107
16, N. line, R. R., -	127
16, mid. line, bank of lake, -	93
16, mid. line., R. R.,	94
17, near mid. N. line,	94
17, mid. W. line, -	73
17, mid. line, Washington Road,	91
17, N. W. corner, -	62
18, N. line, river,	52
19, N. line, river, -	49
19, mid. N. line, -	65
19, N. line, Good Hope,	90
19, N. W. corner,	120
19, W. line, N. E. qr., plank rd.	70
19, mid. line, S. E. qr., plank-rd.	75
20, N. W. corner,	95
20, W. line, S. W. qr.,	42
20, W. line, river,	45
20, mid. W. line N. E. qr.,	114
20, center N. E. qr.,	120
20, mid. line Wash. rd., -	105
21, N. line, M. L. S. & W. R. R.,	85
29, center N. E. qr.,	70
29, W. line, river,	40
29, mid. N. line S. E. qr., -	71
30, N. W. A. R. R. & G. B. rd.,	60
30, mid. N. line,	65
30, N. line; river -	40
30, N. W. corner, -	102
30, center, -	50
30, center, N. E. qr., - -	55
31, mid. N. line,	50
31, N. line, creek, -	40
31, mid. N. line N. W. qr.,	50

List of Elevations above Lake Michigan — *continued.*

	Feet.
Milwaukee. T. 8, R. 22 E. — (con.)	
Sec. 31, N. W. corner,	60
31, R. R. bridge, Milwaukee R.,	51
Lindwurm station,	56
Sec. 32, mid. N. line,	60
33, N. line bank of lake,	80
33, N. line R. R.,	73
33, N. W. corner,	73
33, mid. W. line,	74
33, mid. N. E. qr., bank of lake,	75
33, N. line, bank of lake,	80
33, mid. line, S. E. qr.,	75
Milwaukee. T. 7, R. 22 E.	
Sec. 3, N. line,	95
3, N. W. corner,	92
3, mid. W. line,	112
3, center N. E. qr., bank,	105
3, mid. line, bank,	108
3, center S. E. qr., bank,	110
4, mid. N. line N. E. qr.,	93
4, N. line R. R.,	71
4, mid. N. line,	64
4, W. line, river	30
4, center S. W. qr., river,	21
4, N. W. corner,	59
5, N. line R. R.,	57
5, N. line N. E. qr.,	59
5, mid. N. line,	59
5, N. W. corner, river,	37
5, W. line R. R.,	98
5, W. line, Green Bay rd.,	114
5, center,	71
5, mid. line R. R.	80
5, mid. line, river,	36
6, N. line, Green Bay road,	68
6, mid. N. line,	70
6, N. W. corner,	66
6, center N. E. qr.,	81
6, R. R. & Green Bay road,	98
7, mid. W. line,	98
7, mid. line near S. line,	124
8, mid. N. line,	94
8, N. line, Green Bay road,	121
8, W. of center,	155
9, Humbolt Junction	61
9, mid. N. line,	84
River at Humbolt Bridge,	15
Sec. 9, mid. W. line N. E. qr.,	60
9, center,	63
9, mid. W. line R. R.,	90
10, N. line, bank of lake,	102
10, N. W. corner,	90
10, mid. W. line,	47
10, mid. W. line, S. W. qr.,	78
10, center N. E. qr., Lake Ave.,	105
10, mid. line, Lake Avenue,	83
10, S. E. qr., Lake Avenue,	98
10, S. line, Lake Avenue,	88
Mitchell. T. 14, R. 20 E.	
Sec. 2, near mid. S. line,	580
9, S. E. corner, high hill,	566
10, S. E. corner,	510
21, mid. E. line,	491
27, N. W. qr., Stanley Creek,	391

	Feet.
Montpelier. T. 23, R. 23 E.	
Sec. 25, near center,	181
25, mid. S. line S. E. qr.,	138
Morrison. T. 21, R. 21 E.	
Sec. 28, N. W. corner, Dry Run,	237
34, mid. W. line, stream,	240
34, mid. S. line,	284
Mosel. T. 16, R. 23 E.	
Sec. 4, S. line R. R.,	51
5, mid. S. line, stream,	83
5, S. line S. W. qr.,	112
16, mid. N. line N. E. qr R. R.,	51
16, N. line N. W. qr., stream,	56
27, mid. N. line,	50
Bank three-qr. mile N. of pier,	48
Mount Pleasant. T. 3, R. 22 E.	
Sec. 4, N. W. corner,	150
4, near mid. S. line,	147
9, near mid. S. line,	158
12, N. E. qr.,	105
17, center,	151
20, S. E. qr.,	158
20, S. hf.,	178
W. U. Junction,	143
Sec. 21, S. E. qr.,	126
22, S. E. qr.,	95
23, E. hf.,	120
25, N. W. corner,	141
26, N. W. corner,	92
28, mid. S. line,	129
30, N. E. qr.,	168
30, N. W. qr., Windsor,	203
—— T. 3, R. 22 E.	
Sec. 5, S. line,	45
19, S. E. corner,	80
19, N. E. qr.,	78
20, S. line,	40
21, Racine Junction,	43
Vaughn's Quarry,	58
Horlick's quarry,	46
Sec. 32, center,	38
32, S. line,	40
Mukwonago. T. 5, R. 13 E.	
Sec. 6, marsh,	305
14, S. W. corner,	335
Mukwonago village,	276
Muskego. T. 5, R. 20 E.	
Sec. 13, mid. E. line,	205
13, mid. S. line,	227
33, near mid. S. line,	191
Muskego lake,	191
Newark. T. 1, R. 11 E.	
Sec. 1, N. E. qr., spring,	258
1, S. W. qr.,	362
3, N. W. qr.,	328
10, mid. W. line,	342
11, S. W. qr.,	357
11, S. W. qr., hill,	379
13, W. line near mid.,	313
13, S. E. corner,	263
13, S. E. qr., flat,	193
14, N. W. qr.,	305
14, S. W. qr.,	331
15, S. W. qr., stream,	296
16, S. E. corner of S. W. qr.,	244

List of Elevations above Lake Michigan — *continued.*

	Feet.
Newark. T, 1, R. 11 E. — (con.)	
Sec. 16, S. W. qr., Coon creek,	183
20, mid. S. line, ridge,	318
24, N. E. qr., stream,	196
25, center W. hf.,	252
25, S. E. qr.,	274
28, N. E. qr., creek,	190
29, N. E. qr., quarry,	222
31, center E. hf,	222
31, near center,	263
31, W. of center,	275
31, W. hf,	249
32, center,	281
33, near center,	207
33, mid. W. line,	220
33, bottom of outcrop,	245
34, center, ridge,	207
35, center, creek,	144
New Berlin. T. 6, R. 20 E.	
Sec. 21, mid. N. hf,	291
22, general level E.,	336
32, N. W. corner, Prospect hill,	344
New Denmark. T. 22, R. 22 E.	
Sec. 7, N. E. qr., Two Rivers,	218
17, N. line N. W. qr.,	295
28, near N. W. corner,	328
35, S. W. qr., Kettle range,	307
New Holstein. T. 17, R. 20 E.	
Sec. 30, S. W. qr.,	484
32, N. W. corner,	402
34, N. W. qr.,	426
Newton. T. 18, R. 23 E.	
Sec. 1, N. line, R. R.,	77
1, creek,	52
4, S. line S. E. qr. of S. W. qr.	190
12, N. line R. R.,	79
13, N. line R. R.,	85
17,	166
23, N. line R. R.,	80
26, N. line R. R.,	74
27, creek,	57
30, mid. W. line, S. W. qr.,	140
34, N. line R. R.,	77
Norway. T. 4, R. 20 E.	
Wind lake,	190
Sec. 8, N. line,	198
8, S. line,	198
18, S. E. corner,	221
19, S. W. corner,	224
Oak Creek. T. 5, R. 22 E.	
Sec. 1, N. line, bank of lake,	80
1, N. W. corner,	75
2, mid. N. line,	90
2, N. line R. R.,	96
2, mid. line N. W. qr.,	112
3, mid. N. line,	122
3, N. W. corner,	96
4, mid. N. line,	115
4, mid. N. line N. W. qr.,	149
4, N. W. corner,	161
5, mid. N. line,	149
5, mid. N. line, N. W. qr., Lake station,	154
5, mid. N. line W. hf. N. W. qr.,	160

	Feet.
Oak Creek. T. 5, R. 22 E. — (con.)	
Sec. 5, N. W. corner,	152
5, mid. W. line N. W. qr.,	164
5, mid. W. line,	161
5, mid. W. line S. W. qr.,	158
6, N. W. corner,	185
6, mid. W. line N. W. qr.,	205
6, mid. W. line,	210
7, mid. N. line N. E. qr.,	160
7, mid. N. line,	175
7, mid. N. line N. W. qr.,	170
7, N. W. corner,	195
7, mid. W. line N. W. qr.,	180
7, mid. W. line,	175
8, mid. N. line N. E. qr.,	133
8, mid. N. line,	150
8, N. line R. R.,	147
8, N. W. corner,	155
8, near mid. S. line,	129
9, mid. N. line N. E. qr.,	96
9, mid. N. line,	111
9, mid. N. line N. W. qr.,	155
9, N. W. corner,	134
10, N. line, Oak creek,	71
10, mid. N. line N. E. qr.,	80
10, mid. N. line,	119
10, mid. N. line, N. W. qr.,	138
10, N. W. corner,	82
11, N. line, Oak creek,	45
11, N. line, Chicago road,	74
11. N. line, R. R.,	94
11, N. line N. W. qr.,	111
11, N. W. corner,	82
11, center, Oak Creek station,	86
11, mid. line,	107
12, N. line, bank of lake,	80
12, mid. W. line N. E. qr.,	84
12. N. W. corner,	65
14, N. line, Chicago road,	108
14, mid. N. line N. W. qr.,	89
14, N. W. corner,	105
15, mid. N. line N. E. qr.,	91
15, mid. N. line,	96
15, N. W. corner,	102
15, mid. N. line N. W. qr.,	126
15, mid. W. line S. E. qr.,	88
15, mid. W. line N. E. qr.,	101
15, center,	112
16, N. line, Oak Creek,	77
16, mid. N. line N. E. qr.,	77
16, mid. N. line,	91
16, mid. N. line N. W. qr.,	113
16, N. W. corner,	142
16, mid. W. line N. W. qr.,	134
16, mid. W. line,	136
16, mid. W. line S. W. qr.,	122
17, mid. N. line N. E. qr.,	130
17, mid. N. line, R. R.,	129
17, mid. N. line N. W. qr.,	136
17, N. W. corner,	140
17, mid. W. line N. W. qr.,	125
17, mid. W. line,	130
17, mid. W. line S. W. qr.,	140
17, mid. W. line S. hf. S. W. qr.,	155
17, mid. S. line S. W. qr.,	116

List of Elevations above Lake Michigan — *continued.*

Oak Creek. T. 5, R. 22 E. — (con.)	*Feet.*
Sec. 18, N. W. corner,	160
20, mid. N. line N. E. qr.,	125
20, mid. N. line,	143
20, N. line, R. R.,	116
20, mid. N. line N. W. qr.,	130
20, N. W. corner,	140
20, mid. S. line S. W. qr.,	111
21, N. W. corner,	121
22, mid. N. line N. E. qr.,	104
22, mid. N. line,	83
23, N. line, R. R.,	105
23, mid. N. line,	111
23, mid. N. line N. W. qr.,	103
23, N. W. corner,	119
23, mid. line, R. R.,	110
23, mid. line, Chicago road,	116
23, cent. N. hf. S.E. qr., Ch. rd.,	127
26, N. line, Chicago road,	117
26, mid. line, Chicago road,	128
27, mid. W. line,	85
27, mid. W. line S. W. qr.,	94
28, mid. N. line,	87
28, mid. N. line N. W. qr.,	108
28, N. W. corner,	99
28, mid. N. line S. E. qr.,	94
28, center,	106
28, mid. W. line N. E. qr.,	112
29, mid. N. line N. E. qr.,	108
29, mid. N. line,	100
29, mid. N. line N.W. qr., R. R.,	111
29, N. W. corner,	111
29, mid. S. line S. W. qr.,	105
30, mid. N. line N. E. qr.,	110
30, mid. N. line,	113
30, mid. N. line N. W. qr.,	124
30, N. W. corner,	120
30, mid. W. line N. W. qr.,	110
30, mid. W. line,	132
30, mid. W. line S. W. qr.,	136
31, mid. N. line N. E. qr.,	133
31, mid. N. line,	136
31, mid. N. line N. W. qr.,	147
31, N. W. corner,	150
32, mid. N. line N. E. qr.,	145
32, mid. N. line,	135
32, mid. N. line N. W. qr.,	105
32, N. W. corner,	119
33, mid. N. line N. E. qr.,	100
33, mid. N. line,	110
33, mid. N. line N. W. qr.,	125
33, N. W. corner,	133
34, mid. N. line N. E. qr.,	87
34, mid. N. line,	88
34, mid. N. line N. W. qr.,	88
34, N. W. corner,	94
34, mid. W. line N. W. qr.,	92
34, mid. W. line,	85
34, mid. N. line S. W. qr.,	88
34, center,	81
34, mid. N. line S. E. qr.,	79
35, mid. N. line N. E. qr.,	105
35, mid. N. line,	95
35, mid. N. line N. W. qr.,	91
35, N. W. corner,	86

Oak Creek. T. 5, R. 22 E. — (con.)	*Feet.*
Sec. 35, mid. W. line,	77
35, mid. N. line S. W. qr.,	80
35, center,	78
35, mid. N. line S. E. qr.,	96
36, N. W. corner,	114
36, mid. W. line,	104
36, mid. W. line S. W. qr.,	102
36, mid. S. line S. W. qr.,	118
36, mid. S. line,	121
36, S. line, R. R. station,	117
36, Chicago rd. on County line,	110
36, S. E. corner,	130
Top of bank (Sec. 31, T. 5, R. 23),	80
Oak Grove. T. 11, R. 15 E.	
Horicon Junction,	306
Minnesota Junction,	348
Rolling Prairie station,	363
Juneau station,	335
Oakland. T. 6, R. 13 E.	
Lake Ripley,	239
Red Cedar lake,	233
Sec. 4, S. W. qr.,	266
5, S. half,	280
7, W. line N. W. qr.,	271
13, mid. W. line N. W. qr.,	343
16, S. E. corner,	330
18, S. E. qr. of S. E. qr.,	246
19, near N. W. corner,	264
19, center S. E. qr.,	251
19, S. W. qr.,	234
25, near N. W. corner,	363
25, W. line N. W. qr.,	270
28, mid. E. line,	253
28, near mid. S. line,	227
30, S. W. qr.,	257
30, near center S. W. qr.,	253
31, S. W. qr.,	214
31, S. line S. W. qr.,	210
Oconomowoc. T. 8, R. 17 E.	
Lac La Belle,	273
Oconomowoc station,	283
Osceola. T. 14, R. 20 E.	
Sec. 1, mid. W. line,	500
4, N. E. qr., cross roads,	458
11, S. W. qr., stream,	453
13, Long Lake,	443
30, E. hf., pond,	413
32, N. line,	518
34, general level,	504
35, N. hf., Canton,	566
Palmyra. T. 5, R. 16 E.	
Palmyra station,	260
Sec. 20, E. hf.,	266
20, N. W. qr.,	278
22, S. E. qr.,	290
23, N. E. qr.,	271
28, N. line,	241
29, S. E. qr.	220
31, center,	221
32, W. line,	221
Paris. T. 7, R. 21 E.	
Sec. 18, center, prairie,	191
Pensaukee. T. 27, R. 19 E.	
Sec. 23, N. branch, Pensaukee road,	139

List of Elevations above Lake Michigan — *continued.*

Locality	*Feet.*
Pensaukee. T. 27, R. 19 E. — (con.)	
Sec. 35, Pensaukee river,	128
Pewaukee. T. 7, R. 19 E.	
Pewaukee Lake,	263
Pewaukee station,	263
I. N. Stewart's place,	316
Sec. 1, center,	262
12, highland,	358
12, mid. S. line,	268
13, mid. N. hf.,	254
16, S. E. qr.,	284
26, quarry,	248
26, railroad crossing,	248
32, W. hf.,	330
Pierce. T. 24, R. 24 E.	
Gen. level, E. of Casco village,	203
Sec. 28, center, high bluff,	188
28, river,	30
32, N. E. qr.,	44
32, N. E. qr., top of Wilmot's quarry,	126
32, N. E. qr., outcrop,	61
32, N. E. qr., above outcrop,	77
33, S. W. qr.,	179
Pierce. T. 24, R. 25 E.	
4½ miles S. W. of Ahnapee,	144
Bank at Alaska,	58
Sec. 20, N. W. qr.,	141
31, S. E. corner,	99
Pleasant Prairie. T. 1, R. 22 E.	
Kenosha Junction,	101
Pleasant Prairie station,	119
Eau Pleine river, near state line,	77
Sec. 1, mid. N. line N. E. qr.,	50
1, mid. W. line,	70
1, S. W. qr.,	44
2, mid. S. line S. W. qr.,	105
4, near mid. N. line,	100
4, near mid. S. line,	101
7, W. line,	106
9, mid. N. line, railroad,	101
10, W. line,	120
16, W. line,	150
16, mid. S. line S. W. qr.,	98
18, Eau Pleine river,	73
20, mid. S. line S. E. qr.,	97
24, N. E. qr.,	72
29, mid. S. line S. E. qr.,	95
32, mid. S. line S. E. qr.,	90
32, center E. hf., railroad,	93
33, S. E. corner,	134
35, 40 rods W. of mid., S. line,	160
Pleasant Prairie. T. 1, R. 23 E.	
Sec. 18, S. E. qr., beach I,	26
18, S. E. qr., beach II,	39
31, S. W. qr., beach III,	64
Beach I, near state line,	34
Beach II, near state line,	55
Plymouth. T. 2, R. 11 E.	
Hanover Junction,	209
Sec. 1, S. W. qr.,	261
9, N. E. corner, railroad,	225
28, mid. W. line,	395
33, N. E. corner,	342
35, mid. W. line,	412
Plymouth. T. 15, R. 21 E.	
Plymouth station,	262
Red Clay, E. of Plymouth,	305
Sec. 3, N. W. qr.,	343
16, S. E. qr., stream,	252
31, S. line, Onion river,	232
32, S. E. qr., 1st Kettle Ridge,	309
33, S. line S. E. qr.,	340
34, S. line, railroad crossing,	224
36, S. E. corner, hill,	253
Polk. T. 10, R. 19 E.	
Cedar Creek village,	481
Cedar Lake,	442
Schleisingerville station,	474
Ackerville station,	480
Sec. 6, mid. N. line N. W. qr.,	448
6, N. line N. E. qr.,	480
6, N. E. corner.	594
33, mid. E. line,	535
Porter. T. 4, R. 11 E.	
Sec. 1, N. E. corner,	284
3, N. E. qr., Catfish river,	196
3, N. line N. W. qr.,	265
3, S. W. qr., stream,	196
5, N. E. corner,	247
5, mid. N. line N. W. qr.,	261
6, mid. E. line,	261
9, N. W. qr.,	250
9, mid. E. line N. E. qr.,	260
Portland. T. 9, R. 13 E.	
Crawfish, E. of Portland,	214
Sec. 1, N. W. corner,	250
6, N. W. qr.,	296
6, N. W. qr., marsh,	286
6, center W. hf.,	307
7, W. line N. W. qr., marsh,	276
8, mid. W. hf., stream,	259
17, near mid. S. line, marsh,	241
18, mid. N. line,	268
18, N. W. corner,	297
19, N. W. qr., marsh,	244
27, N. hf.,	253
27, N. W. qr., Crawfish,	221
27, top of conglomerate,	269
29, center E. hf.,	259
29, near S. line,	279
31, N. E. corner,	290
31, near mid. N. line,	270
31, N. W. corner,	340
31, S. E. corner,	308
34, mid. N. line N. W. qr.,	330
35, S. W. qr.,	219
35, mid. E. line,	214
36, mid. N. line S. W. qr.,	295
Preble. T. 24, R. 21 E.	
Top of beach line, 1 mi. E. of Green Bay,	14
Sec. 26, mid. E. line,	152
27, fork of roads,	25
33, mid. of W. line,	11
34, N. W. qr.,	*59
34, top of highland,	155
34, center, highland,	144
35, S. E. qr., gen. level of highland,	157

List of Elevations above Lake Michigan — *continued.*

	Feet.
Preble. T. 24, R. 21 E. — (con.)	
Sec. 36, N. E. qr.,	189
36, mid. N. hf.,	180
9, S. hf., T. 23,	91
Randall. T. 1, R. 19 E.	
Lake Elizabeth,	196
Sec. 18, Power's Lake,	265
18, S. E. corner,	282
19, mid. S. line,	289
21, E. hf., R. R.,	201
35, mid. S. hf.,	298
36, S. hf. of S. E. qr.,	340
Rantoul. T. 19, R. 20 E.	
Sec. 4, mid. E. line (est.),	271
Hilbert Station,	250
School house S. of Hilbert,	301
Raymond. T. 4, R. 21 E.	
Sec. 7, mid. W. line,	203
18, S. W. corner,	238
21, N. W. qr.,	179
36, N. line N. E. qr.,	89
Red River. T. 25, R. 23 E.	
Mayville beds in N. part of town,	163
Sec. 20, S. E. qr.,	186
21, S. line S. E. qr.,	138
21, S. E. qr., smooth thin beds,	138
22, S. E. qr.,	168
22, mid. S. line, highland,	249
23, S. line S. W. qr., swamp,	176
24, S. line S. W. qr. (?), outcrop,	268
27, N. W. qr.,	203
33, N. line N. E. qr., stream,	125
34, N. W. qr. N. line, stream,	144
35, N. W. corner, highland,	274
36, N. E. corner, gen. level,	285
Rhine. T. 16, R. 21 E.	
Elkhart Station,	362
Sec. 1, mid. N. E. qr.,	341
13, N. E. corner,	211
18, center E. hf., R. R.,	316
19, S. E. qr., summit,	426
24, E. line N. E. qr.,	327
33, S. W. qr., stream,	300
Richfield. T. 9, R. 19 E.	
Richfield Station,	381
Sec. 3, mid. E. line,	413
3, 20 rods W. of mid. E. line,	542
4, mid. E. line,	528
10, mid. E. line,	530
15, S. E. corner,	430
22, S. line, Bark river,	367
22, S. E. qr.,	498
26, N. E. qr.,	379
36, N. E. corner,	429
36, E. line of S. E. qr.,	300
Ripon. T. 16, R. 14 E.	
Ripon Station,	352
Cliff, W. of road,	341
City. Falls under tressel bridge,	332
Top of St. P., near limekiln,	351
Top of Hill, W. of limekiln,	373
St. Peters, W. of last,	358
Coombs quarry, bottom,	370
Sec. 2, (est.), S. E. corner,	309
19, mid. W. line,	304

	Feet.
Ripon. T. 16, R. 14 E. — (con.)	
Sec. 20, N. W. qr. of N. W. qr.,	327
20, N. W. of center, quarry,	400
20, little W. of center,	397
20, near mid. S. line,	350
20, S. W. qr. of S. E. qr.,	351
20, N. E. qr. of S. W. qr.,	381
21, Quarry S. W. of Mr. Starr's,	364
26, N. W. qr.,	366
28, N. line N. E. qr.,	370
29, N. E. qr. near center,	350
29, N. E. qr., top of limestone,	370
29, 20 rods S. of last,	341
35, S. E. qr.,	364
36, S. E. qr., stream,	343
Rochester. T. 3, R. 19 E.	
Sec. 2, mid. S. line,	203
14, N. E. qr., river,	187
15, S. E. qr., bluff,	276
15, mid. S. line S. E. qr.,	200
Rock. T. 2, R. 12 E.	
Afton	206
Sec. 7, N. E. qr., summit,	306
8, N. W. qr., R. R., marsh,	265
20, mid. W. line, Bass creek flat	183
21, mid. W. line,	206
Rockland. T. 19, R. 21 E.	
Rockland ledge,	300
Sec. 4, S. E. qr., outcrop,	310
4, mid. E. line,	258
Rockland. T. 22, R. 20, E.	
Sec. 3, N. hf.,	22
3, S. E. qr. E. of east river,	30
14, mid. E. line, base of ledge,	267
24, mid. E. hf., level above ledge	320
Rosendale. T. 16, R. 15 E.	
Rosendale station,	313
West Rosendale station,	304
Rubicon station,	440
Sec. 4, S. W. qr.,	288
4, S. W. qr., quarry,	278
28, N. W. qr., river,	271
32, S. E. corner,	345
Russell. T. 16, R. 20 E.	
Sec. 31, W. line N. W. qr., Sheb. riv.	325
36, E. line S. E. qr., hill,	244
Salem. T. 1, R. 20 E.	
Salem station,	198
Fox river station,	200
Fox river at Wilmot,	154
Sec. 32, N. E. qr.,	161
Saukville. T. 11, R. 21 E.	
Saukville station,	181
Sec. 2, E. line S. E. qr.,	249
26, N. E. qr., quarry,	212
34, mid. S. line, outcrop,	187
35, S. line, R. R. crossing,	181
Schleswig. T. 17, R. 21 E.	
Rockville,	286
Sheboygan river under bridge between Rockville and Kiel,	272
Kiel station,	333
Sec. 6, N. E. qr., gen. level,	295
17, N. W. corner, gen. level,	350
20, N. W. qr.,	359

List of Elevations above Lake Michigan — *continued.*

	Feet.
Scott. T. 13, R. 20 E.	
Sec. 9, Stanley creek,	324
10, -	326
19, Tamarac swamp, -	392
27, mid. N. line,	328
27, Stanley creek, -	284
Scott. T. 24, R. 22 E.	
Sec. 7, W. hf., Cowles well,	124
19, (est.), - -	222
Scott. T. 24, R. 21 E.	
Top of Mayville beds, - -	70
Sec. 12, Outcrop, Cincinnati,	73
24, E. hf., - - -	168
Sevastopol. T. 28, R. 26 E.	
Racine limestone near Whitefish bay,	33
Sandbank, R. 27, E., Whitefish bay,	15
Sec. 10, S. W. qr., gen. level, -	127
18, S. line, -	80
20, bank, - - -	193
21, N. E. qr., - -	133
27, S. W. qr. (est.), ridge,	100
28, mid. E. line, -	116
28, S. E. qr., stream,	56
29, N. E. qr., - -	155
33, S. E. qr., hill, -	62
Sheboygan. T. 15, R. 23 E.	
Sheboygan post-office, -	53
Sheboygan and Fond du Lac R. R. station, - -	5
Lake Shore R. R. station, -	7
Lighthouse point, bank of lake,	46
Sec. 4, near N. E. corner R. R.,	60
4. mid. N. line,	85
6, mid. S. line, Sheboygan riv.,	74
6, S. E. corner, highland,	149
7, center, N. hf., Rabe's quarry,	73
9, S. E. qr., Roth's quarry,	17
River opposite quarry, -	13
Sec. 10, near center, -	55
10, near center, R. R. crossing,	46
10, Pigeon river above dam, -	16
16, N. hf., rising to W.,	25
16, mid. S. line, -	126
21, near center, highland, -	127
30, N. E. qr., gen. level,	111
33, S. E. qr. of S. E. qr.,	58
34, mid. N. W. qr.,	62
Sheboygan Falls. T. 15, R. 22 E.	
Decca Station, -	179
Sheboygan Falls Station, - -	85
School house, -	118
Sec. 2, mid. W. line N. W. qr.,	202
11, N. E. corner, - -	199
12, mid. E. line S. E. qr.,	122
18, S. W. corner, -	190
21, near center, saw mill,	139
24, N. E. corner, -	116
27, mid. E. line S. E. qr., stream, -	93
27, near center, hill, - -	159
35, S. W. qr., R. R. crossing,	96
35, S. W. qr., Sheboygan river,	129
Sherman. T. 13, R. 21 E.	
Union river, - - -	212
Sherman. T. 13, R. 21 E. — (con.)	
Sec. 25, quarter mile from White Cedar swamp,	473
27, W. hf., highland,	339
34, N. W. corner, (est.),	218
Shields. T. 9, R. 14 E.	
Sec. 32, quarry, - - -	214
Somers. T. 2, R. 22 E.	
Sec. 1, mid. S. line S. E. qr.,	44
3, S. W. qr., Pike river,	30
4, mid. N. line, R. R.,	131
4, mid. S. line, R. R., -	124
9, mid. S. line, R. R.,	118
10, mid. E. line, -	80
16, mid. S. line, R. R., -	103
21, mid. S. line, R. R., -	109
28, mid. S. line, -	101
34, center, - -	129
Somers. T. 2, R. 23 E.	
Kenosha Station, - -	40
Sec. 5, S. W. corner, -	50
7, S. line, R. R., - -	35
18, S. line, R. R., -	50
19, center, R. R.,	45
19, S. line, R. R., - -	40
Spring Prairie. T. 3, R. 18 E.	
Smith's quarry, - - -	188
Sec. 5, S. W. qr., highland,	401
7 and 8, average, -	340
8, S. W. qr., - -	231
17 and 18, average, -	370
20, mid. W. line,	352
26, E. hf, -	201
27, S. W. corner, stream,	284
29, center,	382
34, N. W. qr., stream,	245
Spring Valley. T. 2, R. 10 E.	
Orford Station,	313
Sec. 2, mid. E. line,	350
3, N. line of N. E. qr.,	418
3, S. E. qr., - -	334
3, S. W. qr. of S. W. qr.,	314
4, N. W. qr., stream, -	291
4,	338
4, S. W. qr., flat,	253
4, S. E. qr. of S. E. qr.,	352
9, center, - -	321
11, N. E. qr., -	423
11, S. W. qr., -	342
11, hill, - -	396
12, center N. hf., -	389
12, S. E. qr., flat. -	283
12, outcrop, -	301
13, mid. N. line,	300
15, S. E. qr., - -	321
17, S. E. qr., stream,	215
18, S. W. qr., Taylor's Creek,	204
19, N. W. corner, -	220
21, N. E. qr. of N. W. qr., R. R.	236
24, E. line of S. E. qr.,	405
28, N. E. qr., -	296
33, S. E. qr., - -	268
34, N. W. qr., Galena limestone, - -	345
34, N. W. qr., summit,	394

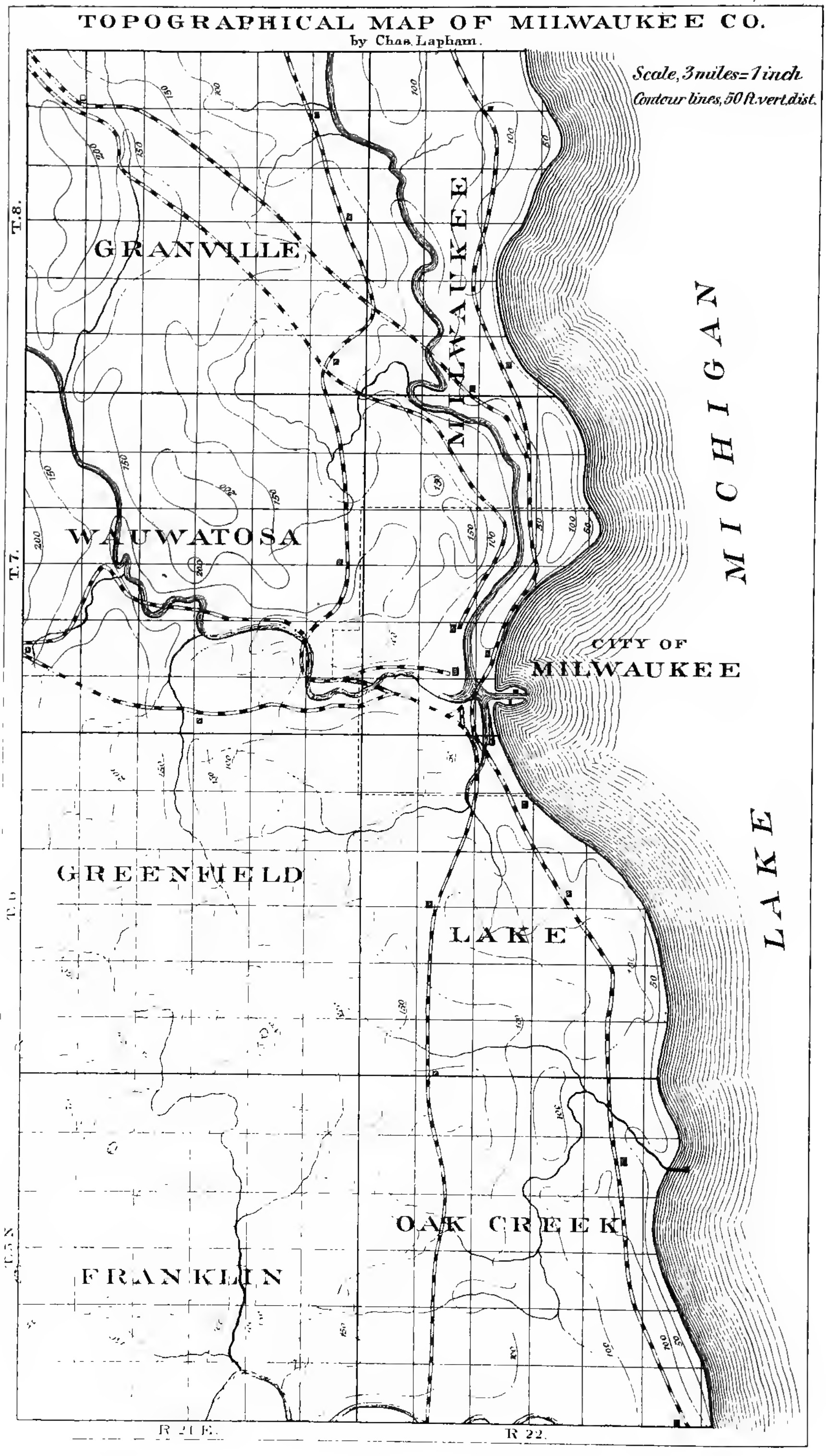
LIST OF ELEVATIONS ABOVE LAKE MICHIGAN — *continued.*

	Feet.
Spring Valley. T. 21, R. 13 E.—(con.)	
Sec. 34, S. line S. W. qr.,	336
Stockbridge. T. 19, R. 19 E.	
Fork in roads going to Chilton and Sherwood,	397
Three miles N. of Stockbridge village,	388
Two miles N. of Stockbridge village,	383
One and a half miles N. of Stockbridge village,	358
Four corners N. of Stockbridge village,	214
Stockbridge village,	231
Sec. 28, mid. N. line N. W. qr.,	399
Sturgeon Bay. T. 27, R. 26 E.	
Top of hill N. of Sturgeon Bay village,	113
Sec. 5, junction Racine and Coral beds,	58
5, top of rock,	75
5, valley,	44
9, E. hf, ridge,	62
9, S. W. qr., top of rock,	44
9, S. E. qr., top of rock,	61
Sugar Creek. T. 3, R. 16 E.	
Sec. 4, S. W. qr. W. line,	353
5, Holden's Lake,	325
5, mid. N. line,	367
9, near center,	340
23, N. W. corner, creek,	312
36, mid. N. line,	420
36,	460
Summit. T. 7, R. 17 E.	
Silver Lake,	278
Nemahbin,	289
Sumner. T. 5, R. 13 E.	
Lake Koshkonong,	184
Sec. 7, center S. hf, creek,	188
18, near center,	228
Taycheedah. T. 16, R. 18 E.	
Lake Winnebago,	162
Sec. 5, mid. N. line N. W. qr.,	305
5, centre,	386
22, S. W. corner, hill,	450
22, mid. N. line,	438
25, N. line, hills,	408
25, N. line, valleys,	358
29, S. W. qr. of S. E. qr.,	341
32, N. W. qr., R. R.,	219
Trenton. T. 11, R. 20 E.	
Newburg, outcrop on river,	225
Sec. 6, mid. E. line,	314
12, mid. S. line,	342
14, (?) hill,	345
25, N. W. qr.,	299
Troy. T. 4, R. 17 E.	
Sec. 2, N. W. corner,	253
10, S. E. corner, R. R.,	317
11, E. hf. center,	313
11, S.W. qr., Castleman's quarry,	233
15, S. E. qr.,	295
22, R. R. crossing,	300
27, centre N. hf.. stream,	273
33, mid. S. line, hill,	310
Turtle. T. 1, R. 13 E.	
Crest of hill E. of Beloit,	405
Sec. 5, level Rock prairie,	217
9, N. E. qr.,	227
9, N. W. qr. of S. E. qr.,	225
13, S. E. qr.,	330
13, mid. S. line S. W. qr.,	306
15, N. E. corner,	222
16, center,	223
19, center,	202
21. mid. S. line,	228
22, N. W. qr.,	270
22, N. E. qr.,	280
22, N. hf., near R. R. cut,	302
22, bottom of Galena Exposure,	246
22, summit of hill,	276
23, N. E. qr.,	280
28, mid. E. line,	325
29, near center,	218
31, N. E. corner,	211
31, N. of center,	188
32, center N. hf.,	229
33, N. E. corner,	266
Two Rivers. T. 20, R. 24 E.	
Sec. 22, N. W. qr.,	53
River at Neshoto,	29
R. R. crossing near Two Rivers,	14
Utica. T. 17, R. 15 E.	
Pickett's station,	266
Pickett's quarry,	242
McFarland's quarry,	264
Fisk's corners,	259
Flat E. of Rush Lake,	235
Union. T. 4, R. 10 E.	
Evansville station,	325
Sec. 1, N. W. corner,	321
1, N. E. qr. of. N. E. qr., mill,	238
2, N. W. corner,	336
2, N. W. qr.,	339
2, N. W. qr., stream,	288
4, N. W. qr.,	379
5, N. E. qr.,	379
6, N. W. corner, R. R.,	400
6, W. hf., marsh,	377
6, S. W. corner,	427
7, N. W. qr.,	442
10, W. hf., Union village,	375
12, N. W. qr., hill,	412
12, near center,	298
13, N. W. qr., stream,	293
14, center E. hf.,	339
18, mid. W. line, stream,	382
18, S. W. qr., flat,	368
19. S. W. qr.,	391
19, N. W. corner,	382
22, (est.)	407
26, S. E. qr.,	334
26, near N. E. corner,	389
29, center S. hf., flat,	367
30, S. E. qr., well,	402
30, S. W. qr., valley,	345
30, near center W. line,	336
31, N. E. qr.,	383
31, N. E. qr., summit,	423
31, S. W. qr.,	290

LIST OF ELEVATIONS ABOVE LAKE MICHIGAN — *continued.*

	Feet.
Union. T. 4, R. 10 E. — (con.)	
Sec. 33, near center stream,	352
34, near N. W. corner,	400
Vernon. T. 5, R. 19 E.	
Fox river at Big Bend,	268
Sec. 10, mid. E. line,	359
11, N. W. corner,	369
28, valley,	291
Washington. T. 11, R. 22 E.	
Highland N. of Port Washington,	108
Top of bank N. of Port Washington,	115
Hill W. of Port Washington,	159
Port Washington station,	87
Port Washington, beach formation,	40
Sec. 4, N. line,	144
9, N. line,	157
9, center N. E. qr.,	128
9, center,	172
16, N. line,	127
16, Sauk river,	87
30, center S. E. qr.,	226
32, center,	108
Waterford. T. 4, R. 19 E.	
Fox river above dam at Waterford,	246
General level E. of Waterford,	265
Sec. 6, N. line,	330
28, Vernon valley,	291
36, mid. N. line,	211
Waterloo. T. 8, R. 13 E.	
Waterloo Station,	241
Sec. 3, S. W. qr.,	237
5, N. W. qr.,	340
6, N. E. corner,	341
9, near mid. N. line,	222
9, mid. N. line, R. R.,	217
9, center, creek,	209
11, near center S. W. qr.,	211
16, N. W. qr., marsh,	275
17, center W. hf., hill,	329
17, center, marsh,	218
18, N. W. corner,	297
19, S. E. corner,	279
23, center S. hf., hill,	401
24, Crawfish marsh,	248
25, N. E. qr.,	300
25, near center E. hf.,	260
27, S. E. qr.,	289
29, near center, creek,	220
29, E. hf.,	245
30, mid. N. line N. E. qr.,	320
31, N. W. corner,	326
31, S. W. qr. of S. W. qr.,	350
32, near center S. hf.,	310
32, mid. E. line S. E. qr.,	322
35, S. E. qr.,	299
35, mid. E. line, hill,	326
36, center,	266
Watertown. T. 8, R. 15 E.	
Watertown Junction,	243
Sec. 21, mid. E. line S. E. qr.,	345
Waukesha. T. 6, R. 19 E.	
Waukesha Station,	225
Waukesha School House,	243
Junc. of Niagara and Racine, village	250
Sec. 13, mid. N. E. qr.,	336
Waukesha. T. 6, R. 19 E. — (con.)	
Sec. 13, mid. E. line, hill,	298
17, N. W. qr., creek,	305
Waupun. T. 13, R. 15 E.	
Waupun Station,	314
Horicon marsh,	280
Wauwatosa. T. 7, R. 21 E.	
Wauwatosa Station,	73
Sec. 1, N. line N. E. qr.,	71
1, N. line N. E. qr., R. R.,	72
1, mid. N. line,	80
1, N. line W. hf. N. W. qr.,	69
1, center N. hf. S. W. qr.,	83
3, N. W. corner,	123
3, mid. W. line,	121
3, S. ⅛ post, W. line S.W. qr.,	178
3, near S. W. corner,	193
3, E. line, plank road,	85
4, mid. N. line,	160
4, center N. E. qr.,	167
4, mid. W. line,	161
4, center N. E. qr.,	145
4, mid. line, Fond du Lac Rd.,	167
5, mid. N. line,	142
5, N. W. corner,	150
5, mid. W. line N. W. qr.,	140
6, N. line, river,	115
7, N. line, Menomonee river,	104
7, N. W. corner,	159
7, mid. W. line,	174
8, mid. N. line N. E. qr.,	155
8, mid. N. line,	161
8, mid. N. line N. W. qr.,	122
8, N. W. corner,	163
9, mid. N. line N. E. qr.,	172
9, mid. N. line,	203
9, N. W. corner,	169
10, mid. N. line,	157
10, N. W. corner,	186
10, mid. W. line,	217
10, plank road, W. line,	199
11, mid. N. line,	118
11, N. W. corner,	136
12, N. line, R. R.	80
12, mid. N. line N. W. qr.,	110
12, N. W. corner,	104
13, mid. N. line,	114
13, N. E. qr., R. R. and plank r'd,	100
13, N. W. corner,	125
14, mid. N. line,	150
14, N. W. corner,	180
15, N. line, Fond du Lac road	192
15, mid. N. line W. hf. N. E. qr.,	186
15, mid. N. line,	206
15, mid. N. line N. W. qr.,	199
15, N. W. corner,	174
15, mid. W. line,	176
16, mid. N. line,	174
16, N. W. corner,	164
17, N. line, river,	100
17, N. W. corner,	139
18, mid. N. line,	159
18, N. W. corner,	199
19, mid. N. line N. E. qr.,	186
19, mid. N. line,	180

PLATE, VIA


TOPOGRAPHICAL MAP OF MILWAUKEE CO.
by Chas. Lapham.
Scale, 3 miles = 1 inch
Contour lines, 50 ft. vert. dist.
GRANVILLE
MILWAUKEE
WAUWATOSA
CITY OF
MILWAUKEE
GREENFIELD
LAKE
OAK CREEK
FRANKLIN
LAKE MICHIGAN
T. 8.
T. 7.
R. 22.

List of Elevations above Lake Michigan — *continued.*

Wauwatosa. T. 7, R. 21 E. — (con.) *Feet.*
Sec. 19, mid. N. line N. W. qr., 207
19, N. W. corner, 228
19, mid. W. line N. W. qr., 218
19, mid. W. line, 202
20, N. line, river, 95
20, mid. N. line, 115
20, N. W. corner, 141
20, N. line S. W. qr., R. R., 115
21, mid. N. line N. E. qr., 132
21, mid. N. line, 143
21, mid. N. line N. W. qr., 134
21, N. W. corner, 119
21, W. line, R. R., 100
21, mid. line, R. R., 80
22, mid. N. line, 134
22, mid. N. line N. W. qr., 166
22, N. W. corner, 201
22, mid. W. line, 134
22, near center S. W. qr., pl. road, 141
23, N. line N. E. qr., plank r'd, 148
23, mid. N. line, 169
23, mid. N. line, N. W. qr.. 179
23, N. W. corner, 150
23, W. line on Holston road, 115
24, N. W. corner, 140
24, W. line N. W. qr., plank r'd, 136
24, W. line S. W. qr., Wauwatosa road, 120
24, W. line N. E. qr., Lisbon r'd, 123
24, R. R., Lisbon plankroad, 104
26, center S. E. qr., 94
26, W. line N. E. qr., 43
27, N. line, R. R., 64
27, E. line, Spring road, 116
28, W. line, Spring road, 172
28, mid. line, Spring road, 113
28, mid. N. line, 107
28, center S. E. qr., 90
29, W. line, Spring road, 207
29, mid. line, Spring road, 195
30, mid. line, Spring road, 226
30, center S. W. qr., R. R., 163
31, center, 175
32, W. line, R. R., 161
32, center, R. R., 195
33, W. line, R. R., 169
34, W. line, R. R., 125
34, center, R. R., 144

Wayne. T. 12, R. 18 E.
Kohlsville, river, 409
Sec, 34, mid. S. line S. E. qr., 590
36, knoll, 517
36, mid. S. line S. W. qr., 511

West Bend. T. 11, R. 19 E.
Barton village, S. side, 461
West Bend Station, 314
Sec. 2, mid. S. line S. W. qr., 461
5, W. line N. W. qr., 505
10, N. E. qr., 353
14, N. line N. W. qr., 330
17, mid. N. line, 517
18, mid. N. line N. E. qr., 564

Westford. T. 12, R. 13 E.
Head of Beaver Lake, 282

Westford. T. 12, R. 13 E. — (con.) *Feet.*
Sec. 1, S. E. qr., 314
6, S. line S. W. qr., 372
7, S. line S. W. qr., 375
19, center S. E. qr., 298
19, N. W. qr., stream, 412
25, near center, 330
25, 276
26, and W. marsh, 292
30, near N. line N. W. qr., 378
31, N. line N. W. qr., 382
31, near center E. hf., hill, 412
34, S. E. qr., 327

Wheatland. T. 2, R. 19 E.
Sec. 29, mid. E. hf., 206
29, near S. W. corner, 270
31, near S. E. corner, 280

Wheatland. T. 1, R. 19 E.
Sec. 4, general level, 231
6, S. E. corner, 287
7, S. E. corner, 268

Whitewater. T. 4, R. 15 E.
Whitewater Station, 241
Whitewater Normal Hill, 307
Whitewater creek, 228
Whitewater lake, 317
Sec. 2, S. E. qr., 242
2, S. W. qr., 259
4, E. hf., 249
4, W. hf., 232
19, N. hf., 297

Wilson. T. 14, R. 22 E.
Sec. 5, S. line S. E. qr., R. R. cross'g, 115
5, near N. line R. R., 133
6, N. W. corner, general level, 131
6, mid. N. line, kettles, 114
8, N. line R. R., 115
17, N. line, R. R., 105
20, N. line, R. R., 102
30, N. line, R. R., 109
31, N. line, R. R., 102

Woodville. T. 20, R. 19 E.
Dundas Station, 160
Stream 3 miles E. of Sherwood, 256
R. R. crossing 2½ m. E. of Sherwood, 252
Highland E. of Sherwood, 318

Wrightstown.
Ledge, 240
Wrightstown village, 35
Sec. 1, S. E. qr., highland, T. 21, R. 20, 331
8, mid. S. line T. 21, R. 20, 154
35, mid. N. line T. 22, R, 20, 332
35, mid. E. line T. 22, R. 20, 292
35, S. E. qr.. swamp, T. 22, R. 20, 284

Yorkville. T. 3, R. 21 E.
Sec. 10, S. W. corner, Root river, 128
11, S. W. corner, 188
11, mid. S. line, branch Root R., 155
12, S. W. qr., Ives Grove, 204
26, N. E. qr., 207
27, N. E. qr., 177
28, mid. E. hf., 137
29, S. E. qr., 162
30, Union Grove, 192

CHAPTER II.

HYDROLOGY.

Drainage. On the average, about 165,512,000,000 barrels of water fall annually upon the district under discussion. Of this, about one-half is lost by evaporation and absorption, and the remainder runs away, constituting the drainage of the district. Were the slope of the surface much increased, the water would be discharged so rapidly as to do much permanent damage by erosion and the rapid removal of our fertile soil. Were its inclination much less, the drainage would be imperfect, and our noble water powers destroyed. In the golden mean presented, a mutual adaptation to the twin industries, agriculture and manufacture is fortunately secured. The drainage of the region forms part of two great systems, the Mississippi and the St. Lawrence. Perhaps one-fourth belongs to the former and the remainder to the latter.

The watershed between these systems is very peculiar. On the Illinois line, the divide is *within three and one-half miles* of Lake Michigan, and is only 160 feet above that body of water, while the surface to the west continues to rise by undulations to 400 feet and upwards. A little north of the state line, several of the streams, notably the White river, the outlet of Lake Geneva, flow to the *north-east*, and yet reach the Mississippi.

From the state boundary, the line of the watershed pursues a northwesterly course, becoming more and more elevated till it passes the Kettle range at about 500 feet above Lake Michigan, whence it continues still to the northwest till it suddenly drops 200 feet into the Green Bay and Rock river valley, whence it curves more to the west, until, on the highlands of Metomen, at about 400 feet elevation, it turns abruptly southward, giving rise to another anomaly. The streams that here flow *east* discharge into the Mississippi, while those that flow *west* empty into Lake Michigan. Following the watershed onward from this point, it gradually curves to the westward, descending to the portage between the Fox and Wisconsin rivers, where its elevation is little more than 200 feet. From thence it pursues a northward course to the highlands of Michigan. A section along the line of the watershed across the Green Bay and Rock river valley, would exhibit its peculiarities almost as conspicuously as if taken at any other point, and so, to almost the same extent, would a projection of the whole line exhibit the valleys, slopes and ridges that constitute the salient topographical features already described. It is evident then, that the present drainage systems are not the cause of these features.

At some points the elevation constituting the watershed is so slight as to be scarcely perceptible. A notable example of this is found in Racine county, in the relations of the head waters of the Eau Pleine river, a tributary of the Mississippi, and those of the Root river that flow into Lake Michigan. Both have their rise in an extended marshy valley, so nearly level that it is at times very difficult to determine which way the water flows. On the county and state maps the divide is placed *seven* miles from the point where it was at the time of my visit.

The *Mississippi basin* is represented in the district by *the Rock river system*, comprising that river and its tributaries, and *the Illinois river system*, embracing the (Illinois) Fox river and the Eau Pleine river, with their branches.

The St. Lawrence basin includes *the Lake Michigan system*, of which the principal streams are the Root, Milwaukee, Sheboygan, Manitowoc, Twin, Kewaunee and Ahnapee rivers, and *the Green Bay system*, to which the important Fox, Wolf, Oconto, Peshtigo and Menomonee rivers, with several minor streams, belong.

A moment's attention to the courses of these streams reveals many striking peculiarities, for most of which, upon careful study, there is an obvious cause. Some of these are worthy of special attention, not only from the inherent interest which they possess, but because they illustrate the dependence of such important features as rivers, which often determine the location and relations of great business centers, upon surface geology.

Beginning at the south, *the streams of Walworth and adjacent counties* on the east first claim attention, and form an interesting group, most conspicuous among which are White river, Sugar creek and Honey creek. These streams all flow in an easterly or northeasterly direction for a distance, and then abruptly turn south, uniting with each other, and at last joining the Fox river, which continues south until it unites with the Illinois river, through which its waters finally discharge into the Mississippi and the Gulf. All the group occupy *deep parallel valleys* in the upper part of their course, and it is only when they debouch into the lowlands of the Fox river that they turn southward.

The contour of the adjacent country forbids the supposition that these valleys were excavated by simple drainage erosion. Their direction corresponds to that of the drift movement to which they are undoubtedly due. They bear the distinctive marks of troughs, *up* which the ice mass moved from the northeast, as will be explained subsequently. On either hand there are vast accumulations of drift, heaped up in the form of an irregular moraine, or of rounded hills and parallel ridges. When the streams reach the lower land, they follow southward along the foot of the drift hills, in what was formerly, to some extent at least, the bed of an elongated lake.

It is noticeable, also, that the numerous beautiful *lakes* of this region fall into line along these glacial valleys, and owe their existence to the same general cause.

The Pike river in Kenosha county is but an insignificant stream, but its course is very instructive. In the upper portion it flows in a meandering manner toward the lake in the direction of the general slope of the surface. But when within about one mile of the lake shore, it turns abruptly southward and runs parallel to it for about four miles. It formerly extended farther, but the encroachment of Lake Michigan cut across the narrow tongue of clay that separated the river from it at one of the bends just above Kenosha, and allowed the stream to discharge at that point. But the old gorge reënters the shore bluff farther down and again joins the lake at Kenosha harbor. Drs. Lapham and Hoy have both previously called attention to this interesting instance of lake encroachment.

At the point where the stream now discharges, a sand bar is formed which turns it southward. With a single unimportant exception, all the streams, great and small, along the Wisconsin shore of the lake, so far as they have come under my observation, are turned to the southward, in a similar way, by an accumulating bar at the mouth. This fact has heretofore been remarked by several observers.

It is noticed also that where piers are extended into the lake, the sand rapidly accumulates on the north side, forming "made land," while that which collects on the south side is inconsiderable.

These facts show clearly that the drift along the present shore is to the *southward* and would seem to warrant us in saying that there is a southward lake current along the Wisconsin shore. This furnishes the key to the explanation of the course of the Pike river. Formerly the lake stood relatively about 50 feet higher at this point than it now does and extended inland beyond the position of this portion of the

Pike river, and left its record in a low beach ridge. The Pike river seems, at that time, to have discharged directly into the lake, and it would appear that there was then as now, a southerly current which forced the stream southward by the formation of a bar and gave it its present course. The gorge it now occupies, it has since cut from the yielding clays. This little river then seems to teach us something of the past history of Lake Michigan, and since the present shore current is believed to be due to the prevailing direction of our winds, it perhaps also teaches us something of ancient meteorology.

The course of *the Milwaukee river* is even more interesting. It originates chiefly in Fond du Lac and Sheboygan counties from a number of nearly parallel southward-flowing streams, which gradually unite to form the main river. At West Bend it turns abruptly eastward. After passing Newburg it makes a rude sigmoid flexure to the north, and resumes its eastward course. When within about nine miles of the lake, it bends suddenly to the right and flows almost directly south parallel to the lake shore for more than 30 miles, being distant from it at some points in its course less than two miles. It really then consists of three portions: the southward-flowing parallel branches, the eastward-flowing portion, and the main trunk flowing south as last mentioned. The course of the river in each of these three parts requires a different explanation.

The parallel branches occupy so many valleys enclosed by the ridges of the Kettle Range which here develops a more than usual parallelism among its component ridges. At the occasional breaks in these ridges, the streams find the means of uniting.

At West Bend, where by taking advantage of these interruptions the united stream has reached the east flank of the Kettle Range proper, its course is intercepted by an east and west valley, attended with "kettles" and serpentine ridges, and corresponding to the direction of drift movement, in short, a glacial valley. This, the stream follows to the vicinity of Newburg, when it passes across to a parallel valley on the north. These two east and west valleys are entirely analogous to those in Walworth county, already mentioned; indeed, they belong to one system of topographical features, occupying more or less conspicuously the whole territory between them, and due to the same glacial action.

Near the great bend, in the town of *Fredonia*, the stream reaches an ancient beach line, which marks the shore of the lake at the time of the deposit of the Lower Red Clay, yet to be described. The river follows along this beach line to its mouth at Milwaukee. The conclusion can scarcely be avoided then that it owes its course to this relationship, and that the explanation is the same as that given for Pike river — and that the same inference as to a southward lake current is justified.

We have a similar phenomenon in connection with the east member of Two rivers, or the *East Twin river*, which marks, though much less definitely, the western limit of the Upper Red Clay, following in a similar way the sandy beach deposit, that marked the shore line of the lake at the time of its formation. It would seem then that as far back as we can trace the history of the lake, by these means, it has had a southward-flowing shore-current along the Wisconsin side.

The courses of several other streams belonging to the Lake Michigan system are to be explained in a similar way.

The upper portions of the *Wolf*, *Oconto*, *Peshtigo* and *Menomonee rivers* are essentially similar to each other. Rudely parallel among themselves, they flow in the direction of the general inclination of the surface, exhibiting nothing peculiar while they are passing over the region of the granitic and other Archæan rocks, but after entering upon the territory underlaid by Paleozoic formations, their several directions become exceptional.

The Oconto river, after flowing parallel to the Wolf for thirty-five miles, turns at a right angle to the east, and flows directly to Green Bay, while the Wolf river continues straight on its course for thirty miles, when it turns with equal abruptness to the *west*, afterwards more gradually to the south, and then east, and at Lake Winnebago its current is reversed and flows northward, so that after a circuit of about 140 miles, it reaches the mouth of the Oconto and mingles with its waters, which have only traveled thirty miles since the rivers parted company.

The distance between the *Wolf* and *Oconto* where this divergence takes place is only about twelve miles, more than half of which is occupied by Shawano lake and its outlet, and only drift accumulations of no very considerable magnitude make up the divide.

The *Menomonee and Peshtigo rivers* make similar abrupt changes in their direction.

By referring to the map, showing the geological formations of this region, the explanation of these anomalies becomes at once apparent. It will be seen that the boundaries of the formations are zig-zag, or step-like, and that the rivers follow the softer formations along the face of these steps.

The *Wolf river*, from Shawano south, follows along the nearer or more remote cliffs of the Lower Magnesian limestone, its bed lying in the soft Potsdam sandstone, until in the town of Ellington, along the line of an apparent fault, the limestone is brought athwart its course, and it turns to the west, still following the face of the Lower Magnesian cliffs, until they turn southward in the town of Mukwa, when the river curves in the same direction, and at length in the bed of Poygan lake and the basin of the Fox river, it finds its way across the obtrusive formation. Its waters then reverse their course and flow back along the face of the projecting cliffs of the Niagara limestone for a hundred miles, when Porte des Morts allows them to escape into the great lake, at a point not half the distance from their source that they have traveled.

The Oconto river, on the contrary, on encountering the resisting Lower Magnesian limestone, turns sharply to the east and flows along the north face of the formation for some distance, when it forces its way across it, forming the beautiful falls of the Oconto, and keeps directly on its course to the bay. The falls are occasioned by a soft shaly stratum near the middle of the formation, there being hard, heavy bedded layers of dolomite above and below. The softer stratum, being more easily eroded, permits the water to undermine and throw down the heavy beds above it, thus keeping the face of the cliff vertical and causing the falls to slowly recede. The perpendicular fall is about twenty-two feet, with a considerable descent upon the rapids above and below.

The deflection of the *Menomonee river* to the eastward (town 33, ranges 21 and 22 E.) is to be attributed to the barrier interposed by the same formation, though in this instance it is far less conspicuous, as the formation does not immediately adjoin the river on the south, nor does it anywhere in the vicinity project in mural cliffs, according to its habit, to the southward. Yet its influence on the drift accumulations is apparent, and it is none the less the cause of this deviation of the river from its general course. At Grand Rapids the river crosses the formation, the rapids being due to the same cause as the falls of the Oconto. The shaly stratum is here harder, however, and the layers above less massive, making the resisting power of the two portions less different, so that the result is a series of rapids instead of vertical falls. Immediately on passing this barrier, the beautiful river recurves to the south, indeed to the west of south, and follows the horizon of the St. Peters sandstone, having the Trenton limestone on the east, until within about eight miles of its mouth, where it crosses the latter formation by a succession of rapids. It is true that between the Grand Rapids and those last mentioned, neither the St. Peters sandstone nor Trenton limestone appear as obvious barriers, the channel of the stream being excavated in drift, but there is good reason to believe that the original surface of the drift, which controlled the direction of the stream, was determined by these underlying formations, and that they are none the less truly, though remotely, the governing influences. This view of the ease is supported by the unquestionable facts relating to the similar detour, though in an opposite direction, of the Peshtigo river at a point nearly opposite.

Although perhaps more than usually winding in its minor features, the general course of the *Peshtigo river* is exceptionally direct, and almost exactly southeast. The only noteworthy deviation is that to which attention is now called. From the outlet of Lake Noqueba, its course is nearly due south until it crosses the western edge of the Lower Magnesian limestone near the third correction line, when it immediately sweeps round to the north of east, and flows nearly at right angles to its general course for about nine miles, approaching the Menomonee within less than three miles, when it reverts to its southeastward course.

Throughout this northeasterly course, it is flanked on the southeast by a wall of Trenton limestone and St. Peters sandstone, the former appearing at points in naked ledges left projecting by the disintegration of the latter. The present bed of the stream is excavated below the horizon of these formations, and lies in a trough cut from the Lower Magnesian limestone, for the greater distance. But the dip of the formations to the eastward is greater than the descent of the stream, so that it is finally enabled to surmount them at Potato and White rapids, when it returns to its original direction.

The controlling influence of this barrier is also shown to the southward in the courses of the "*Little river*" of the Peshtigo, and the "*Little river*" of the Oconto.

Perhaps the conjecture may be ventured that the Peshtigo and Menomonee rivers, before the drift period, united near their point of nearest approach on the west side of this limestone barrier, and passed it through a common, but now drift-filled and concealed, channel, for it is abundantly evident that they did not then pass it, at the same points they now do, and this vicinity appears to present the lowest point to which the western edge of the Trenton limestone is depressed within the basin of these rivers.

On the flats below the village of Peshtigo, the tortuous course of the river reminds us of the Asiatic Meander.

If the limitations of our space allowed us to go more into detail, and to examine *the minor streams*, we should find equally instructive, though less conspicuous, phenomena. We can find room for only one example, that of the *East Branch of the Rock river*, which joins the main stream in Horicon marsh.

This river has its source in a broad, deep valley, extending from the southeast to the northwest (about N. 30° W.) for a distance of upwards of 20 miles. In the towns of Wayne, Theresa, and Lomira, the width is from one to two miles between the foot of the hills that rise somewhat abruptly on either side. The valley is occupied very extensively by marsh. Branches from the north and south unite near the center and form the main stream, which taking a direction nearly at right angles, and pursuing a serpentine course among the parallel north and south ridges of this region, finally discharges its waters into Horicon Marsh, thus forming a rude italic *T*, the upper portion being formed by the branches first mentioned. These branches are not large, nor is the area drained by them considerable. The valley which they occupy may be traced onward to a northward connection with the valleys crossing the ledge in Byron.

It is scarcely credible that this valley with all its peculiarities was due to the unaided erosion of the streams occupying it. Though partially filled with drift accumulations, it is really channeled from the Niagara limestone, which distinguishes it from the class last under consideration, where the essential condition was two formations of different resisting power. In explaining its origin we must again have recourse to glacial action. We find that the drift movement was southward along the axis of Lake Winnebago, but on surmounting the ledge on the east and south, it turned somewhat eastward and followed down the slope of the surface and dip of the rocks, eroding furrows that have a southeasterly trend. One of these is the valley in question, which is doubtless more extensive and well defined than the adjoining ones, because it lies south of Lake Winnebago, that is, more nearly in the line of heavy glacial action. The angle in the ledge just north of it doubtless contributed to the same result.

Relationship of some of the streams on opposite sides of the Kettle Range. One further feature relating to certain streams and their attendant topography deserves notice. It consists of a certain peculiar and definite correlation between the streams on the east and west sides of the great dividing drift ridge.

Where an extended ridge-like watershed exists, it is to be expected that streams on the opposite sides will rise near each other and flow in opposite directions, at right angles to the ridge, but in the present instance they are arranged *in pairs*, and connected across the summit by more or less well defined *valleys*, so that the relationship cannot be looked upon as being merely fortuitous.

My attention was first called to those in Walworth county some years since by Dr. H. Hunt, of Beloit. The fluvial pairs and the essential facts are briefly as follows:

1. Geneva Lake and Big Foot Prairie, in Walworth county. The bluffs on either side of Geneva Lake rise upwards of 100 feet above its surface, but at its head the valley extends westward, though much narrowed, and joins the more elevated level area, known as Big Foot prairie, whose present drainage is southwestward, the watershed being on its margin next Geneva Lake, and less than two miles from it. The surface is more elevated on either side of the prairie, which bears evidence of having formerly been occupied by a lake.

2. Delavan Lake and the White river, in Walworth county. The valley of Delavan Lake is very similar to that of Lake Geneva, but it lies on the western slope. From it a well defined valley extends across the divide and connects with the valley of White river, but the elevation of the summit is greater than in the previous instance.

3. Turtle creek and Sugar creek, in Walworth county. The head waters of Turtle and Sugar creeks are connected by a narrow band of marsh, bordered on the south by a line of bluffs, and on the north by a more gentle ascent. Its whole aspect is that of a fluvial flat.

4. The Bark and Oconomowoc rivers and the branches of Cedar creek, in Washington county. These streams constitute a double pair, each of the rivers rising in a marshy valley in very close association with the headwaters of Cedar creek, the elevations separating them being very slight.

5. Rubicon river and the northern branch of Cedar creek, in Washington county. Between Cedar lake and the headwaters of the Rubicon river lies an elongated marsh, occupying a notable depression in the otherwise elevated ridge.

These facts naturally suggest the question, Did the streams on the east side formerly flow across the present summit, or was the reverse the case; or, again, are these facts to be otherwise explained? In answer, it is to be remarked, in the first place, that the watershed in question is either formed by, or is closely related to, the great drift ridge previously described, and that this, as I shall hereafter attempt to demonstrate, is a moraine, formed as an accumulation along the foot of an immense sheet of moving ice. If this can be clearly pictured to the mind, it will at once become evident that the waters from the melting ice mass must find their way across the accumulated drift, and as the amount of water discharged must have been immense, deep valleys would be cut at intervals of no great distance. This is probably the true explanation of the initial formation of these valleys across the summit.

Origin and Geological Relations of the Lakes of Eastern Wisconsin. Analogous to the topics which have been under discussion, is the consideration of the position and cause of the numerous lakes which lend their attractions to the beautiful scenery of this portion of the state.

It has already been said that *the great lake* on the east lies in a basin excavated chiefly from the soft rocks of the Devonian age, and that its western edge rests upon the Upper Silurian limestone along the trend of which it lies. The fact that its bottom lies three hundred feet below the level of the ocean, shows that it could not have been eroded by running water in its present position; and its width and the regular contour of its bottom forbids the supposition, even if the proper elevation and slope were given it. The drift on its margin contains material that there is every reason for believing came from its bed, and the polishing and grooving of the rocks that form its rim show that it has been the theatre of powerful glacial action, and to this cause its present regular outline and great depth and breadth are undoubtedly due. That it may have been deeply channeled by running water before the glacial period, and that such channels may have had a directing power over the subsequent and more powerful glacial action is not improbable. The fact that it lies within seventy miles — less than its own breadth — of a region where the drift action was very slight, and the preglacial contour of the surface was not more than slightly modified, a region whose present elevation is less than three hundred feet above the lake surface, and beyond which the drift shortly disappears entirely, lends support to this view.

Green Bay, Lake Winnebago and the former Lake Horicon occupy portions of a similar glacial channel, and owe their origin to slight drift obstructions thrown across the valley. The fact that Lake Winnebago discharges through a channel having a rocky bottom does not militate against this statement, for the real channel of the *valley* is nearer Clifton, on the east side of the lake. The drift blocks this up, and the lake pours over a low rock barrier that separates it from the parallel valley of Butte des Morts, which occupies a lower geological horizon.

Were the drift removed, a channel between Menasha and Clifton would, without question, drain the lake.

Lake Horicon was originally confined by drift, which, in time, by its own outflow, was cut away. Its place was subsequently supplied by an artificial dam, which restored the lake. This, again, was removed, and the area is now a marsh.

Lake Poygan seems to have been excavated by glacial action, chiefly from the yielding Potsdam sandstone, the direction of drift movement being here to the westward. It is probable that a river channel existed there previously, which enabled the ice to act with greater efficiency.

Green Lake, Puckawa Lake and Rush Lake all lie in one valley along which the glacier plowed its way. Rush Lake was eroded from the soft St. Peters sandstone, having the harder Lower Magnesian limestone for its bed, while the Trenton limestone borders it on the east. The rise that separates this from Green Lake is scarcely perceptible. The east end of the latter lake occupies the same geological horizon, but the dip of the strata is such at this point that, in its length, the lake cuts across the Lower Magnesian limestone, the Madison sandstone, the Mendota limestone, and into a still lower division of the Potsdam sandstone. At the west end it is confined by a range of drift hills crossing the valley. To these this beautiful lake may be said to owe its existence. If they were removed, the lake would discharge itself into Lake Puckawa, to the west, its elevation being the greater. The contour of these hills shows their morainic character and indicates that they were heaped up there by the tongue of ice that filled and in part eroded the valley.

Lake Puckawa was eroded in the same way, but from still lower strata. On its south side there rises a cluster of hills of Archæan rocks, which, by their hardness and powers of resistance, may have forced the ice mass to more deeply erode the softer sandstone reposing on their flanks.

Lake Shawano lies along the northern base of an east and west line of bluffs capped by Lower Magnesian limestone resting upon Potsdam sandstone, from which the basin of the lake has been excavated. Its longer axis harmonizes with the direction of glacial movement, which in this region was from the east to the west. We have, then, an easily eroded stratum, adjacent to a more resisting one, with a competent eroding agency acting in a favorable direction, resulting in the formation of Lake Shawano.

Lake Koshkonong likewise lies in the direction of glacial progress and is due to the ease with which the St. Peters sandstone was excavated. An ancient stream had probably cut down to and perhaps through it — for such is the fact in reference to the preglacial Rock river channel farther south — and the ice plow, taking advantage of this, furrowed and filled, leaving a wide, shallow basin.

The foregoing lakes, it will be noticed, have a definite relationship to the geological formations adjacent and subjacent to them, and are all to be accounted for on essentially the same principle, viz.: The unequal hardness of the strata acted upon by a powerful excavating agency, that, unlike rivers, did not carry away its rubbish as fast as formed, but heaped it up promiscuously in its own track as it melted backward, the inevitable result being the formation of lakes along its abandoned channels.

The number originally thus formed was vastly greater than the number now in existence, the great majority having cut down their own barriers and drained themselves.

These may then be said to be *glacial lakes*, for there is no reason to suppose that any one of those described, existed before the drift period. But as the most of them were probably represented as river valleys or gorges, and as their present existence is due also to the unequal powers of resistance of the rock formations, this class of lakes is not entitled to be termed glacial lakes in the same sole-dependent sense as the following, the most of which show little or no relationship or dependence on the underlying strata, but are drift lakes in an exclusive sense.

The class now to be described may be subdivided into two subordinate ones. The first are those which lie in valleys, whose greatest length is in a line with the glacial grooves, and in this respect are like the last class, differing from them only in being independent of the strata beneath. These were formed in drift troughs by the retreating glacier, very much as the class above described were, only the troughs are not excavated rock channels, but valleys, between drift ridges.

The other kind are those whose greatest length lies at right angles instead of parallel to the glacial grooves.

These lie between the ridges that accumulated at the foot of the glacier and which were rudely parallel to each other, yet sometimes joining mutually, and again separating to a considerable interval, they left enclosed hollows, which on filling with water, became lakes.

We would perhaps be justified in being even more specific than we are in calling these drift lakes, by designating them *moraine lakes.*

From the nature of the case, forms intermediate between all the foregoing are to be expected, and are found to occur, and with the general explanations given, it will be needless to designate in the case of each of the numerous small lakes, the precise method of formation, although it is, in most cases, sufficiently clear.

More than one hundred of these lakes lie along or adjacent to the Kettle Range, and form an important element of its picturesque scenery. Among the most noteworthy are *Geneva*, *Delavan*, *Como*, *Turtle*, *Bass*, *Holdens*, *Otter*, *Silver*, *Pleasant*, *Green* and the *Troy* lakes in Walworth county; *Mary*, *Elizabeth*, *Camp* and *Silver* lakes in Kenosha county; *Wind*, *Long* and *Brown's* in Racine county; *Muskego*, *Pewaukee* and that beautiful cluster known as the *Oconomowoc* lakes, about forty in number, in Waukesha county; *Cedar*, *Little Cedar* and *Silver* lakes in Washington county; *Long* and *Round* lakes in Fond du Lac county; *Elkhart* and *Bear* lakes in Sheboygan county, and *Cedar*, *Pigeon* and *Wilke* lakes in Manitowoc county. *Rock* lake in the town of Lake Mills, Jefferson county, and *Clear* lake, near Milton, Rock county, belong to the same category, though unconnected with the main chain of the Kettle Range.

Of the foregoing, *Muskego*, *Wind* and several smaller lakes associated with these, bear evidence of having formerly constituted parts of a much more extensive body of water, that leveled by erosion and deposition the original uneven surface in their vicinity, so that its primitive drift features disappeared and with them the corresponding features of those lakes, so that they do not now present those characteristics which are common to the majority of the others.

There is also some evidence that the comparatively level area in which the *Oconomowoc* lakes are embosomed was, immediately after the glacial period, occupied by an extensive lake that reduced the general surface to its present degree of uniformity by washing down projecting points, while it was unable to fill the present lake basins, they being below the line of its wave action.

The value of the lakes of eastern Wisconsin is much greater than is sometimes apprehended. Beauty is not an unimportant element of value. Attractive scenery adds materially to the worth of both rural and urban property.

The *wealth* of eastern Wisconsin has been materially increased during the last decade, simply through the charm of its beautiful lakelets. Thousands of citizens of other states have visited them, and large hotels and beautiful summer residences have been erected as substantial tokens of the enduring admiration which these gems of nature have awakened.

The salutary influence which they exert over the people of our own state by tempting to healthful recreation and by the cultivation of æsthetic tastes is scarcely to be estimated.

To those who admire a broad expanse of water, *Lake Winnebago*, with its cliffs on the one hand and its wooded plains on the other; *Green Bay*, with its rocky battlements on the right, its forests on the left, its viewless limits on the north, its islands and harbors, and, par excellence, the oceanic *Lake Michigan* present their varied attractions.

Among the smaller lakes that have been accorded the greatest measure of admiration, attention may be called to the deep, clear waters and wooded, gravelly shores of the picturesque *Geneva*, the charming variety of the two score lakelets of the *Oconomowoc* cluster, the emerald waters and picturesque glens and cliffs of *Green Lake*, the romantic little *Elkhart*, a gem in a rustic framework of wooded drift knolls and kettles, and the quiet, restful beauty of *Rock*, *Brown*, *Clear* and *Delavan* lakes. Lakes *Koshkonong*, *Pewaukee*, *Puckawa* and others are favorites with sportsmen.

These lakes abound in a variety of excellent fish, and are the resort of large numbers of water-fowl. Through the labors of the state fish commissioners, and the enlightened and generous action of private citizens, some of them have recently been stocked with choice varieties of fish from other waters, and it is confidently believed that they will, under a continuance of this enlightened policy, render a handsome contribution of excellent food in return.

Their value as *water power reservoirs*, though not as yet appreciated, will, in the unfoldings of the resources of this region in the future, perhaps surpass both the considerations above mentioned. This point will receive brief consideration under the head of water power, a few pages in advance.

Water Supply. The surface soil possesses, on the average, a fair degree of absorptive power, and the underlying strata, both of the drift and rock formations, consist of alternating pervious or impervious layers, thus presenting suitable conditions for an excellent water supply. A less absorptive soil would cause a greater proportion of the rainfall to be lost by surface drainage, and a uniformly porous or uniformly impervious rock structure beneath would be less favorable to frequent springs or veins of water that could be reached by wells. As it is, there are few localities at which an abundant supply of water cannot be reached at moderate depths.

Attention will here be chiefly confined, however, to the natural sources of supply provided in *springs*. To casual observation these appear to be scattered promiscuously over the region, without any definite geological relations, but such is not the fact. There are *two general systems of springs;* those that originate in the drift deposits, and those that flow from the rock. The springs of each group occupy several different horizons, which it will be interesting to notice briefly, as the subject is one of great importance. It is estimated by some authorities that one-third of the diseases which afflict mankind are due to the use of impure water. Though this estimate may be too high, it is abundantly demonstrated that some of the most terrible diseases are directly attributable to this cause. If unaided nature has provided us any means of escape from this prolific source of danger, it is quite certain to be found in our deep seated springs.

There are several reasons why *spring water* is more likely to be pure than that of wells. On the average it comes from greater depths and has passed through a greater extent of the deeper strata which are comparatively free from organic impurities, than has the water of wells, which is usually drawn from the surface of the water level beneath the location of the wells. Artesian fountains are not here taken into account. The water of wells is usually stagnant, while that of springs is active, "is living water."

There are some exceptions to the first part of this statement. Occasionally a well is sunk upon an active, flowing, underground stream, in which case the superior character of the water will usually be very marked. The water of springs is not liable to so many sources of contamination, and they more readily discharge impurities that may find their way into them. In view of these facts, the study and utilization of the numerous springs of the state become of much importance. So far as possible all cities should be supplied by water from springs or Artesian wells.

The *lowest noteworthy horizon* from which springs arise is the vicinity of the *junction of the Potsdam sandstone and the Lower Magnesian limestone.* The water from this source usually has a temperature of 48° to 50°, and is clear and comparatively free from organic impurities, but contains a small percentage of the carbonates of lime and magnesia, and in some cases a very small percentage of iron, with usually some silica, alumina and chloride of sodium. But the combined amount of these is small, and the water is "soft," and very pleasant to the taste. A small amount of free carbonic acid is usually present, which enhances the grateful effect of the water upon the palate and stomach. The springs from this horizon are not numerous. *Mitchell's* spring near Berlin is a fine example, and deserves the attention of the people of that place as a source of pure water for domestic purposes, and as furnishing favorable conditions for trout raising. Another notable spring of this class lies near the road between New London and Hortonville (S. W. ¼ of N. W. ¼ Sec. 28, T. 32, R. 15 E.), which is very much superior to the water from the drift wells of those places.

Above this horizon springs occur but rarely till we reach the *junction of the St. Peters sandstone with the Trenton limestone.* Some shaly impervious layers mark this division, while the limestone above is fissured and the sandstone below is porous. It hence follows that the springs may arise either above or below the impervious stratum according to circumstances. (1) Water descending from above may be caught and carried out where the strata are cut across to the proper depth; and (2) water that gained access to the sandstone at some distant and more elevated point may rise from below at places where the confining stratum is removed. So that it is proper to include in this group some that issue from ledges somewhat above or below the junction of the formations. These springs are similar in general character to the last, but usually contain a more considerable percentage of the several mineral ingredients, at least that portion of them that are derived from the limestone, which still retains traces of many of the salts that we have reason to suppose were incorporated with it when it was formed beneath the ancient ocean.

To this class belong most of the springs that issue from the rock in the western half of the counties of *Rock*, *Jefferson*, *Dodge and Fond du Lac*. Though differing among themselves, they are, as a class, of most excellent quality, and should be substituted for the well water of those regions, so far as practicable.

A number of springs in the vicinity of *Beaver Dam* issue from near the junction of the Trenton with the Galena limestone; and at other points, streams issue from the latter formation, but they do not seem to be confined to any single stratum, and there is nothing in the nature of the rock to ead us to expect any well marked system.

By far the most remarkable water-bearing horizon is found at the *upper surface of the Cinninati shales*, the dividing plane between the Upper and Lower Silurian formations. The upper part of the shale is little else than a stiff, compact, blue clay, and is the most impervious stratum in this portion of the state. Above it there lies a varying thickness of fissured, cavernous Niagara limestone, through which the water descends till its progress is arrested by the clay from the surface of which it flows out wherever opportunity offers. Along the east side of the Green Bay and Rock river valley, the junction of these strata is exposed at frequent intervals for one hundred and fifty miles, so that hundreds if not thousands of springs, great and small, mark this horizon. When a heavy mass of drift clay lies against the line of junction, the water sometimes issues from layers of the limestone, several feet higher, and where much loose rock has fallen from the cliffs above, the stream runs in a concealed channel down the slope, and appears to issue scores of feet, sometimes, below its true point of exit from the strata. Yet, notwithstanding these facts, with proper caution, the point at which the clay and limestone join, even when concealed, may be traced approximately by this line of springs.

Many of these fountains are very large and strong; indeed, some of them are rather to be conceived as streams, issuing from the rock full fledged, than as the bubbling source of a rivulet, implied by the term spring. In some places they furnish, without further augmentation, sufficient power for efficient flouring mills. In one case two mills are supplied by using the water in succession, within one-half mile of the source.

The quality of the water of this class varies more than that of the preceding, owing, as it may be conjectured, to the greater or less effect of the shales upon it. These contain organic matter, iron pyrites, and other ingredients which on exposure indicate their unstable chemical nature, by changes of color and otherwise, and, by so doing, warrant the belief that they sometimes make unfavorable contributions to the stream in contact with them. The water of most of them, however, is clear, cool and refreshing, and in character very similar to those of the preceding classes, though somewhat harder, on the average. Several are supercharged with lime salts, which are deposited as travertine about the spring, on the escape into the atmosphere of the carbonic acid which held them in solution. The temperature is also varying, being dependent of course upon the thickness of the limestone above.

Above this generous horizon there is no well marked water-bearing stratum of rock, although there are numerous fine springs issuing at various points from the Niagara limestone. The widely known *Waukesha springs* are examples. *Druecker's spring*, near Ozaukee, and several fine ones near Sturgeon Bay, belong to a similar geological position.

The foregoing are all derived from rocks that were laid down under the ancient Silurian ocean, rocks whose ages are to be reckoned by myriads of years, and from which there has at least been a liberal allowance of time for the removal of whatever soluble matter may have been originally incorporated in them; and yet we find in all that have been analyzed, varying quantities of the oceanic salts. The remainder issue from loose material of much more recent origin, formed by the agency of ice and fresh water, so far as the evidence goes; and yet, as this material was derived from the preceding oceanic formations in great part, the same ingredients may and do occur in the water. They are as a class more superficial than the preceding, and more liable to contamination from surface impurities, and for a like reason their temperature is often less constant and their flow less regular. While this is true, some magnificent springs belong to this class. It will not be necessary to enter so much into detail here, as in many cases the water-bearing stratum is merely local.

The *Kettle Range* is lined through its whole extent with springs. Its "pots and kettles" are peculiarly adapted to catch and temporarily hold the rainfall, while it is being discharged at the foot of the range, and at other convenient points, in limpid springs. From the depth of drift which the water penetrates, many of these become very constant in flow and uniform in temperature. Dousman's magnificent trout spring in the town of Ottawa probably belongs to this class, though it lies so near the great water-bearing horizon between the Lower and Upper Silurian formations, that it may really originate there, though it issues from the drift. Starin's spring, near Whitewater, the "Big Spring," near Palmyra, and a large number of others in the flats adjacent to the range, without much question, have their reservoirs among its hills.

The numerous lakes along the range are largely fed from similar sources, which accounts for the clearness and purity of their waters.

Near Lake Michigan, where the lowest beach deposit rests upon the blue bowlder clay, an almost continuous line of small rivulets issues from the junction of the two formations, the clay intercepting the descending water while the sand and gravel of the beach formation furnishes a ready passage for it. They are quite varying in chemical character, but are usually inferior in purity and changeable in temperature.

Analagous to this, there is another line along the lake shore at the upper surface of the lower red clay, which is overlaid by the second beach formation. In cause and character these are altogether similar to the last.

It would be fitting in this connection to give *the analyses* of such of the foregoing springs as have received quantitative examination, but a number of these have already been given by Dr. Lapham, in his report on mineral waters, to which the reader is referred. It is proper to add here, however, several analyses made since the writing of that report.

SUPPLEMENTARY TABLE OF ANALYSES OF SPRING WATER.

	Bethesda Springs, Waukesha, by C. F. Chandler.	Iodo-Magnesian Springs, Beloit, by C. F. Chandler.	Hygeia Spring, Waukesha, by O. A. Thiele.	White Rock Springs, Waukesha, by G. Bode.	Horeb Mineral Springs, Waukesha, by G. Bode.	Fountain Spring, Waukesha, by J. V. Z. Blaney.	Gihon Springs, Delavan, by G. Bode.
Chloride of Sodinm	1.160	0.3362	1.250	1.170	0.1702	trace.	0.4704
Bromide of Sodium	....	trace.	....	....	....	....	....
Iodide of Sodlum	....	0.0049	....	....	....	....	....
Bicarbonate of Lime	17.022	14.5196	16.726	11.716	10.7520	13.778	10 2704
Bicarbonate of Magnesia	12.988	12.2803	13 142	5.311	6.8768	9.195	7.1450
Bicarbonate of Soda	1.256	0.1406	2.265	1.181	....	1.021	....
Bicarbonate of Iron	0.042	0.0396	0.575	....	....	0.048	0.1960
Sulphate of Lime	....	0.1326	....	....	....	....	....
Sulphate of Soda	0.542	....	0.524	1.091	1.2432	0.360	0.9520
Snlphate of Potassa	0.454	0.3123	0.820	....	....	....	....
Phosphate of Soda	trace.	0.0104	0.040	....	....	....	....
Alumina	0.122	0.0590	0.720	....	0.2252	0.097	0.1288
Silica	0.741	0.7581	0.150	1.036	0.7336	0.554	0.7560
Organic matter	1.983	trace.	trace.	....	....	0.311	....
Total per U. S. gallon of 231 cubic inches	35.710	28.5936	38.211	21.505	20.0200	25.367	19 9126

The source of the substances found in these springs is quite clear. The salts of lime, magnesia, silica, alumina and iron, are the rock substance dissolved, these being the essential constituents of the strata from which the waters flow or through which they have percolated. It is to be noted that the relative proportions of these substances in the analyses bear a close correspondence to that which they sustain in the rock. The compounds of sodium and potassium are for the most part those found in sea waters, whence they were derived at the time of the deposition of the formations beneath the Silurian ocean. The leaching of ages has not sufficed to completely remove them from the interior of the strata, and these analyses show that they are still being dissolved out and borne back to the ocean. The iodine which distinguishes the Beloit springs is doubtless derived from the ancient sea weed that is imbedded in abundance in the rock from which its flow is derived. It is true, iodine exists in sea water, but in a much less proportion than bromine, while here it is greater. It is further to be noticed that the ratio of iodide of sodium to chloride of sodium, the common salt of the ocean, is greater than in sea water. These facts warrant the belief that the trace of bromine was entrapped by the forming rocks in the same manner as the more common salts, but that the iodine arises from the sea weed that was buried by the accumulating sediments. The *proportion* of iodide of sodium to chloride of sodium — common salt — is greater, with one exception, than that found in twenty-two other springs containing iodine, with which it was compared.

The small amount of organic matter in these springs is doubtless derived from the surface by the descending water.

To enter into a consideration of the *medicinal character* of those springs that have attained a reputation for remedial virtues, would transcend our space, if not our province, and so long as medical science depends rather upon experimental results than theoretical considerations, it might possess little value if attempted. The use of these waters has been recommended by many physicians of high standing, and the results that have attended such use have been of a highly satisfactory character. That there are differences in the comparative merits of the several springs is undoubted, but it is not the prerogative of this report to decide between them. It may be said of them as a class that they are free from any excessive amount of salts, which are objectionable when present in large quantities, though useful when the amount does not exceed the demands of the human system. For example, a certain amount of lime is needed by the body for the maintenance of its bony frame-work and the performance of other functions, and in the opinion of many authorities this may be advantageously supplied through the medium of the water ingested; but an excessive amount of lime salts is conceded to be conducive to certain ailments. If the amount exceeds that which can be held in solution in the various conditions through which the water passes in the system, it is certainly to be regarded as excessive, for a portion of it must be deposited. The quantity of lime salts of most of the noted springs elsewhere exceeds by many fold the average quantity found in these. It is to be further noticed that most of these ingredients are invariable, if not normal, constituents of the human body, and that the hygienic character of the water is beyond question.

It remains to consider briefly the *geological position* of those that have attained a greater or less reputation for medicinal properties. The *Bethesda*, *Hygeia*, *Mineral Rock*, *White Rock*, and *Fountain Springs* at Waukesha, flow from the upper portion of the middle division of the Niagara limestone which is capped, in the vicinity, by the upper beds, known as the Racine limestone.

The *Horeb Spring* of this place issues from the drift, which is here largely gravel or marly clay derived from the above formations. The *Beloit Iodo-Magnesian Springs* flow from the lower portion of the Trenton limestone, a lower horizon than the preceding or following.

The *Siloam* of Milwaukee, the *Oakton* of Pewaukee, the *Palmyra* springs, the *Sheridan* of Geneva, the *Gihon* and *Barnes* of Delavan, the *Nemabin* of Oconomowoc, *Richmond's*, near Whitewater, and the *Cedarburg* spring, issue from various portions of the drift. It is possible that a concealed connection with the rock may exist in some of these; but evidence of the fact is wanting. *Telulah Mineral Springs*, near Appleton, flow from the drift a few feet from the surface of rock belonging to the Galena horizon, and from the fact that water of similar character flows from a drilling in the rock in the immediate vicinity, it is claimed that the flow is from that source.

The following classified list of springs, though far from being exhaustive, may be serviceable.

Sulphur Springs. In all these the sulphur exists in the condition of sulphuretted hydrogen, which, being volatile, soon escapes into the atmosphere, and so unless the chemical determination be made at the spring, or special precautions taken, it fails to appear in the analysis. This is the case with Richmond's spring near Whitewater, which is very strongly impregnated with this gas, no indication of which appears in the analysis.

The sulphur is derived without doubt in most cases from the decomposition of iron pyrites, specimens of which in the state of decomposition are occasionally to be found.

PLACE.	OWNER.	SOURCE.
Whitewater, Sec. 1, near center	A. M. Richmond	Drift.
Whitewater, Sec. 1, N. W. qr. of S. E. qr.	H. J. Starin	Drift.
La Grange, Sec. 9, N. W. qr. of S. W. qr.	P. Oleson	Drift.
La Grange, Sec. 36, N. W. qr	D. Williams	Drift.
Appleton, below city	J. E. Harriman	Drift.

Chalybeate Springs. These are characterized by the presence of iron compounds, usually derived from the decomposition of iron pyrites, and so are closely allied to the preceding.

LOCATION AND CHARACTER.

Ahnapee, T. 25, R. 26 E. Sec., N. W. qr. Temperature 45° (August 19), flow moderate but brisk; little sulphur, much iron, taste pleasant.
Byron, Sec. 16, S. E. qr., large but not very strongly impregnated.
Empire, Sec 18, N. E. corner, small.
Herman, Sec. 29, N. E. qr., small, but strongly impregnated.
Hortonia, on Mr. Briggs' place, Sec. 18, two small springs strongly charged.
Lake Mills, Sec. 1, N. hf., contains also a little sulphuretted hydrogen.
Grand Chute, Sec. 31, S. W. qr., rather small, much iron.
Whitewater, Sec. 1, S. E. qr., limited flow, much iron.
Whitewater Village, small, but strongly impregnated.

Travertine Springs. These contain an excess of bicarbonate of lime and magnesia held in solution by the presence of free carbonic acid in the water, which on escaping into the atmosphere causes a deposition of the excess of the lime and magnesia as travertine. It frequently *coats* moss and other vegetation, which are then erroneously said to be petrified. Where the base of the moss is coated without destroying its form, while the upper portion is still green, as not unfrequently occurs, the error is a very pardonable one. The deposit is also called calcareous tufa.

LOCATION.

Empire, Secs. 6 and 7, several.
Hartford, Sec. 24, S. W. qr., several.
Walworth, Secs. 11, 14 and 15, several.
Whitewater, Sec. 1, near center.
Taycheedah, Sec. 21, S. E. qr., large deposit.
Brooklyn, Sec. 35, Lovers' Glen.
Delavan, village, several.

Trout Springs. The following were noted as possessing sufficient volume and apparent purity to justify further attention with a view to the raising of trout. In the absence of analyses, their fitness is not here asserted and they are named only as being worthy of a more careful examination by those who may be interested. Their position in general is favorable, having a rapid fall and being unexposed to dangerous floods:

LOCATION.

Ottawa, Sec. 14, owned by W. James.
Ottawa, Sec. 11, N. E. qr., volume limited.
Hubbard, Sec. 12, N. W. qr., volume medium.
Hubbard, Sec. 5, N. W. qr., several, medium seize.
Delafield, Sec. 30, S. E. qr., Maxwell's.
Herman, Sec. 5, N. E. qr., several, very large.
Herman, Sec. 6, N. W. qr.
Theresa, Sec. 28, N. E. qr. of S. E. qr., large but perhaps not uniform enough in temperature.
Ottawa, Sec. 4, S. E. qr., Dousman's, already successfully utilized.
Taycheedah, Sec. 21, S. E. qr., large.
Taycheedah, Sec. 16, N. W. qr. of S. W. qr., very large.
Taycheedah, Sec. 9, S. E. qr. of S. W. qr., very large, rocks colored, but no iron taste distinguishable.
Ellington, Sec. 27, center, large.
Hortonia, Sec. 28, N. W. qr., large.
Berlin, Sec. 14, Mitchell's.
Port Washington, J. Druecker's.
Cedarburg, now utilized.
Sturgeon Bay, opposite village.

Artesian Wells. The term Artesian is sometimes applied to very deep wells without regard to whether the water flows at the surface or not, but it will here be confined to flowing wells without regard to depth. It will promote clearness of understanding to call to mind the *requisite conditions* which will be found more amply stated in Vol. I. They are as follows: There should be an impervious stratum to prevent the escape of the water below; a previous water-bearing stratum upon this to furnish the flow of water; a second impervious layer upon this to prevent the escape of the water above, it being under pressure from the fountain head. These must dip, and there must be no adequate outlet for the water at a lower level than the well. There must also be a sufficient collecting area or reservoir in connection with the porous stratum and it must have sufficient elevation to act as a fountain head. As these wells depend for their essential conditions upon the character of the strata, it will be necessary to anticipate some things subsequently given in connection with the formations involved. To these, the reader, who desires a more perfect understanding than can be obtained from the necessarily brief sketches that follow, is referred. It would doubtless best subserve the interest and convenience of the general reader, to *classify* the numerous wells according to the formation from which they derive their flow, and to treat them as thus grouped. Were this method pursued, the classes would be six in number, as follows:

1. Those that derive their flow entirely from the drift, clay layers forming the upper and lower confining strata and sand or gravel the the water-bearing seam. The last is usually a beach deposit and at least one of the others a lacustrine clay. This group includes the fountains of *Taycheedah*, *Calumet*, *Poysippi*, *Rushford*, *Auroraville*, *Whitewater*, *Byron*, and a part of those of *Fond du Lac*, *Oakfield*, and *Oshkosh*, with some in the vicinity of Lake Michigan.

2. Those that derive their flow from the junction of the drift with the indurated rocks below. In these the drift clays resting on the rock constitute the upper confining stratum and the subjacent formations, the lower, while a layer of sand or gravel or the open nature of the rock surface affords passage for the water. This class includes most of the fountains at *Fond du Lac*, *Oshkosh*, *Oakfield*, and *Green Bay*.

3. Those that originate in the Niagara limestone. This body of limestone furnishes in itself, locally, the necessary pervious and impervious strata. The *Manitowoc* wells belong here.

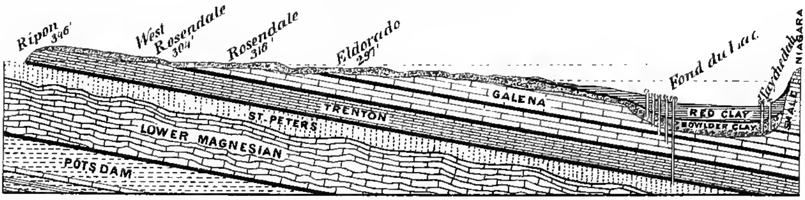
4. Those that arise from the Galena and Trenton limestones. These formations, like the Niagara, aided by the overlying drift, present all the needed conditions. There are embraced here, most of the *Watertown* fountains and a portion of those at *Oshkosh* and *Fond du Lac*.

PLATE, V

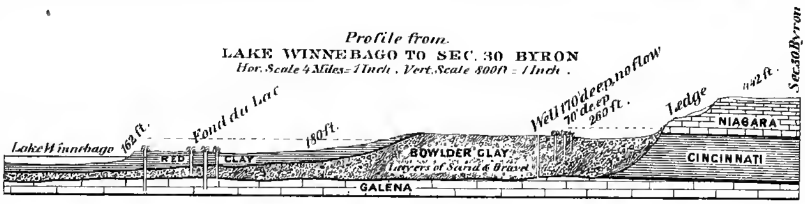
PROFILES ILLUSTRATING ARTESIAN WELLS

by T. C. Chamberlin.

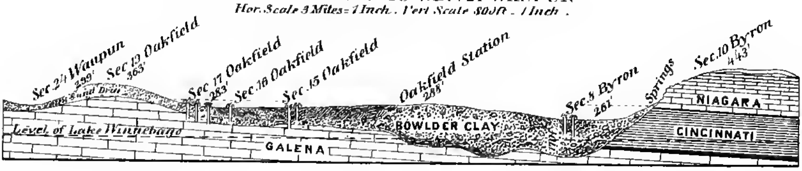
Section from
TAYCHEDAH TO RIPON
Hor. Scale 2 Miles = 1 Inch. Vert. Scale 200ft = 1 Inch.



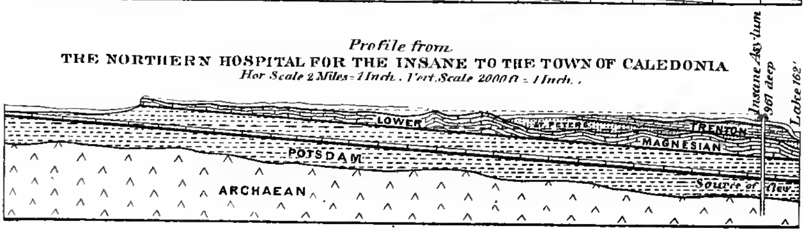
Profile from
LAKE WINNEBAGO TO SEC. 30 BYRON
Hor. Scale 4 Miles = 1 Inch. Vert. Scale 800ft = 1 Inch.



Profile from
SEC. 10 BYRON TO SEC. 24 WAUPUN
Hor. Scale 3 Miles = 1 Inch. Vert. Scale 800ft = 1 Inch.

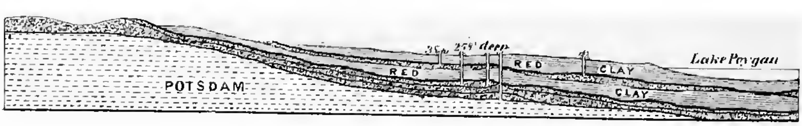


Profile from
THE NORTHERN HOSPITAL FOR THE INSANE TO THE TOWN OF CALEDONIA
Hor. Scale 2 Miles = 1 Inch. Vert. Scale 2000ft = 1 Inch.

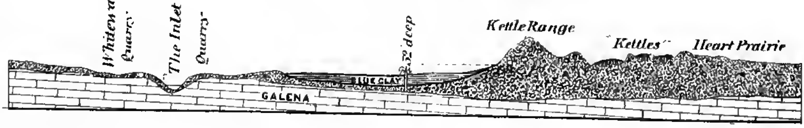


Section from

LAKE POYGAN WESTWARD



Profile from
WHITEWATER TO HEART PRAIRIE
Hor. Scale 8 Miles = 1 Inch. Vert. Scale 800ft = 1 Inch.



The Milwaukee Litho & Engr. Co.

5. *Those from the St. Peters sandstone.* This is by far the most widely available, and, except locally, the most important source of Artesian wells in eastern Wisconsin. The lower layers of the Trenton limestone, resting upon it, form an efficient confining sheet above, and the formations below are saturated by water having a higher source than that of the St. Peters sandstone, so that there can be no loss, but may be gain from beneath. Aside from the porous character of the sandstone, it is much fissured in vertical, oblique and irregular directions, enabling the water to readily traverse it. From this horizon arise the deeper seated fountains at *Watertown*, *Wild's* well and several more recently sunk at *Fond du Lac*, the "*oil well*" *at Palmyra*, the exceptionally saline well at *Sheboygan*, and those at *Milwaukee*, *Racine and Western Union Junction.*

6. *Those from the primordial zone.* The well at the *Northern Hospital for the Insane*, at Oshkosh, represents this class. The public well on *Algoma street*, *Oshkosh*, the water of which, though it does not flow at the surface, rises within a few inches of it, may be also classed here. So also the well on the *Fair Grounds at Janesville*, which flows through the aid of hydraulic appliances. A portion of the flow of the Racine well is from this horizon.

These six classes, it may again be remarked, furnish the most systematic grouping for study and description, but it will doubtless be most convenient and interesting to the people of the state for whose benefit the survey was instituted, to describe these wells by the localities in which we find them situated.

In number and variety of source, the flowing wells of *Fond du Lac* stand preëminent. They represent four of the six systems above mentioned. The accompanying profiles represent much more clearly and satisfactorily the conditions under which these fountains are secured than an elaborate description, and will only need to be supplemented by some additional and explanatory statements. And I desire here to express my special indebtedness for many facts, otherwise beyond my reach, to Mr. C. O'Connor, who has sunk many of these wells. From his statements it appears that there are three classes of comparatively shallow wells that derive their flow from within twenty feet of the surface of the rock, either above or below it, it being from two to nearly one hundred feet beneath the soil. In the first, flowing water is found in the blue clay which underlies the superficial red clay. The water is usually reached in a stratum of quicksand, from six inches to six feet in thickness. In the second, the flow is obtained between what is locally known as the "concrete" and the rock. This concrete, which varies from two to twenty feet in thickness, is the lowest member of the drift at this point, and seems to consist of partially cemented sand and gravel. The first flow of water is usually accompanied by a green or brown sand. The flow of the third class originates in the rock, within from six to twenty feet of its surface, and is unaccompanied, in general, by sand of any kind. The vast majority of the wells of the city belong to one of these three classes. The generous well of Mr. George Hunter, known as "Hunter's Magnetic Saline Fountain," derives its flow from the deeper limestone strata, as is shown from the following section furnished through the kindness of the proprietor:

	Feet.
Red clay	26
Blue clay, bowlders and concrete	30
First water course at	56
Brown limestone	14
Second water course at	70
Brown limestone	40
Third water course at	110
White limestone	30
Fourth water course at	140
Crystalline cherty limestone	20
Cherty limestone	27
Fifth water course at	187
Total depth	187

The following is an analysis of the rock taken from this well, made by Rev. A. C. Barry:

Lime	28.90
Magnesia	20.76
Protoxide of iron	2.19
Soda	.20
Chlorine	trace.
Sulphuric acid	.10
Carbonic acid	45.51
	97.66

From which it appears that this rock, in common with nearly all so-called limestone of eastern Wisconsin, is really a dolomite. The following is the analysis of the water of this well, published by the proprietor. As the form is somewhat unusual, the letter communicating it is published:

KEOKUK MEDICAL COLLEGE, *February 9, 1874.*

GEORGE HUNTER, ESQ.:

Dear Sir: — I have, to-day, completed the quantitative analysis of your mineral water, and with the following results. Out of one gallon of water I obtained 19 grains as residuum.

The analysis is an approximate, leaving off decimals in calculating the proportions. In 100 parts, the following are the proportions of each ingredient:

1. Carbonate of lime	5
2. Carbonate of potash	4
3. Carbonate of magnesia	6
4. Carbonate of soda	4
5. Sulphate of lime	12
6. Sulphate of potash	10
7. Sulphate of magnesia	17
8. Sulphate of soda	13
9. Chloride of sodium	14
10. Chloride of potassium	3
11. Silica	5
	93
12. Traces of iron	—
14. Traces of bromine	—
14. Free carbonic acid	—
Waste	7
	100

To my surprise, I found a trace of bromine in it. I did not estimate the free carbonic acid.

Very respectfully yours,
E. J. GILLETT.

The water has been extensively used for its remedial qualities.

The magnificent fountain on First street, belonging to Messrs. B. Wild & Co., represents a yet more deep seated system. This well is 326 feet deep, and passes entirely through the Galena and Trenton limestones, reaching the St. Peters sandstone below, whence it derives a flow of forty-eight gallons per minute. The stream has been carried by pipes 53 feet above the surface. It flows with such force that, with hose and quarter-inch nozzle attached, it projects a stream from 30 to 35 feet high, and 48 feet horizontally. An analysis of the water of this well will be found in the report of Dr. Lapham, *ante*, p. 31, of this volume.

The following is the section of the well on the high school grounds, kindly furnished by Senator W. H. Hiner:

	Feet.
Drift, red and blue clay	95
Magnesian limestone (Trenton and Galena)	195
St. Peters sandstone	135
Total	425

In searching for the *fountain head* of the first class, or those which belong entirely to the drift, we find possible sources on almost every side, to the east, south, west and northwest. To the east and south there lies a ledge of Niagara limestone, underlaid by impervious shale from the surface of which issue frequent springs. The clay deposits of the basin, in which the city lies, abut against and overlap this shale. The junction is in all probablility permeable to water, which would thus reach the porous strata of sand and gravel that are found within the blue clay. That this is the true explanation of the Artesian wells of Taycheedah and Byron is more than probable. To the west, the blue clay rises to the surface and lies upon, or graduates into, the more gravelly drift hills of that region, and may not inprobably derive its water supply from thence.

The fountain heads of the second and third classes, viz.: those that rise from the concrete and from the limestone, are doubtless the same, or at least their fountain heads are associated, except perhaps those of the deep wells, whose reservoir is more distant; in all cases it is probably to the westward. Lamartine and adjoining townships furnish favorable conditions. The surface of the rock, as well as its layers, rise in that direction. The slight local exception to this in the western portion of the city is not sufficient to affect the general problem. The rock appears at the surface to the southwest, along Seven Mile creek, at an elevation of 122 feet above Lake Winnebago. The general surface of the town of Lamartine is about 150 feet above Lake Winnebago, if a single series of aneroid measurements is to be trusted, and consists of low hills and ridges interspersed with marshes. The surface drainage is very imperfect. The hills and ridges are composed of the varying mixed material of the unassorted drift, and are more or less permeable to water.

Phenomena connected with the boring of wells in this region show that certain of the layers of the underlying magnesian limestone are practically impervious to water, while others are not. These with the clay above furnish the necessary pervious and impervious strata, and complete the requisite conditions.

The fountain head of Mr. Wild's well is to be found along the line of outcrop of the St. Peters sandstone within which its reservoir undoubtedly lies. Near Ripon, the St. Peters sandstone outcrops at an elevation of about 325 feet above Lake Michigan, or about 150 feet above the surface of the well, thus giving an abundant elevation.

The flowing wells of **Taycheedah** are from 60 to 70 feet deep, but do not reach the rock. It seems most probable that they derive their flow from veins having their origin at the surface of the shale beneath the ledge, as already explained, and as shown in the sections. The water in some of the wells is highly impregnated with sulphuretted hydrogen.

In the town of **Byron**, adjoining Fond du Lac on the south, on the farms of Mr. Henry Bush, Mr. D. D. Jones, and Mr. Searles, there are several wells having a rather scanty and variable flow. They are not, however, immediately affected by rains. The wells belonging to Mr. Jones are 70 feet in depth. The vein was found in a bed of quicksand at least 10 feet thick. Rock was struck at Mr. Searles' at a depth of 170 feet — but did not yield a flow. The fountain head of these is probably in the bluffs to the south, as indicated in the profile.

The Artesian wells of the town of **Oakfield** are located in sections 9, 15, 16 and 17, and occupy an extensive depression stretching northeastward to Fond du Lac. Mr. H. D. Hitt has three wells from 68 to 74 feet deep. He gives the following as a typical section:

1. Surface soil.
2. Marl.
3. Blue clay.
4. Small vein of sand.
5. Alternating blue clay, sand and gravel.
6. Rock at from 48 to 54 feet from the surface.

Water flowed in a small stream before the rock was struck. On the same authority I learn that Mr. Whittaker secured a fine stream in a vein of sand beneath blue clay, at from 20 to 22 feet from the surface. Mr. S. Scovil, residing on section 17, has two flowing wells, one 48 feet and the other 75 feet deep. The former, as I was informby the proprietor, is 37 feet in blue clay and 12 feet in limestone. It is situated near the western extremity of the depression before mentioned, where the surface gradually rises toward the drift hills that form the "divide" between the Mississippi and St. Lawrence basins. The latter lies somewhat farther eastward, and penetrates 50 feet of pure clay without seams of sand or gravel, and extends 25 feet into the limestone beneath. This well has a brisk steady flow about one inch in cross section, and is not noticeably affected by rains. The former one, when visited, had but a slight stream which broke into drops in falling six inches, and was said to be much affected by rains, the change being noticeable within 24 hours. The wells of Mr. Hatch and Mr. Wells are similarly affected. These are said not to penetrate the rock. We gather from these facts that there are two systems here, the more superficial, whose veins lie near the junction of the drift and limestone, being sometimes above and sometimes below, and whose reservoir is in the vicinity and is superficial; and the deeper one, whose fountain head is more distant. The reservoirs in both cases are probably to the westward or northwestward.

The shallower system of Artesian wells at **Oshkosh** is quite similar to that of Fond du Lac, already described. They vary in depth from 15 to 100 feet, and derive their flow variously from within the drift, at the surface of the rock, and at varying depths within it. The source of their supply is undoubtedly to the westward and less than ten miles distant.

The deeper wells possess unusual interest from the facts they develop relating to the strata beneath. Unfortunately no complete reeord of the formations passed through in sinking the well at the Northern Hospital for the Insane seems to have been made, and nothing is now available but the very general statements of the person who drilled the lower portion, and an inspection of the mingled drillings at the well. These showed that variously colored sandstone strata had been penetrated to a considerable depth, and that a reddish granitic rock had been entered.

The following items were furnished by Mr. J. H. Johnson, who drilled the lower portion:

Struck limestone at	60	feet.
" sandstone at	300	"
" water at	800	"
" red sandstone at	540	"
" white sandstone at	585	"
" granite at	714	"
" white granite at	935	"
Bottom	961	"

Mr. Johnson expressly stated that below 300 feet it was all sandstone till the granite was reached.

In regular order we should expect in descending, Trenton limestone, the St. Peters sandstone, the Lower Magnesian limestone, and the Potsdam sandstone, including a calcareous stratum, and the granitic rocks at the bottom as found. The question is naturally suggested, Is the St. Peters sandstone wanting, bringing the Trenton and Lower Magnesian limestones together; or is the Lower Magnesian limestone wanting as such, bringing the St. Peters and Potsdam sandstones together?

Much light is thrown on this interesting question by the very excellent record and the drillings of a public well, subsequently sunk within the city of Oshkosh, preserved by Mr. K. M. Hutchinson, and submitted to me by the kindness of Dr. Lapham.

The record is incorporated in my notes, on an examination of the drillings, which are as follows:

1. Drift 92 feet.

2. From 92 to 300 feet, a hard, bluish-grey, close-textured, semi-crystalline magnesian limestone. A few scales of sesqui oxide of iron present.

3. At 300 feet, reddish, *calcareous* clay, containing angular fragments of limestone and sesqui oxide of iron.

4. At 308 feet, chiefly red silicious sand of varying coarseness, mixed with fragments of dark shale.

5. At 400 feet, light orange, silicious sand, the constituent grains of which are irregular in form and surface. White clay-like fragments, appearing like kaolin, and insoluble in hydrochloric acid, probably chippings of soft chert, also present.

6. At 416 feet, dirty red sand, mingled with fragments of magnesian limestone, and also lumps of sand and limestone cemented with a reddish or whitish *calcareous* clay.

7. At 425 feet, white and orange, rather coarse, silicious sand, and a little of the kaolin-like material, almost all the fragments of which are marked upon one side by metallic iron, evidently from the drill, showing that they were clipped with difficulty from a larger mass.

8. At 435 feet, yellowish-orange, silicious sand; the grains of medium size, and numerously marked with adherent specks of oxide of iron. Many fragments of chert drillings, marked with metallic iron, also present.

9. At 500 feet, very fine grained silicious sand; a few minute lumps consisting of grains of sand cemented by finer material; no effervescence in heated or cold hydrochloric acid; color, yellowish white; some chert drillings present.

10. At 557 feet, drillings light pinkish grey, appearing like crystalline powder. Examined under microscope, found to be composed of grains of limpid quartz and particles of chert associated with the more finely powdered material that gives rise to the color. No effervescence when tested with cold or hot hydrochloric acid.

11. From 580 feet to 618 feet, the drillings are similar to the above, but the quartz grains are larger, more numerous and conspicuous, and the finer material is white. A very small amount of oxide of iron is present. No action when treated with acid.

12. From 685 feet to 695 feet, orthoclase feldspar predominates, attended by considerable quartz and a less quantity of a dark mineral, probably hornblende.

Classified, the two sections become:

	At Hospital.	*On Algoma St.*
Drift	60 feet.	92 feet.
Limestone	240 "	208 "
Sandstone	414 "	380 "
Granite rock	248 "	15 "
Total	961 feet.	695 feet.

The correspondence between the two is quite marked. In the southwestern portion of the city the rock of the region is exposed in quarries at an elevation very nearly the same as the surface at these wells. This rock is clearly shown by its fossils to belong to the Galena limestone, in the modified character which that formation bears in this region. It is seemingly the lower portion of the formation, and there is good reason for believing it to be entirely wanting at the locality of the wells where the drift is deep. The lower strata of the Trenton limestone are found at the surface at a distance of less than six miles to the west. Now between Ripon and Fond du Lac, along a parallel and not distant line, the dip of the lower face of the Trenton limestone is accurately ascertained to be 23 feet per mile to the eastward. Calculating upon the basis of this dip, and making allowance for the drift, there should be less than fifty feet of the Trenton limestone at the location of the well on Algoma street.

This result is confirmed by calculations based on different data, and by a general inspection of the problem. Assuming this to be correct, the thickness of limestone below is sufficient to occupy the whole horizon of the St. Peters sandstone and Lower Magnesian limestone; or in other words, the 208 feet of limestone in the one case, and the 240 feet in the other, just about fill up the space that we should expect would be occupied by the Trenton, St. Peters, and Lower Magnesian formations. What then has become of the St. Peters sandstone? One of the more recent discoveries of the survey makes this perfectly clear. The upper surface of the Lower Magnesian limestone in this region is very undulating; we might say, billowy. The St. Peters sandstone lies in the troughs between these billows, and usually covers their crest, but sometimes the Trenton rests directly upon the elevated portions of the lower limestone, and the St. Peters sandstone is entirely wanting. This has actually been observed in some cases, and drilling at other points has left no doubt that this is not an uncommon fact. If we suppose then that the Trenton limestone here rests directly on the Lower Magnesian as it does near Ripon, the whole of the difficulty disappears. See Plate VI.

The calcareous material found in the sandstone below, doubtless represents the Mendota limestone, and must be regarded as confirming the above conclusions.

The well at the Hospital discharges about 22,000 gallons per day. This, accepting the foregoing views, is derived from the Potsdam sandstone, below the calcareous Mendota stratum. Its collecting area is probably twenty-five miles to the northwestward, and has but a slight elevation.

At the mill of W. N. Davis, on the shore of lake Winnebago, in **Calumet,** are two fine wells, giving a copious flow of clear, cold, sparkling water, impregnated with considerable iron and some sulphuretted hydrogen. The proprietor gave the depth as about 90 feet, but was not certainly informed whether rock was reached or not, as the well was not sunk by him. These are probably to be classed with the Taycheedah wells, having their source to the east, though it is not impossible that they belong to the Oshkosh system, as the fountains surrounding the lake indicate that its bed is impervious.

The Lake Winnebago System. All the drift wells of Oshkosh, Fond du Lac, Taycheedah, Calumet, and their vicinity, may be considered as constituting one group, owing their origin to the basin-shaped depression occupied by the lake, the superficial layer of which is impervious and prevents the water from escaping into the lake until pierced.

The wells at Green Bay and other points in the valley of the lower Fox river derive their flow from, at, or near the surface of the rock, and may be classed with the above system.

The Poygan Lake System. The numerous wells in **Rushford, Aurora, Poysippi** and vicinity, are located in part in the valley of the Fox river, but they all belong to a common depression filled by a continuous lacustrine clay deposit, and are essentially alike in nature and origin. They all belong to the drift, and owe their existence to the alternate porous and impervious character of the red clay and associated beach deposits. The surface of the area is level and considerably below that of the surrounding country. The flow is obtained at various depths, but not without some degree of uniformity, giving rise to the popular terms "forty foot vein" and "eighty foot vein." The wells rarely exceed 100 feet in depth.

The material penetrated is usually red clay, with occasional seams of sand and gravel, the whole attaining a thickness of from 80 to 100 feet. There seems good reason for considering the "forty foot vein" as being derived from the beach deposit between the upper and lower red clays hereafter to be described, and the "eighty foot vein" as corresponding to the beach formation between the lower red clay and the blue bowlder clay. These beach deposits are preëminently porous and water-bearing elsewhere in the state, and from the nature of the red clay it would be difficult to account for two veins so persistent as these seem to be, on any other supposition. These wells frequently interfere with those near them so that it is necessary to adjust the penstocks to the same level. This shows that they are derived from a common stratum, and lends support to the view given above. The flow is usually brisk and abundant, and in some cases is very copious. The water is mostly excellent and generally rather soft. Occasionally it is impregnated with iron and sulphur.

The *source* of the flow of these wells is quite obvious. The clay strata terminate on the margin of the basin adjacent to and in association with sandy drift hills of highly absorbent character. Around the rim of the basin thus constituted the water finds access to the porous layers and through them supplies the fountains. The number of these wells is large and constantly increasing, as the clay may be bored with the greatest facility and at trifling cost.

The Artesian wells of **Watertown** belong to two classes, the one, including the greater number, arising from the Trenton limestone, the other embracing the deeper wells from the St. Peters sandstone. The first class vary in depth from 18 feet to 100 feet; the second from the latter depth to 215 feet.

One of the most interesting of the latter class is located near the shops of the Milwaukee & St. Paul Railway Company, to whom it belongs. The following record was furnished Dr. Lapham through the kindness of Mr. G. W. Waring, who superintended the work of sinking it:

Depth of soil	50	feet.
Depth of limestone	57	"
Depth of sandstone	108	"
Total	215	"

Water began to flow when a depth of 107 feet was reached, and could be raised 10 feet above the surface.

The two following brief records will sufficiently illustrate this class. They were furnished through the courtesy of Mr. S. S. Woodward, who has taken a deep interest in the subject:

Drift	10	feet.	15	feet.
Limestone	93	"	103	"
Sandstone	...		23	"
Total	103	"	141	"

If we assume that the flow of the former was from the surface of the St. Peters sandstone, the upper face of the sandstone will be 107 feet, 103 feet, and 118 feet, respectively, below the surface, at the three wells, facts which may be of service in sinking others.

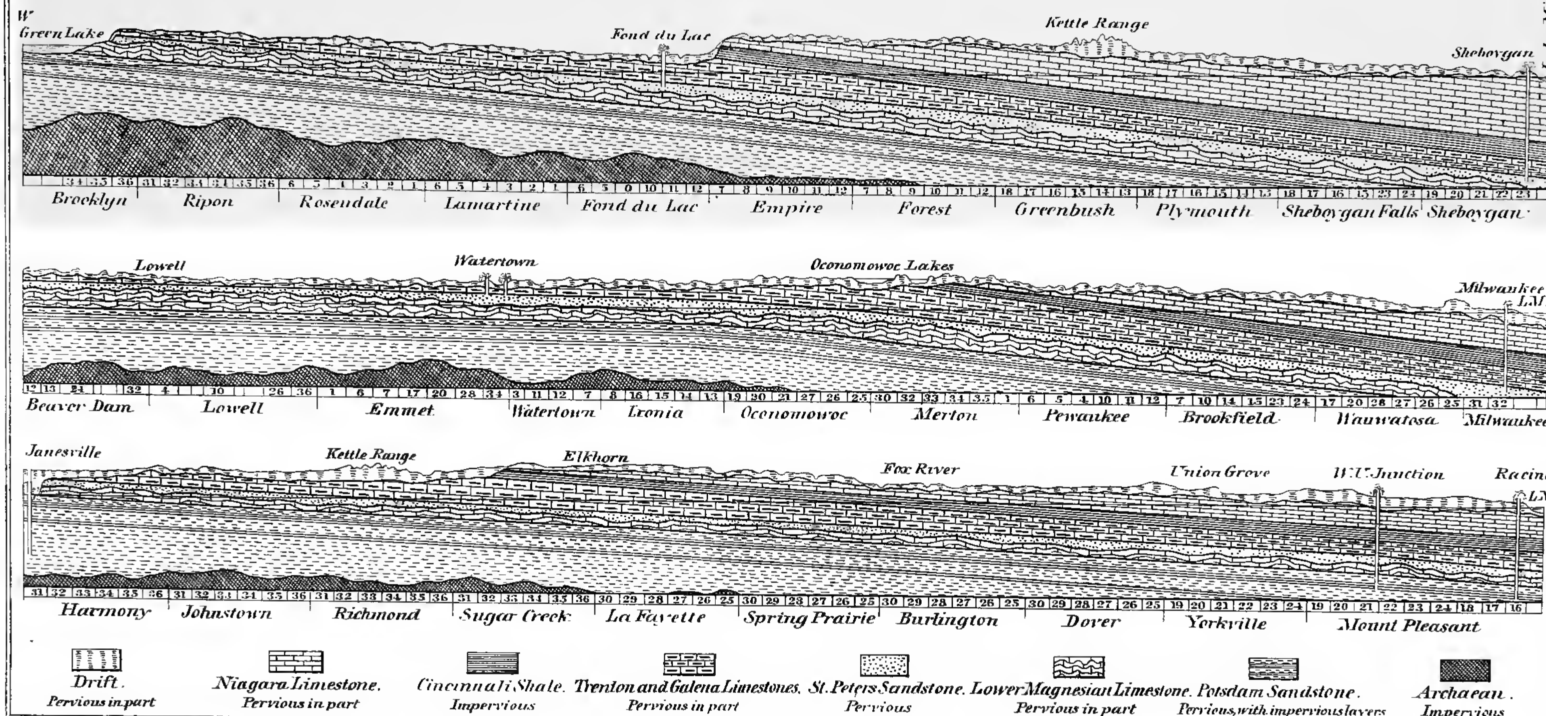
The first one, that of the Railway Co., is 243 feet above Lake Michigan, and hence its bottom is 28 feet above the lake level.

The *source* of supply for both classes seems to lie to the west of north, where, both near and distant, occur many depressions entrapped between limestone and drift ridges, giving abundant superficial reservoirs, while in this direction also may be found the outcropping edge of the sandstone. This sandstone likewise comes to the surface to the west of Watertown, but the low elevation in that region seems to indicate that the flow is not from that quarter. The western edge of the sandstone, where it comes to the surface, follows the east bank of the Crawfish river, from Lowell to Aztalan, and at no point between those places has it an elevation much greater than the railroad junction at Watertown. It is not to be expected then that fountains can be obtained from the St. Peters sandstone, which will flow at a much

PLATE VI

Profiles elucidating the Geological Structure of Eastern Wisconsin with reference to Artesian Fountains.

by
T. C. Chamberlin
1876



greater elevation than that already attained, viz.: 253 feet above Lake Michigan. By penetrating the Potsdam sandstone there is a reasonable probability that a flow competent to rise to a higher elevation could be obtained.

The following is an analysis of the water of Mr. Buckhert's fountain, by Dr. L. Brandecke:

	Grains in 1 gal.
Bicarbonate of soda	1.898
Bicarbonate of magnesia	5.818
Bicarbonate of lime	12.094
Bicarbonate of iron	0.100
Sulphate of potassa	0.054
Silica	0.305
Organic matter	0.346
Total	20.615

While the above mentioned facts are still in mind, it will be convenient to speak of the **Palmyra** "oil well." A failure as a source of oil, it yet has proved of some value in demonstrating the possibility of Artesian wells in that and similar situations. The following is the record kindly furnished me by Dr. Lapham:

Palmyra Artesian Well (1865). Begun about 250 feet above Lake Michigan (828 feet above the sea).

46 feet.	Drift — struck limestone.
176 "	Limestone; supposed to be "Blue Limestone."
229 "	Water.
235 "	Slate and sand.
255 "	"Good show of oil." (!)
257 "	"Big show of oil." (!!) Struck sand rock.
263 "	Great flow of water.
283 "	Metal 2 inches. (Iron ore ?).
350 "	Supposed Lower Magnesian limestone; Calciferous sand rock.
412 "	White sandstone.
421 "	Gray sandstone.
455 "	Red sandstone.
461 "	Black sandstone.
...	Hard sandstone, 3 feet.
480 "	Gray sandstone.
482 "	Soft sandstone.
489 "	Hard sandstone.
507 "	Soft sandstone.
587 "	Red sandstone.
600 "	Gray sandstone.
615 "	Red sandstone.
660 "	Drab or cream colored sandstone.
683 "	Soapstone or shale.
687 "	Gray sandstone to bottom of well.
750 "	Bottom of well, being 500 feet *below* Lake Michigan; 78 above the sea.

These may be distributed as follows:

46 feet.	Drift.
130 "	Galena limestone.
81 "	Trenton limestone.
93 "	St. Peters sandstone.
62 "	Lower Magnesian limestone.
338 "	Potsdam sandstone.

The *flow* is derived from the St. Peters sandstone. It cannot have its source in that formation directly to the west, since the outcrop is lower than the surface of the well. The fountain head is probably in the same region as that of the Watertown wells of its class. I was told that originally the stream was very large, and could be raised 30 feet above the surface, but at the time of my visit it was meager, and would rise less than four feet. Whether this was due to defective tubing, as was claimed, could not be ascertained.

The flowing wells at **Whitewater** are confined to the drift, and owe their origin to the fact that a bed of lacustrine clay rests upon the flank of drift hills to the southeast, that are admirably adapted to serve as collecting areas. The well of Mr. P. Dorr is 52 feet deep in a stiff blue clay. Its flow is copious and is charged with iron and sulphuretted hydrogen.

The number of these wells may be somewhat increased in all probability, but the limited extent of the clay deposit will confine them to the localities occupied by it.

The surface of the Niagara limestone at **Manitowoc** is thickly covered by impervious drift, and the strata beneath rise to the westward, and are partially permeable to water, so that the requisite conditions for a flowing well are found at no great distance within the limestone, if the boring is fortunate in striking a suitable vein. At the well of Mr. William Rahn, the drift is sixty feet deep and the rock was penetrated ninety feet. The wells at Washington Park and at Woodman's Tannery are given as about the same. An analysis of the water of Mr. Rahn's well is given in the report of Dr. Lapham, in this volume, *ante*, p. 31.

The following section of the well at **Western Union Junction** is prepared from data furnished my predecessor by John C. Gault, from the general manager's office of the Milwaukee & St. Paul Railway Company, to whom the well belongs. This and the following are of especial interest as giving, at a point so near the southeast corner of the state, the thickness of several of the formations, and as furnishing data for the reliable estimate of dip, and for other calculations:

	Feet.
Drift	147
Niagara limestone	233
Cincinnati shale	200
Trenton and Galena limestones	285
St. Peters sandstone (small flow)	100
Lower Magnesian limestone	141
Potsdam sandstone	157
Total	1263

The record says that fifteen feet of limestone were passed through in this lower sandstone; but at what depth is not stated. It also adds that red rock mingled with the sand from below. These facts leave no doubt that this is the Mendota limestone, which, at the typical locality near Madison, has its upper surface 35 feet below the superior face of the sandstone.

The surface of this well is 144 feet above Lake Michigan, and hence its bottom is 541 feet beneath the ocean level. The water rose at the time of drilling to the height of 40 feet above the surface, or 184 feet above Lake Michigan. As only a few points in the eastern part of Racine and Kenosha counties exceed that elevation, this well has demonstrated the possibility of obtaining fountains over a considerable area.

At **Racine** a fine flowing well has recently been secured, of which Dr. P. R. Hoy has kindly furnished me the data which show the following section:

		Feet.
Drift		115
Niagara limestone		305
Cincinnati shale		185
Galena and Trenton limestones		283
St. Peters sandstone		48
Lower Magnesian limestone		100
Potsdam group —		
Madison sandstone	47	...
Mendota limestone	31	....
Red sandstone	110	.. .
Hard sandstone	10	....
Soft sandstone	6	....
		204
Total depth		1240

When the St. Peter's sandstone was reached, a flow was secured, which was increased on reaching the Madison, and still further augmented when the soft sandstone was struck. The water rose in a tube 65 feet above the surface. This record is valuable in that it demonstrates the existence of three water-bearing strata above the middle Potsdam.

The following is the section of the well at **Milwaukee:**

Drift	170 feet.
Niagara limestone	267 "
Cincinnati shale	165 "
Trenton and Galena limestones	253 "
St. Peters sandstone	193 "
	1048 "

The surface of the well is about ten feet above Lake Michigan. Its flow is strong enough to fill a four-inch pipe at sixty feet above the surface. From the pressure at the surface, it was estimated by the engineer of the company that the water would rise 100 feet above the surface, or 110 feet above the lake, which makes it probable that a similar flow might be obtained at other localities in this region whose altitude does not exceed that. By consulting the table of elevations, it will be seen what territory is included in this limit.

It will be observed that this flow is from the St. Peters sandstone. By sinking deeper to the Potsdam, a vein capable of rising higher, as at Western Union Junction, would probably be reached.

The well of Sen. W. H. Jacobs, in the suburbs of Milwaukee, is 1,200 feet deep, and delivers 300 gallons of water per minute. The flow may be carried over 50 feet above the surface. An analysis of the water by Gustavus Bode shows it to have the following composition:

	Grains in 1 gal. U.S. measure.
Chloride of potassium	0.2745
Chloride of sodium	0.6405
Sulphate of soda	8.8572
Sulphate of lime	14.5485
Bicarbonate of lime	8.6925
Bicarbonate of magnesia	6.6307
Bicarbonate of iron	0.1342
Alumina	0.1891
Silica	2.3790
Total	42.3462

The city of **Sheboygan** has recently sunk a public well that possesses unusual interest, both in reference to the strata passed through, and the character of the water obtained. The data for the following section were furnished through the courtesy of Mayor George End:

Drift	92 feet.
Niagara limestone	719 "
Cincinnati shale	240 "
Trenton and Galena limestones	213 "
St. Peters sandstone	212 "
Total	1475 "

The exact depth of the well is 1,475 feet and 4 inches. At the bottom, a very hard rock is said to have been struck, which was believed to be granite, and which may have been one of the Archæan rocks, as they rise into that horizon occasionally. The surface of the well is 42 feet above Lake Michigan; its bottom 855 feet below the ocean level.

Flowing water was obtained at 1,340 feet, being in the upper portion of the St. Peters sandstone. The pressure at the surface is sufficient to raise a column of water 104 feet above the surface, or 146 feet above the lake, which differs only two feet from that obtained from the same formation at Western Union Junction. The discharge of water is 225 gallons per minute. Temperature, 59.1° Fahr. Our deep seated springs range from 47° to 48° Fahr., as taken in connection with field work, during the summer season, when they would be warmest, if they vary at all. This seems to show that the water of the well is influenced by the depths from which it comes.

The following is an analysis of the water by Dr. C. F. Chandler:

	Grains per U. S. Gallon.
Chloride of sodium	306.9436
Chloride of potassium	14.4822
Chloride of lithium	0.1062
Chloride of magnesium	54.9139
Chloride of calcium	27.8225
Bromide of sodium	0.1873
Iodide of sodium	trace.
Sulphate of lime	169.8277
Sulphate of baryta	trace.
Bicarbonate of lime	13.6585
Bicarbonate of iron	0.5044
Bicarbonate of manganese	0.1742
Phosphate of lime	0.0383
Biborate of soda	trace.
Alumina	0.1283
Silica	0.4665
Organic matter	trace.
Total	589.2536
Density	1.0093

The large variety and quantity of salts contained in this water have naturally attracted much attention, and experience will doubtless soon demonstrate the specific medicinal effect of the combination here presented.

At first thought it would seem not a little remarkable that so saline a water should be obtained from the St. Peters sandstone, a formation composed almost exclusively of quartzose sand, and one whose waters elsewhere contain rather less than the usual quantity and variety of salts found in our native waters. But we must consider that there is here a depression of the strata, the sandstone being here lower by several hundred feet than it is either north, south or west, and it is not known to outcrop anywhere to the eastward, though the strata above and below again come to the surface in Canada.

The facts of the case warrant us in believing that there is no escape for the waters in that direction. We have then here a basin reaching hundreds of feet below the ocean level. Its waters have no outlet and no escape except by the slow process of diffusion and percolation through almost impervious strata.

That the water should, under these circumstances, become highly charged with saline ingredients is not at all remarkable, though the facts are of an exceedingly interesting nature.

The well at **Janesville** is located upon the Fair Grounds, at an elevation of about 295 feet above Lake Michigan. The following is the section developed by an examination of a series of drillings preserved by Mr. Cyrus Miner, to whose kindness also I am much indebted for other information relating to the well:

DRIFT.

From 1 to 100 feet, open well through gravel.

From 100 to 240 feet, "running gravel."

At 240 feet, sand and gravel of drift origin; several kinds of rock represented.

At 259 feet, sand, gravel and calcareous clay.

From 215 to 240 feet, calcareous arenaceous clay.

From 260 to 350 feet, sand and gravel, largely quartz and chert, a little granite, diorite and some limestone.

POTSDAM.

From 350 to 360 feet, a red ocherous material mixed with a nearly equal quantity of green particles much resembling the green sand of the Upper Potsdam. Drift gravel, probably from above, also present. The red and green mixture effervesces tardily in cold acid (hydrochloric), but very briskly in hot, showing a calcareous and magnesian element present.

At 390 feet, light colored quartzose and cherty sand, with a few granitic and calcareous grains.

At 400 feet, fine-grained white, chiefly quartzose sand, but indicating the presence of calcareous material by a slight effervescence with cold, and strong action with hot acid.

At 450 feet, essentially the same as above.

At 515 feet, quartzose sand, red ocherous material, and particles of a purplish shaly rock partially soluble in hydrochloric acid.

At 530 feet, reddish ochcrous material, dark calcareous shale and small drift pebbles.

At 565 feet, greenish blue calcareous shale containing minute glistening scales resembling mica.

From 560 to 570 feet, similar to the last.

At 615 feet, fine grained light yellow quartzose sand; slight effervescence.

At 630 feet, fine grained white quartzose sand; slight effervescence.

At 640 feet, fine grained quartzose sand, with slightly reddish clay-like calcareous material.

At 710 feet, fine grained, light colored, quartzose sand; slight effervescence.

At 758 feet, rather coarse, white and slightly greenish quartzose sand, with a little clayey material; no effervescence.

At 940 feet, coarse white quartzose sand.

At 975 feet, similar to above, but coarser.

At 1022 feet, very coarse, transparent quartz sand, some of the grains one-sixth of an inch in diameter.

Bottom, 1033 feet.

SUMMARY.

Drift	350	feet.
Red and green rock, probably Mendota horizon	10	"
Fine grained, slightly calcareous sandstone	155	"
Calcareous shale	80	"
Fine grained, very slightly calcareous sandstone	163	"
Coarse non-calcareous sandstone	275	"
Total	1033	"

Drift, 350 feet. Postdam, 683 feet.

Probably 40 to 50 feet of the upper portion of the Potsdam has been removed, making the thickness about 725 feet, with the bottom not reached.

In the upper portion of the Potsdam horizon, a vein was struck which gave a permanent rise in the tube of 48 feet above the water level in the open well, without the aid of a seed-bag or other apparatus for preventing lateral leakage. This corresponds, according to aneroid measurement, to 147 feet above Lake Michigan, or 7 feet above the depot at Janesville.

The *unusual thickness* of the drift is probably due to an old preglacial cañon of Rock river, now filled, as the full series of formations, up to the Trenton limestone, occurs on the opposite side of the river, and also at a short distance to the east. The circumstances that necessitated the selection of the fair grounds for this test well are to be regretted, since at the locality for which my estimate was given, the exceptional difficulties with the drift would not have been encountered, and a satisfactory flow would undoubtedly have been obtained. Nevertheless, through the enterprise and ingenuity of the parties having the matter in hand, a success scarcely less satisfactory has been attained. Advantage has been taken of the rise of 48 feet in the tube above that in the well, to raise a portion of the generous flow to the surface by hydraulic appliances.

Possibilities of obtaining wells at other points. Reference has been had to this important practical question in the foregoing descriptions, and in the subsequent treatment of the geological series, large, and it is hoped ample contributions will be made to it, though it will not be always specifically designated, as that would burden the report to the exclusion of other valuable matter. Special estimate should be made for every locality before commencing to sink an expensive well, as there are often local elements that enter into the problem and determine success or failure. It needs also to be borne in mind that even in a favorable locality, failure may result, as the strata are not uniformly porous, and it is possible to bore through a formation that is in most parts highly water-bearing, without striking a vein or seam. Only a single marked instance of this, however, has come to my notice. Failure, also, often results from not properly controlling the water, by the intelligent use of tube and seed-bag, or equivalent apparatus, and by failure to recognize a suitable vein when reached. These and other matters will be found more fully discussed in the general article on the subject in Volume I.

Bearing these points in mind, and leaving out of consideration the drift system of wells which, from their superficial character and the nature of the formation, have only a local importance, there are *three extensive areas* over which there is a reasonable presumption that fountains may be obtained.

The first is a belt adjoining Lake Michigan. Where the elevation is but a few feet above the lake surface, streams will be found, in some cases, in the Niagara limestone, which, if intelligently controlled, will furnish a flow at the surface. This source will be, however, uncertain. But by penetrating to the St. Peters sandstone, the probabilities of success will be large, and they will be reinforced by the chances lying in the Potsdam sandstone below, though the depth of this will be considerable. Near the lake level, the chances from these sources will be good for the whole of the lake border. From Manitowoc county southward, they may be said to hold good for elevations not exceeding 100 feet above the lake, and to be fair up to 140 feet, but slight above 150 feet, though perhaps possible in some locations at 200 feet or more.

The elevations previously given in this report, and the topographical map will show what localities fall within the limits of these conditions. The facts connected with the wells already described, and the data given in relation to the several formations, will permit an approximate calculation of the depth, nature of the drilling, and consequent cost.

The second area consists of the Green Bay valley, from Fond du Lac northward. In the vicinity of Lake Winnebago, a flow from either the St. Peters or Potsdam sandstones can not be relied upon at an elevation exceeding 15 feet above the lake surface, though Mr. Wild's well has demonstrated that it is possible at 50 feet. On the other hand, however, the wells at Oshkosh show that the limit given is the extreme one that is reasonably trustworthy.

To the north of Lake Winnebago the limit in altitude descends at about the same ratio as the general surface of the valley. It must be remembered, however, that the St. Peters sandstone is not so reliable in this region as farther south, where its thickness is more uniform. The Potsdam sandstone should, however, present reasonable probabilities for the region along the Bay, at elevations not exceeding 25 or 30 feet above its surface, with slight chances for greater altitudes.

The third district lies in the valley of Rock river. An elevation of 250 feet must be taken as the upper limit of favorable chances. That a flow at this altitude is attainable is shown by the wells at Watertown, Palmyra and Janesville. The St. Peters sandstone is available for only a portion of the area that falls below that altitude, since in some parts of it, this formation is deeply eroded by the streams, and its fountain-forming possibilities destroyed. Success in these portions will be chiefly dependent on the Potsdam sandstone.

The list of elevations and the maps will be found indispensable to an intelligent calculation of probabilities in this region, and something more than wonted caution may here be recommended, because of the nature of the formations, their nearness to the central anticlinal axis of the state, and the presence of deep ancient river gorges now filled and concealed by drift.

As the majority of the deep seated wells of eastern Wisconsin derive their flow from the St. Peters sandstone, it is important to know at what elevation the upper face of that formation outcrops. The following list will supply the requisite data:

ELEVATIONS OF THE JUNCTION OF THE ST. PETERS SANDSTONE AND TRENTON LIMESTONE.

	Feet.
Rock County.	
Avon —	
Sec. 5, N. E. qr.,	272
9,	250
Beloit —	
Sec. 3, S. W. qr.,	229
3, S. W. qr. of S. W. qr.,	196
10, N. E. qr.,	180
10, S. E. qr.,	200
Fulton —	
Sec. 10, S. W. qr.,	219
Newville bridge, Rock river,	208
Rock County — (con.)	
Magnolia —	
Sec. 6, S. W. qr.,	309
7, S. E. qr.,	433
28, S. W. qr.,	339
R. R. cut,	330
Porter —	
Sec. 9, N. W. qr.,	250
Rock —	
Sec. 32,	189
Afton,	206

ELEVATIONS, etc. — *continued.*

	Feet.
Rock County — (con.)	
Spring Valley —	
Sec. 3, S. W. qr. of S. W. qr.,	314
4,	338
9, center,	321
13, mid. N. line,	300
15, S. E. qr.,	321
28, N. E. qr.,	296
33, S. E. qr.,	268
Union —	
Sec. 12, near center,	298
Jefferson County.	
Lake Mills —	
Sec. 3, N. W. qr.,	319
4, N. W. qr.,	330
Milford —	
Sec. 7, S. W. qr.,	251
33, N. E. qr. (est.),	257
Oakland —	
Sec. 18, S. E. qr.,	246
16, N. W. corner,	264
28, mid. E. line (est),	233
Sec. 30, N. W. qr.,	253
Sumner —	
Sec. 18, (est.),	202
Waterloo —	
Sec. 31, county line (est),	323
35, S. E. qr. (est.),	277
Dane County —	
Christiana —	
Sec. 24, N. hf (est.),	261
Medina —	
Sec. 25, E. hf (near),	331
Dane County — (con.)	
Rutland —	
Sec. 34, S. E. qr.,	348
Dodge County.	
Elba —	
Sec. 25, (very near),	254
Fox Lake —	
Sec. 17, S. E. qr.,	294
31, N. W. qr. of N. W. qr. (est.),	368
31, mid. W. line N. W. qr.,	329
Lowell (T. 10, R. 14) —	
Sec. 19 (est.),	195
Portland —	
Sec. 6, N. W. qr.,	296
31,	248
Shields —	
Sec. 32 (near),	214
Westford (T. 12, R. 13) —	
Sec. 25,	266
Fond du Lac County.	
Metomen —	
Sec. 31, S. W. corner,	412
Ripon —	
city, 30 rods. W. of P. O. (near)	381
city, falls under tressel bridge,	333
W. of city,	414
Sec. 20, N. W. qr. of N. W. qr.,	328
20, little W. of center,	297
21, S. E. qr. of S. W. qr.,	364
29, N. E. qr.,	350
29, E. hf, valley,	341

Those marked estimated, or near, are cases in which the actual junction was not seen, but was calulated from the thickness of the Trenton limestone above.

Water Power. The great interior and the west are laboring under a serious error which intelligent action may remove. They produce vast quantities of crude material needing manufacture. This bulky and heavy matter they transport a thousand miles to be worked up. They likewise produce immense quantities of food. This they carry the same thousand miles to feed those who manufacture the other material. They then bring back the manufactured artiele murmuring at its expense and praying for cheap transportation. More simply and truly stated, the situation is this: At one end of a thousand miles is a man and his tools; at the other end is the heap of the crude material he is to manufacture, the bulky food he is to eat, and the market for his products; and the problem is, Shall the mountain go to Mohammed or will Mohammed come to the mountain? An intelligent practical answer to this will go some way toward solving the problem of cheap transportation. Agriculture, mining, and manufacture form a triangle of industries that are mutually dependent, and the nearer they can be brought together the more successful will each be.

The question then, What facilities for manufacturing does our state present? becomes one of the highest importance, especially so to our preponderating agricultural interests. Chief among these is water power.

In the district under consideration there is a vast amount of *water power* situated in the heart of an exceedingly rich farming country, with abundant facilities for transportation, and, not by any means a subordinate consideration, in the midst of an intelligent, cultured society. The object of this chapter will be to give trustworthy facts for the guidance of capitalists, who may have the prescience to foresee that the natural facilities for manufacturing in the interior must in the immediate future be utilized to their utmost capacity and must become correspondingly valuable.

Water Power of Rock river. For a portion of the facts here given, credit is due the report of Brevet Maj. Gen. James H. Wilson, on the survey of Rock river, under the direction of the U. S. Engineer Department, and for another portion to a very careful survey of the lower portion of the river by Edward Ruger, C. E., made to determine the availability of Lake Koshkonong as a storage reservoir. I am indebted for the use of the latter to the kindness of J. M. Cobb, Esq., through whose efforts the enterprise has been brought to a successful issue. The remaining data have been gathered during the progress of the present survey.

The entire area drained by Rock river and its tributaries in Wisconsin is 3,635 square miles. From the Table of Rainfall at Milwaukee, given in Dr. Lapham's report, this volume, it appears that the average rainfall for the past thirty years is 30.27 in., which may be assumed as at least approximately correct for the Rock river valley. The average fall for some portions of Wisconsin is given in Gen. Humphrey's work on the hydraulics of the Mississippi at 35 inches. But reckoning at 30 inches, the rainfall upon the drainage area under consideration would be 253,344,960,000 cubic feet. Now it is asserted by various authorities, based on experience, that one-half the rainfall can be utilized. This would give 126,672,480,000 cubic feet per annum. Mr. Ruger says: "From personal observations, and after consulting many authorities as to rainfall, springs, evaporation, filtration, etc., I estimate that the total annual quantity of water passing in Rock river at the state line, including Turtle Creek, is 98,437,536,000 cubic feet," which may be regarded as a safe estimate. The daily supply, by this estimate, would be 269,691,879 cubic feet. We need next to ascertain what is the average descent of this volume. Some of it falls over 600 feet, while other portions practically no distance.

The average elevation of the rim of the basin above the point where the river leaves the state is about 250 feet, its average distance about 50 miles, showing an average fall of about five feet per mile. But this is less to the point than the following.

The average elevation of fifteen powers, the first of importance on their respective branches is about 155 feet above the surface of the river where it leaves the state at Beloit. The average fall from these powers to the state line is a little less than three feet per mile.

With these general statements, we will set aside the tributaries, several of which are important, and consider more accurately the main stream between Horicon and Beloit. The collecting area above Horicon is 436 square miles, upon which the annual rainfall, reckoned at thirty inches, would be 30,387,456,000 cubic feet. Allowing one-half for evaporation, filtration, and other sources of loss, the theoretical discharge at the outlet of Horicon marsh would be 15,193,728,000 cubic feet. Reckoned at the lowest rainfall in the last thirty years, the amount would be 10,114,749,120 cubic feet. Col. Worrall gives in the report previously referred to, as the result of a careful measurement of the flow at a time when the volume was estimated to be only three-fourths of the average, a supply of 27,651 cubic feet per minute, or 14,533,365,600 cubic feet per annum, from which it would seem that the calculated amount is not far from the truth. From the foregoing data, estimating the accession from tributaries, it is thought to be safe to consider the *average* flow between Horicon and Beloit as in round numbers 50,000,000,000 cubic feet per annum. The fall from Horicon to the state line is 127 feet. An estimate of the theoretical power generated by the main river shows it to be upwards of 20,000 horse power. Of the 127 feet fall, less than 60 feet are utilized. Of the unused portion there is more than 30 feet fall between Horicon and Watertown, corresponding to above 1,600 horse power, and about 23 feet fall between Janesville and Beloit, equal to upwards of 7,000 horse power. A portion of this latter may readily be made available at Beloit by means of a race leading from a dam situated above the slack water of the present one. Another power near the state line can also be utilized to the profit of this place. Upon the river and its tributaries are a large number of lakes that may be utilized as storage reservoirs, thus affecting a much greater economy in the use of the water.

Water power of the Fox river.[1] The upper Fox river from its

[1] For the leading facts here given, I am indebted to an article prepared for the Centennial Commission by Pres. G. M. Steele, of Lawrence University. I am also indebted to Prof. J. C. Foye of the same institution for similar favors.

slight descent furnishes no water power, a fact which is compensated for by the facilities it offers for navigation. But the lower Fox river presents an almost continuous series of rapids from Lake Winnebago to Green Bay. In this distance of about thirty-five miles it has a fall of 170 feet, so distributed as to be completely and economically utilized. The powers upon this river possess an immense advantage in the grand natural reservoir furnished by lake Winnebago, which embraces an area of about 350 square miles. Neither floods nor drouth cause any considerable or inconvenient fluctations in its level, and the steady reliable flow thus secured at all seasons is a vast advantage. The channel of the river consists of a gorge between clay banks, with a floor of heavy bedded limestone, so that it may be dammed with material taken from its own bed, and without overflowing adjacent lowlands. The great reservoir makes it unnecessary to have more than a limited local one, sufficient to guard against interference from other powers.

The minimum flowage is estimated at 150,000 feet per second, this amount being available at all seasons of the year. The height and power of the several falls estimated on this basis are as follows:

Names of places.	*Height of fall.*	*Horse power.*
Neenah and Menasha	10	3,000
Appleton	38	11,500
Cedars	10	3,000
Little Chute	38	11,500
Kaukauna	40	14,500
Rapid Crosche	8	2,300
Little Kaukauna	8	2,300
De Pere	8	2,300
Total	150	50,400

At Neenah, Menasha, Appleton and De Pere, a considerable percentage of the power is now utilized, though a large amount is still unimproved, particularly at Appleton. But at the other points only the merest fraction is now used, and a wealth of power remains unoccupied. Attention has already been called to the facilities for transportation available to manufacturers in this valley, and by consulting subsequent portions of this report it will be seen that the agricultural and other industrial capabilities of the adjacent and tributary regions are very great.

On the upper portions of the **Wolf, Oconto, Peshtigo and Menomonee** rivers are numerous falls and rapids furnishing immense power, but these lie chiefly beyond the limits of the district under description. The falls of the Oconto, however, where, by including the rapids above and below, a descent of about 60 feet may be made available, and the lower rapids on the Peshtigo and Menomonee lie within our province and also within the limits of settlement, and must, in the not distant future, be improved.

On the **Lake Michigan slope** all the available power must soon be called into use by the rapid development of that region.

The average height of the watershed is over 300 feet, and its average distance from the lake less than 30 miles, giving a fall, if a direct course to the lake were pursued, of more than 10 feet per mile. Or to put it in a more utilitarian form, a dam might be constructed at the end of every mile, having a fall of eight feet, and still leave descent enough to cause a rapid flow. The crooked course of the rivers however very much reduces the rapidity of descent.

The **Milwaukee river** is first utilized as a water power at a height of about 475 feet above Lake Michigan. At Barton it has become a very considerable stream, and is still 311 feet above the lake level. Between West Bend and its mouth, it has a fall of 295 feet. If it pursued a direct course to the lake, it would have a fall of 16½ feet to the mile. If it pursued a direct course to its mouth, it would have a fall of 9½ feet to the mile. As it is, notwithstanding its tortuous course, it has an average fall, as nearly as I can estimate it, of five feet per mile. A portion of the power thus given is not yet improved.

The **Sheboygan river** is utilized at a height of about 320 feet, and is capable of affording an extensive reservoir at that elevation.

The **Manitowoc** is a very considerable stream at an elevation of 275 feet, and has a very rapid descent in the lower half of its course.

Many of the smaller streams also furnish efficient water power.

Changes in Drainage. A comparison of the streams and smaller marshes, as laid down on the government plats and earlier maps, with the present facts show important changes in the drainage of the region. Large areas that are represented as marsh on the plats of the government survey are now comparatively dry and arable. Many of the smaller streams have disappeared or become mere periodical runs. On the accompanying maps the areas laid down as marsh by the original govenment survey have been indicated with such corrections as could be made. They are, however, designated as wet lands, since a large part are not now really marsh, and indeed a portion is cultivated in all but very wet seasons. They are as a class among the most valuable lands in the state. The mapping of these areas, besides being valuable as topographical and geological data, has a historical significance; since it shows what was regarded as marshy at the time of the government survey, and thereby indicates the changes that have since ensued. These changes have been much more marked in the forest regions than in the more open country, and are so intimately connected with the clearing away of the timber that it is a fair inference that this is the main cause.

The timber is often very heavy, and consequently permits but a very feeble undergrowth. The removal of the original forest thus leaves the surface almost entirely bare, and it is usually at once put under cultivation. The effect of so great a change would naturally make itself felt upon the drainage of the region. To the extent to which this has gone thus far, it has doubtless on the whole been a benefit to the region, as it has induced a drier, lighter, warmer soil, and more healthful atmosphere. But the limit of benefit in this direction may be assumed to have been reached except in certain localities, and the danger now to be apprehended is that it will proceed to an injurious extent. This, however, can easily be avoided, if clearly foreseen and justly appreciated.

CHAPTER III.

NATIVE VEGETATION.

The most reliable natural indications of the agricultural capabilities of a district are to be found in its native vegetation. The natural flora may be regarded as the result of nature's experiments in crop raising through the thousands of years that have elapsed since the region became covered with vegetation. If we set aside the inherent nature of the several plants, the native vegetation may be regarded as the natural correlation of the combined agricultural influences of soil, climate, topography, drainage and underlying formations and their effect upon it. To determine the exact character of each of these agencies independently is a work of no little difficulty; and then to compare and combine their respective influences upon vegetation presents very great additional difficulty. But the experiments of nature furnish us in the native flora a practical correlation of them. The native vegetation therefore merits careful consideration, none the less so because it is rapidly disappearing, and a record of it will be valuable historically.

It is rare in nature that a single plant occupies exclusively any considerable territory, and in this respect there is an important difference between nature's methods and those of man. The former raises mixed crops, the latter chiefly simple ones. But in nature, the mingling of plants is not miscellaneous or fortuitous. They are not indiscriminately intermixed with each other without regard to their fitness to be companions, but occur in groups or communities, the members of which are adapted to each other and to their common surroundings. It becomes then a question of much interest and of high practical importance to ascertain, within the region under consideration, what are the *natural groupings* of plants, and then what areas are occupied by the several groups, after which a comparison with the soils, geological formations, surface configuration, drainage and climatic influences cannot fail to be productive of valuable results.

The following natural groups are usually well marked, though of course they merge into each other where there is a gradual transition from the conditions favorable for one group, to those advantageous to another. In some instances it is unquestionably true that other circumstances than natural adaptabilities control the association of these plants, and an effort has been made in the study of the region, to discern these cases and eliminate them from the results, so that the groups which are here given are believed to be natural associations of plants. Their distribution is held to show in what localities conditions peculiarly advantageous to them occur, and hence advantageous to those cultivated plants that require similar conditions.

A. UPLAND VEGETATION.

(1) *Herbaceous.*

Class I. *Prairie Group.* One of the most natural and sharply defined groups is constituted by our prairie vegetation. It differs from all other groups that grow upon the uplands, in being almost exclusively herbaceous, and in the fact that the species composing it, more rarely intermingle with the other groups. It is more distinct from them than they are from each other, and justifies the division of the upland flora into prairie and forest vegetation. Its characteristics are too well known to need further definition here.

(2) *Arboreous.*

Class II. *The Oak Group.* This is most nearly related to and most closely associated with the prairie group. The prairies are rarely contiguous to any other form of arboreous vegetation.

The Burr Oak (*Quercus macrocarpa*), the White Oak (*Quercus alba*), the Red Oak (*Quercus rubra*), the Pin Oak (*Quercus palustris*), are the most prominent species, and give name to the whole. The Chestnut Oak (*Quercus prinus*) is associated with these just north of Janesville, but I have observed it at no other point within the state. The common Poplar or Aspen (*Populus tremuloides*) is the most conspicuous associate of these oaks, but it is not confined to this association. The Large-toothed Poplar (*Populus grandidentata*) is sometimes found with this group, but much prefers association with the maples. This and the preceding species are in a sense the complements of each other. Those associations that are avoided by the one are sought by the other, though they not unfrequently mingle. The *Populus balsamifera* and *P. candicans* have not been observed mingling with this group. The Shell-bark Hickory (*Carya alba*) is another prominent member of this cluster. The Pignut Hickory (*Carya glabra*) is occasionally, but not frequently found in this group. It sustains the same relation to the Shell-bark Hickory that the Great-toothed Poplar does to the Trembling Aspen. The Crab Apple (*Py-*

rus coronaria), the Wild Black Cherry (*Prunus serotina*), the Choke Cherry (*Prunus Virginiana*), and the Wild Plum (*Prunus Americana*), represent the Rosaceæ. The Sumac (*Rhus typhina*) is common, but not significant, as it is a member of other groups.

The attendant underbrush is equally characteristic. The Hazelnut (*Corylus Americana*) is almost everywhere present with this group, though rare or wanting in connection with the others. The Panicled Cornel (*Cornus paniculata*) is very common, and with the Hazel constitutes the chief underbrush. The Wild Red and Black Raspberries (*Rubus strigosus* and *occidentalis*) and the High-bush Blackberry (*Rubus villosus*) are all present, but seem to prefer association with the other groups.

If we descend to the herbaceous vegetation beneath, similar facts will be found, but it would transcend the brevity desirable in this report to enter fully into the details. And there is this further reason for not doing so in this connection, that many of these plants are more dependent upon the conditions furnished by the overshadowing vegetation, than upon the nature of the soil, and are therefore less instructive as to agricultural questions.

This group as here constituted includes both the "Oak openings" or "Oak orchards," and the denser oak forests. There are sufficient reasons, however, for separating them into two classes, as they indicate different, though allied, agricultural capabilities. The oak openings are most nearly related to the prairies, while the oak forests graduate towards the following classes. Those plants which have been mentioned as preferring association with the subsequent groups, as the Pignut Hickory, Great-toothed Poplar, etc., are found chiefly in the forests, and much more rarely in the openings, while of the species common to the prairie and oak groups, the majority are only found in the openings, and but few in the denser oak forests.

Class III. *The Oak and Maple Group.* It is difficult to draw sharp lines of demarkation between the several classes of heavy forests, and to circumscribe the areas occupied by each. The fact is, that no abrupt line of separation exists. But perhaps the distinctions here attempted are as clear and as legitimate as in many other departments of science, where such distinctions are sanctioned, and for the practical ends for which this investigation is made, it is essential that such divisions should be attempted, and besides the *tout ensemble* is distinct, though the constituents may be linked into the groups on either hand. These observations seem especially demanded as an introduction to the definition of this class. The oaks which have been made the most conspicuous characteristic of the preceding group are made joint partners in naming this division, and will be found to mingle with those that follow. The maples which are here introduced to our attention will also play a conspicuous part in subsequent classifications. This group is not then characterized by the exclusive presence of any prominent plant, but by a distinctive association of plants common to several classes.

The White Oak is the most prominent of its genus, and attains a large size. The Red Oak and Burr Oak are usually present. Their proportionate number is very much the same as in the denser oak groves of the preceding group. But to these oaks there is added the Hard or Sugar Maple (*Acer saccharinum*), and the Red Maple (*Acer rubrum*). The latter seems to have its best development in this association. The Elms (*Ulmus Americana* and *U. fulva*) are more or less present, but not prominent, as also the Linden or Basswood (*Tilia Americana*). The Ironwood (*Ostrya Virginica*), and the Beech (*Fagus ferruginea*) are excluded from this group. The White Ash (*Fraxinus Americana*) is rarely seen in this connection, but the Black Ash (*Fraxinus sambucifolia*) is common in contiguous lowlands. The Hazel (*Corylus Americana*) is not prominent though present, and the *Cornus paniculata* of the last group is largely replaced by *Cornus circinata.*

Class IV. *Maple Group.* The leading member of this group is the Sugar Maple (*Acer saccharinum*); not that at every point it is more numerous than any and all others, but that on the average it surpasses the other species. This is, however, in a high sense, a mixed group, and embraces some of the densest forests of the state. The Oaks of the last group are present here also, but in less numbers and in subordination to other species. The Linden (*Tilia Americana*) is very numerous. The White Elm (*Ulmus Americana*) which in the areas occupied by the foregoing classes was chiefly confined to the low lands and river bottoms, here extends itself more upon the highlands, and is intimately intermingled with a large assemblage of species. The *Ulmus fulva* is also present. Both the White and Black Ash are found, the latter in the lower lands. The Ironwood (*Ostrya Virginica*) is abundant and highly characteristic. The Black Walnut (*Juglans nigra*), and the Butternut, (*Juglans cinerea*) are common. The *Carya alba* (Hickory) is chiefly replaced by *Carya glabra* (Pignut), and similarly the *Populus tremuloides* gives place to the *Populus grandidentata.* The White Thorn (*Cratægus coccinea*) is common, while the Crab Apple (*Pyrus coronaria*) is correspondingly rare. The Wild Plum (*Prunus Americana*) is less abundant than in the Oak group, while its congener, the Black Cherry (*Pru-*

nus serotina) grows to ampler proportions. The Paper or Canoe Birch (*Betula papyracea*) is occasionally found in favorable localities, but is not strictly a member of the class. The Beech (*Fagus ferruginea*) is excluded and made characteristic of the following group.

Of shrubs, the Round-leaved Cornel (*Cornus circinata*) exceeds all others, and almost entirely excludes the Hazel and Panicled Cornel, the dominant forms in the Oak group.

The herbaceous vegetation is similarly well characterized, but for the reasons previously assigned, will not be dwelt upon here. This is a well marked group, and its distribution is highly significant.

Class V. *Maple and Beech Group.* This group is essentially the same as the preceding, with the addition of the Beech (*Fagus ferruginea*). This separate class for a single tree and a few subordinate associates is thought to be justified by the fact that the Beech is confined to the lake region,[1] and appears to be especially indicative of lake influence, as it occupies different classes of soils and covers different geological formations. There is less oak in this than in the preceding class.

Class VI. *The Hardwood and Conifer Group.* This class consists of a modification of the last, and the important addition of the Conifers. One of the more conspicuous modifications is the more or less complete disappearance of those representatives of the Oak group that have lingered through the foregoing classes. The Ironwood is far less abundant; the Black Walnut and Butternut are rare; the Witch Hazel (*Hamamelis Virginica*), and the Mountain Maple (*Acer spicatum*) appear more prominently among the underbrush. The berry-bearing plants are multiplied, as if to compensate for the disappearance of the larger fruit-bearers. These changes are progressive as we penetrate the area occupied by this class.

Of the Conifers, the first to be introduced is the White Pine (*Pinus strobus*), if we except the Arbor Vitæ (*Thuja occidentalis*), which from its proneness to swampy land and other selected localities can scarcely be considered a member of this, as an upland group. Farther to the north, the Red Pine, commonly called Norway Pine (*Pinus resinosa*), becomes somewhat common. The Hemlock (*Abies Canadensis*) is one of the most prominent and abundant members of the group. The Balsam Fir (*Abies balsamea*), although preferring the immediate vicinity of water, mingles somewhat with the group, especially in its northern extension. It is especially abundant on the shores of the Green Bay peninsula. An occasional Spruce (*Abies*

[1]See article of I. A. Lapham, Trans. Wis. State Agri. Soc., 1854-5-6-7, p. 236.

nigra) wanders away from its marshy habitat, and the Arbor Vitæ extends itself quite freely upon the uplands.

Class VII. *Pine Group.* This includes the well known vegetation of the "Pine Lands." It is here made to include those regions over which the pine is predominant in distinction from those in which it is simply scattered through prevailing hardwood timber, as in the preceding group. The leading tree is the *Pinus strobus.*

Class VIII. *Limestone Ledge Group.* This is a small but interesting vegetal cluster, covering limited areas in which there is the most meager soil, resting upon limestone. In this heavy drift region, such areas are few and small, but the distinctness of the flora is so marked, and so well illustrates the fundamental principle upon which the value of all these observations rests, that it merits a name and place as a separate class. The Poplars (*Populus tremuloides, grandidentata*, and *balsamifera*), the Canoe Birch (*Betula papyracea*), the Snowberry (*Symphoricarpus racemosus*), the Smooth Sumac (*Rhus glabra*), with the Conifers, constitute the major vegetation, and rather from the *combination* than from the constituents, cause it to stand out in marked contrast to the heavy timber by which it is frequently encompassed. It forms a thicket rather than a forest. The most characteristic feature is the abundance of the Poplars and the Birch.

The *Populus tremuloides* is not common in the forests by which the typical areas of this class are surrounded, which makes its abundance here the more conspicuous.

The *Rubus strigosus, Cornus circinata* and *Lonicera parviflora* are attendant shrubby plants. The herbaceous vegetation is also peculiar.

Class IX. *The Comprehensive Group.* This class consists of a commingling of nearly all the arboreal species of the foregoing groups. Clusters may be selected that are representatives of nearly all the other classes, but in general the species are curiously mingled, and do not array themselves in the definite associations that characterize the preceding groups. It is most nearly allied to the Maple, Beech and Conifer group, and lies contiguous to it, and near the limit of marked lake influence.

B. MARSH VEGETATION.

Class X. *The Grass and Sedge Group.* This includes the well known occupants of our open meadow marshes. It corresponds to the prairie group among upland vegetation, and in many cases graduates imperceptibly into it. It embraces several subordinate groups which are very indicative of the nature of the marsh bottom on which they grow, but which can scarcely be described in a manner intelligible to the general reader, although they are readily distinguished by observing farmers. It may be remarked in general, however, that the better class consist of the grasses proper (*Gramineæ*), not only because they are in themselves valuable, but also because they indicate a bottom susceptible of easy improvement by the substitution of more valuable grasses. The Sedges (*Cyperaceæ*) in general occupy marshes that are of inferior value now, and are less promising of immediate returns to labor spent in improvement. Fortunately the former class largely predominate.

CLASS XI. *The Heath Group.* This association of swamp vegetation is characterized by the predominance of the members of the Heath family (*Ericaceæ*). Among these the most characteristic plant is the Leather Leaf (*Cassandra calyculata*), and the most important one is the Cranberry (*Vaccinium macrocarpon*). The Willow, Larch and Sphagnum mosses and a variety of other plants are very frequent associates. This class is worthy of attention, not so much in view of its prominence as a botanical group, as on account of its present and prospective economic importance. The actual existence of the cranberry plant in its native state assures us of conditions favorable to its growth and indicates where cultivation will be most likely to prove remunerative. Where the cranberry itself is not present, it is eminently desirable to know what plants are its habitual associates and demand similar conditions of soil and moisture, since these may be almost equally good guides in the selection of a suitable marsh for improvement. Of plants which serve this purpose the *Cassandra calyculata* is regarded as the most reliable. On this point an excellent work on the subject says: "In selecting a location it is very important to observe the varieties of plants or trees existing upon the ground. Although no cranberry vines may be growing there, yet the presence of other plants requiring similar conditions of soil and moisture indicate a soil congenial to the growth of the cranberry. For instance, the Feather-leaf, also called Gander-bush and Leather-leaf (*Cassandra calyculata*), so abundant in heath ponds, is considered a sure indication of a proper locality."[1]

The distribution and additional facts relative to this group will be given a few pages in advance.

CLASS XII. *The Tamarac Group.* The name is perhaps a sufficient definition even to the commonest observer. The Tamarac or American Larch (*Larix Americana*) constitutes the entire arboreal

[1] Cranberry Culture, by J. J. White.

growth; the *Ericaceæ* form the chief undergrowth, and the Sphagnoid mosses carpet the peaty bottom, forming a well-marked flora.

Class XIII. *The Arbor Vitæ Group.* This is similar to the last save that the Arbor Vitæ, or White Cedar, as it is frequently called (*Thuja occidentalis*), takes the place in whole or in part of the Tamarac. Usually the Tamarac is present in greater or less numbers. A not unfrequent arrangement consists of a predominance of the Arbor Vitæ around the borders of the swamp, and of the Tamarac toward the center. The latter is a more thoroughly swamp species (although occasionally seen on the hillsides) than the former.

Class XIV. *The Spruce Group.* This is similar to the two preceding groups, except that the Black Spruce (*Abies nigra*) is the chief arboreal form. The Larch and Arbor Vitæ are frequently present. As the Spruce is confined to the northern regions, more of the northern forms of minor vegetation are associated with this group, although the same tendency is shown in the other classes in the same latitude.

From the habit of these three paludal conifers of mingling, it is sometimes difficult to classify a given swamp, and it has not been thought important to distinguish them on the accompanying map of vegetation, although they were so distinguished on the original map.

C. GROUPS INTERMEDIATE BETWEEN THE UPLAND AND MARSH GROUPS.

Class XV. *The Black Ash Group.* In this, as the name implies, the Black Ash (*Fraxinus sambucifolia*) is the predominating plant.

The Black Alder (*Alnus incana*) is a subordinate and quite constant associate, and the two characterize the group. The Arbor Vitæ is frequently present, and sometimes the Witch Hazel. Otherwise, as far as observed, the association is not constant.

Class XVI. *The Yellow Birch Group.* This is not altogether a well defined group. The abundance of Yellow Birch (*Betula lutea, excelsa*) is the most marked feature of the vegetation. The Hemlock is very common, and the Maples and Beech are present. Under the dense shadow of these, several species of Lycopodium, the Dwarf Yew (*Taxus Canadensis*), the large Purple-flowered Raspberry (*Rubus odoratus*), the Ericaceæ (*Pyrola rotundifolia* and *secunda*), the Cohosh (*Actea spicata*, var. *alba*) abound among others, though the most of these are present in other groups. This group occupies only some limited areas in the peninsula east of Green Bay, and in the press of other duties, sufficient opportunity was not afforded for satisfactory study.

Distribution. On the accompanying map of vegetation, the district covered by each of these classes is delineated, with as much of detail and accuracy as was compatible with the demand of other departments of the survey, and with the rapidity necessitated by the large area examined. As that presents their distribution far more vividly and accurately than any verbal description, I need only add here a few supplementary remarks.

It will be seen by consulting the map, that *the prairies* are almost exclusively confined to the southwestern portion of the district, or chiefly to the Mississippi drainage system, though this fact perhaps has no special significance. The surface of a portion of these prairies is level, and bears evidence of having formerly been a lake bottom, while that of others is elevated and undulating, and bears no evidence of having been submerged since the retreat of the glacier. The areas of prairie and forest are so intermingled as to forbid any topographical distinction between them, and to negative any explanation of their origin that is dependent on surface features. It is not proposed to enter here upon the much discussed question of the *origin of prairies*, but simply to remark that the tenor of the facts in this region, bearing upon the question, supports the general views so ably presented by Profs. Dana, Newberry, Guyot and others, and at the same time harmonizes with the observations of Prof. Whitney, to the extent that the nature of the soil is the most essential primary agency. It is not however because the soil is incapable of supporting trees, for when planted upon the prairies they flourish luxuriantly, and when the soil is cultivated or shaded so that a proper degree and constant supply of moisture is secured, trees are propagated from the seed with facility. In the first case, in planting the trees, the superficial compact soil, which is believed to be the real barrier to the extension of the forests in *this* region, is penetrated, and the roots of the tree placed below it, and it is at the same time loosened, and mingled with the subsoil; and in the second case, artificial stirring of the soil or special conditions supply the moisture essential to the growth of arboreous vegetation. But in its native, undisturbed condition, the fine superficial soil becomes exceedingly dry at intervals during the season, and renders it impossible or exceedingly difficult for the young seedling to maintain its existence until it can gain a foot-hold upon the deeper and uniformly moist subsoil. This difficulty is increased by the antagonism of the grasses that can successfully withstand these variations of moisture, and by annual fires. The latter have doubtless modified the form and extent of the prairies in some degree, but it is generally conceded by those who have studied the subject comprehensively, that it is entirely inadequate as an explanation of prairies in general.

The Oak group is likewise chiefly confined to the southwestern part of the district. It occupies all classes of topography and all elevations from the lake level to 500 feet above it. It shows a tendency to invade the districts of the heavier forests, along the line of the Kettle Range. This is due to the nature of the soil that accompanies the Range, as will be seen hereafter.

The Oak and Maple group usually lies contiguous to the last or along the Kettle Range. It was in the latter relationship that its peculiarities were first and chiefly noticed. This seems to be due to the fact that the soil is adapted to the Oak group, while the surroundings are favorable to the propagation of the Maple and its associates. A conflict of conditions is the result, in which neither has a decided advantage.

The Maple group occupies an irregular belt that has a northwest and southeast trend, bordered chiefly by Oaks on the south and Beech and its associates on the north. It is quite distinctly limited in the direction of the Oaks, but much less so toward the Oak and Maple, and the Maple and Beech groups, into which it merges almost imperceptibly. It reaches from the lake shore to about 500 feet in elevation.

The Maple and Beech group covers a large surface stretching from the lake shore northwestward, a direction which neither corresponds to geological nor topographical lines, but is none the less instructive on that account. It does, however, correspond very closely with the isothermals for the summer months;[1] which, with the other elements of the lake influence, as already intimated, are undoubtedly the controlling agencies.

To the north of this *the Hardwood and Conifer group* extends to Port de Morts, being more extensive than either of the others. The greatest elevation within its area is less than 400 feet above Lake Michigan.

The Comprehensive group occupies a portion of the crest and western slope of the outcropping rocky ridge of our district. It is limited chiefly to the Green Bay region. It seems to be the result of the conflicting demands of lake and boreal influences, on the one hand, and of soil and warm, dry southwest winds, sweeping up the Green Bay valley, on the other.

[1] See Map of Wisconsin with lines showing the Remarkable Effect of Lake Michigan in Elevating the Temperature for January and Depressing that of July, by I. A. Lapham, 1865. Also Transactions Chicago Academy of Sciences, Vol. I, Plate X, 1865. See also, The Isothermal Lines of Wisconsin, by J. G. Knapp, Transactions Wisconsin Horticultural Society, Madison, 1871.

In the lowlands, the *Grass and Sedge marshes* which correspond to, and in many cases are, unquestionably the forerunners of the prairies, are like them, chiefly confined to the southwestern region.

As we enter the dense forests to the north, the *Tamarac swamps* almost entirely replace them, and these in turn, in the still higher latitudes, are in part replaced by the *Cedar* and *Spruce swamps.* The Ash swamps are more abundant and extensive at the north, and the Yellow Birch flats are entirely northern.

The distribution of the *Heath, or Cranberry group*, is not less interesting than important. The marshes occupied by this class readily arrange themselves, on inspection, into four clusters, having a definite relationship to the geological formations. Those in the northwestern part of the district are to be grouped with the great marshes near Berlin and to the westward, and rest upon the Potsdam sandstone. Those in the western part of Jefferson county lie upon, or near, the St. Peters sandstone. Those in Oconomowoc, Concord, Hebron, Summit, Delafield, Ottawa, Eagle, Richmond and Sugar Creek, form a numerous group of small marshes, and rest upon a sandy district that seems to have had its origin in drift from the arenaceous layers of the Cincinnati shale, subsequently modified by lake action, of which the swamps are the lingering representatives. The fourth group comprises those that lie along the line of the ancient sand beaches of Lake Michigan, of which the marshes near Sturgeon Bay and Peshtigo are examples. *The demand for silica is thus shown in the natural distribution of the plant*, and we have in this a beautiful illustration of the fundamental principle insisted upon in this report. Native cranberries occur at the following locations:

Sugar Creek, T. 3, R. 16 E. Sec. 18.
Richmond, T. 3, R. 15 E. Sec. 18.
Eagle, T. 5, R. 17 E. Sec. 31, N. W. qr.
Ottawa, T. 6, R. 17 E. Secs. 32 and 28.
Hebron, T. 6, R. 15 E.
Lake Mills, T. 7, R. 13 E.
Concord, T. 7, R. 16 E. Sec. 26.
Summit, T. 7, R, 17 E. Secs. 9 and 12, N. W. qr.
Delafield, T. 7, R. 18 E. Sec. 34, N. E. qr., and sec. 27, S. E. qr.
Oconomowoc, T. 8, R. 17 E. Sec. 4.
Oakland, T. 6, R. 13 E. Sec. 3, S. W. qr., and sec. 17.
Sturgeon Bay, T. 27, R. 26 E. Sec. 12, W. hf.
Caledonia, T. 21, R. 14 E. Sec. 29.
Peshtigo and Marinette, T. 30, R. 23 E. Sec. 21 and adjoining.
Aurora, T. 18, R. 13 W., where the marshes occupy several sections east and southeast of the village of Auroraville, and are among the most extensive and productive in the state.

Doubtless they occur also at other points that escaped my knowledge. When it is considered that the size of the district required the inspection of from 3,000 to 4,000 square miles each season, some omissions in matters not specifically geological will doubtless be pardoned by a generous public.

The elements of success in cranberry culture, so far as they are relevant here, seem to be the following, as I glean from several authorities:

I. *A Suitable Bottom.* A good bed of peat is the best, that being the principal food of the plant. At the east, cedar swamp bottoms are preferred by many. Our tamarac swamps will doubtless be equally satisfactory; indeed, native cranberries are sometimes found growing on them.

II. *Facilities for drainage*, and complete control of it, so that the marsh may be drained or flooded, as may be demanded.

III. *A Sufficient Supply of Silica.* This is sometimes already present, but is usually to be supplied by covering the surface with sand. "Silica plants" differ from "peat plants" in appearance and mode of growth, and in yielding at least three times the amount of fruit produced by the latter. The successful culture of the cranberry is also limited to certain latitudes. If too far north, the early frosts prevent their maturing and render them a precarious crop. If too far south, the heat interferes with their proper development. Actual experience is the best guide in respect to this, as well as the other conditions, and hence the value of observations on the experiments that Nature has herself made.

CHAPTER IV.

SOILS.

There are few subjects upon which it is more difficult to make an accurate, and at the same time an intelligible report, than upon soils. This difficulty arises partly from the nature of the subject, and partly from the vagueness of the terms used in speaking of soils. Aside from the vagueness, these terms have a different signification as used by different persons, which adds to the difficulty. We speak of "light soils" and "heavy soils," and perhaps, without thinking, we suppose that these terms refer to actual weight, or, in the terms of science, to specific gravity. But such is not usually the fact. Thus, we say, "a heavy clay soil" and "a light sandy soil," but in fact the weight of the clay soil is only about three-quarters of that of the sandy soil, measure for measure. These terms, as commonly used, really refer to adhesiveness, degree of comminution, or power of holding water, or, more properly, perhaps, to the way in which the soil "works." Again, the term "sandy soils" is supposed, even by persons somewhat versed in the sciences, to mean those that are made up of grains of quartz; or, in other words, are silicious, and hence are more or less barren. But this is not always true. Some sandy soils are composed of grains of limestone, and are very fertile, an instance of which will be described presently. So, a clay soil is supposed by many somewhat intelligent in chemistry, to be composed of aluminous material, but this is far from always being the case, as the term is commonly used.

This obscurity will, however, in a measure, disappear as we proceed to consider the *origin* of the soils of Eastern Wisconsin, which appropriately claims our attention here.

The organic constituents of the soil have manifestly been derived from the plants that the soil has itself produced, and are only the result of accumulated self-enrichment. Local exceptions to this are to be found in those cases where soils have received organic material washed from adjacent areas. This vegetable matter takes various forms, but all may be spoken of under the comprehensive term, humus. In marshy locations, the moisture prevents the decay of vegetable accumulations to such an extent that the resulting humus forms the main constituent of the soil, and the mineral ingredients are entirely subordinate in amount and function, thus forming a soil of vegetable origin.

With this exception, *the leading elements of our soils are derived directly or indirectly from the rocks*, either through their powdering by mechanical means, or disintegration by chemical agencies. The chief mechanical agent in pulverizing the rocks has been water in its various states, especially in the form of glacial ice. When the great glacier plowed over this region, it broke fragments from every formation over which it passed, ground them to various stages of comminution, and left the commingled mass spread over the face of the country, forming a most excellent foundation for our soils. Subsequently, water in the form of lakes and rivers washed out and redeposited a portion of this material, giving rise to sandy beach lines and lacustrine and fluviatile deposits of clay.

But this material was still too crude to constitute a fertile soil, and besides, over many small areas, these agencies left the rock entirely bare. Then followed a process of disintegration, of a chemical or chemico-physical nature, popularly spoken of as the action of the elements, by which the surface of this material, and the rock surface, where exposed, was reduced to the condition of soil, which in the progress of ages enriched itself by its own vegetation. It appears, then, that (1) a portion of our soils were derived directly from the glacial accumulations, and are properly called drift soils; that (2) a portion were derived from the same kind of material, but after it had been washed and redeposited by lake and river action, forming soils of lacustrine and fluviatile origin; and (3) that another portion had their origin in the direct decomposition of the undisturbed rock formations. It will now be clear that the character of a soil will depend upon (1) the nature of the rock from which it was derived; (2) the manner and degree of its reduction; (3) the amount lost by leaching and otherwise; and (4) the amount gained by vegetation from above or capillary action from beneath. Or, to put the matter much more simply, a soil depends chiefly upon (1) the chemical nature of the material, and (2) its physical state or the degree of fineness to which it is reduced. These elements will receive prominent attention in the descriptions of soil that follow.

To fully understand the nature of the material, all the rock formations of the region and those that lie to the north and east, whence the glacier came, should be studied, since they have all made contributions to our highly composite soils, and herein the strictly geological relations of the subject are apparent. It will be sufficient here, however, to call attention to the four general classes of rocks that have chiefly entered into the formation of the soils of the part of the state under consideration, and for fuller knowledge, refer the reader to the general report. These are (1) *the Archæan rocks*, whose mineral nature is very complex, but which give rise chiefly to silicious and aluminous material; (2) *the sandstones* that contribute silica; (3) *the shales*, that are chiefly aluminous; and (4), most abundant and important of all, *the dolomites or magnesian limestones*, that contribute lime and magnesia. Soda, potash, phosphorus, and other ingredients, exist in small quantities in the several formations. The lime and magnesia occur chiefly in the form of carbonates, and their presence is manifested by effervescence on the application of acid, with which the soils were extensively tested in the field.

The following descriptions of the soils of the district under consideration relate rather to the subsoil than the soil proper; at least there has been an effort to set aside purely surface characters, first, because the surface soil is subject to so many local and changeable influences, and has been so much modified by cultivation and other artificial causes, that a series of observations upon typical or "virgin" soils was scarcely possible, and secondly, because the future of our agriculture depends not so much upon the present soil as upon the subsoil, since winds, waters and cropping are rapidly sweeping the surface away, and but comparatively few years will pass before our present subsoil will be at the surface, and for the further reason that the power of the surface soil to retain the strength it has, and to draw mineral resources from below, is most evidently dependent on the subsoil.

If, in reading the descriptions that follow, the reader will be kind enough to place before him Plate III of the accompanying atlas, the areas occupied by each class will be seen more definitely than they could be presented by description, which will then be for the greater part omitted. It will be readily understood by every one, that soils vary much in every section, and even on the same farm, and that the varieties graduate into each other in the most intricate and imperceptible manner, and yet at the same time every region has a prevailing character that can be classed, described and mapped. The accompanying map is only intended to indicate such prevailing kinds, and of course each color covers patches of greater or less size, of different kinds.

Notwithstanding the impracticability of mapping these local variations and intermediate varieties, it is believed that the map given will prove of some essential service to the increasingly large number of our agriculturists who desire to study the interests of their profession in a comprehensive and philosophic manner. The following descriptions will, however, be found quite closely applicable in detailed study.

Class I. *Prairie Loam.* This class is too well known to need much description. It sometimes arises from the decomposition of the underlying limestone, sometimes from the disintegration of limestone gravel, and sometimes it arises from the deposit of an ancient lake. There are several varieties, but all have at least a moderate degree of fineness of texture while some manifest this quality in a very high degree. This is more particularly true of those that are derived directly from the decomposition of the limestone, the type of which is a black "light" soil, that works like an ash bed when dry, and rolls into little pill-like pellets when wet, and refuses to scour except with the very best of plows. It is a warm soil, but not so rich as its blackness might lead one to suppose, yet very responsive to proper fertilizers. This particular variety occupies but limited areas. The other kinds are slightly more arenaceous and work with the greatest ease.

In chemical composition, silica is the chief ingredient, with which is associated a variety of mineral substances that constitute plant food, as shown by the analysis at the close of these descriptions.

The small quantity of the carbonates of lime and magnesia may seem at first strange, since the soil is chiefly derived from magnesian limestone, but it becomes clear enough when we consider that the disintegration by which it was formed consisted of the dissolving out of the lime and magnesia, leaving the residue. But as these substances exist in abundance in the stratum immediately beneath, and impregnate the water, they are brought to the surface in dry weather by capillary action so that these soils rarely suffer for the want of mineral substances. In judging of the strength of our soils from analysis it should be borne in mind that there exists in the immediate substratum an inexhaustible supply of the soluble mineral substances needed for plant food. Our soils are new geologically as well as new in the history of cultivation.

Vegetable matter in the form of humus penetrates this soil to greater depths than in most of the following classes, and imparts to it a darker color.

The areas occupied by it will be found on the map above referred to. It will be observed that they are mainly confined to the southwestern third of the district under consideration, or, as it happens, perhaps casually, to the Mississippi basin.

CLASS II. *The Lighter Marly Clay Soils, or Clayey Loams.* These are drift soils, having been derived chiefly from a calcareous bowlder clay, which in turn was formed by the powdering of various kinds of rocks, but chiefly magnesian limestones, by glacial agencies. It therefore contained originally a large proportion of calcareous and magnesian material, and a less amount of silicious and aluminous; but the leaching action of water and the growth of vegetation has removed a much larger amount proportionally of the lime and magnesia than of the other ingredients, so as to leave these the chief constituents at the surface. But the deeper subsoil is highly marly in its nature. There is just enough of sandy material in it to make it loamy. The dark vegetable matter does not penetrate as deeply as in the prairie loam, so that the plow frequently turns up the reddish or yellowish subsoil containing very little humus. This soil works with the utmost facility, indeed is unsurpassed in this respect. It stands both wet and drought well, and is a very durable and fertile soil.

This class graduates into the sandy loams on the one hand, and heavier clayey loams on the other. It prevails in the same general region as the prairie loams, its areas being irregularly interwoven with them.

CLASS III. *The Heavier Marly Clay Soils, or Heavier Clayey Loams.* This class is similar to the preceding, both in origin and character. But the drift from which it was derived contained more Archæan bowlders, especially those containing feldspar, hornblende, and similar minerals in large proportion. From the powdering and disintegration of these, a large amount of clay proper was derived, mingled, however, with the quartzose material of the same rocks and with much calcareous and magnesian clay, derived in a similar way from the dolomites which usually form a prominent part of the drift. This is not then a true clay soil, for there is a notable proportion of lime, magnesia and free silica present, but it is, as named above, a marly clay, of the heavier class, when compared with the foregoing. The term loam is not properly applicable to the subsoil, but at the surface, drainage has exercised an assorting influence over it, separating and carrying away the finer material, and leaving the sand, which gives to the surface a lighter loamy character. This surface soil rarely gives any effervescence when submitted to the action of hydrochloric acid, while that from greater depths usually responds with vigorous action. We find here again what I have found to be true everywhere, that the surface soil is almost entirely exhausted of the carbonates of lime and magnesia, even where they exist in great abundance in the deeper subsoil. And it is for this reason that the origin and nature of the comparatively unmodified subsoil must be studied if we are to arrive at any reliable conclusions as to the permanent resources of our soils. A considerable proportion of iron exists, as might be expected, from the decomposition of the hornblende and allied minerals, and gives to the soil a yellowish orange or reddish color. The high color indicates the presence of the sesquioxides; and the more or less chalybeate character of the waters demonstrates the existence of the more soluble compounds; while a magnet drawn through the pulverized soil frequently brings forth a bristling edge of magnetite, showing the presence of iron in that form. The surface is frequently strewn with bowlders, chiefly "hard-heads," while cobble stones and pebbles mingle more or less with the soil, though not to an extent that would often justify the term gravelly. The vegetable mold is confined mainly to a few inches at the surface.

This soil works with more difficulty than the last, but is strong and enduring, and will improve rather than otherwise with use. It becomes lighter and warmer as it is stirred, and is gradually becoming fitted for crops that did not at first flourish upon it. This is the prevailing soil in the heavily timbered regions in the central portions of our district.

Class IV. *The Red Marly Clay Soils.* The term "red clay" is popularly applied to a very extensive deposit in the northeastern part of the state, and to the soil derived from it. It is very properly denominated a clay, if we use the term in a simply physical sense. It is finely comminuted, close, compact, adhesive and almost impervious. It washes, cracks and otherwise deports itself as a clay. These qualities, however, do not reach an excessive development. It never possesses that extreme tenacity when wet, or that obdurate hardness when dry, that characterizes the typical aluminous clay. It contains, moreover, in most localities, fragments of limestone, and occasionally other rock, which modify these qualities. In chemical composition, however, it is not a true clay. Beside the aluminous element, there is a varying proportion of silicious matter, a notable ingredient of carbonate of lime and magnesia, and a very constant intermixture of hematite and magnetite. It is rarely that a magnet drawn through a handful of dust fails to bring forth grains of the latter. In like manner the application of acid to the unleached subsoil seldom fails to give a prompt and vigorous effervescence. The opposite is true, however, of the surface soil. The difference between the two is also usually indicated by physical characteristics. One of the most noticeable of these is the intimate fissuring of the upper subsoil when dry, by innumerable little cracks that divide the mass into small rudely cubical blocks, so that when dug up it is neither pulverulent nor aggregated in rounded clods, as is the case with arenaceous and loamy soils, but is simply a heap of little blocks. From this portion the carbonates have been pretty thoroughly removed. Hydrochloric acid seldom produces effervescence, never any vigorous action. The fissuring is to be regarded as the cause rather than as the result of this removal of the soluble carbonates. The color of this portion is also somewhat duller and more inclined to a mottled and brownish hue than the lower unmodified portion, which is usually a pinkish or purplish red. This lower portion is the true subsoil, and is the part previously described. The immediate surface has an ash color.

This soil needs thorough working, which is not so easily accomplished as with the loamy arenaceous soils, but it yields excellent returns. It is an exceedingly strong, durable, fertile soil. Its strength lies in its native constitution and not in a superficial layer of vegetable mold, soon to be exhausted. Cultivation improves rather than exhausts it, and it will still continue to yield bountiful harvests when many other soils will need the constant stimulus of fertilizers. The stirring, the washing out of the finer materials, and the exposure to the air incident to cultivation, give it a lighter and warmer character, so that after a few years cultivation, crops may profitably be introduced that at first were unsuccessful.

The map shows it to occupy a belt along Lake Michigan, from Milwaukee to Sturgeon Bay, widening to the northward until it passes the summit between the lake and the great valley, and occupies the basin of the Fox river and Lake Winnebago.

Class V. *The Limestone Loam.* This is not a very sharply defined class. It appears to have its origin in the decomposition of the magnesian limestone upon which it rests. It thus differs from either of the marly clays, to which it is most nearly allied, in not being a drift soil. It is usually yellowish or reddish in color, rather plastic and adhesive, moderately comminuted, of only medium porosity, and in chemical nature it is chiefly silicious and aluminous, or in the language of its origin, the insoluble residue of the limestone. The carbonates of lime and magnesia, though, forming the chief constituents of the original rock, are present in the soil in very limited quantities. This makes the use of the name here given objectionable, if it is thought to indicate the composition of the soil. It was selected for want of a better one to indicate its origin.

The depth of the soil, except in the valleys, is not considerable, and the rock itself is really to be regarded as the permanent subsoil. It is reached even by the roots of cereals over much of the area occupied by this class. It is a fertile soil, is easily worked, and supports a dense growth of timber.

Class VI. *Silicious Sandy Soils.* This class needs little attention here, because, in the first place, it is too well known to require elaborate definition, and, in the second place, it fortunately occupies so little area that it posseses no great importance in considering the district as a whole. As found in this region, it had its origin in beach deposits made by the lake in former times, and in drift from silicious rocks. As it occurs chiefly in narrow strips surrounded or bordered by clay soils, it may not on the whole prove a great disadvantage, although of itself it is a sterile soil, for when it mingles with the adjoining clay it produces a rich, fertile loam, better adapted to some crops than the clays themselves.

Class VII. *The Calcareous Sandy Soils.* My attention was first called to this class by observing a heavy growth of maple and associated trees upon a sandy soil. This was so contrary to previous observations that it led to an examination of the sand. This showed it to be composed of small crystals of dolomite mingled with a varying quantity of silicious grains. From the immediate surface the more soluble dolomite has been removed, leaving the silicious sand at the top in such a way as to disguise the true nature of the subsoil. This surface soil is light, warm and arenaceous, but, to casual observation, would give no promise of permanent fertility. The fact that the subsoil is so largely dolomitic, instead of silicious, adds not less than one hundred per cent. to the value of the land. A general knowledge of this fact on the part of the proprietors ought not only to add to the appreciation in which their land is held, but enhance their returns by guiding them in selecting those crops for which their soil is peculiarly adapted. This also presents a rich field for the study of agricultural problems relating to sandy and calcareous soils. This is not, however, the sole occupant of any considerable area, but is freely intermingled with marly clay and gravelly soils and various intermediate grades, as well as the silicious variety. It is a drift soil. The calcareous sand had its origin in the granular dolomites of the Niagara Group.

Class VIII. *The Humus Soils.* Under this head is grouped those soils in which humus in some of its varieties, chiefly peat and swamp muck, is the predominant element, and in which the mineral ingredients are largely concealed by it. The peaty soils are the type of the class. In these, not only the surface but the subsoil is chiefly of organic origin. Soils simply covered with a layer of vegetable mold are not here included. Almost all the swampy, and a large portion of the bottom lands, are covered by this soil. But it is not so easy to define the adaptabilities of this class, or measure its fertility. Some portions, with simple drainage, will produce the most luxuriant growth of grass or grain. Others are impregnated with organic acids derived from the humus, and are known as "sour soils," and are unfit for the growth of the cereals and the better class of grasses. Others still are so largely composed of organic matter that they do not contain the requisite amount of mineral ingredients. The character of the vegetation naturally growing upon it is the best indication of the nature of any given example of this class.

Alluvial Soils. Closely associated with this last class, and intermediate between it and the prairie loam, we find a soil formed by the accumulation of sediment washed from the uplands and deposited on the bottom lands adjacent to streams, and in other favorable localities. It is better marked in its origin than in its character, for when mineral ingredients predominate, it very closely resembles the prairie loam, both in the fineness of the material and in its chemical nature, and when vegetable matter becomes predominant it does not differ essentially from the humus soils. For this reason, and because its distribution has no special significance in studying agricultural problems, it has not been mapped as a separate class, although it occupies in the aggregate a large area, and is an exceedingly fertile and valuable soil. The following analyses are by Mr. Bode:

Analyses of Soils.	100 parts of the dried soil contain		
	Prairie loam from south central Wis.	Peaty soil from bottom lands.	Red marly clay from Kewaunee county.
Soluble in hydrochloric acid—			
Organic matter	4.24	21.40	5.84
Oxide of iron	2.88	3.59	3.03
Alumina	2.34	2.52	2.82
Silica	0.60	0.07	0.50
Oxide of manganese	0.18	0.13	0.12
Lime	0.18	0.28	4.02
Magnesia	0.04	0.03	3.48
Soda	0.49	0.51	0.15
Potassa	0.19	0.14	... .
Phosphoric acid	0.06	0.12	0.19
Carbonic acid	0.52	0.25	7.08
Sulphuric acid	0.03	0.08	0.02
Insoluble in hydrochloric acid—			
Silica	78.99	64.42	59.76
Oxide of iron	5.28	2.15	1.36
Lime	1.12	1.34	1.01
Magnesia	1.03	0.69	....
Alumina	1.83	2.28	10.62
	100.00	100.00	100.00

Magnesian Character of these Soils. It is worthy of notice here that these soils are magnesian. This, I believe, in the future unfoldings of agricultural science, will be found to be a very important fact. Magnesia has been a much abused substance. It was formerly supposed that magnesian limestone made an inferior quick lime, and it long lay under disfavor. But experience has finally shown that precisely the opposite is true. It is far superior to pure limestone for this purpose. It was long, indeed almost even now, thought to be unsuited for flux with iron ores, but this opinion has recently been modified. Magnesian limestone, burned to quicklime, was formerly prohibited as a fertilizer, and the ban has been only recently removed. That some such revolution of opinion must take place in reference to its utility as an ingredient of the soil seems to be forcibly suggested by the following extracts from analyses taken from Prof. Johnson's excellent treatise "How Crops Grow," "being the average of all trustworthy analyses published up to August, 1865":

	MAGNESIA. *Per cent.*	LIME. *Per cent.*
Wheat	12.2	3.1
Rye	10.9	2.7
Barley	8.3	2.5
Oats	7.3	3.8
Maize	14.6	2.7
Buckwheat	13.4	3.3
Flax	13.2	8.4
Beet	18.9	15.6
Turnip	8.7	17.4
Carrot	6.7	38.8
Peas	8.0	4.2
Field beans	6.7	5.2
Garden beans	7.5	7.7
Clover seed	12.2	6.2
Potatoes	4.5	2.3

From which we see that in the grains, the magnesia predominates decidedly. In the fibrous part of the plant the opposite is true; as follows:

	MAGNESIA. *Per cent.*	LIME. *Per cent.*
Winter wheat straw	2.6	6.2
Rye	3.1	7.7
Barley	2.4	7.6
Oats	4.0	8.2
Maize	5.5	10.5
Peas	7.7	37.9
Field beans	7.8	23.1
Garden beans	5.2	27.4
Buckwheat	3.6	18.4

	MAGNESIA. Per cent	LIME. Per cent.
Oak, body wood	4.8	73.5
Oak, small branches with bark	7.5	54.0
Poplar, young twigs	7.5	58.4
Elm, young twigs	10.0	37.9
Elm, body wood	7.7	47.8
Linden (Bass wood)	4.2	29.9
Apple tree	5.7	81.0
Apple tree, entire fruit	8.8	4.1
Beech	45.8	16.8
White pine	5.9	50.1
Larch	24.5	27.1

The percentages relate to the ash of the plant.

For other facts of similar import, see the work cited above. These facts go to show that magnesia is more concerned in fruit production, and lime in the formation of fiber. In view of this it may be asked whether the well known superiority of Wisconsin wheat is not due to the magnesian element in her soils.

If we compare the map of soils with the map of vegetation we shall find some interesting and important relations. The Prairie Loam is of course covered by prairie vegetation. The Lighter Marly Clays are chiefly occupied by the oak group, the Heavier Marly Clays by the vegetal groups in which the maples are prominent, The Red Marly Clay by very much the same; the Limestone Loam by the maple, beach and conifers in the peninsula and chiefly by the oaks elsewhere, this difference being due probably to climatal influences; the Silicious Sandy soils by the conifers chiefly; the Calcareous Sandy soils by the maple and oak and the maple and beech groups. The Humus soils are occupied by the several classes of swamp vegetation. Where a patch of heavy clay occurs in an area of the lighter class it usually sustains heavy oak timber, especially white oak, rather than the "openings," and where the reverse is true, the oak and maple group usually displaces the other maple groups. The pine is frequently found on soils that are quite decidedly clayey in nature, but in many of these cases a substratum of sand is to be found within a few feet of the surface.

These correspondences, which are susceptible of being carried out to much greater detail, illustrate the mutual relations of soil and native vegetation, and open to the agriculturist a wide field for profitable study.

CHAPTER V.

QUATERNARY FORMATIONS—THE DRIFT.

The formations of this region consist of two great classes, the one made up of indurated rock, the other of loose material in the form of clay, sand, gravel and bowlders. The former had their origin in deposits made by the ancient ocean, which have become hardened to the state in which we now find them. The others had their primary origin, as is now generally believed, in the action of ice in the form of a glacier. Subsequently a large portion of this material was washed out and redeposited or otherwise modified by the action of lakes and rivers. That portion which remains in the condition in which it was originally left by the glacier is known as unmodified drift, while that which has been rearranged and redeposited by the subsequent action of water is termed modified drift. Taken together, they constitute the chief Quaternary formations. Since they occur at the surface and are diverse from the bedded rocks below, in their nature and origin, it will be most convenient to consider them independently.

The primary drift, or that portion of the material which exists in the condition in which it was left on the retreat of the glacier, will be considered under the head of (1) moraine ridges, and (2) bowlder clay or till. The secondary or modified drift consists of a series of beach deposits of sand and gravel, and of lacustrine deposits of clay. In addition to these there are many local deposits made by running streams and small lakes that will not receive special consideration.

Glacial Movements. To clearly understand these drift formations, it will be desirable to first study the character of the glacial movements which gave rise to them. At the commencement of the great cold period which led to the vast accumulations of ice which overspread this portion of the continent, this part of Wisconsin had already been long elevated above the surface of the ocean, and had been subjected to very great erosion, by which extensive and deep valleys had been formed. There can be no doubt that the Green Bay and Rock River valleys were already in existence, though doubtless presenting many features very different from those exhibited at the present time. There is abundant evidence that some of the streams had cut channels from one to three hundred feet deeper than those which they now occupy. These preëxisting features of the surface, exerted a very marked and peculiar influence upon the direction of glacial movement.

FIG. 2.

A striated half-cone of rock on a glaciated surface of limestone, seen at Pelton's quarry, Pewaukee. The parallel lines represent the striæ. The base of the cone is not striated and the adjacent surface is at first rough, but becomes gradually smoothed, and at length merges into the polished plane surface, demonstrating the direction of glacial movement.

In its progress the ice mass abraded the surface of the rock, carrying away and grinding up the material detached, and by means of it, embedded in its base, polishing and scoring the ledges below, thereby indicating the direction of its movement, and leaving us its own history engraven on the surface of the rock. By careful observation of these scratches or striæ, it has been found possible in all except a few cases to tell the point of compass towards which the movement took place. By such observations it appears that the movements of the ice in this region were of an exceedingly interesting character. On the east side of the Kettle Range, with some unimportant exceptions, the direction of movement was in a westerly or southwesterly direction, or *towards the Range.* The exceptions are cases in which two sets of striæ are present, the one set corresponding to the general direction just indicated, the other to the general trend of Lake Michigan. On the other side of the Kettle Range, between it and the crest of the ledge that borders the Green Bay valley, heretofore described, the direction is to the *southeasterly toward the Kettle Range.* Within the great Green Bay valley the direction is uniformly *parallel to its trend*, and the cutting and planing indicates a long continued and powerful action. To the west of this valley, the striæ have a *westward and southwestward direction*, the tendency being in general more to the westward as the slope is ascended. It appears then that the movement on the east side of the Kettle Range was up the slope obliquely towards it; that on the west side of the Range, between it and the margin of the Green Bay valley, the movement was obliquely down the slope toward the Range; that within the Green Bay valley the ice moved up it until it reached the dividing ridge between it and the Rock River valley, when it descended the latter, the lines gradually diverging as it did so; and that on the west side of the valley, the movement was again up the slope, and gradually divergent. Over the Green Bay peninsula, striations are very rare, on account of the absence of conditions favorable to their preservation, but there is unquestioned evidence that the movement was obliquely across the peninsula *from the Green Bay valley to the trough of Lake Michigan.* In the following table the striæ have been classified with reference to these general movements:

I.—Between the Kettle Range and Lake Michigan.

Horlick's quarry, Racine (doubtful)	S. 26° W.
Schwickhart's quarry, Sec. 26, N. W. qr., Wauwatosa	S. 49° W.
Sheboygan Falls, village	S. 64° W.
Sheboygan Light-house—	
First set	S. 56° W.
Second set	S. 4° W.
Howard's quarry, Sec. 16, Sheboygan Falls	S. 78° W.
Kuntz' quarry, on Manitowoc river, Sec. 15, Manitowoc Rapids	S. 81° W.
One half mile below the above, Sec. 15, Manitowoc Rapids	S. 79° W.
Moody's quarry, 4th Ward, Milwaukee	S. 86° W.
Pelton's quarry, Pewaukee	S. 82° W.
Delafield, Sec. 20, S. E. qr	S. 116° W.
Pewaukee, Sec. 18, N. W. qr	S. 92° W.
Lisbon, Sec. 35	S. 96° W.

II.—Between the Kettle Range and the Green Bay and Rock River Valley.

Casco, Sec. 14, S. W. qr., T. 24, R. 23, on summit of ridge	S. 4° E.
" on east brow of the ridge, on top and edge of layer	S. 21° W
Marshfield, J. Steffer's quarry, Sec. 30, S. W. qr	S. 28° E.
Taycheedah, T. 16, R. 18, Sec. 29, S. W. qr. of S. E. qr	S. 10° E.
Empire, Sec. 5, N. W. qr	S. 18° E.
Ashford, R. R. cut, Sec. 11	S. 59° E.
Elmore, Ashford, Sec. 26, N. E. qr	S. 44° E.
Whitewater, near Kinney's	S. 7° E.
Whitewater, S. E. of Cravath lake	S. 12° W.

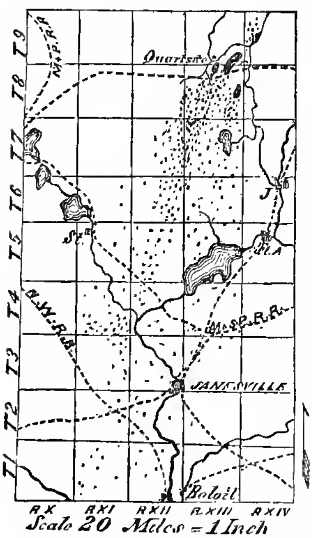
III.—In the Trough of the Green Bay and Rock River Valley.

Ft. Howard, Sec. 10, Bennett's quarry, Duck creek	S. 29° W.
" " North quarry	S. 20° W.
Peshtigo, T. 30, R. 22, Sec. 4, near center	S. 41° W.
Peshtigo, T. 30, R. 22 E., Sec. 21, E. hf. S. W. qr	S. 27° W.
Oneida Reserve, mill on Duck creek	S. 20° W.
Menasha, Sec. 11, E. hf. of S. W. qr	S. 21½° W
Neenah, Sec. 34, N. E. qr	S. 27° W.
Fond du Lac, Moore's quarry	S. 15° W.
Taycheedah	S. 15° W.
Byron, Sec. 10	S. 3° W.
Beaver Dam, Sec. 20, S. E. qr	due south.
Koshkonong Prairie	S. 7° E.
Fulton, Sec. 12, N. E. qr	S. 13° W.

III.—On the West Slope of the Green Bay and Rock River Valley.

Portland, Sec. 35, S. E. qr	S. 30° W.
Milford, Sec. 33, S. W. qr	S. 30° W.
Calamus, Sec. 18, near center	S. 36° W.
Westford, Sec. 19, middle S. E. qr.—	
First set	S. 24° W.
Crossed by second set	S. 46° W.
Trenton, McFarland's quarry	S. 50° W.
Green Lake, Sec. 36	S. 45° W.
Green Lake, Sec. 3	due west.
Ripon, Sec. 19	S. 82° W.
Metomen, Sec. 1, N. E. qr	S. 45° W.
Nepeuskin, Sec. 4, near middle south line	S. 94° W.
Nepeuskin, Sec. 15, N. W. qr	S. 87° W.
Nepeuskin, Sec. 15, near center	S. 84° W.
Black Creek, watering station G. B. & M. R. R	S. 72° W.
Peshtigo, T. 33, R. 20, Sec. 21, E. hf. of S. W. qr	S. 82° W.

Fig. 3.



IV.—Green Bay Peninsula, Fiord Region.

Liberty Grove, T. 31, R. 28 E., Sec. 25, near North Bay.	
First set	S. 9° E.
Crossed by second set	S. 4° E.

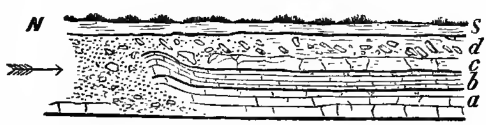
Besides the striæ, there is abundance of evidence from other sources, testifying to these movements. Where Archæan masses protrude through the Paleozoic formations, as in the towns of Berlin, Marquette, Green Lake, Portland and Waterloo, trains of bowlders stretch away from them in the direction of glacial motion. In the latter case these trains have been traced to the southern line of the state, 50 miles distant, as illustrated in the accompanying map.

Evidence of a similar nature, though less conspicuous, is furnished by drift from peculiar beds of Paleozoic formations.

In addition to this, the contour of the rock surface furnishes corroborative testimony. Elongated domes of rock having a linear arrangement, with their longer axes parallel to each other, indicate the direction of the moving ice. In the same way elongated drift hills and ridges, often of a very great length, indicate the direction of movement, either because they lie in it, in which case they have a rounded, flowing contour, or because they lie transverse to it, in which case they usually have a sharp or irregular outline. On the east side of the Kettle Range, in the region of southwestward-pointing striæ, the rock ridges and drift ridges of flowing outline have a westerly or southwesterly trend. On the west side of the Range and adjacent to it, they have a southerly or southeasterly inclination. In the upper portion of the Rock River valley, they are often exceedingly conspicuous in their southerly, southeasterly or southwesterly trend according to their position within, on the east, or on the west of the main line of glacial movement. The persistency and uniformity of this arrangement in Dodge and Jefferson counties is something remarkable. As will be observed, in all these cases, the arrangement of this class of drift hills corresponds to the direction of the glacial grooves.

In this connection we need to consider some *peculiar phenomena* that occur at Mr. Smith's quarry, near Burlington, and at Mr. Castleman's, in East Troy. The position of these quarries is such as to make the following facts of much interest in relation to the Kettle Range, aside from that which attaches to them independently. The accompanying sketch represents a vertical section along the east side of Smith's quarry. The upper four or five feet consist of soil and debris resting upon the regularly bedded argillaceous limestone. The upper portion of the loose material is a marly clay of dark reddish brown color, and partly stratified. The lower portion is made up of fragments of the limestone that forms the body of the quarry, imbedded in sand, clay, and gravel. The blocks of limestone are angular and unworn, and sometimes not even separated from the layers with which they were contiguous before disturbance. They are almost uniformly tilted, so as to dip at high angles toward the south or southwest, as represented in the figure. The number of the titled blocks is so great, and their position so constant, that the phenomena cannot be regarded as a mere chance occurrence.

FIG. 4.



a. Solid beds of limestone. *b.* Shaly beds. *c.* Thick layer of limestone fractured at the left. *d.* Drift containing tilted blocks of limestone.

The surface of the undisturbed rock is frequently smoothed, but no distinct striæ could be found. On the opposite side of White river, five or six rods distant, the surface is thoroughly smoothed, but presents no striæ, and although planed to a general level, undulating portions are smoothed in a way not readily attributable to ice. Taken altogether, the phenomena seem to point to original polishing by glacial agencies, and subsequent modification by water.

In the northern part of the quarry, the strata are removed to a lower level. The upper layer represented in the sketch is firm and compact, but fractured, as shown. Just below this lies a softer and more yielding shaly layer. At the left, where unprotected by the layer above, it is sharply arched. Unfortunately, debris obscured the section beyond this point. Enough, however, was removed to show all the essential features.

At Castleman's quarry the loose pieces were tilted more irregularly, but the surface of the rock is smoothed, and some obscure striæ are to be found whose direction is S. 45° to 50° W.

The combined import of these facts is, that the force producing the phenomena acted from the northeast. This demonstration is the more important since we have little other evidence of a decisive nature relating to the direction of glacial movement in this region. But such evidence as can be derived from the drift and topography corroborates this conclusion.

The combined testimony of these several witnesses establishes, beyond question, the remarkable character of the glacial movements above indicated. The accompanying diagram (Plate VII) exhibits these movements to the eye. The outlines of the main rivers, and the principal bodies of water, are indicated by dotted lines. The rock ledge that forms the eastern margin of the Green Bay valley is indicated by a line of small crosses.

Fiords. In addition to what has been said, the peninsula lying east of Green Bay, merits special consideration, by virtue of its peculiar features. The Green Bay side of the peninsula is high, bold and precipitous, while the Lake Michigan shore is low and inconspicuous. But while the two sides are in striking contrast in this respect, they are conspicuously similar in the deep indentations that characterize either side. And that which gives especial interest to this is the correspondence that exists between them —*they are in pairs.* At the extreme north is Hedge-hog Harbor, opposite which, to the southeast, lies Big Sandy Bay, with a lake between them. A little south lies Ellison's Bay, and over against it Rowley's Bay. A few miles further south we find Sister Bay mated with North Bay. At an equal distance farther south Eagle Harbor stretches far in toward Douglas' and Bailey's Harbors. Again, Fish Creek and Kangaroo Lake form a pair, and Egg Harbor is linked across to White Fish Bay by lakes and streams, while Sturgeon Bay well nigh severs the peninsula, and Little Sturgeon Bay is wedded to the estuary-like Ahnapee river. Nor is this a mere arbitrary or fanciful linking. By consulting the topographical map accompanying this report, it will be seen that deep valleys connect these indentations, and that a depression of less than 100 feet would reduce the peninsula to a linear

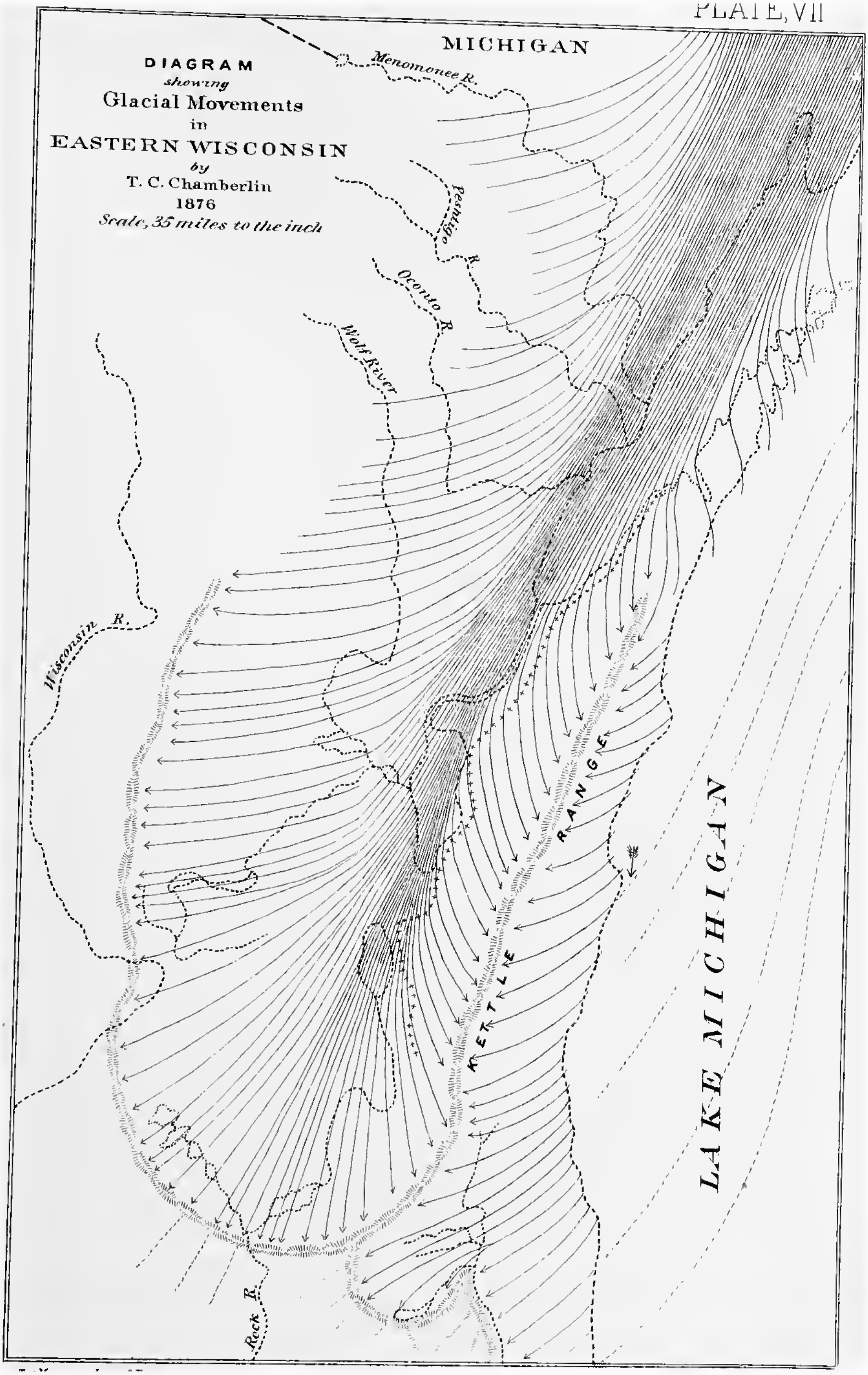


DIAGRAM
showing
Glacial Movements
in
EASTERN WISCONSIN
by
T. C. Chamberlin
1876
Scale, 35 miles to the inch
MICHIGAN
Menomonee R.
Peshtigo R.
Oconto R.
Wolf River
Wisconsin R.
Rock R.
KETTLE RANGE
LAKE MICHIGAN

group of islands, whose counterpart we now have in the chain that stretches onward to the north.

Near North Bay the surface of the rock is beautifully striated in a direction varying from S. 1° W. to S. 13° E. These striæ are near the summit of a slightly elevated but nearly level area, and present no indications of local modification. An inspection of the more accurate maps shows many features in the outline of the inlets and coast that harmonize with these south and south-easterly groovings. The conclusion is forced upon the mind that the inlets are glacial troughs, *fiords*, perhaps, we should call them, though they were not formed by the descent of a glacier from the interior of the peninsula toward the coast on either side, but by the passage of the ice mass *across* the peninsula, forming the indentations on the Green Bay side, in its *ascent* of the ridge, and those on the Lake Michigan side in its *descent*. The charts of the U. S. Lake Surveys show that, with this explanation, the term fiord is entirely applicable. These troughs are continued far out under the surface of the water. On the Lake Michigan side they reach from twelve to fourteen miles at least from the heads of their respective bays. At from eight to ten miles out they show a tendency to curve to the southward, i. e., to take a direction more nearly parallel to the axis of the great depression in which the lake lies. Prof. N. H. Winchell has called attention to some of these features, and has associated them in a very interesting way with the general glacial phenomena of the region.[1] I was not aware, however, at the time the fiord-like characters first forced themselves upon my attention that he had used the same term to characterize them.

GLACIAL DRIFT.

I. Moraines.

1. Kettle Range. The term "*Potash Kettle Range*" has been popularly used to designate an extensive series of drift hills and ridges in eastern Wisconsin, whose full extent and relationship were unknown previous to the investigations of the present survey, and concerning the true nature and origin of which, diverse opinions have been held. As the term "Potash" has no special significance in this connection, it will be discarded. The northern terminus of the range lies in the town of Casco, Kewaunee county. From this

[1] The Glacial Features of Green Bay of Lake Michigan, with some observations on a probable former outlet of Lake Superior. Am. Jour. of Science and Arts, Vol. II, July, 1871.

point it stretches away to the southwestward, through the counties of Manitowoc, Sheboygan, Fond du Lac, Washington, Waukesha, and into the northern portion of Walworth. At this point it divides, one portion extending southward, through the towns of Richmond and Darien, thence eastward, though not at this point conspicuous, to Lake Geneva, whence the main portion extends northeastward to the vicinity of Burlington, and then southward into Illinois. The other portion, branching from the main range in the town of Whitewater, about twenty miles north from the state line, extends westward to Rock River, after crossing which, it curves gradually to the northward, and enters the district examined by Professor Irving, and will be found described and mapped in his report in this volume. A portion of this part is outlined upon the accompanying diagram for the convenience of the reader.

The peculiar feature of this range that gives rise to its descriptive name, consists of numerous depressions in the drift variously known as "*Potash Kettles*," "*Kettles*," "*Potholes*," "*Pots and Kettles*," "*Sinks*," etc.[1] Those which have most arrested popular attention are circular in outline, and symmetrical in form, not unlike the homely utensils that have given them a name.

Occasionally they approach the form of a funnel, or of an inverted bell, while the shallow ones are mere saucer-like hollows. But it is important to observe that large numbers of these depressions are not perfectly circular, but rudely oval, oblong or elliptical, or are extended into trough-like, or even winding hollows, with irregular departures from all these forms.

In depth, these depressions vary from the merest indentation of the surface, to bowls sixty feet or more deep, while in the irregular forms the descent is not unfrequently more than one hundred feet. In most of these cases, however, the rim is irregular. Symmetrical cavities seldom exceed sixty or sixty-five feet in depth. The slope of the sides varies greatly, but in the deeper ones it very often reaches an angle of 30° or 35° with the horizon; or in other words, is about as steep as the material will lie. In horizontal dimensions, those that are popularly recognized as kettles seldom exceed 500 feet in diameter; but considered with reference to their origin and structural nature, they cannot be limited to this dimension, and it may be difficult to assign definite limits for them. One of the peculiarities of the range is the large number of small lakes without inlet or outlet that dot its course. So true is this, that in field work I soon learned to anticipate the

[1] Compare, On the Fresh Water Glacial Drift of the Northwestern States, by Charles Whittlesey, Smithsonian Contributions to Knowledge. 1866.

position of the Range from the distribution of these lakes on the map. Some of these are merely ponds of water at the bottom of typical kettles, and from this they graduate by imperceptible degrees into lakes of two or three miles in diameter. These are simply kettles on a large scale.

Next to the kettles themselves, the most striking feature of this peculiar formation is their counterpart in the form of rounded hills and hillocks, which may not inaptly be called inverted kettles. These give to the surface an irregularity sometimes designated, not inappropriately, as knobby drift. The trough-like, winding depressions have their counterpart in sharp, serpentine ridges. The combined effect of these elevations and depressions is to give to the surface an entirely distinctive character.

These features, however, may be regarded as subordinate elements of the main range, since these hillocks and depressions are variously distributed over its surface. They are usually most abundant upon the more abrupt face of the range, but occur in greater or less degree on all sides of it, and in various situations. Not infrequently they occur extensively distributed over comparatively level areas adjacent to the range. Sometimes they prevail in the valleys, the adjacent hills being free from them; and again they are present upon the hills, but are wanting in the adjacent valleys. These facts have an important bearing in considering the question of their origin, which may best be deferred until all the facts are presented. The range itself is of composite character, being made up of a series of essentially parallel drift ridges that unite, interlock, separate, appear and disappear in an irregular and intricate manner. At least four of these subordinate ridges are often clearly discernible, and at points the number is considerably increased. Associated with the main range, there are occasionally sharp gravel ridges, known as "hog's-backs," rising as abruptly as the nature of the material will admit, to the height of 20 or 30 feet, and occasionally to 60 feet, or even more. These usually lie upon the flanks of the more massive ridges, and are distinguished from the serpentine ridges spoken of before in no essential way except in their greater size, extent and distinctness. It is usually between the parallel ridges, and occupying depressions evidently caused by their divergence, that most of the larger lakes associated with the range are found. Ridges running across the general trend of the range, as well as transverse spurs extending out from it, are not uncommon features. The component ridges are themselves exceedingly irregular in height and breath, being often much broken and interrupted. The combined effect of all the foregoing features is to give to the formation an exceedingly irregular and complicated aspect. It is apparently the equivalent of the Kames of Scotland, and Prof. Geikie's graphic description is specifically applicable to our Kettle Range:

"The sands and gravels have, as I have just said, a tendency to shape themselves into mounds and winding ridges, which give a hummocky and rapidly undulating outline to the ground. Indeed, so characteristic is this appearance, that by it alone we are often able to mark out the boundaries of the deposit with as much precision as we could were all the vegetation and soil stripped away and the various subsoils laid bare. Occasionally, ridges may be tracked continuously for several miles, running like great artificial ramparts across the country. These vary in breadth and height, some of the more conspicuous ones being upwards of four or five hundred feet broad at the base, and sloping upwards at an angle of 25° or even 35° to a height of 60 feet and more, above the general surface of the ground. It is most common, however, to find mounds and ridges confusedly intermingled, crossing and recrossing each other at all angles, so as to enclose deep hollows and pits between. Seen from some dominant point, such an assemblage of *kames*, as they are called, looks like a tumbled sea—the ground now swelling into long undulations, now rising suddenly into beautiful peaks and cones, and anon curving up in sharp ridges that often wheel suddenly round so as to enclose a lakelet of bright, clear water."

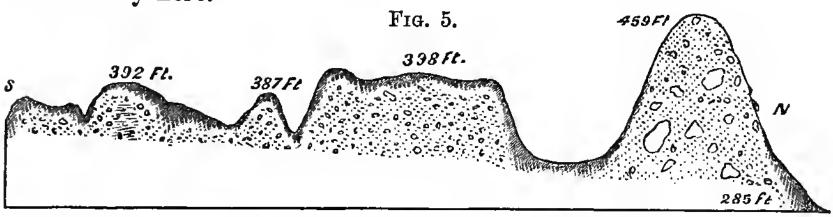
The *width* of the Range is from one to ten miles, and its peaks occasionally rise 300 feet above its base.

Gravel, sand, bowlders and clay constitute *the material* of the Range, and are variously intermingled in its composition. On the whole, gravel is the most prominent element exposed to observation. It is usually coarse but very irregular, and frequently full of rounded bowlders. It is to be noticed that the cobble stones are *spherically* rounded and not flat, as is common in the beach gravel along Lake Michigan. They are chiefly composed of the magnesian limestone of the region. *The sand* is usually associated with the gravel, and it is only occasionally that a deposit of pure sand, free from gravel or bowlders, is found. *The clay* is usually of a light color, moderately tough, calcareous in composition, and contains imbedded in it erratics of all sizes from those more than ten feet in maximum diameter down to pebbles. Bowlders of Archæan rock are subordinate in numbers to those of the Paleozoic formations, except where clustered in particular localities, as occasionally happens. But from the fact that no Archæan formation is known to exist near the Range, the special distribution of this class of bowlders is of little importance. Quite the contrary, however, with the limestone erratics, which are especially demonstrative of its origin and formation.

Near Burlington there is an exposure of a thin-bedded, rather argillaceous dolomite, different from any seen elsewhere, and containing the Trilobite, *Illænus imperator*, in considerable numbers, with but few other fossils. Nothing that could be mistaken for it by a careful observer has yet been found elsewhere in the state. In the Kettle Range, southwest of Burlington, large quantities of this rock are found, and at heights very considerably above the present surface of the rock. The blocks are usually somewhat worn, but still sub-angular. Their identity is put beyond question by the presence of *Illænus imperator*.

Passing northward along the Range, in the town of Whitewater, there appear large masses of the subjacent Galena limestone, distributed upon and through the drift, being found at from 150 to 175 feet above the bed rock in the vicinity. These erratics are frequently very little worn, and in one case a stratified mass that seemed to have been bodily transported was found at least 100 feet above the bed rock. Metamorphic and igneous erratics occur in great abundance and variety here.

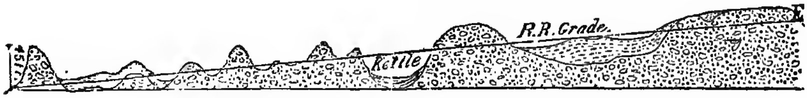
FIG. 5.



Section of the Kettle Range on the line of the C., P. & L. S, R. R., southeast of Whitewater. The figures show the elevation above Lake Michigan. The north ridge is composed of exceedingly coarse, mixed material.

In the towns of Palmyra and Eagle where the Range crosses the Cincinnati group, large quantities of the peculiar areno-argillaceous and calcareous shales, belonging to the lower portion of that formation, and which on the east side of Lake Winnebago lie at from 175 to 200 feet below the upper face of the group, are found in the ridges of the Range. It is a soft rock that could not resist much abrasive action, and yet it predominates in some of the ridges over all other forms. It contains an abundance of small linguloid fossils, rendering its identification beyond question. Although so abundant here, these bowlders are found but very rarely except for six or eight miles along the Range where it crosses the formation from which they were evidently derived. They are most abundant in the ridges on the west side of the Range.

FIG. 6.



Profile across the Kettle Range from Eagle westward.

In the same region, *bowlders of clay*, which probably originated in the argillaceous layers of the Cincinnati group, occur, imbedded in the common drift mass.

Immediately beyond this, in the northern part of Eagle, and onward, where the range passes over the thick, heavy beds of the Niagara Group, the drift is characterized by great blocks of that formation, often but little eroded. Here, as well as southward, there is present a very considerable portion of well-worn, white, compact, fine-grained, often cherty, dolomite, that probably came from the Waukesha beds of the Niagara Group, on the east side of the Range.

When we reach the central and northern parts of Washington county, large quantities of dolomitic sand enter into the composition of the drift. This is especially true of the eastern flank. The sand arises unquestionably from the crushing of the granular dolomites of the Racine limestone, which is the prevailing rock to the east and which underlies the Range in part in this region. The northern and southern limits of this sand are very nearly coincident with the northern and southern limits of the granular rock in the vicinity of the Range.

Large bowlders of brecciated limestone, containing *Pentamerus oblongus*, are found in this region, and on the west side of the Range in the towns of Kewaskum, Ashford and Auburn, beds crowded with this fossil are found *in situ*.

In the northern part of Sheboygan and the southern part of Manitowoc counties, blocks from the Upper Coral and Racine beds, along which the ridge runs, form the most marked constituent of the drift, and similar facts are true to the extremity of the Range.

It appears then that throughout its extent, the neighboring or underlying rock has contributed a noticeable element to the composition of the Range. To this extent its *local origin* is clearly demonstrated. At the same time it is an equally conspicuous fact that there is present at all points a large percentage of material which had a more remote origin. It is not difficult at a single point to find specimens representing several of the formations of this state besides those of Michigan. *Native Copper* is found quite frequently at all points along the Range, and must have traveled from one to three hundred miles. It is evident then that the agency which produced the Range, *gathered its material all along its course for at least three hundred miles to the northward, and that its largest accumulations were in the immediate vicinity of the deposit.*

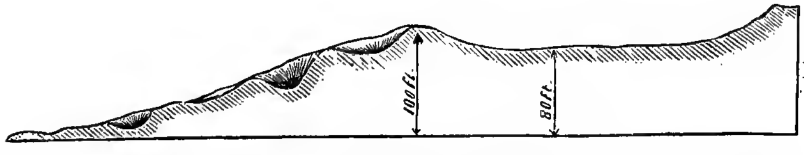
Structure.—The formation presents both the stratified and unstratified condition. If we could trust to such exposures as we see along highways and streams, the stratified condition would unquestionably be considered the prevailing form of structure, but these are very often deceptive. The flanks of all drift ridges become stratified by wash, winds and gravitation, whether originally so or not, and the excavation of a road or stream is much more apt to expose this portion than the real nucleus of the hill. The deeper excavations that have been made, however, demonstrate that to a large extent, at least, the core of the Range is unstratified.

A few additional features deserve consideration, among which is *the comparative abruptness of the opposite slopes of the Range.* In treating of this and the following topics, reference will be had chiefly to the eastern and main portion of the Range, since the recurving western branch is not sufficiently conspicuous to render observations of this kind of special value.

In the town of Randall, Kenosha county, the eastern face is quite abrupt. Between Burlington and Lake Geneva, the more abrupt face is toward the northwest. The same is true in the towns of Richmond, Whitewater, La Grange, Palmyra, Eagle, Ottawa, and Delafield. In Washington county the difference in the abruptness of the two sides is less marked, but the general truth is the same. Likewise in Sheboygan county, in general. In the towns of Plymouth and Rhine, the eastern face is well defined, but the fine development of kettles, mentioned and figured by Col. Whittlesey, occurring near Greenbush, lie upon the northwestern flank, and the western face in the town of Rhine is also sharply limited, and the peculiar features of the Range are more strongly marked on this than upon the opposite side. In Manitowoc and Kewaunee counties both flanks as well as the whole Range are much subdued and neither presents sharp outlines.

It is a general and, indeed, a pretty well sustained fact that the westward face of the Range is the more abrupt, and that the more conspicuous peculiarities of the formation lie upon that side. Long, sharp ridges, termed hog's backs, occur in Walworth and Waukesha counties, flanking the main ridge, but have no counterpart upon the east side of the Range.

FIG. 7.



Profile across the west branch of the Kettle Range south of Whitewater, showing the position of the "kettles" on the northern slope.

The general relationship of this Range to the rock terrane that underlies it has already been stated under the head of Topography, viz.: that the southern portion rests upon its crest, and the northern upon its eastern slope. Instead of lying along the ridgepole of this rocky, one-sided roof, the northern end has slid half way down to the eaves. But something more of detail as to its topographical relations is needed.

Beginning again in the town of Randall, its abrupt face looks out eastward upon a comparatively level surface with no intervening land of equal height between it and the lake. The opposite side in the town of Walworth is also higher than the surface west of it. The Range between Burlington and Geneva faces higher land on the opposite side of the White river. In the northwestern part of Walworth county there is a broad area of much lower land to the northwest, while on the opposite side of the Range the surface rises toward Elkhorn, which is the highest portion of the county. The surface in Mukwonago rises higher than that of the Range in Eagle, and in Waukesha county generally, the surface is higher to the east than the base of the Range, although its peaks are the highest points in the county. Throughout Washington county, except along the northern line, the ridge is conspicuously higher than the surface on either hand. In Sheboygan and Fond du Lac counties, it is much higher than the surface east, but barely equals the highlands of Taycheedah, Empire and Eden on the west. Beyond this it is higher than the surface east, but lower or barely equal to that west.

It should be borne in mind that these comparisons have reference to the *summit* of the Range, and that the base may be reckoned 200 feet lower on the average. This fact is the more important, since in considering the question of its origin, the elevation of the base and not of the summit is the important consideration.

Taking this into account, it becomes a conspicuous fact that, setting aside the irregularities near the state line, the Kettle Range in the southern portion is flanked on the east by higher lands, that near the center it attains the supremacy, and that in the northern portion it is overtopped by highlands on the west.

This is not to be considered as at variance with the statement already made in reference to the rock ridge that underlies it, for the highlands to the east of it in the southern portion are great drift hills, but of regular, rounded contour as previously described.

And I may here again call attention to the fact that the hills and ridges on the east of the range have an east-west trend, and those on the opposite side, a north-south trend, or unessential variations from these.

All these facts, which have been matters of careful attention, are of supreme importance in considering the origin of this remarkable formation.

The summit altitudes of a few of the more prominent points will be of interest in this connection. Others, if desired, may be found in the list of elevations previously given, or, in a general way, by reference to the topographical map.

In Sec. 36, S. hf., S. E. qr., Randall, near the state line	340	feet.
Near the state line in the towns of Linn and Walworth, above	400	"
The observations not being sufficiently reliable to warrant a more exact statement.		
Tree Bluff, Sec. 24, near center, Whitewater	457	"
Bald Bluff, Sec. 33, S. E. qr., Palmyra	463	"
Government Hill, town of Delafield	611	"
Lapham's Peak, Sec. 14, Erin	824	"
Sugar Loaf in Sec. 24, near middle S. line, Hartford	740	"
Hill near middle S. line, Sec. 2, Mitchell	580	"
Top of Range, N. W. qr., Sec. 5, Memee	348	"
Last prominent hill in the Range at the north, middle W. hf., Sec. 13, Casco	235	"

The Range then reaches its culmination in Lapham's Peak, 824 feet above Lake Michigan. Several of these hills rise from 150 feet to 250 feet above their immediate bases. The depth of the drift cannot be less than 300 feet at many points along the ridge, from which we see that the accumulation is vast, and that the force that heaped it up must have been powerful.

The foregoing facts gather themselves into a mass of evidence whose force is altogether irresistible. *The Kettle Range is evidently a gigantic moraine.* The main Range from Kewaunee county to Walworth county marks the westward limit of the glacier that occupied the basin of Lake Michigan, and the eastern limit of the one that plowed through the Green Bay valley. The branch that extends southward into Illinois, is the continuation of the terminal moraine of the Lake Michigan glacier. The branch that recurves through the northern part of Rock county and thence northward, is the terminal moraine of the Green Bay glacier, upon that side.

Neither of these indicates the extreme limits of the glacial movement, for in the eastern part of Rock county, although striæ are absent, the contour of the hills, together with the composition of the drift, show that the movement was from the eastward. In the vicinity of Beloit, fossils of the Racine limestone are common. On the other hand, the train of bowlders extending southwestward from the quartzite in the towns of Portland and Waterloo, stretches directly across the Range and onward into Illinois. It seems evident, then, that before the formation of the Kettle Range, the glacial movements were essentially the same as they were subsequent to its formation, and that its accumulation was due to unusual conditions affecting the rate of the recession of the glaciers. The structure of the Range seems to indicate an alternating retreat and advance of the ice-mass. During the former, debris was thrust out at the foot of the melting mass, which, when the glacier advanced, was plowed up into immense ridges.

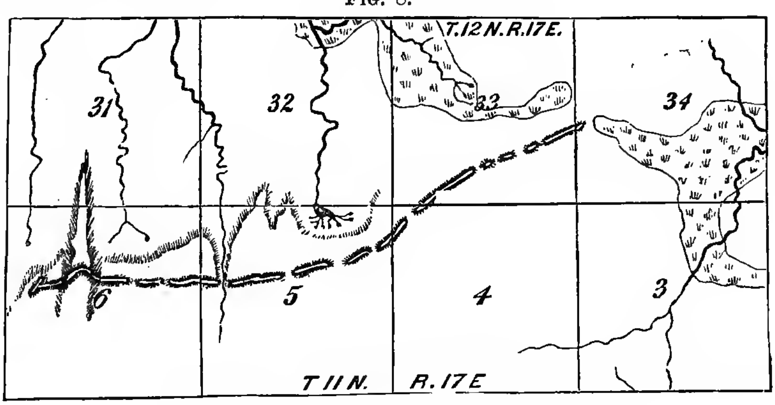
If this process be supposed to be repeated several times, parallel ranges will be accounted for, and the irregularities incident to such retreat and advance will explain the complexity of the Range. Where the later advances were equal to the earlier ones, the whole accumulation of drift material would be forced into a single massive ridge. Where any advance failed to equal a former one, an interval between the accumulations of the two would result, giving rise to a depression whose form would depend upon the relations of the two accumulations, but would, in general, be more or less trough-like in character. Where tongues of ice were thrust into the accumulated material, a serrated edge or projecting spurs and corresponding indentures would result. If masses of the ice became incorporated within the drift, as has been suggested, their subsequent melting would give rise to a depression constituting one form of the kettles which characterize the range. The suggestion just made, with reference to the irregular advance of the ice mass, accounts for other forms, and at the same time for the irregular hills, mounds and ridges that are so conspicuous a feature of the Range.

Certain of the "kettles" may have an origin diverse from either of the causes above suggested. A portion of the material of the formation is a loose quicksand, easily removed by the action of water. The irregular surface of the Range, and its porous character, facilitate the collection of water, which issues from its base in numerous perennial springs; indeed, in some cases, brooks of no inconsiderable size flow full-fledged from its base. These are entirely competent to carry away, through their underground channels, quicksand and similar material, thus undermining the surface and causing a depression. It may be prudent to remark in this connection, that depressions altogether similar to many of those under consideration occur within eastern Wisconsin, which are manifestly due to very different causes. One of these is the well known formation of sink-holes in limestone districts, by the dissolving out and removal of the rocks by underground drainage. Of similar nature to these are those cases in which the drift, by its open nature, furnishes underground channels of drainage. A marked instance of this kind occurs in the vicinity of Beloit. During the spring of 1876 and 1877, a very considerable stream flowed for several weeks into a shallow basin, and was entirely lost. Another class, but of insignificant importance, is due to the action of lakes, in throwing up ridges across small bays or indentures along their shores. These, however, are rarely so symmetrical as to be misleading, and their situation is such as to readily indicate their origin.

In the vicinity of the Kettle Range proper, and at several localities more or less distant from it, there are areas presenting a similar undulating surface, marked by the peculiar hills and basins that characterize that formation. These unquestionably owe their origin to a similar cause, save that it was local and circumscribed in character. Owing to their limited extent and general inconspicuous character, they do not require extended or special description in this connection. One of the best examples of this class is to be found in the vicinity of Rock Lake, in Jefferson county.

2. Minor Moraines. It will be most convenient to consider in this connection certain minor morainic features of no very great extent or importance in themselves, except from their interesting character. The most noteworthy of these occurs in sections 4, 5 and 6 of the town of Herman, and in sections 33 and 34 in the town of Theresa, Dodge county. It consists of a narrow, well defined ridge, rising not usually more than twenty feet in height, extending in a general easterly and westerly direction for a distance of about three miles, with occasional interruptions where it is crossed by streams and dry runs. The accompanying rude map shows its topographical character and relations. At its western extremity it is terminated by a remarkable transverse ridge, oblique to the main range, as is imperfectly represented on the map.

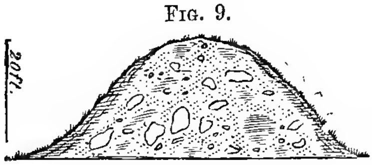
FIG. 8.



Map of Moraine in the towns of Herman and Theresa.

Near the western extremity, there is a conspicuous north and south *drift* range, over which the minor ridge under consideration passes; and in doing so, *it curves to the northward* in a very peculiar manner. Throughout sections 5 and 6, the ridge lies upon an elevated table-land or plateau formed of *drift material.* To the east of this it gradually curves to the northeastward and descends to a considerably lower level, the eastern extremity being very much lower than the western. The two peculiarities worthy of special notice are the fact that it is a drift ridge, superposed upon an evidently earlier drift formation, to whose surface configuration it conforms in a measure, and the fact that its elevation is markedly different in different portions. These facts are sufficient to show of themselves that it could not be formed by the action of water, since no supposable warping of the earth could bring it into such a position as to constitute the margin of a lake or other body of water supposed to be capable of forming such a ridge, and for the same reason its origin cannot be attributed to floating ice. In addition to these facts, its structure and the material of which it is composed, forbid such a supposition. It is composed of confusedly intermingled coarse and fine unstratified material. A large number of bowlders of various classes of rocks — Paleozoic and Archæan — are imbedded in sand, gravel, and clay, in most promiscuous confusion, and in some cases in such a position as would forbid the supposition that they were deposited upon the surface of a gradually accumulating mass. In one instance a mass of finely laminated clay, apparently a clay bowlder, was found surrounded by the commingled unstratified material. The accompanying figure illustrates the general nature of the structure of the ridge. It is apparently due to a local advance of the thinned edge of the glacier upon the surface of drift already deposited, rolling up the ridge in front of it. It will be evident that such an advance would be retarded by the north and south ridge in section 6, if the thickness of ice were inconsiderable, and at the same time its melting hastened, which accounts for the peculiar flexure of the moraine in crossing it.

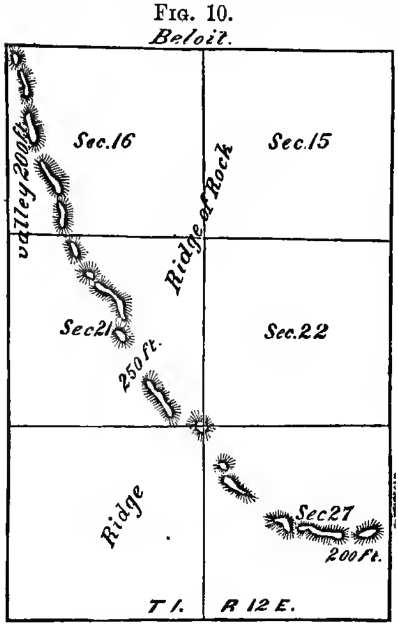
Fig. 9.



Section of Moraine in Town of Herman.

A similar chain of hills and ridges occurs in sections 16, 21 and 27 in the town of Beloit. The base of the chain at its eastern extremity has an elevation of about 200 feet above Lake Michigan. As it extends northwestward, the surface upon which it rests rises until the moraine rests upon the crest of a rock ridge, at least 250 feet in elevation, over which it passes obliquely and descends into a preglacial valley. The material of this chain is chiefly composed of rounded, well-worn limestone gravel, mingled with a large proportion of sand, and more or less clay, with occcasional small bowlders, as in the preceding case. No flexure of the crust can be supposed to have taken place, capable of bringing the bases of these hills and ridges to the same level, which would be necessary in accounting for them by the action of water or floating ice. Besides, the general configuration of the adjacent country and the nature of its superficial deposits preclude the idea of submergence of either side of the range.

Fig. 10.



Moraine in the town of Beloit.

Another case occurs in the valley of Grand river, between the village of Markesan and Manchester, in Green Lake county. The chain of drift hills stretches across the main valley, which is occupied by the Grand river, and was doubtless originally the cause of the detour which that stream makes through the site of the village of Markesan. In all of the three cases above mentioned, the general direction of the ridges is *transverse* to that of glacial movement, which harmonizes with the view here entertained, that they are terminal moraines.

II. Bowlder Clay, or Till.

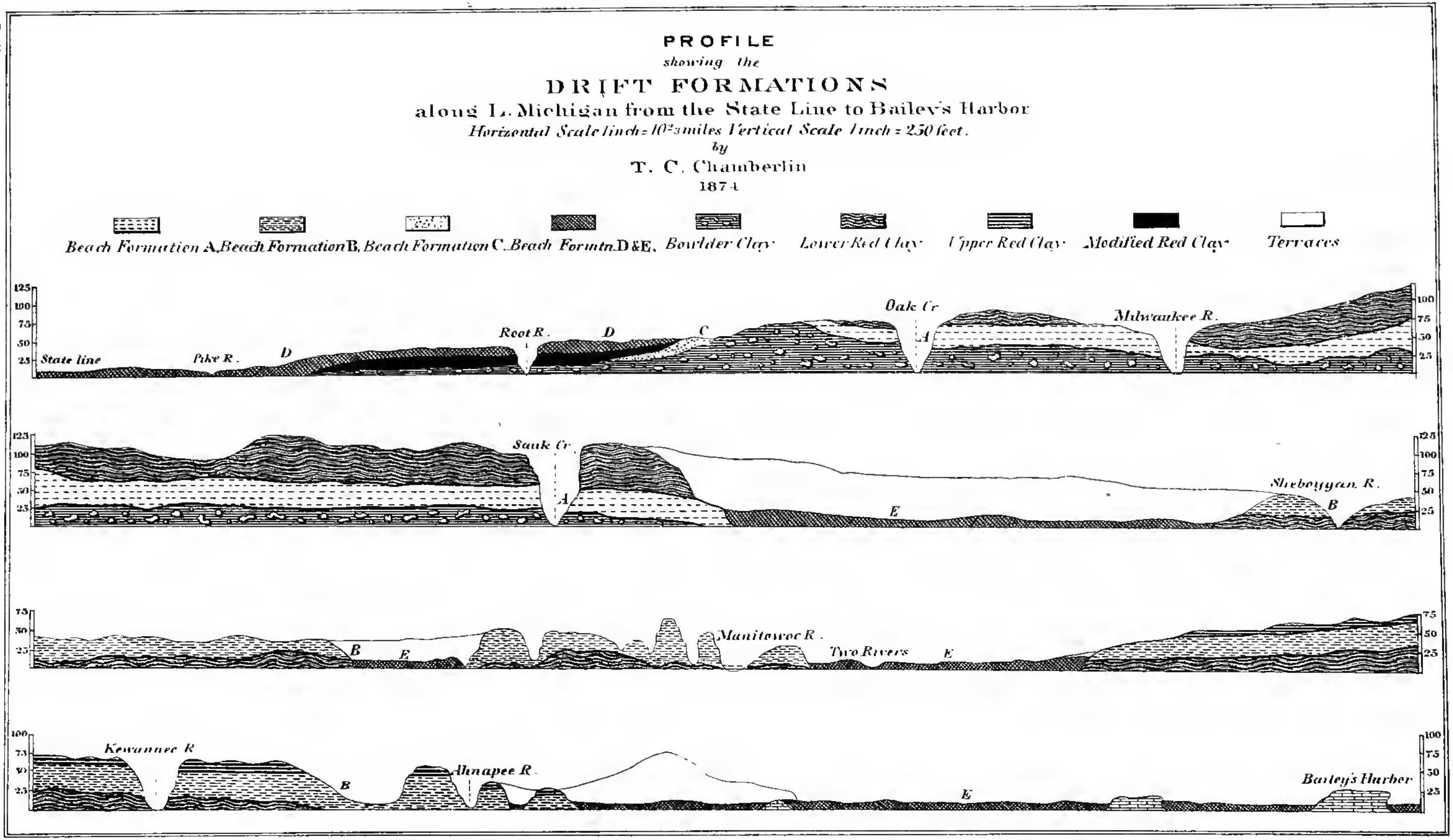
Reference has already been made to the fact, that, previous to the formation of the great moraine, the Kettle Range, the glacier pushed southward in the Rock river valley, abrading the surface, modifying its contour, and finally, on its retiring, left the material strewn upon the surface. This constitutes the earliest drift formation within the limits of the district under consideration. It consists of a commingled mass of clay, sand, gravel, and bowlders variously arranged with reference to each other, and spread out irregularly over the surface of the rock below. As would naturally occur under the circumstances, a portion of this is sorted and stratified, forming beds of brick clay or of sand or of gravel, and leaving in certain localities accumulations of coarser material. This action took place in part simultaneously with the formation of the deposit, and so these rearranged and stratified beds, mingle irregularly with the unsorted material. Taken as a class, this constitutes the original glacial deposit or ground moraine, and in this report it is known by its most characteristic feature, Bowlder Clay, or by the term Till.[1] That portion of the bowlder clay which antedates the formation of the Kettle Range merges into that formation, and on the opposite side, a precisely similar deposit of bowlder clay takes its origin from the great moraine and spreads over the remaining area of the district, although overlaid in part by subsequent formations. So it appears that the Kettle moraine is simply a peculiar and irregular aggregation of this wide-spread ground moraine. In relative age then, a portion of the Bowlder Clay is older than the Kettle Range, and a portion, more recent, there being no essential distinction in character between the two parts.

If we descend to a more special and critical examination of the material of this formation, *the clay*, the chief element, will be found to be of the most heterogeneous character. The prevailing color is blue, but it is not unfrequently reddish, greenish, earthy brown, or ashy. In texture, it varies from that which is highly plastic and adhesive to varieties so arenaceous and friable as scarcely to cohere in lumps. In general, however, it is intermediate between these extremes, being marly in character. The imbeded *bowlders* are of all sizes from those that weigh many tons downwards, and are as various in character. A large proportion of those at any given point are usually from the subjacent rock, or from some formation in the immediate vicinity, but there is usually present, a large proportion of Archæan erratics. Along the lake shore there are many bowlders that represent various formations newer than any known to exist in Wisconsin, having doubtless been derived from the basin of the lake, or from Michigan.

These bowlders show every degree of erosion. Some have not only been thoroughly rounded but have suffered much reduction in size, as is shown by the projection of the harder and more unyielding portions, giving the specimen often a unique and fanciful form. Some specimens are polished and striated on one side, but rough and angular on the others, due doubtless to their having been firmly imbedded in the under surface of the glacier, and so polished as they were forced along over the rocky surface below. Other fragments are almost wholly unmodified, though often of soft and fragile material.

[1] See *The Great Ice Age*, by James Geikie, 1874.

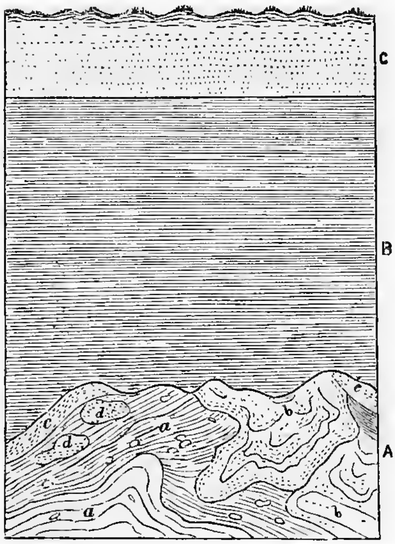
PLATE, VIII



The Milwaukee Litho & Engr Co.

Usually such specimens have been derived from the immediate vicinity, but such does not seem to be always the case.

Fig. 11.



A, Bowlder Clay. B, Stratified Red Clay. C, Stratified Sand Deposit. a, Obscurely stratified bowlder clay. b, Clayey sand. c, Sand. d, Gravel (bowlders).

An interesting peculiarity, sometimes observed, consists of cavities filled with fine uniform gravel, which presents the appearance of having been deposited in the form of *gravel bowlders*, either cemented, or, as suggested by Dr. E. Andrews, in the frozen state. These have been observed of various sizes, from six inches to two or three feet in diameter, and of irregular, though usually somewhat rounded, forms, as shown in the accompanying figure.

This figure also imperfectly illustrates the irregular stratification and lamination which frequently characterize portions of this deposit. Contorted laminations, unsurpassed by anything presented in the metamorphic rocks, are sometimes to be seen, closely associated with bowlders, stratified clays, pockets of gravel, stratified sand deposits, gravel beds and unstratified hard pan, constituting a most changeable and irregular structure. The surface area of this formation is shown on Atlas Plate IV.

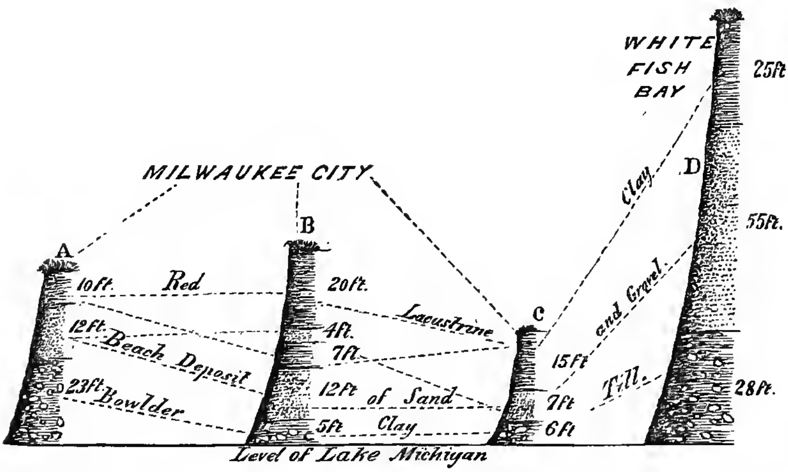
In harmony with the irregular nature of this formation, the rock here and there was left uncovered by it, and at some points it was swept away by subsequent agencies, but with these exceptions, it is to be regarded as covering the immediate surface of the rock over the entire district.

MODIFIED DRIFT—CHAMPLAIN.

I. Beach Formation A.

During the deposit of Bowlder Clay, there is abundant reason for believing that the general surface was more elevated to the northward than at present. Subsequently, however, perhaps cotemporaneously with the retreat of the glacier, and possibly also the cause of its recession, there occurred a relative depression to the northward. This depression was accompanied by a vast accumulation of water in the form of fresh water lakes, which are to be regarded simply as the expanded predecessors of our present great lakes. As this water gradually accumulated and advanced upon the land, it washed out the finer material of the Bowlder Clay, carrying it backward into the still water, where it was redeposited, while it left along the beach the coarser sand, gravel and other material, forming a beach deposit. This deposit, to distinguish it from those which subsequently followed, is here designated Beach Formation A. It is abundantly exposed along the shore of Lake Michigan, above and below Milwaukee, where it overlies the Bowlder Clay and underlies a subsequent deposit of red clay. The accompanying figure illustrates its relations and relative thickness.

FIG. 12.



Sections showing the relations and magnitude of the Bowlder Clay, Beach Formation A, and Lower Red Clay, at and near Milwaukee.

The deposit consists chiefly of sand, gravel and bowlders, with included layers of clay. The material is thoroughly stratified, and exhibits most beautiful and abundant examples of cross and oblique laminæ, which indicate the nature of its origin. The *sand* is usually white or yellow, but sometimes ferruginous or dark colored. The constituent grains are of all sizes, from a fineness that renders the mass compact and almost plastic, and quite indistinguishable at the distance of a few feet from the clay bands, to a coarseness that is only arbitrarily distinguished from gravel. It is banded and laminated in the greatest variety of forms. Horizontal, oblique, undulating, and even contorted laminations, are present in variety.

The *gravel* exhibits every gradation, from sand to that which is so coarse that it is scarcely less than a bed of bowlders. It is chiefly composed of limestone, and is thoroughly water-worn, and frequently shows an oblique arrangement.

Interstratified with these beds of sand and gravel are bands of *clay*, sometimes quite pure, but more frequently arenaceous. These are usually finely laminated, most frequently in a horizontal direction. Occasionally the clay develops to a stratum of several feet in thickness, but more often it only forms narrow bands alternating with the finer grades of sand, which are also more frequently laminated in a horizontal direction than in the coarser kinds, showing that both were deposited in comparatively quiet waters.

An occasional large *bowlder* occurs in the sand and clay as well as in the gravel. Small fragments of rock, usually subangular, are sometimes seen in the clay.

The formation is subject to *rapid changes* as it is traced laterally. At one point the section may be composed almost wholly of fine sand and clay, and within forty rods, these may be entirely replaced by coarse sand and broad bands of gravel. Large lenticular masses of sand, gravel, or mixed material, are not unfrequent. This formation reaches a thickness of about sixty feet.

From its nature this deposit has a very limited *extent* as a surface formation. In the abrupt banks of Lake Michigan, it displays itself abundantly, as represented in plate VIII, which likewise shows its relation to the overlying and inferior deposits. Where it comes to the surface, it displays itself very feebly, and is scarcely distinguishable, if at all, at many points. It forms, where present, a narrow, irregular belt between the surface occupied by the Bowlder Clay and that of the Lower Red Clay.

II. The Lower Red Clay.

Lying upon the formation just described, we find a massive clay deposit. It differs most obviously from the Bowlder Clay, in possessing a deep reddish or purple color, which weathers at the surface to an ashy drab, while the Bowlder Clay, although not infrequently reddish or even purple, is usually blue or drab, and differs also in the great irregularity of its coloration. Hence the formation in question is everywhere known as the "*red clay.*" It likewise differs from the Bowlder Clay in respect to the rock fragments contained in it. In the Bowlder Clay these are extremely abundant, and of all sizes, from mere pebbles to those of many tons weight. In the Red Clay, where they are not entirely absent, they are, with rare exceptions, small, seldom exceeding six inches in diameter, and more frequently they are mere hand specimens. The great majority of these fragments are of magnesian limestone, and were apparently derived from the Silurian formations prevalent in the region. In some instances this is put beyond question by the occurrence of Niagara fossils in them. The surfaces and angles of these fragments are worn, but not to such an extent, usually, as to give them a symmetrical rounded form, and it is especially to be noted that the surface is scratched and subtranslucent instead of having an opaque, somewhat granular surface, such as arises from the wearing and solvent action of water. Occasionally a bowlder of considerable dimensions occurs within the formation, but there is a very marked difference between this formation and the Bowlder Clay in that respect. This fact becomes a very conspicuous one in examining adjacent areas, occupied by the two formations. The surface of the Red Clay is comparatively free from bowlders, while they occur in the very greatest abundance on the surface of the Bowlder Clay. It may be here remarked that there is no such abundance of bowlders on the surface of the Red Clay district as to suggest any other origin than that of wash from the formation itself[1]. The clay which constitutes the chief element is highly calcareous in character. It contains, also, a considerable portion of finely comminuted quartzose material, in addition to true aluminous clay, so that while the whole is quite compact and impervious, it yet has not that extreme toughness and adhesiveness that is possessed by the typical aluminous clays.

A considerable ingredient of magnetite, in the form of minute grains, is present. A magnet drawn through a handful of the pulverized clay usually brings forth more or less of this mineral. Along the lake shore, where the clay is washed away by wave action, the magnetite is left as a deposit of black sand, mingled with the quartz sand of the beach, whence it may be collected in large quantities. The lower part of the deposit is usually very highly laminate, and passes, by alternations and gradations, into the subjacent beach deposit. The main mass of the formation presents little indication of the lines of deposit, but upon close inspection, minute lamination may be observed. The relation of this to the imbedded rock is interesting. As the laminæ approach the fragments, the greater portion curve downward and pass beneath it, while a portion curve over it. It would appear from this fact that the fragments were dropped upon the surface of a yielding clay mass, and covered by subsequent deposit. Near the southern extremity of this formation, it has, along the lake shore, a thickness of from 15 to 20 feet. At Whitefish Bay, above Milwaukee, it is from 20 to 30 feet thick, near Ulao, 40 feet, and in the vicin-

[1] Compare Geological Survey of Ohio, Vol. II, Part 1, page 4.

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ity of Port Washington it reaches its maximum observed thickness of 75 feet, although it doubtless somewhat exceeds this at some points. At many places along the lake shore, owing to slides and washing, it appears to have a thickness considerably exceeding this.

It has a wide surface distribution, as will be seen by consulting the accompanying map. Commencing near Milwaukee, it widens to the north until the Kettle Range is reached, by which its western boundary is deflected to the eastward until it passes that barrier and swings around upon the western side, and, passing the watershed, occupies the Green Bay valley. It ascends this valley to a few miles south of Fond du Lac, and reaches up the Upper Fox river beyond Berlin, while in the Wolf river valley it extends beyond Shawano. West of the bay it appears in much less amplitude than to the southward.

From what has already been said concerning this and the underlying formations, no doubt remains that it was a subaqueous deposit. Its extent should, therefore, indicate approximately the amount of the encroachment of the lake at the time of its formation, and *the altitudes* to which it rises are significant of the amount of relative depression that attended its formation, and hence, an especial interest attaches to its vertical distribution. At its southern extremity, it reaches an altitude of a little more than 100 feet above Lake Michigan. Where its western limit crosses the north line of Ozaukee county it is about 200 feet. A few miles east of this it rises upwards of 300 feet. At the northwest corner of section 36, town of Lynden, Sheboygan county, it is 315 feet. In the town of Rhine, of the same county, the limit is found at 322 feet; at the middle of the north line of section 21, town of Memee, Manitowoc county, at 248 feet, and on the opposite side of the Kettle Range, at St. Nazian, at the same height. North of this its limitation is less well defined. There are some indications that it passed entirely over the Kettle Range, in the central portion of Manitowoc county, or at least that the waters of the period did. Nowhere north of this was it observed at a height exceeding 330 feet above Lake Michigan. Near Chilton it reaches an elevation of 372 feet; north of Stockbridge, 358 feet; south, 390; in section 6, Marshfield, 401 feet; in section 5, Taycheedah (T. 15, R. 23), 315 feet. These have been selected from a large number of observations, either because more reliable, or because more significant, on account of their positions. A more general and comprehensive appreciation of the facts may be gained by a comparison of the map of Quaternary Formations with the Topographical map, both of which will be found upon plate IV, conveniently arranged for such comparison. It will be observed that the formation rises gradually from its southern extremity to the region of Lake Winnebago, beyond which it declines. On Lake Superior an analogous clay rises at least one or two hundred feet higher.

Aside from the *general* northward depression indicated by these facts, a special flexure seems to have taken place in the region of Lake Winnebago, either of the nature of a greater depression during the time of deposit, or of a greater elevation subsequently. This fact is entirely in harmony with the concurrent indications of several peculiar features in the underlying formations and general structure of the region. It is on the basis of this general northward depression, and on the sequence of the formations, that this and the associated deposits are referred to the Champlain period.

III. Beach Formation B.

Reposing upon the Lower Red Clay, there lies a deposit of sand and gravel, with included layers of clay, reaching a thickness of 60 feet or more, and constituting a well defined formation. It differs in no essential respect, so far as its character is concerned, from Beach Formation A, which has already been described, and hence it will not receive special description here. At some points however, where the depositing waters found a rocky shore, instead of the accumulations of clay, sand and gravel, large blocks of the neighboring limestone, more or less eaten by the waters, are strewn on the shore in a manner similar to that which is now being enacted on the rocky beach of the Green Bay peninsula further north. The formation best exhibits itself along the lake shore from Manitowoc northward, where fine vertical sections may be seen, one of which is illustrated in the accompanying figure.

Fig. 13.

Profile Section on Lake Shore, near Manitowoc.

1. Lower Red Clay. 2. Sand Deposit. 3. Alternating Belts of Sand and Clay.

It becomes a surface formation between the Upper and Lower Red Clays. Appearing upon the lake shore in the vicinity of Manitowoc, its surface exposure stretches northward in the valley of the East Twin river into Kewaunee county, whence it curves slightly to the eastward into the basin of the Ahnapee river, from the valley of which it passes over the watershed into the Green Bay valley, which it skirts on the east as far south as Lake Winnebago, whence it returns on the westward slope of the valley, and runs north, parallel to its axis, until it crosses the Menomonee into Michigan. Its highest observed elevation is about 200 feet, in the vicinity of Lake Winnebago. Its section, as shown on Lake Michigan, may be seen on Plate VIII of this volume, and its surface distribution on Plate IV of the accompanying atlas.

IV. Upper Red Clay.

The description that has been given of the Lower Red Clay applies almost completely to this deposit, the only grounds for separating them being the intervention of the beach deposit which has just been described. The similar character of the clay, the angularity of the imbedded fragments of limestone, and their unweathered nature, the high color of the clay, the large content of magnetite, are likewise characteristic of this formation. It covers the northeastern corner of Manitowoc county, the eastern portion of Kewaunee county and the adjoining portion of Door county. It doubtless originally covered the entire Green Bay peninsula and was apparantly swept away by the action of the lake as it gradually retired.

Its thickness is nowhere considerable. Along the lake shore where it is best exposed, and possibly thickest, it rarely exceeds 20 feet.

In Racine and Kenosha counties, there is a yellowish clay deposit quite similar in most of its characteristics to the Red Clays, except in its color and the more frequent presence of bowlders. In addition to the evidence drawn from the nature of the deposit itself, the configuration of the country indicates the modifying action of water. It seems probable that this was more immediately connected with the melting and retreat of the glacier than the formations above considered.

V. Beach Formations C and D, and the Modified Red Clay.

Along the eastern border of Racine and Kenosha counties, extending on the average about one mile back from the lake shore, we find at the surface a deposit of sand and gravel, with a varying but subordinate admixture of clayey and marly material. The gravel is usually fine and thoroughly waterworn, and is interstratified with the sand and occasionally with clay, and almost everywhere presents beautiful examples of oblique lamination. It rarely exceeds twenty feet in thickness, and on the average is about half that amount. At its base, along the lake shore, numerous springs issue, the water being prevented from descending farther by the impervious clay that lies below.

These springs are frequently ferruginous, as are also certain bands of the deposit.

The western limit of this formation is marked by a low flat ridge, usually only six or eight rods in width, and less than three feet in height. At most points, this is composed of fine gravel, except near the state line, where it becomes sandy. The surface between this beach ridge and the lake is level and free from bowlders, but immediately to the west of the ridge, small bowlders occur, except over certain areas that are covered with lacustrine and fluviatile deposits. Here and there a stream has cut a deep, sharply-defined gorge for itself, but broad, sloping valleys are wanting.

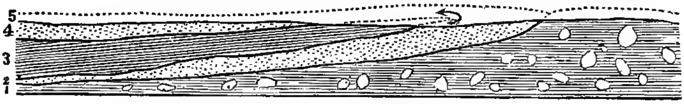
Immediately beneath the above beach formation lies a *finely laminated compact clay.* It has a prevailing reddish hue, which is at some points pronounced, but at others is bluish or dark grayish. It contains but few pebbles and very rarely anything that could be denominated a bowlder. The laminations are horizontal and often exceedingly fine. Some arenaceous layers are usually present, especially toward the top.

In the vicinity of "The Point," near Racine, this clay rests directly upon the Bowlder Clay. The line of junction is most sharply and distinctly marked. The surface of the obdurate hard-pan, which here constitutes the lower formation is sometimes planed almost like a glaciated surface, and the resemblance is enhanced at some points by parallel lines of white material, the significance of which was not ascertained. In other cases it presents an undulatory ripple-like surface, and in still others is more irregular. These observations are made possible by the distinctness of this hard-pan from the fine putty-like red clay that rests upon it. In digging it away, the red clay peels off from the surface of the lower clay, leaving it perfectly clean and distinct.

But as we trace these clays northward a stratum of yellow sand develops between the two and rapidly increases in thickness, while the red clay correspondingly, but somewhat less rapidly, thins out. Four drift formations are well shown at this point; a beach formation (D), at the top, being here a stratum of yellow sand only a few feet in thickness, the red clay (modified) next, and beneath this another beach formation (C), resting upon the Bowlder Clay, as shown in the accompanying figure.

As we advance northward, or more strictly northwestward, the three upper formations rise and disappear at the surface in succession, each seeming to have been cut off above by erosion. This is not accomplished, however, until the thinning out of the red clay, and the approach of the sand deposits above and below, toward each other, have forced the conviction that these latter really join at points where the erosion has not taken place, and that the beach ridge that I have already described marks their junction, and that they enclose the red clay deposit as an equitant leaf does its fellow.

FIG. 14.



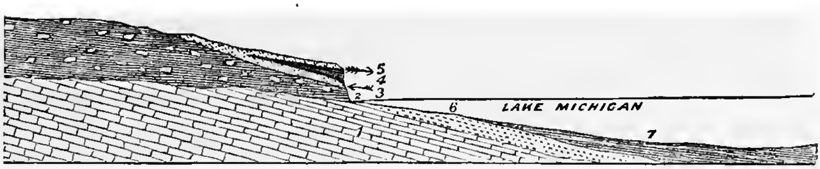
SECTION NORTH OF "THE POINT," NEAR RACINE.

1. Bowlder Clay. 2. Beach Formation C. 3. Modified Red Clay. 4. Beach Formation D. 5. Supposed Original Surface.

It seems clear that these formations were produced by an advance and subsequent retreat of the great lake. The advance was attended by a deposit of sand and gravel along the beach, where the material was acted upon by the breakers, and by a deposit of fine, clayey material on the undisturbed bottom off shore. This progressive movement continued until the position of the beach ridge already mentioned was reached, where a halt was made for a time, during which the ridge was thrown up by the waves, after which the water retired, but at a higher level than the line along which it advanced, as would be necessitated by the filling up caused by the deposits made in the interval. As the lake retired, the upper beach deposit (D) was formed, and the deposit of clay off shore continued. This explains completely the cuneate form of the clay deposit. Taken as a whole, the clay was synchronous with the beach deposits, though in any given vertical section, it was later than that below, and older than that above.

This will be made more clear by an examination of the following partially ideal figure, illustrating these formations.

FIG. 15.



1. Racine limestone. 2. Bowlder Clay. 3. Beach formation C. 4. Modified Red Clay. 5. Beach formation D. 6. Beach formation in progress. 7. Off-shore clay deposit in progress.

These formations are isolated from the red clays and beach deposits previously described, and their relations to them are not certainly established, and therefore the provisional names originally assigned them are retained; and in the absence of demonstrative evidence, and of sufficient space for the wide discussion of the Champlain deposits of the great lake region, to which a proper treatment of the subject would lead, it is deemed best to leave the question for future consideration.

The elevation of the beach ridge which marks the western limit of these deposits above Lake Michigan is as follows:

Near the Illinois line	55 feet.
A little farther north	53 "
In Sec. 18, S. E. qr. T. 1, R. 23 E.	40 "
In Sec. 1, middle S. line S. E. qr. T. 2, R. 22 E.	44 "
In Sec. 19, S. E. corner T. 3, R. 23 E.	80 "
In Sec. 29, S. E. qr. S. line T. 4, R. 23 E.	68 "

TERRACES.

Just north of the lighthouse north of Milwaukee, the bank facing the lake is low, but a few rods back there is a well defined terrace running nearly parallel to the lake shore, and rising from 50 to 100 feet above it. This continues northward, with interruptions, for several miles. A similar terrace accompanies the greater portion of the shore line between Port Washington and Sheboygan, and near Centerville there is a feeble development of the same phenomenon, beyond which it is absent for a considerable interval. Just north of Ahnapee the terrace reappears in sharp and rigid outline, and extends without essential interruption to the vicinity of Sturgeon Bay. It attains in this portion a height of 75 feet. Between the terrace and the lake a mature growth of forest vegetation, of a highly mixed character, is to be found.

Beach Ridge of Sand. In the vicinity of Sturgeon Bay, the terrace is replaced by a beach ridge of rather fine yellow sand. With limited interruptions this ridge extends to Port de Morts.

Beach Ridge of Rock-fragments. As we round the point and return on the Green Bay side, much more frequent interruptions occur from the rocky promontories that characterize this shore; and instead of being sandy, the ridge is here chiefly formed of chip-stone with partially rounded angles, and of the flat pebbles that mark a rocky beach, where the fragments are worn rather by sliding than by rolling. These form sharp ridges, sometimes rising 20 to 30 feet above their bases, on either side, and become a very conspicuous feature at Ephraim, Fish Creek, Egg Harbor, and elsewhere.

Terraces of Rock. Along this shore also, notably between Egg Harbor and the mouth of Sturgeon Bay, terraces of rock sustain a relation to the present shore altogether similar to that held by the clay terraces further south. These rise in some cases almost vertically, to a height of more than 100 feet. The distance between them and the bay varies from a few rods to half a mile or more, and the interval is strewn with water-worn fragments of rock and occasional slight beach ridges.

The three forms united. Near Green Bay (Sec. 24, T. 24, R. 21 E.) there is an inconspicuous beach ridge, formed of worn chip-stone, first appearing on the bay shore and extending a few rods, when it is replaced by a well defined terrace of red clay, which extends southward nearly parallel to the shore for about two miles, when it is in turn replaced by a low, flat, sandy ridge, which may be traced around the extremity of the bay and northward along the western side to the Menomonee and beyond.

The intimate association of the ridges and terraces here exhibited, and found less conspicuously elsewhere, leaves no doubt that they are only different phases of the same formative process.

Between the lake shore and the terrace of red clay and of rock, the surface does not usually exceed fifteen feet above the lake level. The sandy ridge that succeeds the terraces rises to the northward, reaching 44 feet in Sec. 9, T. 33, R. 29 E., being the most northern point at which the elevation was taken. The rocky or gravel ridge attains a greater height.

At Hedge Hog Harbor it is	40	feet.
At Big Sister Bay	65	"
At Eagle Harbor	53	"
At Egg Harbor	50	"
At Fish Creek	55	"

The elevation becomes less again toward the southern extremity of Green Bay. These elevations were all taken upon the crest of the ridge.

Secondary Beach Lines. Between this ancient beach and the present one, there is frequently a second well defined ridge of lower elevation, and occasionally a third. These are sometimes sandy and sometimes composed of rock fragments, like the primary ridges.

GENERAL MOVEMENTS.

The movements made by the agencies which produced the foregoing Quaternary formations are of an exceedingly interesting character. There was first the advance of the great glacier through the deep basin now occupied by Lake Michigan, and through the Green Bay valley. The diagram of glacial movements, given on a previous page cannot be supposed to accurately represent the details of the original advance of the glacier, but rather the movements at the time of its retreat; but there is sufficient evidence to warrant the general statement that the original advance was along the two great valleys mentioned. Then came the melting away and the consequent retreat of the ice mass, leaving strewn over the surface the Bowlder Clay, and by a great halt and advance in the midst of its retreat, forming the great morainic Kettle Range. Following the retreat of the ice sheet, there was an advance of the lake, giving rise to Beach Deposit A, and the off-shore lacustrine formation, the Lower Red Clay. When this advance had reached its maximum extent, the waters were withdrawn, apparently with much rapidity, since we find little or no evidence of beach action on the surface of the red clay. As to how far the lake retreated there is no evidence, but returning, it again advanced upon the land, but to a less extent than before, and in that advance, produced Beach Formation B, and the Upper Red Clay, as the coördinate off shore deposit, after which it again retired, leaving little or no evidence of its retreat upon the surface. A third time it advanced, but at a lower elevation. It cut deeply into the previous deposits, whether of drift or rock, forming the extensive terraces that characterize the shores of Lake Michigan and Green Bay. After this, for a third time the lake retired, and is now advancing at a still lower level. These movements will perhaps be more vividly apprehended by consulting the accompanying diagram.

Fig. 16.

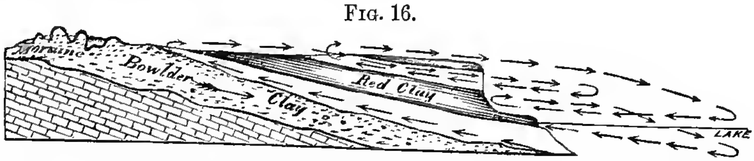


Diagram Illustrating the Advance and Retreat of the Lake Shore, and the Oscillations of the Lake Level, since the Glacial Epoch.

The Moraine and the Bowlder Clay were formed by the Retreating Glacier. The white bands through which the arrows pass represent Beach Deposits A and B, and the lined bands, the Upper and Lower Red Clays.

It has already been stated that some of these advances of the lake were due to relative depression of the land. It becomes evidently a question of the most vital importance to ascertain whether the present advance is due to simple erosion, or to a subsidence of the land, and we are thus led to the subject of *Lake Encroachment.*

Encroachment of Lake Michigan. A considerable portion of the shore of Lake Michigan is formed by high, steep banks of clay, sand and gravel. These are being continually undermined, thrown down, and borne away by the restless activity of the waves. The rate at which the land is thus being swept into the lake becomes a question of importance.

It should be understood that the lake is not advancing at all points, and that the rate of its advance at different points is not uniform. The encroachment seems to be most rapid in the neighborhood of Racine. The land at this point projects into the lake, and is thus more exposed to the action of the waves. To Dr. P. R. Hoy, of that place, I am indebted for data and personal assistance in investigating this subject. He had previously estimated the average erosion in that vicinity at four feet per year. The measurements given on a subsequent page show that for the entire shore line of the county the average advance is 3.33 feet, which shows that the estimate of Dr. Hoy for the more immediate vicinity of Racine, where it is greater, cannot be far from the truth.

As an example of rapid erosion, careful measurements of the cemetery lot at Racine were made and compared with previous surveys, with the following results:

Length on the lake shore...	921 feet.
Width at the south end...	404 "
Width at the north end...	466 "
Average width...	435 "

Amount of land at present date, 9.18 acres. To this is to be added 9 acres sold from the west side, making 18.18 acres. In 1840, there were 25 acres, making a loss of 6.82 acres in 24 years, or more than a quarter of an acre yearly, or, stated in an another form, the lake has been advancing at that point the last 24 years at the rate of 9.73 feet per year. The data for this calculation were furnished by Dr. Hoy, and the measurements were made with his assistance. It is not probable that the erosion at any point exceeds this, and it has recently been checked by break-waters.

The following carefully prepared data were furnished me by Dr. Lapham, and I am glad to substitute them for the less complete measurements made by myself.

"Mr. S. G. Knight, of Racine, has carefully measured for the Geological Survey, from the nearest section corner or quarter post, to the bank of Lake Michigan, along all the section lines in Racine county, the results of which, compared with the government survey made in 1836, are given in the following table. Had these measurements been made at right angles to the shore line, the result would have been a trifle less; but as some portions of the bank have been artificially protected, we may assume the result as a close approximation to the actual amount of loss, during the past thirty-eight years, in Racine county. These measurements will have their value many years hence.

LAKE SHORE IN RACINE COUNTY.

Section Lines.			1836.	1874.	Loss.
North line of Sec.		6, T. 4, R. 23	32.70	30.30	2.40
North	" "	7, T. 4, R. 23	34.68	33.45	1.23
West	" "	8, T. 4, R. 23	30.18	29.70	0.48
North	" "	17, T. 4, R. 23	16.38	14.60	1.78
West	" "	16, T. 4, R. 23	10.86	9.75	1.11
North	" "	21, T. 4, R. 23	15.58	14.50	1.08
West	" "	22, T. 4, R. 23	19.39	18.43	0.96
North	" "	27, T. 4, R. 23	26.39	26.39	0.00
North	" "	34, T. 4, R. 23	16.04	15.47	0.57
West	" "	34, T. 4, R. 23	31.50	30.00	1.50
South	" "	33, T. 4, R. 23	28.87	27.34	1.53
North	" "	4, T. 3, R. 23	28.03	26.50	
North	" "	9, T. 3, R. 23	18.82	18.00	0.82
North	" "	16, T. 3, R. 23	27.80	20.60	6.20
North	" "	21, T. 3, R. 23	21.25	18.00	3.25
North	" "	28, T. 3, R. 23	32.22	31.16	1.06
West	" "	28, T. 3, R. 23	30.20	23.87	6.33
North	" "	32, T. 3, R. 23	34.85	32.40	2.45
South	" "	32, T. 3. R. 23	46.60	44.73	1.87

Mean of 18 places, chains	1.92
Same in feet	126.72
Loss per annum in feet	3.33

The following measurements were made to ascertain the amount of the abrasion of the west shore of Lake Michigan, in Milwaukee county, since the government survey made in 1835 and 1836.

Place.		1835. *Chains.*	1874. *Chains.*	Annual Loss. *Feet.*
On the South line of Sec.	1, T. 5, R. 22	45.61	44.50	1.90
" "	36, T. 6, R. 22	15.90	14.40	2.60
" "	24, T. 6, R. 22	19.29	18.70	1.00
" "	21, T. 7, R. 22	8.72	8.42	0.50
" "	15, T. 7, R. 22	5.37	2.82	4.31
" "	10, T. 7, R. 22	43.35	41.64	2.90
" "	3, T. 7, R. 22	19.34	17.36	3.33
" "	34, T. 8, R. 22	22.00	18.69	5.61
Mean				2.77

The loss in the other counties bordering the lake is less on the average.

These facts are sufficient to show the importance of taking immediate steps to save our territory from the voracity of Lake Michigan. The question naturally arises, Is this advance of the lake due to a subsidence of the land? This question very materially affects the value of all the property along the shore, for if this advance is due to a subsidence, it is largely beyond our control, and where and when it will end could only be conjectured, and it would be practically useless to attempt to permanently stay its progress. But fortunately there nowhere appears to be any evidence of such subsidence. If any considerable movement were in progress it would doubtless have been noticed in some of the harbors, but none has been detected.

It has been shown above that the entire Wisconsin shore of the lake has in recent geological times stood from 10 to 50 feet lower than at present, reckoning the water level as constant, or that the lake is now at a lower level than at that period. It is also known from the same facts that in a period of years that must be reckoned by hundreds, if not thousands, the lake has *on the whole made no advance.* Along 120 out of 200 miles of lake shore the present line is farther east than the ancient one, and the territory of Wisconsin seems to be somewhat greater now than then. The encroachment is hence not a cause of grave apprehension, although it demands energetic attention.

The material washed out from the shore is borne southward and accumulates rapidly on the north side of all the solid piers, that extend out from the shore, forming triangular areas of "made land," as it is termed with questionable propriety.

DUNES.

A few miles south of Sheboygan, and at several other points along the shore, the narrow area between the ancient beach line just mentioned and the present one, is covered with beach sand which the winds are still engaged in heaping up into dunes, which are being cut and shifted after the manner of that formation. From their nature and surroundings they have not and probably never will become large or conspicuous, and are mentioned here rather as a matter of interest than of importance.

EROSION AND DEPOSIT IN PROGRESS.

Aside from the special case of lake encroachment already mentioned, there is a general work of erosion and deposit in progress, as is patent to the commonest observation. This work in the soft drift deposits progresses easily and rapidly. The hills are being swept down and the depressions filled up or excavated deeper, according to their nature. The irregularities of the Kettle Range in particular are gradually losing their conspicuous peculiarities under the gnawings of the "tooth of time." The erosion of the later lacustrine and beach deposits under favorable circumstances is very rapid. We were fortunate enough to secure reliable data in a striking instance of this kind near Racine. The eroding agency is a small rivulet that is usually dry a portion of the year. Twenty-eight years ago, according to Dr. Hoy and others, it was the merest ditch across which two logs and a few puncheons formed a rude bridge. A resident informed me that two years earlier he was accustomed to drive across it without difficulty, no bridge having been constructed at that time. At the point where the bridge is now located, farther up the stream, the lake having cut away the lower portion, the ditch which has been excavated is 120 feet across the top, 40 feet deep, and 23 feet across the bottom.

Farther up the stream, a distance of 1,350 feet, the channel is 40 feet across the top, 16 feet deep and 15 feet across the bottom. It is still a considerable trench at 2,750 feet from its mouth. Throughout it is remarkably uniform in character and direct in course. A very cautious and safe calculation shows the material removed to have exceeded 2,600,000 cubic feet, or more than 3,400 cubic yards per year. It is situated in a level country and does not seem to have been much assisted by freshets.

The upper portion of the material excavated is sand and gravel, an ancient beach deposit, the lower portion chiefly clay. From the surface of this clay numerous little springs seep forth and moisten the sides which slide down to the bottom as soon as they are in the least undermined, and the stream is thus constantly fed with silt. These peculiar conditions might seem to be exceptional, but they are really quite common in the lake border region. The loss from lake erosion is vastly increased by the action of springs similarly situated in the banks facing it. In general it may be said that the erosion of these later deposits, especially of the red clays and the beach deposits, is unusually rapid.

INDUSTRIAL VALUE OF THE DRIFT FORMATIONS.

By far the most important resource springing from the drift of this region has already received consideration. I refer to our fertile and enduring *soils*. The powdering and commingling of such a vast variety of minerals by the glacial forces was a process than which none could be better suited to produce a secure and permanent foundation for agricultural industries; a resource for the many, not the few — a wealth for the people.

Brick. Second only to this in importance are the building materials furnished by this formation, prominent among which are the deposits of brick clay. These belong to two classes, the light colored and red clays. The former are lacustrine, or fluviatile deposits, derived from the wash and redeposit of the bowlder clay, and occur within the area covered by that formation. They are local accumulations, and are of various bluish drab and yellowish hues. A portion of these clays burn to a beautiful cream color, while other portions become red. The superiority of the former in texture as well as color has almost entirely excluded the products of the latter from the market. The second class, the red clays, are simply those portions of the red clay deposits already described as are sufficiently free from pebbles for the purpose. Such portions are almost invariably found at the junction of the beach formations with the main clay deposit. At that horizon are beds of clay and sand, and of the two variously mingled, thus furnishing the two essential ingredients of brick manufacture in the most convenient proximity and association. Very frequently a stratum mingled in the proper proportion by nature may be found. This is a definite and wide spread formation, and affords the most unlimited quantities of excellent material.

Notwithstanding its native red color, it burns to a very desirable white or cream hue. This fact has very justly excited not a little surprise, none the less so because a portion of our light colored clays burn red.

That the light color of the brick is not due to the absence of iron is evident from the manifest presence of that substance as the coloring matter of the clay, and this has been confirmed by analysis. It has been observed that the brick frequently contain small black, glassy points, and it has been thought that, in the progress of burning a process of segregation took place, whereby the iron was concentrated in these concretions, and this view was apparently confirmed by the fact that the brick are red up to a certain stage in the burning. The recent investigations[1] of Mr. E. T. Sweet upon the Milwaukee brick have thrown much additional light upon the subject, though not specifically applicable to the red clays, since the brick of the "Cream City" are made from a light colored clay. For the purpose of comparison, Mr. Sweet analyzed a specimen of the Madison clay, which

[1] Paper read before the Wisconsin Academy of Sciences, Arts and Letters, February 15, 1877.

burns red, and a specimen of clay and of pressed brick from Milwaukee, with the following result:

	Milwaukee Clay.	*Madison Clay.*	*Milwaukee Brick.*
Silica	38.22	75.80	53.78
Alumina	9.75	11.07	13.21
Peroxide of iron	2.84	3.53	4.92
Protoxide of iron	1.16	.31	.26
Carbonate of lime	23.20	2.45	.....
Carbonate of magnesia	15.83	.17	7.41[1]
Lime (CaO)	3.24	.39	17.71
Potash	2.16	1.74	1.54
Soda	.65	1.40	.92
Water in composition	1.85	2.16	.....
Moisture	.95	1.54	.19[2]
	99.85	99.56	99.94

[1] Magnesia. [2] Loss on ignition.

From these analyses it appears that there is even a larger quantity of iron oxides in the Milwaukee clay, that burns white, than in the Madison clay, that burns red, and that in the white brick there are over five per cent. of iron oxides. It is also to be observed that the Milwaukee clay contains a very large ingredient of lime and magnesia, of which the Madison clay contains but little. In view of these facts Mr. Sweet suggests that the ingredients of the clay enter into a combination somewhat analogous to some members of the amphibole group in which the iron does not manifest itself as a coloring material. This view is confirmed by the hard and often semi-vitreous character of the brick, and by the fact that the light color is developed at the point of incipient vitrification. It is at least certain that the light color is not due to the absence of iron, but to the manner of its combination.

The red clays, as has been already repeatedly remarked, are highly calcareous, and from the close similarity of the brick formed from them to the Milwaukee product it is evident that both undergo essentially the same reactions.

It is thought to be entirely safe to say that in quantity, quality, convenience of situation and facilities for shipment, these clays are unsurpassed on this continent. The superiority of the brick is universally acknowledged, and their beauty is a matter of general commendation. The entire number annually manufactured is estimated at 50,000,000, and the value of the product approaches half a million dollars. The test and verdict of the recent great fires has been highly favorable to brick as a building material, and there can be no doubt that in the near future their use, already large, will be vastly increased.

The following statistics, though incomplete, will indicate the methods, extent and local details of the industry (1873 and 1874):

At **Milwaukee** there are six yards, at which about 24,000,000 brick are made annually, which are nearly all needed for the local demand. The common brick are sold at $12 per thousand, and the pressed at $25, the value of the entire annual product being about $300,000. A large proportion of the brick are made by machine, steam power being used. The capacity of each machine is about 30,000 brick per day. The kilns consist of from ten to twenty or more arches, each arch numbering 20,000 brick. The product has the light cream color, so well known in the market as the characteristic of "Milwaukee brick." They are made from a light colored clay, a modified form of the glacial deposit.

At "The Point," near **Racine,** two firms — Messrs. Erskine & Morris, and the Burdick Bros. — manufacture about 3,500,000 cream colored brick per year from red clay and a layer of sand from the overlying beach deposit. Their kilns usually number from 250,000 to 500,000, which require from five to seven days in burning. One cord of mixed wood, at a cost of about $5, burns about 5,000 brick. The molding is done by hand, with water instead of molding sand. About forty hands are employed.

At **Ozaukee** there are two yards where fine cream colored brick are manufactured from red clay derived from the transition beds between Beach Formation A and the Lower Red Clay. The brick are sold at $8 per thousand.

At **Sheboygan Falls** 300,000 excellent cream colored brick are burned annually. The kilns contain about 150,000 and require from seven to nine days in burning, consuming one-half a cord of beech and maple wood per thousand brick, the cost of the wood being $3 per cord. Red clay, to which twenty to thirty per cent. of sand is added, is used. The brick are molded by hand, and sell at from $7 to $10 per thousand.

At **Manitowoc** large quantities of cream colored brick of good quality are made from sandy red clay associated with Beach Formation B. No additional sand is required. The brick are molded dry and by hand. Full statistics were not obtainable.

At **Kewaunee** from 75,000 to 100,000 brick are annually made from clay, of essentially the same geological horizon as the above. The product is light colored, and is sold at from $8 to $10 per thousand.

Near **Appleton** Mr. J. H. Carver burns about 1,800,000 excellent cream colored brick per year. A variegated red clay furnishes the crude material which is wrought by horse power. About three-tenths of a cord of soft wood, worth $2 per cord, burns 1,000 brick, which sell at $8.

At **Neenah** two parties — J. Bailey and E. M. Hulse — manufacture about 1,600,000 per year from red clay, using horse and hand power. The former gentleman makes about 25,000 pressed brick. He uses six grinders and employs from nine to twenty men. Mr. Hulse has three grinders and employs eleven men. About two-fifths of a cord of soft wood, or one-half a cord of mixed wood, is consumed per thousand brick, at a cost of from $2 to $2.50 per cord. The brick are cream colored, and sell at $8 per thousand.

At **Menasha** there are two firms, Messrs. Holke & Schelke, and P. McFadden. Both parties use steam power, and Guard's mixing and molding machine, and make 1,800,000 per year. The clay is red, but burns in six days to a light cream color, consuming one-half cord of mixed wood, which costs $2.50 per cord. About thirty hands are employed.

At **Clifton** a yard producing 1,000,000 per year is owned by B. F. Carter, and one making 700,000, by H. Day & Co., of Oshkosh, the latter under the superintendence of H. W. Carter. Mr. B. F. Carter employs sixteen hands and uses steam power, with a Burnham machine. Nine men are employed at the yard of Day & Co. The crude material is in the form of beautiful laminated red clay and sand. The brick are light colored, and are sold at $7 per M.

At **Watertown,** from 3,500,000 to 4,000,000 excellent cream colored brick are burned yearly by D. S. Chadwick, and about 1,000,000 by F. Black. The crude material is a light colored, sandy, fluviatile clay, about 16 feet in depth. Williams' tempering machine is used, and the molding is done by hand in water. Three tenths of a cord of wood, with one and a half bushels of coal dust ground into the clay, is sufficient to burn 1,000 brick. The coal dust effects a large reduction in expense, and is also used in some of the above mentioned kilns. Mr. Chadwick has ten pits for tempering, and employs forty-five men. Mr. Black has six pits and employs eighteen hands. The brick bring from $7 to $10 per M.

At **Waterloo,** M. J. Rood burns about 600,000, and John Helms from 800,000 to 1,000,000 per year, which are sold at from $7 to $10 per M. A light colored, fluviatile clay is used.

Large quantities are also manufactured at *Jefferson*, *Ft. Atkinson*, *Edgerton*, *Whitewater*, and greater or less quantities at *Johnson's*

Creek, *Geneva*, *Kewaskum*, *Mulheim*, *Two Rivers*, *Northeim*, *Centerville*, and doubtless at other points that escaped our notice.

Tiles, for draining, are manufactured at **Whitewater,** from a light grayish blue clay, by Mr. A. Y. Chamberlin. *Pottery* is also made at the same place from a clay obtained in the vicinity.

The drift formations likewise furnish abundant beds of *sand* of excellent quality for building purposes, and of gravel suitable for roads and other purposes.

Magnetic Iron Sands. It has already been stated that the red clay contains a notable amount of magnetite. As it is eaten away by the lake, the grains of magnetite accumulate on the shore, and form what is popularly known as "Black Sand." Occasionally a layer of three or four inches of this may be found almost free from silicious sand, but usually it is in thinner laminæ, or mixed in varying proportions with common sand. It exists in greater or less abundance along the whole shore line, and the aggregate amount of it is large. It has never been used for economic purposes, so far as I can learn, except as "drying sand," before the era of blotting paper. Similar accumulations are successfully utilized in the manufacture of steel in other regions, and the value of this deposit may be worthy of consideration.

SHELL MARL.

It will be most convenient to consider in this connection a fine deposit of shell marl that occurs in sections 17, 18, 19 and 20, town of Pierce, T. 24, R. 25, Kewaunee county, around the margin of a small lake, and upon a shoal within it, which, by recent drainage has become an island. At some points it is mixed with peat and at others with alluvium, but on this island it is almost perfectly pure shell debris. It is soft, light, porous and pulverulent on the surface. When brought up from beneath the water level, it is a soft, somewhat granular and clay-like mass. A pole was thrust down nine feet without giving any evidence of change in material. A specimen of this marl gave on analysis by Mr. Bode,

Carbonate of lime	86.09
Carbonate of magnesia	7.18
Silica	1.48
Oxide of iron and alumina	0.19
Sulphuric acid	0.44
Water	1.67
Organic matter	2.95
	100.00

For lands deficient in lime this will furnish the needed fertilizer.

In the valley of the Mink river in Door county, at White Clay lake in Shawano county, and, in lesser quantities, at other points, similar accumulations occur, usually associated with peat.

PEAT.

When the glacier retired from our state, it left its debris in the form of drift heaped up in an irregular way over the surface, giving rise to numerous depressions which soon filled with water, resulting in lakes of various forms and sizes. It is perhaps not too much to say that within our district, these numbered thousands. In most cases they soon filled to the brim and then began to overflow their margin at some point, thus forming a channel, which was rapidly cut deeper and deeper, at the same time draining the lake. As the water became shallower, vegetation sprang up in the form of reeds, flags, rushes and the so-called water mosses, which, on dying, fell to the bottom of the lake, and being prevented by the water from complete decomposition, accumulated as a peat deposit. As the draining continued ,these lakes became marshes, and a new class of vegetation sprang up, varying according to the character of the marsh formed.

In the region now occupied by prairies and by oak openings, the marshes were occupied generally by members of the grass or sedge group, accompanied with those mosses that are usually found associated in this group. As the vegetation thus produced died with the succession of seasons, it was added to the accumulating peat deposit. In the more heavily timbered regions of the state, the marshes usually came to be occupied by the swamp-frequenting conifers, the most abundant of which is the tamarac. In association with these there is everywhere to be observed a luxuriant growth of minor vegetation, among which the Sphagnum mosses are most efficient in peat production. These have the property of dying below while growing densely above, and thus they contribute to the rapid accumulation of vegetable debris, and for this reason they take foremost rank as agents of peat formation. They are not confined in their association to the arboreus vegetation named, but in the region under description are most abundant in that connection.

In regard to the amount of peat formed in these several ways, the order will be the reverse of that in which they are named. The accumulation appears to have been much more rapid in the tamarac and similar swamps, than in the open marshes, and as a result the deposits of these marshes are almost universally found to be deeper than those of the other class. The amount of accumulation that took place in the open marshes, after they became such, was undoubtedly much greater than the accumulation during the period that they existed as lakes.

Aside from the accumulation of peat in these extinct lakes, deposits, arising in similar ways, took place in wet localities in connection with running streams, or in wet valleys, that bear no evidence of having once been lakes.

Bearing in mind the method of formation, it will readily be anticipated that great variety in the character of the peat will be the result. Its degree of decomposition ranges from merely dead vegetation to that which has become thoroughly disintegrated, and the value of any given deposit will depend in part upon its character in this respect, since the fibrous condition of peat is one of the serious obstacles to its profitable utilization. It will also be readily understood from its mode of origin, how impurities may become incorporated with it. On the margin of the marsh, the wash from the adjacent uplands will naturally introduce more or less of earth or sand. Near the bottom of the bog, earth will naturally become incorporated with the peat, and in those cases where the surrounding regions have in recent times been cultivated, the unusual amount of earth carried down by the waters will render the entire surface of the peat more or less impure. That portion of the peat which accumulated while the lake was gradually becoming drained to a marsh is more or less filled with the shells of snails, and the remains of other animals that inhabited the lake. In many cases the amount of accumulation of this kind is very considerable, sometimes equaling and occasionally surpassing the accumulation of the peat itself, forming a mixture of marl and peat that will prove very serviceable as a fertilizer. Where the peat accumulated in the vicinity of running streams, their periodical overflow has contaminated the deposit in a greater or less degree. A fourth source of impurity arises from travertine, or calcareous tufa, deposited from springs. This, while it is detrimental to peat as fuel, enhances its value as a fertilizer. Hence, in the selection of peat marshes, those which have been, from their situation and nature, sheltered from these sources of impurity, will, to that extent, be favorable to a pure deposit. The situation and the nature of the marsh will also furnish some indication as to the abundant presence or comparative absence of the acids which interfere with the direct use of peat as a fertilizer. The character of the vegetation growing upon the bog will, however, be a more reliable indication of this. The presence of shells or marl may be taken as satisfactory evidence of the absence of any harmful quantity of these acids. The number of deposits of peat within this portion of the state is very great, and their purity ranges through all degrees, from a very slight impurity, to that which is more properly denominated *muck*. The depth of these deposits is also exceedingly varying. In the investigations of the survey, an auger capable of penetrating 12½ feet was used. In most of the peat deposits occupying open marshes, this was found sufficient to penetrate to the bottom. In most of those arising from the sphagnum mosses in the forest region, the depth was found to exceed that amount. In some cases marshes were said to have a depth of two or even three times that amount. The quantity of peat in eastern Wisconsin is to be reckoned by *millions of tons.*

Details of Borings. The first marsh tested occupies portions of sections 28, 29, 30 and 32, town of Whitewater (T. 4, R. 15 E). Ten borings were made along two lines, one across the marsh and one longitudinally.

1. The first boring was on a springy elevation, near the center of section 32, from which the line stretched northward across the marsh. The peat at this point was very much mixed with shells, travertine, and apparently some argillaceous material. Sandy clay was reached at a depth of 11 feet 4 inches. A ditch near by exposed a washed surface of the upper portion from which were taken fresh water shells of the genera Sphærium Planorbis, Limnæa, and Pupa, the smaller species of these genera being very abundant, the larger, rare. This shows that the peat is of lacustrine origin, and that at no distant day this has been a lake.

2. At 50 rods from the first boring, we find about equal proportions of shell-marl and peat. The following is the section:

Soft, watery, dark reddish, marly peat	4 ft. 6 in.
Thin layer of whitish marl	2 in.
Peat as above	1 ft.
Hard, well decomposed peat	4 ft.
Bluish clay, filled with pebbles at	9 ft. 8 in.

3. The third boring gave the following section:

Marly peat	4 ft.
Hard, compact peat	5 ft. 6 in.
Clay at	9 ft. 4 in.

The bottom of a ditch near by contains calcareous sand, evidently washed from the peat.

4. The fourth boring gave 8 ft. 8 in. of reddish, partially decomposed marly peat, containing shells. Bottom blue clay as before.

A section exposed by a ditch between borings 4 and 5 gave 2 ft. of peat, succeeded by 4 in. of shell-marl mingled with peat.

5. The fifth boring showed 2 ft. of moderately decomposed marly peat as before, 3 ft. somewhat more compact, with hard blue clay at 5 ft.

The remaining borings were on a line from the S. E. qr. of the S. W. qr. of sec. 29, to the N. W. corner of the S. W. qr. of sec. 29.

6. The first two borings were made to ascertain the structure of a mound 6 feet high and about 50 feet in diameter. The boring at the base gave 3 feet of muck-like peat, with clay below; that in the top of the mound gave 7 feet 8 inches of peat, mingled with much travertine, with clay and sand mingled at the bottom, which is about 1½ feet above the bottom of the boring at the base, showing an accumulation of sand and clay beneath the mound, which undoubtedly owes its origin to a spring.

7. Thirty rods farther west, the chief boring showed 8 feet 4 inches of watery, partially decomposed peat, free from noticeable travertine or marl. Bottom, blue clay.

8. The fourth boring, 60 rods from the last, showed 5 feet 6 inches of watery, partially decomposed peat, 3 feet 6 inches of a compact, close textured, reddish, well decomposed peat, with blue clay at 9 feet.

9. The fifth boring showed a similar section, blue clay with shells being reached at 8 feet 4 inches.

The lower compact peat of the last two sections presented all the physical appearances of superior quality, being apparently free from the calcareous material found so abundant in the first series. The marly peat will undoubtedly prove a good fertilizer, and is well adapted to the sandy soil of the neighboring farms.

At the head of Lake Geneva there is a small area of similar marly peat, 8 feet deep.

In section 20, town of Sugar Creek (T. 3, R. 16 E.), there is a peat marsh about one-fourth of a mile wide, which extends eastward for several miles, but is narrow. To the westward it widens and connects with an extensive marsh in the town of Richmond. The following is a typical section from the center of section 20:

1. Surface black and somewhat earthy.
2. Well decomposed, dark peat of moderate compactness .... 5 ft.
3. Firm, well-decomposed peat.... .... 4 ft.
4. Drab clay, mingled with peat, at .... 9 ft.

The narrowness of the marsh at this point, and its evident exposure to wash from the neighboring land, render it probable that a portion of the firmness of this peat is due to very fine silt, that could not be detected by sight or touch. At other points the surroundings were more favorable.

Horicon marsh was tested near its south end, with the following meager results:

First Boring —

1. Surface, loamy peat.
2. Coarse undecomposed peat .... 2 ft. 6 in.
3. Black peaty clay .... 1 ft. 6 in.
4. Blue clay .... 1 ft.
5. Gravel at .... 5 ft.

Second Boring —

1. Peaty soil .... 1 ft.
2. Yellow clay .... 3 ft.
3. Blue clay, lower part sandy .... 2 ft. 6 in.
4. Gravel at .... 6 ft. 6 in.

Third boring essentially the same. Probably other portions of the marsh would show more peat.

A marsh near Berlin, the peat of which, I was informed, had received a favorable opinion from judges at the east, was tested. It lies along the Fox river, whose inundation must be supposed to affect its quality. Three out of several borings will represent its nature:

First Boring —

1. At 1 ft. 6 in., fibrous, not well decomposed.
2. At 3 ft. 6. in., fibrous, not well decomposed, yellowish brown.
3. At 5 ft. 6 in., better decomposed, reddish.
4. At 6 ft., dark greenish blue clay.
5. At 6 ft. 6 in., clayey sand.

Second Boring — near river —

1. At 1 ft., fibrous, loose, dark.
2. At 3 ft., layer of decomposed wood.
3. At 3 ft. 6 in., clay as above.

Third Boring — near center of marsh —

1. At 1 ft., dark, fine fibrous, soft, not well decomposed.
2. At 3 ft. 6 in., less fibrous, reddish.
3. At 5 ft. 9 in., clay as above.

One of the more interesting of the smaller marshes is found in the W. hf. of sec. 30. Beaver Dam (T. 11 N., R. 14 E.). There are perhaps 80 acres of available peat. It is surrounded by timber and has no stream flowing through it, and was formerly a lake, as shown by the shells of Sphærium, Paludina, and Helix, found in the underlying clay. At 8 rods from the edge, there were 4 feet of firm, dry, reddish, well decomposed peat, underlaid by clay. Thirty rods from the edge, the following section was obtained:

1. At 3 feet, firm peat struck; that above, soft.
2. At 5 feet 6 inches, reddish, well decomposed peat.
3. At 7 feet, firm, color of brown paper.
4. At 12 feet, clay and peat mixed.

At the centre of marsh:

1. Upper portion as above.
2. At 6 feet, firm, red, fairly decomposed, apparently derived from wood.
3. At 12 feet (length of auger), bottom not reached; material much resembling brown paper pulp; contained the shells mentioned above.

In the town of Calamus (T. 11, R. 13 E.), N. W. qr. of sec. 25, and S. W. qr. of sec. 24, lies a marsh of 200 acres. A small stream flows through it. The following may represent five borings of similar import:

1. At 2 feet, well decomposed, firm, black.
2. At 3 feet, well decomposed, firm, black.
3. At 5 feet, well decomposed, firm, yellow.
4. At 5 feet 9 inches, well decomposed, firm, color brown paper.
5. At 7 feet, well decomposed, firm, color brown paper.
6. Blue marly clay, containing shells.

The peculiar brown material was found to be sandy in two of the borings.

In the town of Lake Mills, secs. 1 and 2, a large marsh, partially covered with tamarac, gave the following sections:

First. — Nine rods from the edge:

1. At 4 feet, dark, well decomposed.
2. At 7 feet 6 inches, dark, well decomposed.
3. At 10 feet, reddish, woody, sandy.
4. At 11 feet, sandy, blue clay.

Second. — Forty rods from the edge:

12 feet of soft, wet, not well decomposed, dark, reddish, woody peat.
No evidence of sand; bottom not reached.

Third. — Nearer the edge:

1. At 6 feet, firm, half decomposed, dark reddish, woody fiber.
2. At 10 feet, dark, well decomposed, firm, apparently excellent.
3. At 12 feet, sandy; bottom not reached.

As an example of the greater depth in tamarac marshes, I may give the section obtained in the smallest marsh tested during the summer, consisting of only a few acres, in W. hf. of S. E. qr. of sec. 11, Summit (T. 7, R. 17 E.). It was tested within six or eight rods of the edge, with the following result:

1. At 6 feet 6 inches, began to be wet.
2. At 10 feet 8 inches, spongy, undecomposed mosses.
3. At 11 feet 8 inches, still in peat; bottom not reached.

Tested in a dry ditch, nearer the edge, to a depth of over 13 feet, without finding bottom.

The foregoing may be taken as representing the *average* character of the open peat bogs of the region. There are deeper and more extensive deposits than the ones given — the selection of those to be tested having been controlled by the necessities of other departments of the survey.

Peat has been used in this region to some extent as a fertilizer, and always with good results. Its value is much increased when mingled with other kinds of fertilizers, and it is especially efficient in absorbing the liquid manures that are usually wasted. The good results of the few trials that have been made, corroborated as they are by experience elsewhere, and justified by reasoning from the nature of the peat, commend this subject to the earnest attention of our agriculturists. In reference to the last point, I may be allowed to present succinctly those properties of peat that render it valuable as a manure, chiefly on the high authority of Prof. S. W. Johnson:

1. It absorbs moisture both as a liquid and a vapor, and so counteracts the effects of droughts, and makes it invaluable to the more arid soils. This hygroscopic property indicates a natural adaptation to use as a fertilizer rather than as a fuel, it being detrimental in the latter respect.

2. It improves the texture of the soil.

3. By its decay it furnishes ammonia and carbonic acid, and some mineral substances.

4. It assists in the disintegration of other substances in the soil.

5. It absorbs ammonia from the air, and thus furnishes it to the plants.

6. By its dark color it absorbs heat from the sun, and thus increases the temperature of the soil.

Attempts have been made to utilize it as a fuel at several points with varying success. In almost all cases it seems to have furnished a very fair fuel, and in some cases it is claimed to be equal to the best hard wood. The general tenor of the results, where machinery has been used, is unfavorable; where the simpler methods have been employed, the prospect is more encouraging. In reference to the want of entire success in the former case, I gather the following causes:

1. Too much is expected, and consequently too great expense is incurred and too great risks taken. Theoretical calculation readily shows immense profits, and leads to manufacturing on a false basis, unless large deductions are made for practical difficulties, and larger margins left for unforseen contingencies. The manufacture of peat in this state should only be undertaken on the basis of reasonable, not immense, profits, as the result of judicious and careful management.

2. The price of other kinds of fuel in some places leaves too small a margin for profit.

3. Errors in the selection of the marsh. The simple existence of peat of a suitable depth does not ensure a suitable quality. The eye and the fingers often reveal fatal impurities, and of those that pass the examination of the senses, chemical analysis will show that some are unsuitable. The proximity of a stream that habitually inundates the bog is a *prima facie* cause for suspecting the peat to be impure.

4. Errors arising from using that which is too near the edge, top, or bottom of the bed. The edge and bottom are impure for obvious reasons. Before the surrounding country was cultivated, the top was as pure as other portions; but cultivation has immensely increased the amount of earthy material carried into our marshes by the water, and thus rendered the surface peat more impure.

5. Errors in the manufacture. Prominent among these is the failure to suitably dry the peat. Much of it contains, when taken from the bed, *ninety* per cent. of water. This must be reduced to about *twenty* before it becomes suitable fuel. The peculiar hygroscopic property of peat, which is one of its valuable qualities as a fertilizer, is a source of difficulty here. Our dry and windy climate is however favorable, and if this difficulty has been overcome elsewhere, it may most assuredly be here.

6. Want of the best conveniences for burning it. Our stoves and furnaces are especially adapted to coal or wood, and although peat may be used in either, it is placed at a disadvantage. It must compete with them on their own ground.

7. Want of knowledge on the subject, and a natural indisposition to change habits.

These and other errors will readily be corrected by experience, and if the laudable efforts that are being made to develop this new source of fuel are sustained and encouraged by an enterprising public spirit, we may confidently anticipate a final success.

GEOLOGICAL STRUCTURE OF EASTERN WISCONSIN.

The rocks of the district under consideration consist of two great classes, widely distinguished in age and character. The more ancient one consisted originally of sedimentary materials which were subsequently metamorphosed into quartzites, granites, porphyries and similar rocks, and were folded and tilted at various angles. These (formerly known as Azoic or Eozoic) constitute the Archæan formations. Upon these were afterwards deposited a series of sandstones, shales and limestones that have remained essentially unaltered and undisturbed to the present day, which constitute the Paleozoic formations.

The following table exhibits in their natural order the formations that will claim our attention:

HAMILTON,	*Devonian,*	PALEOZOIC.
LOWER HELDERBERG,	*Upper Silurian,*	
NIAGARA,		
CINCINNATI,	*Lower Silurian,*	
GALENA,		
TRENTON,		
ST. PETERS,		
LOWER MAGNESIAN,		
POTSDAM,		
HURONIAN,	*Archæan.*	
LAURENTIAN,		

CHAPTER VI.

ARCHÆAN FORMATIONS.

The district under consideration is occupied almost exclusively by Paleozoic formations. The Archæan rocks form the great sloping floor upon which these later deposits rest, and rise to the surface along their northern border. But the Archæan surface is very irregular, and here and there knobs rise through the superincumbent formations, giving rise to isolated hills of quartzite, porphyry and granite in the midst of the areas of later rocks. It is to these protruding, *but not intrusive*, masses that our attention will be chiefly confined.

Along their northern border, the Paleozoic formations lap upon an immense series of granitic and allied rocks, that will receive due consideration in the several reports upon the Archæan regions. They are here referred to as a convenient point of departure in describing the isolated areas above referred to, whose main importance depends upon their position with reference to this Archæan region, and their relations to subsequent formations.

The Mukwa Granite.

The isolated outlier found in the S. E. qr. of the N. E. qr. of Sec. 26, and the N. W qr. of the S. W. qr. of Sec. 25, town of Mukwa, Waupaca county, lies nearest the main Archæan area. This outcrop seems to have been unknown to the geologists heretofore, and came to my attention through information derived from Mr. Carr, of New London.

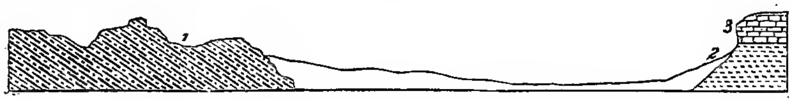
It consists of three large, and as many small, rounded, elongated, dome-like outliers, arranged nearly in a line trending W. 35° to 40° N., and rising near the center to a height of nearly 70 feet.

The *rock* consists chiefly of red feldspar, with which is associated a less quantity of quartz and a small and varying amount of a dark mineral, which was not seen in the distinct crystalline form, but which seemed to be an aggregation of minute blended blades of biotite. The crystals of feldspar are never large, seldom exceeding a quarter of an inch in length, and are usually quite minute, so that some portions, from which the dark mineral is absent, closely resemble red quartzite in appearance. The rock is intersected in various directions by veins of quartz. It is also cut into pyramidal masses by smooth, straight fissures, which are usually inclined at an angle of from 60° to 85° to the horizon. In trend these fissures constitute three groups: the first nearly north and south; the second nearly east and west; and the third northwest and southeast. There are also large irregular fissures, and occasionally points are to be observed from which an unusual number, both of the smooth and the irregular ones seem to radiate.

The rock is very little affected by weathering, and affords an excellent building material, though the form of the blocks is unfavorable, and it is somewhat hard to dress.

No rock was found in contact with it, but, about half a mile to the southeast, in the line of its trend, the Lower Magnesian limestone appears, into whose horizon the outcrop rises, though it lies chiefly in that of the Potsdam sandstone, as shown in the accompanying profile.

Fig. 17.



Profile Section showing the Relations of the Mukwa Granite.
1. Outlier of Granite. 2. Potsdam Sandstone. 3. Lower Magnesian Limestone.

The Berlin Porphyry.

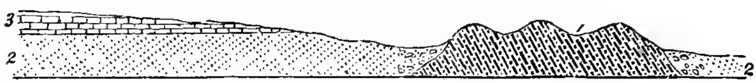
At Berlin, thirty miles south of the above, we next find an outstanding Archæan mass,[1] consisting of three large elongated domes arranged *en échelon*, bearing northeast. The rock is composed essentially of small crystals of orthoclase feldspar dissiminated through a peculiar cryptocrystalline base of felsite and quartz, forming a quartz-porphyry. The crystals of feldspar are usually grayish before weathering, becoming reddish afterward. The base in its unweathered state very much resembles quartzite, and is of dark grayish cast with a very slight reddish tinge, so modified by its translucency as to give to the whole what may be called a water hue. Very thin splinters may be fused before the blow-pipe with difficulty, forming a transparent glass-like bead. The effect of weathering is marked and peculiar. The color changes to a light reddish, pinkish, or grayish white, and occasionally to a bright red, while the mass becomes opaque and finely granular, and so soft as to be easily cut. There are occasionally spots, streaks, or leaves of dark material in the base, which

[1] Comp. Dr. Percival's Report of 1856, p. 106.

are doubtless the portions referred to by Dr. Percival as "interlaminated hornblende and mica."

The rock is very uniform in character at all points exposed. It presents an obscure parallel structure giving rise to a somewhat definite system of cleavage, but traces of distinct bedding were not observed. The mass is traversed by extensive fissures which are readily arranged into three groups, the predominant one of which bears N. W., and the smaller ones E. of N. and N. of E., respectively, thus dividing the horizon into nearly equal arcs; but none seem to be dependent on the cleavage structure of the rock.

Fig. 18.



East and West Section through the Berlin Porphyry.
1. Porphyry. 2. Potsdam Sandstone. 3. Lower Magnesian Limestone.

On the south slope of the hill, and within a few rods of the exposure of porphyry, occurs a sandstone in which are imbedded masses of the porphyry of various sizes. The sandstone also contains several species of Potsdam fossils, demonstrating the presence of the porphyry as an island or reef during the deposition of the sandstone. These facts entirely negative the view that these hills were either ejected as an igneous mass, or thrust up as such by upheaval. They are simply projecting points of an eroded formation.

The Quartz-Porphyry of Pine Bluff.

Seventeen miles south of Berlin there rises out of the flood plain of the Grand river a conspicuous mass of quartz-porphyry known as Pine Bluff. It ascends by steep, and even precipitous acclivities to a height of one hundred feet, and being entirely isolated from surrounding elevations, and largely bare of soil and vegetation, becomes a striking object. The rock consists of white, gray and flesh colored crystals of orthoclase, and of glassy feldspar, set in a very hard, gray or black quartz-felsite base. The crystals of feldspar vary in size from three-tenths of an inch in length, downwards, but are rendered conspicuous by contrast of color. The rock is susceptible of very high and beautiful polish, but is wrought with difficulty on account of its hardness. The dip is about 20° to the E. of S. Obscure glacial striæ, still preserved, testify to its endurance. Their direction is S. 45° W. The accompanying profile exhibits its relations to the

Silurian formations, from which it will be seen that it rises to about the base of the Galena limestone.

FIG. 19.

NORTH AND SOUTH SECTION THROUGH PINE BLUFF.

1. Quartz-Porphyry, Pine Bluff. 2. Lower Magnesian limestone. 3. St. Peters sandstone. 4. Trenton limestone. 5. Galena limestone.

THE QUARTZ-PORPHYRY OF MARQUETTE.

Near Marquette, a little more than twelve miles west of Pine Bluff, very similar quartz-porphyries display themselves in more considerable force, constituting a group of prominent hills. A portion of the rock is precisely identical in character with that of Pine Bluff, and the greater mass is but an unimportant variation from it, but certain portions depart from the porphyritic character, and become almost, or entirely, crypto-crystalline. One variety of this kind very closely resembles the more homogeneous of the red Huronian quartzites, and another is a compact close-textured rock, usually of dark color, but sometimes greenish. Neither of these varieties occupies exclusively any one horizon, but the quartzite-like variety is found in the more southern outcrops, the last mentioned kind immediately north of that, the darker porphyries next, and the coarser, lighter colored ones in the most northerly exposures.

The bedding is very obscure, but the laminations of certain portions and belts of particular varieties of rock show the strike to be northeastward. The dip is made out with much less certainty, but appears to be to the northward, and to vary from 15° to 45°.

Though the Berlin porphyry differs from that of Pine Bluff and of Marquette in the absence of glassy feldspar, yet the close lithological alliance of the three is very evident, and they doubtless all belong to the same group of the Archæan series. The general strike of these formations, projected westward, encounters several similar outliers, that are described in Prof. Irving's report, and still further southwest he has found similar quartz-porphyry overlying the Baraboo quartzite. There seems to be sufficient reason for regarding the latter as Huronian, so that the porphyries must be regarded as a newer portion of that formation.

All of these masses present the rounded contour of glaciated surfaces, and still bear the glacial groovings, and, in some cases even remnant polished spots, and from all these, trains of porphyry bowlders stretch away in the direction of the striæ.

The Quartzites of Portland and Waterloo.

Thirty-five miles south of Pine Bluff, over an area entirely covered by Paleozoic rocks, some as recent as the Galena, we again encounter the Archæan rocks in the form of the quartzites of Portland and Waterloo.

The outcrops in the town of Portland[1] are several in number. The most southwesterly is an oval island, lying mostly in the S. E. qr. of Sec. 33, and is entirely surrounded by lowland or marsh. The outcrop attains but a slight elevation, and its rounded contour shows abundant evidence of the glacial agencies that have swept over it. Not only striæ, but deep, broad furrows, show the direction of movement to have been S. 15° to 20° W. Bowlders appear in great force upon the protected side of the island, and doubtless thickly underlie the deep morass in that direction, as they appear again upon the hills beyond. Directly to the east, in sec. 34, there is a slight exposure near the base of a somewhat elevated north and south ridge, of which it doubtless forms the nucleus, if not the chief portion.

Less than one mile north of these outcrops, the quartzite again discovers itself on the brow and west flank of the ridge facing Waterloo Creek. There is no evidence that any later formation overlies the quartzite between this and the two preceding outcrops, and so the three will be found mapped as constituting a single Archæan area. A short distance further to the north (N. W. qr., sec. 27), the quartzite rises in the midst of a marsh-like lake, constituting Rocky Island. It may be characterized as a low dome covered with unsymmetrical *roches moutonées.*

About two miles southeast, at the foot of a hill, and on the edge of a marsh, occurs a low and limited outcrop (sec. 35, S. E. ¼, and sec. 36, S. W. ¼). One-half mile to the northeast, across a marsh, there occurs another exposure, similarly situated in the southern extremity of a north and south ridge, and about the same distance to the southwest, still another one may be seen; the three lying nearly in a straight line, and separated by marshes. They are regarded as being projecting knobs of a common area, and are so mapped. Between these and the three outcrops first mentioned, as also between both these and

[1] See note on the Age of the Metamorphic Rocks of Portland, Dodge Co., Wis., by R. D. Irving, Am. Jour. Sci., Third Series, Vol. V, p. 282.

Rocky Island, later formations intervene, so that they must be regarded as forming three distinct, though closely associated, surface areas.

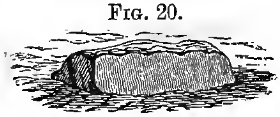
The first mentioned outlier of the last group still preserves on its exposed surface the scorings of the drift forces, there being two sets, the one pointing S. 33° W., and the other S. 55° W.

From the several outliers there stretch away to the southwestward *trains of bowlders* of quartzite, which gradually spread out into a fan-like form, the fragments meanwhile becoming more rounded, smaller, and scattered. I have traced them fifty miles distant into Illinois. A figure illustrating these facts has already been given. Their special significance here relates to the question whether other masses of quartzite protrude through the Paleozoic formations in this region. If so, they should indicate their presence by erratics in the drift. Bowlders, in limited numbers, reach about three miles east, and a somewhat greater distance north of the outcrops, but as traced in those directions, no concentration toward a point of origin was observed with sufficient definiteness to locate their source.

The discovery of a train in the town of *Waterloo* led to more satisfactory results. The abundance of angular blocks in the drift led to the conviction that their source was in the immediate neighborhood, and, under the guidance of the Rev. G. S. Hubbs, the actual outcrop was found. Like the others, it lies at the foot of a ridge on the border of a marsh. The exposure is small, but interesting.

At one point there is a very fine exhibition of ripple marks running parallel to the dip, thus demonstrating the true tilting with certainty. This was found to be $46\frac{1}{2}°$ N. E., the strike being N. 45° W.

Fig. 20.



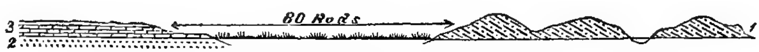
Ripple-marked Outlier. Town of Waterloo.

The rock of all these outcrops is a hard, thoroughly metamorphosed red, or gray quartzite. Metamorphic conglomerates occur in certain portions. In others there is a foliated material of talcose appearance, yet seldom sufficient to give the rock a schistose structure. The gray variety of quartzite predominates, especially in the more westerly outliers, while the red is more abundant in the eastern.

The relations of these quartzites to the surrounding formations are exceedingly interesting. About eighty rods south of the outlier in Waterloo, the lower layers of the Trenton limestone, reposing upon the St. Peters sandstone, occur *at the same level* as the quartzite, with no indication of disturbance. The accompanying figure will render the situation clear.

In the intermediate space are bowlders of conglomerate, the pebbles of which are of quartzite, precisely similar to that of the outliers, while the matrix is of white sand similar to that of the St. Peters sandstone. There are also fragments of sandstone containing the cylindrical cavities known as Scolithus. A single bowlder was also found uniting the two. I have found Scholithus tubes in the upper transition layers of the St. Peters sandstone, and as there is no known Potsdam sandstone along the line of drift for more than one hundred miles, and rarely then, in contact with quartzite, it seems altogether most rational to conclude that the St. Peters sandstone was laid down around the island of quartzite from which the pebbles

Fig. 21.



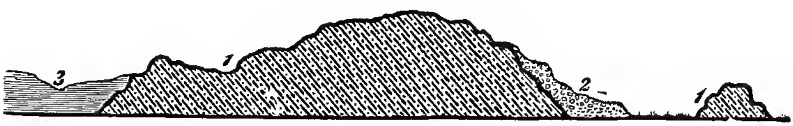
Profile Section showing the Relations of the Waterloo Quartzite.
1. Quartzite. 2. St. Peters Sandstone. 3. Trenton Limestone.

of the conglomerate were derived by beach action, and that the bowlders in question were derived from the deposit thus formed. The greater fineness of the rock, which is a matter of observation, may account for the preservation of the Scolithus tubes, which are very rare in the more friable portions. This view is both corroborated and complicated by the still more interesting facts observed in the town of Portland. Opposite Rock Island and near the water's edge, we find a white sandstone bearing abundant well preserved Scolithus tubes. This graduates above into a fine conglomerate, which becomes coarser and coarser until at a height of 48 feet, where it adjoins the quartzite, it consists of bowlders three or four feet in diameter, imbedded in finer grades of conglomerate. There is here no question as to the origin of the conglomerate, or of the relations of the *Scolithus* to it. The quartzite rose as a rocky island in the depositing seas, and yielded its material to the beating of the waves, by which the conglomerate was formed.

But on the opposite side of the ridge, somewhat more than a mile distant, a peculiar shaly, arenaceous rock is found at the same elevation. One variety of this rock is exposed in the railroad cut in Sec. 3 of the town of Waterloo. It is of variegated, reddish aspect and irregular texture, and closely resembles the variegated shales of the Mendota beds of the Potsdam, and also some of the modified forms of the St. Peters sandstone, where it lies contiguous to the domes of Lower Magnesian limestone, subsequently to be described. It has been penetrated at several points in the vicinity by wells which in some cases reach the quartzite underneath it. The owners of the wells usually describe it as a red, sandy rock. At one point (middle

N. line of N. E. qr. of S. W. qr., Sec. 35, Portland), a rock of similar nature, but of light buff color, was penetrated to a depth of 18 feet, below 36 feet of drift, when quartzite was reached. In the S. E. qr. of Sec. 3, town of Waterloo, after 18 feet of drift, 41 feet of what was described as a rather soft, sandy red rock, was penetrated, below which a hard rock, probably quartzite, was found. The accompanying cut shows the relations of this rock with the quartzite and conglomerate.

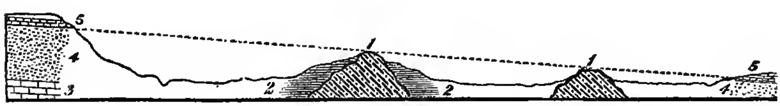
FIG. 22.



NORTH AND SOUTH SECTION THROUGH PORTLAND QUARTZITE.
1. Quartzite. 2. Conglomerate. 3. Shaly Sandrock.

Figure 23 shows the horizon which the quartzite and the accompanying formations occupy. The nearest approach of the Trenton and St. Peters, in their normal character, is about two miles.

FIG. 23.



PROFILE SECTION, SHOWING THE RELATIONS OF THE PORTLAND QUARTZITE.
1. Quartzite. 2. Shaly Sandrock. 3. Lower Magnesian Limestone. 4. St. Peters Sandstone. 5. Trenton Limestone.

Without assuming demonstration, it seems most in harmony with all the facts, and freest from gratuitous assumptions to refer the conglomerates, sandstones and shaly sandrock to the period of the St. Peters, and they will be found so mapped.[1] It is to be remarked (1) That these quartzites were originally sandstones and conglomerates. (2) That they were metamorphosed before the deposit of the neighboring horizontal rocks, since the pebbles included in the latter are metamorphic. (3) That they were tilted before the deposit of horizontal rocks, as shown by their unconformability. (4) That their upheaval and metamorphism were probably synchronous and congenite. (5) That extensive erosion took place before they were completely covered and protected, as shown by the fact that they expose

[1] On the accompanying map the area of quartzite in Sec. 34 is placed one-third mile too far north.

in great thickness their truncated edges and dip at a high angle in a common direction — northeast. (6) That there was a vast lapse of time in which the erosion might take place. These rocks are undoubtedly a portion of the Baraboo quartzite series which has been proven to be pre-Potsdam, and since the Portland and Waterloo quartzites rise at their highest points into the Trenton horizon, there must at least have elapsed time enough for the deposit of 1,200 feet of sandstone and limestone before they were finally covered in the Trenton period.

CHAPTER VII.

LOWER SILURIAN.

POTSDAM SANDSTONE.

There rests upon the very irregular surface of the metamorphic rocks above described, filling up its depressions and for the most part surmounting its hills (over the area so occupied), a deep and extensive deposit of sandstone, known under the above name. That it is the exact equivalent of the Potsdam sandstone of New York, as would seem to be implied by the name, is not absolutely certain, but as the term has been used to designate this formation in previous reports upon the geology of the state, and as the weight of evidence and authority favors this view, the name Potsdam sandstone will be used without further qualification in this report.

The upper surface of this formation is essentially uniform and nearly horizontal, and is overlaid by the Lower Magnesian limestone. These two formations, then, the limestone above and the Archæan rocks below, furnish one of the means by which the sandstone may be identified and its position and thickness determined. Since its upper surface is nearly uniform, and its bed very irregular, it necessarily varies greatly in *thickness*, the known range within the state being from zero to about 1,000 feet. Within our district its variation in thickness is known to be but little short of this, and from the nature of the case, it is evident that the extreme thickness of this rock may much exceed that which has been observed. *This irregularity in thickness* should be kept in mind in making any calculations dependent upon the depth of this formation.

General Character. The rock is chiefly composed of cemented grains of silicious sand. To the unassisted eye, these grains appear spherical, but upon examination under the microscope, they are seen to be more or less angular and irregular, and show that they have been formed from small fragments, and in some cases, perhaps, minute crystals of quartz, which have been worn by friction to their present form. These grains vary much in size in different localities, and in the various strata of the formation.

In general, as seen in outcrops in eastern Wisconsin, they are neither very coarse nor very fine, but range through the medium varieties. Near the base of the formation a very coarse grained sandstone occurs, but it is not known to outcrop in the district. In some cases these grains are embedded in more finely comminuted silicious powder, doubtless worn from the grains themselves, so that the rock possesses considerable compactness, but only a small degree of cohesive power. In other cases, the filling between the grains is a clayey material, or a green earth, forming an argillaceous sandstone, or one of the varieties of greensand.

Still again, and very commonly, the grains of sand are firmly cemented by calcareous or ferruginous matter. In many cases this is not so much a filling of the spaces between the grains as it is a coating of the grains themselves, by which they are firmly bound together. It is this variety that furnishes the most serviceable building material.

As a result of these facts, the formation presents several varieties of sandstone, which may be known respectively as the calcareous, the non-calcareous, the argillaceous, the ferruginous, and the green sand. Sandstone entirely free from calcareous matter is rare in this formation in eastern Wisconsin.

Whether we examine outcropping ledges, artificial exposures, or the drillings of Artesian wells, the presence of more or less of lime is usually indicated, except in the lowest stratum of the formation. As has been before remarked, the waters issuing from this formation usually contain a small percentage of lime salts. Whether they derive their calcareous burden from the sandstone, or, on the contrary, are the sources in part of the lime in it, having obtained it originally from the limestone above and yielded it to the sandstone in passing through it, may be a matter of doubt, in some cases, but a portion of the lime was undoubtedly deposited at the same time with the sand.

All of the *non-calcareous sandstones*, observed in the district under consideration, crumble so easily as to be of little industrial importance except as a source of sand, and as they form a sterile soil, their rarity may be considered a matter of good fortune.

In the argillaceous class, the clayey material sometimes becomes so abundant as to render the rock shaly, and in some cases it so far predominates that the rock is known as a shale, rather than a sandstone. These argillaceous layers are usually impervious to water, and demonstrate their utility by giving origin to valuable springs.

There are *two classes of green sand*, one, which consists of grains of quartz colored by some substance — iron in those cases which I have examined — the other and much more prevalent, which consists of a mixture of ordinary white quartz grains, and deep-green grains of glauconite, or a closely allied mineral.

The ferruginous varieties embrace at one extreme, those in which the amount of iron oxide is barely sufficient to color or cement the mass, and at the other, those in which it becomes so great as to justify calling the mass an iron ore. Neither of these classes is abundant in this portion of the state, though important features in other parts. The sandstone of this region is usually very light colored, and nodules, seams, or layers of iron, though present, attain to no significant development.

As has been already remarked, the great mass of this sandstone is more or less *calcareous*. The limy portions become so great in some layers that they are more properly limestones than sandstones. The lime in this case, as is usual in this state, is associated with magnesia, so that these layers become really arenaceous dolomites. In some portions, the calcareous matter, instead of being disseminated through the rock, forms concretions, by binding lumps of sand into hard spherical masses, giving the beds a nodular structure.

The foregoing general statements may perhaps suffice to indicate the prevailing chemical and molecular nature, and the minute structure of this formation. More specific facts will be found in connection with the local sections and descriptions. We may now consider its more *massive characters*. Where bedding is distinctly marked the layers are not usually more than three or four feet in thickness. From this thickness they are to be found of all lower dimensions down to layers of slate-like thinness. The beds show oblique lamination, ripple marks, and other evidences of shallow water deposit.

Owing to the prevalence of heavy deposits of drift, exposures of this formation in eastern Wisconsin are quite unfrequent, and very limited in extent; a very fortunate circumstance for the agriculturist, though quite the reverse for the geologist. However, by diligent search and careful collating of data, it appears that the formation consists of *six subdivisions*, as follows, beginning at the top:

Sandstone (Madison)	35	feet.
Limestone, shale and sandstone (Mendota)	60	"
Sandstone, calcareous	155	"
Bluish shale, calcareous,	80	"
Sandstone, slightly calcareous,	160	"
Very coarse sandstone, non-calcareous,	280	"

The thicknesses given are subject to considerable variation. As a general rule they grow less toward the northeast. Where the total thickness of the formation is reduced by the inequalities of its Archæan bottom, it is by the loss of the lower members of the group and not by the thinning of all.

1. Madison Sandstone. This name has been assigned, by Prof. Irving, to the uppermost subdivision, from its occurrence in the vicinity of the capital, where it is extensively used, under that name, as a building stone. He regards this as a member of the Calciferous group above, rather than of the Potsdam, in respect to which, however, I feel compelled to differ from him, for reasons given below.

At its more typical localities, this sandstone is a rather coarse grained, thick bedded, compact, but soft, slightly calcareous, light colored sandstone. It is best shown at Lucas Point, on the southern shore of Green Lake, a few miles west of Ripon, where, however it is more than usually fine-grained.

At this point it is horizontally laminated, and marked by wavy lines of reddish yellow iron stains, though these are probably not constant characters. In its upper portion, immediately beneath the lower magnesian limestone, it is at most locations coarse, and the topmost layer is often broken up and mixed with calcareous material, giving it a coarsely brecciated structure. This layer, or its equivalent, usually marks the upper limit of the formation with distinctness, though more or less of sand mingles with the lower ledges of the limestone above.

2. Mendota Limestone. This name has been given to this group of strata, by Prof. Irving, from its occurrence on Lake Mendota, near Madison. The term limestone is applicable, however, to this division in eastern Wisconsin, only in a qualified sense. It consists really of a group of alternating strata of arenaceous magnesian limestone, sandy calcareous shales, and shaly and calcareous sandstones. The limestones are soft, granular, porous, friable, rather thin bedded, buff colored, and frequently contain seams of greensand.

They resist erosion to a greater degree than the sandstones above and below, and so sometimes form the protecting cap of terraces.

The shales are variegated with yellow, red and purple. Those of the latter class are quite characteristic, though something very similar occurs at a few exceptional localities in the St. Peters sandstone. The purple portion, which only makes up a part of the mass of the rock, consists of irregular layers, lumps and patches mixed with reddish and yellowish portions, giving the whole a peculiar mottled appearance. The lighter colored shales occur intimately associated with these. Both classes are more or less arenaceous and calcareous, are soft and brittle, easily crushed, and readily decomposed under the action of atmospheric agencies.

The sandstones are of two kinds, those consisting of the common white, buff, yellow or orange quartzose sand, with more or less of calcareous and aluminous admixture, and those formed by a mingling of the common quartzose sand with green particles of glauconite, and altered forms of it, producing as a result various shades of gray, yellow, green and mottled sandstones. The component grains frequently have but a slight cohesion, so that the mass is fittingly termed green sand.

The upper and lower limits of the Mendota group are scarcely definable. It graduates above into the Madison sandstone, so as to make it difficult to draw a line between the two, and below, the alternation of calcareous and arenaceous rock make it equally difficult to say where the series ends.

A *thickness* of fifteen or twenty feet would include the greater portion of the lime rock, while about sixty feet would be required to cover the entire alternating series. This will be clearly seen by inspecting the local sections subsequently given.

This constitutes one of the objections to separating this from the Potsdam sandstone series, and grouping it with the Lower Magnesian series. The lower limit of the Magnesian limestone is in this region and elsewhere so far as I have personally observed, well defined, although sandstone mingles with the formation above and calcareous strata extend scores, if not hundreds, of feet below into the Potsdam sandstone. Aside from other objections, there seems to me no good reason for placing the dividing horizon at any other point than that which has very generally been recognized by geologists, viz.: at the top of the Madison beds.

It is to be remarked, however, that in central Wisconsin where the Mendota beds develop a greater thickness and purity of dolomitic character as well as greater lithological similarity to the Lower Magnesian limestone, they have heretofore been mistaken for that formation, and something of confusion introduced into the geology of this horizon, which the distinct recognition of the Mendota beds by Prof. Irving has removed.

The paleontological evidence very strongly corroborates the view here taken. Without attempting an exhaustive discussion, it may be remarked that the Mendota beds are undoubtedly the eastern equivalents of Dr. Owen's Fifth Trilobite bed, the common horizon being characterized by the presence of *Dicellocephalus Minnesotensis*, *D. Pepinensis*, *Lingula aurora*, *L. mosia*, and a few other species of limited horizontal distribution. The primordial aspect of this fauna is unquestionable. The collections of this season have shown *Lingula* *mosia* to be associated with *Lingulepis pinniformis*, which is considered by Owen and Hall as characterizing the lower beds of the Potsdam, and *Dicellocephalus Pepinensis* was found with *Illænurus quadratus*, which Prof. Hall refers to the middle Potsdam, thus showing specific paleontological bonds with the lower strata.

On the other hand there is not, so far as I am aware, any case of the occurrence of any of these species in the Lower Magnesian limestone, as limited in this report, there being ample reasons for believing that in all cases where *Dicellocephalus Minnesotensis* has been doubtfully referred to this horizon, the specimens really belonged to the Mendota or other intercalated beds.

The lower divisions, constituting the main body of the Potsdam sandstone, present but very few exposures in this region, and these of very limited extent, so that we are dependent chiefly on the evidence derived from Artesian wells for positive knowledge of their nature. So far as thus indicated, there are four subdivisions.

3. That which lies next below the Mendota beds is a light colored, fine to medium grained sandstone. The constituent grains are chiefly quartz, with a less quantity of chert and a few limestone and granitic particles in some portions. It is slightly calcareous, even where the limestone particles are not observable.

4. The next division consists of a bluish green shale of highly calcareous nature, containing minute, glistening, mica-like scales. It was not seen in outcrop, and may be quite local, though it appears to be represented in the northwestern part of the state.

5. The fifth division is very similar in nature to that above the last, being a rather fine grained, light colored quartzose sandstone, containing occasionally some clay-like calcareous matter.

6. The lowest subdivision is a very coarse, non-calcareous sandstone, composed of large grains of transparent, light colored quartz of irregular but rounded form.

Organic Remains. The following is a list of the fossils found in the Potsdam in this portion of the state. These, and all subsequent identifications in this report were made by Prof. R. P. Whitfield, whose eminent qualifications are a guaranty of their correctness:

PLANTS.

Paleophycus. Sp. und.

MOLLUSCA. — BRACHIOPODA.

Orthis Pepina.

ARTICULATA. — ANNELIDA.

Tubes of scolithus?

TRILOBITES.

Conocephalites diadematus, H.
Conocephalites minor, Shum.
Conocephalites Gibbsi, n. sp.[1]
Dicellocephalus Misa, H.

This is probably very far from being a fair representation of the actual fauna, but the meagerness of the outcrops in this region, and the fact that the rock is very rarely quarried, make it practically impossible to secure a full collection.

Method of Deposit. That this sandstone was deposited beneath the ocean is shown by the remains of marine life found in it. That the water was comparatively shallow is indicated by the ripple marks and beach structure that abound in the formation. The rounded and yet irregular character of the grains of sand that constitute the chief element of the rock leaves no doubt that they were originally small, angular grains of quartz that have been worn by friction to their present form. The fact that this formation lies upon the surface of the Archæan rocks, which abound in quartz in the form of irregular grains and crystals, and in mica, feldspar and other minerals found in the sandstone, that these rocks have been decomposed and eroded to an enormous extent, and that they were, at the time this deposition was in progress, exposed to the action of the waves and atmospheric influences, make it certain that the sandstone was derived from these older rocks, and that this was accomplished by the same process of wear, decay, and redeposit that is in action at the present time, producing similar accumulations of sand, that may in time become hardened to rock. The clayey material was doubtless derived in the same way from the feldspar and other aluminous ingredients of the same granitic rocks, but the calcareous portion was doubtless chiefly formed through the agency of marine life.

A microscopic examination of the grains of sand is entirely fatal to the view still occasionally advanced, that they were produced by crystalization from solution, as they neither have in general the crystalline nor concretionary form, nor one that would naturally be derived from either of these by friction, if indeed friction were supposable under that theory.

Extent. It has heretofore been remarked that the Potsdam sand-

[1] The names of new species given in this volume are from the manuscript of Prof. Whitfield, which will be published at an early day. They are here introduced for the obvious value they will give the report when the descriptions shall be published, and with no reference to any claim to priority of publication.

stone in Wisconsin has the general form of a crescent. We have the right or eastern horn of this crescent under consideration. It enters the district obliquely from the southwest, and occupies the western margin of Green Lake, Winnebago and Outagamie counties, from whence it extends to the northeastward, passing into Michigan across the upper great bend in the Menomonee river. It is much narrower in this than in the central portion of the state, averaging only from ten to fifteen miles in width. The formations in this part of the state have a rudely zigzag or stair-like outline, in which this sandstone participates. This is more especially true of its upper limit or eastern boundary, where it is overlaid by the Lower Magnesian limestone. Its lower limit cannot be mapped with equal precision, owing to the unevenness of the underlying formation and the ever present obscuring drift accumulations. Beyond the limits marked on the maps, where detailed investigations have not yet been made, isolated patches will doubtless be found resting upon the Archæan rocks.

A more clear and accurate view of the surface extent and location of this rock than it is possible to convey by verbal description, may be obtained by consulting the accompanying maps, to which the attention of the reader is respectfully invited.

The formation dips to the east, and passes under all the formations lying in that direction, as shown in the sections on the accompanying maps, and in this volume under the head of Artesian Wells, so that it underlies at varying but ascertainable depths the whole of the eastern part of the state.

SECTIONS AND LOCAL DESCRIPTIONS.

The township of **Kingston** in the southwest corner of Green Lake county, being the most southerly town in the district under consideration that is occupied to any extent by this formation may serve us as a suitable point whence to proceed northward in sketching such local developments of this formation as may seem to demand notice, the more fittingly so because it presents several prominent elevations that expose the formation. The most satisfactory of these is **Bartholomew's Bluff**, in sec. 15, S. hf of N. E. qr., T. 14, R. 11 E. This hill is conspicuously terraced, the lower shelf being capped by the Mendota beds and the upper by the more enduring Lower Magnesian limestone. The sandstones that form the rest of the hill, being soft, have been more affected by eroding agencies, leaving limestone-capped benches as seen in the accompanying figure.

The following is the section exposed at this point, in descending order:

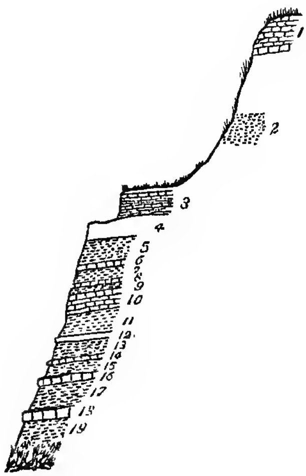
1. Bluish-gray, thick bedded, sub-crystalline, slightly silicious dolomite, uneven texture, granular in part, compact in part, and approaching a brecciated structure in portions, weathering to a rough ragged aspect; fossils absent or very rare; the bottom layers of the Lower Magnesian limestone, not completely exposed but probably about 20 feet in thickness.

2. Slope of the terrace, concealed by debris; known to be occupied in part at least by a yellowish quartzose sandstone, with slight calcareous cement. It is probable, from ob-

servations elsewhere, that the whole slope is underlaid by the Madison sandstone. Thickness 30 feet.

3 Rotten calcareous chipstone, occupying the surface of the lower terrace, derived by disintegration from a rock similar in character to the stratum below. Thickness 3 feet.

Fig. 24.



PROFILE SECTION OF BARTHOLOMEW'S BLUFF.

4. Light buff, thin bedded, impure, granular, porous, soft, easily fractured magnesian limestone, marked with fucoidal impressions and interlaid with thin seams of green sand. Examined under the microscope, the component grains appear very angular and in the dry state mostly opaque. On the addition of acid, part are dissolved with effervescence, leaving many transparent angular particles insoluble in warm acid. Used for building purposes. Thickness 8 feet.

5. Unexposed, 4 feet.

6. Greenish and grayish, scarcely coherent sandstone, composed of white or light colored grains of quartzose sand and green grains of glauconite. Thickness 6 feet.

7. Calcareous, banded and mottled white and orange, coarse granular, sandrock, partly formed of quartz grains and partly of small crystals of dolomite. Thickness, 5½ inches.

8. Soft, white, very friable, quartzose sandstone. Thickness, 2 feet and 5 inches.

9. Calcareous layer of mottled, greenish and orange color, coarse granular, uneven texture and medium hardness, graduating into the green sand below. Thickness, 9 inches.

10. Green sand of deep color, speckled with reddish iron stains, very friable, graduating into the layer above. Thickness, 21 inches.

11. Porous, granular, crystalline dolomitic layers, marked by nodules of hematite. One layer is 7½ inches thick, and firm and excellent for building purposes. The layers are separated by thin seams of green sand. Thickness, 3 feet and 6 inches.

12. Greenish white sandstone containing spherical concretions and Scolithus tubes. The walls of the tubes are usually cemented with iron oxide and the fossil stands out beautifully on the weathered surfaces. Thickness, 6 feet.

13. Orange yellow, calcareous sand rock, containing crystals of calcite. Thickness, 13 inches.

14. Sandstone, containing spherical concretions. Thickness, 4 feet.

15. Orange yellow, calcareous rock, as above. Thickness, 1 foot.

16. Dirty greenish white sandstone, full of the spherical concretions and blotched with iron stains. Thickness, 3 feet.

17. Orange yellow, calcareous rock, with calcite crystals imbedded. Thickness 15 inches.

18. White friable sandstone, the upper foot filled with concretions, the lower three and one-half with Scolithus. Thickness, 4 feet and 6 inches.

19. A layer consisting of quartzose sand cemented by calcareous material, containing calcite crystals, and marked with limonite. Thickness, 8 inches.

20. Sandstone filled with concretions. Thickness, 8 inches.

21. Soft, friable, dirty yellowish sandstone of very uniform medium grain. Thickness, 6 feet.

The concretions above referred to are globular aggregations of quartz sand cemented by calcareous material, in size and form, resembling a boy's marbles. They are frequently attached to each other, producing odd and fantastic forms.

On **Mt. Maria**, two and a half miles southwest, the main exposure is the Lower Magnesian limestone, but at the base of it, at some points, sandstone is exposed and contains Scolithus tubes within two and a half feet of the limestone above. On the eastern slope of the hill the calcareous shales of the Mendota horizon may be seen.

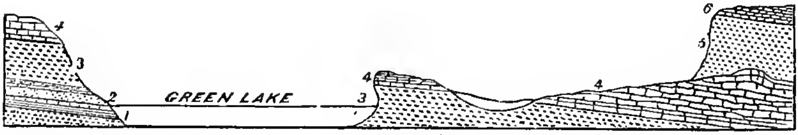
Near the center of *section 24* of the same town the gulley of the road exposes imperfectly a considerable portion of the Mendota formation, which is here more shaly than at Bartholomew's Bluff and does not expose any firm thick layers of limestone, the section being composed chiefly of shales and sandstones, as follows:

1. Coarse yellow crystalline limestone, graduating into sandstone. 1 foot.
2. Green and orange sandstone with calcareous matter in seams and aggregations. 2 feet.
3. Green calcareous sandstone. 6 inches.
4. Orange sandstone, 1 foot.
5. Slope, covered, about 3 feet.
6. Whitish sandstone containing Scolithus, 3 feet, 3 inches.
7. Orange calcareous sandstsone, 8 inches.
8. Yellow sandstone containing spherical concretions, 1 foot.
9. Calcareous sandstone, 1 foot.

Farther south the section is extended upward about 36 feet, by aneroid measurement, and consists of arenaceous and calcareous shales, interstratified with and graduating into green sandstone, and, more rarely, into gray sandstone. Some of the shales appear highly argillaceous, and some near the middle pass into an impure limestone. An adjacent hill is capped with Lower Magnesian limestone, to whose enduring character it owes its existence.

Less than a mile west of this, **Bow's Hill**, likewise indebted to a protecting cap of Lower Magnesian limestone for its origin, presents along its slopes partial exposures of the formation under discussion. At this point, red and purple shales are found, associated with the various varieties of rock described at the previous localities. These red and purple shales have already been described as a characteristic of the Mendota group, but as shown by the previous sections, they are not always present. These shales are well shown in the town of **Dayton**, Sec. 27, N. W. qr. of S. W. qr., in a little quarry along the brook not far from the road.

Fig. 25.



Profile section from N. W. to S. E., across Green Lake, showing (1, 2 and 3) Potsdam group, (2) Mendota beds, (3) Madison sandstone, (4) Lower Magnesian limestone, (5) St. Peters sandstone, and (6) Trenton limestone.

They are again seen on the shores of **Green Lake**, toward its western extremity. On the south side of the lake they occur as a low exposure at the water's edge, covered by drift. On the opposite side, north of Norwegian Bay, there is a more considerable display of Mendota strata. The cliff has a protecting cap of Lower Magnesian limestone, from which descends a steep slope covered with debris that doubtless conceals the Madison sandstone, below which there comes in a series of impure limestone layers. These are thin bedded, inclined to be shelly, of earthy fracture, soft and quite argillaceous, the aluminous material forming shaly partings. Below this follow a group of arenaceous shales and shaly sandstones, chiefly of greenish and purple casts, whose structure is somewhat changeable as traced horizontally. Oblique lamination is most beautifully shown in some portions. Underlying these are heavy beds of calcareous sandstone, of yellowish color, and rather uniform, firm texture, below which lie purple, iron-stained arenaceous shales, succeeded by calcareous sandstone similar to that above. The exposure reveals a low axis, the strata dipping both east and west from its center.

Sugar Loaf, on the opposite side of the Bay, discovers essentially similar strata. Surmounted by like Lower Magnesian ledges, its talus-covered slope of 60 feet is succeeded by alternating layers of the Mendota group.

Limited outcrops of the Potsdam strata occur at several points in Green Lake county, which cannot here be specially described for want of space, but which the accompanying maps will enable any one to identify, who may desire to do so.

At **Berlin**, adjacent to the porphyritic ledges, a coarse silicious sandstone occurs, containing, imbedded in it, fragments of the porphyrite, often of large size. These fragments are sometimes well worn and rounded, but oftener angular. Fortunately these beds are also fossiliferous, and the following species have been identified from the collection made by Mr. F. H. King: *Paleophycus, Sp. und., Orthis Pepina, Scolithus, Conocephalites diadematus, C., minor, C., Gibbsi, n. sp., Dicellocephalus Misa.* These show that this sandstone, conglomerate and breccia, is of the Potsdam age. The position at which these occur in the western part of the state would indicate that these beds belong to the middle portion of the formation, though the elevation as compared with that of the Lower Magnesian limestone, which occurs a little to the east, is such as to lead to the belief that it belongs to a higher horizon.

The conglomerate and breccia were undoubtedly formed by the beating of the waves against the adjoining porphyrite cliffs, which formed a rocky island in the ancient ocean.

From this point northward the Potsdam beds are almost wholly concealed by drift, except as a few feet are exposed here and there at the base of the Lower Magnesian ledges, that mark the western limit of that formation. Such exposures occur in the towns of *Winchester, Caledonia, Mukwa, Hortonia, Ellington, Cicero, Shawano* and *Gillette*, but nowhere is more than a few feet of the upper part of the formation shown.

Near the "**Big Bend**" of the Oconto river, the bluffs on the south side are crowned with impure limestone very meagerly exposed, below which the Potsdam sandstone occasionally shows itself. About two miles below the bridge, the "*Flat Rock*" is formed by beds of quartzose sandstone, stretching across the river and forming gentle rapids. The rock is grayish white, mottled with yellow, and composed of well rounded grains of transparent quartz of varying size, cemented with a little calcareous matter. The beds dip gently to the southeast. The face of the layers, as they cross the river, is pitted with "pot holes" not often exceeding the size of the homely utensil that gives them a name, in some of which the gravel is still eddying about, continuing the process of formation.

At **Little Falls** on the Peshtigo river, a lower portion of the formation is presented, consisting of white friable sandstone, composed of nearly uniform, well rounded grains of quartz, with very little cementing material. The upper beds are thick and massive; below these, the layers are thinner and softer, beneath which again are thicker beds. The falls owe their origin to this irregularity.

Several miles down the river in Sec. 12, T. 31, R. 20 E., there is a low exposure containing Scolithus tubes, and representing a higher horizon.

The formation barely demonstrates its presence where it crosses the Menomonee river into Michigan.

LOWER MAGNESIAN LIMESTONE.

Reposing upon the upper face of the Potsdam sandstone lies a group of silicious dolomitic beds, to which the term Lower Magnesian limestone was applied by Dr. Owen, to distinguish them from the Galena and Niagara dolomites, which constituted his Upper Magnesian limestone. The former name has very properly been retained, while the latter, for good reasons, has been discarded. The term Calciferous sandrock, applied to the near equivalent of the Lower Magnesian limestone at the east, is not admissible in this state, from the lithological nature of the rock.

General Character. It is, as the name implies, a magnesian limestone or dolomite, sufficiently pure to burn to a serviceable quicklime in its lower, middle and upper portions, though not in each layer of these subdivisions. The chief impurities are quartz, clay, iron and greensand.

The dolomite occurs in the earthy, the granular crystalline, and the cryptocrystalline forms. The second is the more prevalent form. Even when the rock has a decided earthy aspect and fracture, examination with a lens often shows a large element of crystalline grains, and on the other hand, in most of the cases where the crystals seem to have completely blended with each other, concealing themselves in the common mass, the crystalline facets are apt, upon close examination, to be more or less discernible, so that, except where the rock is silicious, the cryptocrystalline form is not common. In some portions the mass of the rock is formed almost exclusively of small crystals of dolomite, rather loosely aggregated, leaving minute, angular spaces between the crystalline grains, forming a very pronounced granular rock. There are occasional evidences of what is probably the common fact, that this crystalline structure was assumed after the deposition of the beds, and it may have been synchronous with their dolomization. The silicious material is present in four principal forms: that of dissemination through the mass of the limestone, of concentration in nodules of chert or flint, of aggregations of quartz crystals, and of scattered grains of quartzose sand.

The amount of silica disseminated through the rock is less than, I think, is commonly supposed, which is likewise true of the quartzose sand. The granular character of the rock causes it to weather to a harsh sand-like surface, which appears more silicious than it really is. Judging from the analyses made, the silicious ingredient rarely exceeds ten per cent., and occasionally falls below two.

The chert, of which the quantity, on the whole, is large, is not con fined to any one horizon, though most abundant in the middle portion. Its distribution is irregular, though the nodules are frequently arranged in layers along the bedding planes of the limestone.

The more distinctly crystalline quartz forms, in some portions of the deposit, multitudes of little clusters, completely filling small cavities in the rock mass, and in other portions, where the cavities are larger, the crystals only form a lining, producing drusy little grottoes, some of which are very beautiful. The quartz is most frequently transparent or opalescent, but it is sometimes red, brown, or rose colored. The crystals are sometimes grounded on a chalcedonic base, forming a beautiful combination.

The quartzose sand is confined chiefly to the vicinity of the junction with the sandstone below and above, and to a subcentral band of shale, subsequently described. A portion of the oölitic grains have a silicious core.

Argillaceous material is not abundant in the formation, except in shaly bands, where it sometimes constitutes as much as 20 per cent. of the whole. In the upper part of the formation it sometimes amounts to six per cent., but it is seldom that the rock is notably argillaceous. Neither is the amount of iron conspicuous, though its compounds sometimes reach four or five per cent. The rock seldom appears ferruginous.

In addition to these chemical and crystalline characters, *the oölitic structure* distinguishes some portions. In most cases, the spherules differ but little in size from those of the roe of our common fish, which they so much resemble, but some, as those at Oconto Falls, reach a much larger size. It is a significant fact that the oölitic structure is confined to essentially the same horizon with the sand above mentioned. A portion of the spherules are simply grains of sand, coated with concentric layers of carbonate of lime and magnesia.

Passing from these to *the more massive features*, the rock presents a very irregular structure, owing to unevenness of hardness and composition, and inequality of deposition. The effect of weathering is to exaggerate this, and hence outliers of this formation present a very rough and often grotesque exterior. A portion of the rock is brecciated, having been apparently once broken up by the waves, and in some cases somewhat rounded by rolling, and afterwards recemented by material similar to the fragments themselves. These layers add to the coarse aspect of the rock. In addition to this, the bedding is often very irregular, and sometimes obscure, and the beds not unfrequently undergo change when traced horizontally. The color of the weathered and leached portions is a dirty white, gray, or very light buff On the interior, the rock often has a greenish blue or gray cast. Some of the thinner beds and shaly layers are variegated with red and purple. From the ease with which the sandstone below is eroded, the lower portion of the formation is often left projecting in mural cliffs, or forming a protecting crown for some isolated hill, which owes its existence to such defensive covering. The strata dip to the eastward, and are soon lost beneath the later formations, by penetrating which the formation may be reached at continually increasing depths, as we go eastward.

The floor of the formation, so far as has been ascertained, is essentially plane, but *the upper surface* is highly undulating or billowy, for the latter term very accurately pictures to the mind its remarkable nature. The billows of this petrous sea vary in height, from a gentle swell to elliptical domes rising one hundred feet above their bases, while their length ranges from a few rods to a quarter of a mile or more, and their width, from one-third to one-half the length. The regularity of outline here indicated is a frequent and typical, but not universal, fact. The slope of the sides varies from 30° downwards. The axes of these domes lie in an easterly and westerly direction, much more commonly than otherwise.

FIG. 26.

EAST AND WEST SECTION NEAR RIPON.

1. Lower Magnesian limestone. 2. St. Peters sandstone. 3. Trenton limestone.

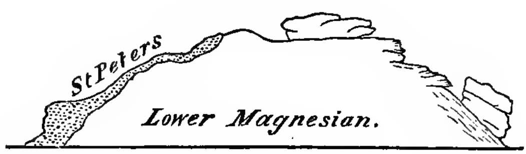
The superficial strata of these rock-billows *dip in every direction* from the center, most rapidly at the sides, and less so at the extremities; or, in other words, they are essentially concentric with the surface.

These statements are made with reference to the original condition of the mounds before erosion. There are satisfactory evidences that during the deposit of the St. Peters sandstone upon this unequal surface, the exterior of these prominences was somewhat eroded, and in the removal of the latter formation by the elements and the drift forces, resulting in their present exposure, they were still further acted upon.

The eastern and northeastern extremities suffered considerable abrasion from the latter cause. But neither of these agencies modified, except superficially, the form of these prominences, while they served to demonstrate more satisfactorily the quaquaversal character of the dip.

Unfortunately, little is positively known to me concerning their interior. The deeper strata observed were of very irregular character, being either brecciated or showing a tendency to a rude concretionary grouping of material into irregular lump-like enlargements of the layers. In a very few instances, supposed to belong to this class, notably an outlier one mile south of the village of Markesan, the whole of the rock exposed is a thoroughly brecciated mass, with obscure or absent bedding lines. This may, perhaps, be the remnant of a larger mass that formed the nucleus over which the sloping strata were deposited, for the weight of evidence goes to show that this is a phenomenon of deposition and not of upheaval.

FIG. 27.



SECTION (north of Stiles) SHOWING THE RELATIONS OF THE ST. PETERS SANDSTONE AND LOWER MAGNESIAN LIMESTONE.

Organic Remains. These are very meager. Fucoidal remains, Salterella (?), an undetermined species of Stromatopora; Ophileta uniangulata, two undetermined species of Trilobites, doubtfully referred to the genus Barthyurus, embrace those found in this region.

Area. It has been remarked that the Potsdam sandstone area forms a rude crescent, the eastern limb of which enters the district under consideration in Green Lake county, and extends thence to the Menomonee river. The Lower Magnesian limestone forms a serrated band or a fringe on the convex edge of this crescent, averaging about seven miles in breadth. It barely enters the district on the western margin of the counties of Jefferson and Dodge, but invades Green Lake county with its full width, and thence passes diagonally onward to the northeast, through Winnebago, Outagamie, Shawano, and Oconto counties, as exhibited on the accompanying maps.

Thickness. Owing to the uneven surface, the thickness varies greatly. The observed extremes in this region are 62 feet and 141 feet. Calculations based on dip give very similar results, but it is highly probable that the thickness sometimes exceeds these limits.

Local Descriptions. The most southerly point at which the Lower Magnesian limestone appears within the eastern district, is at **Waterloo**, in Jefferson county. Along the stream below the lower bridge, at the village, a low ledge presents its rough, weathered face to view. It consists of a coarse, cherty, buff, silicious dolomite, in medium beds of rough, uneven texture, owing in part to irregular cavities and granular porous spots, and in part to the presence of nodules of chert. This inequality of structure is exaggerated by the effects of long weathering, giving the surface a very ragged aspect. The exterior of the chert is usually white and rather soft, while the interior is dark or reddish, hard, translucent and flint-like. The outcrop represents the upper portion of the formation.

This limestone next appears to the north, within our district, on the Crawfish river, two miles below Columbus, in a low exposure in the banks of the stream, similar to the above. Three-quarters of a mile northeast from this, near the center of the S. E. ¼ sec. 19, town of **Elba**, a quarry exposes the following section of impure magnesian limestone:

1. A brecciated stratum, composed of small, compact, dark gray fragments between which are numerous irregular spaces filled with white pulverulent material. Thickness, 2 feet.

2. Beds more homogeneous than the above, yet porous in parts and compact in others, containing nodules of chert. Thickness, 4.6 feet.

3. A very highly brecciated layer, formed of compact. dark colored dolomitic fragments, covered with black dendritic crystals, and full of small, irregular crystal lined cavities. Thickness, 1.45 feet.

4. A stratum of very uneven texture and composition, containing silicious nodules. Thickness, 5.7 feet.

5. A single thick-bedded, porous, moderately soft dolomitic layer of uneven texture. Thickness, 2.3 feet.

6. A band of rather thin sheets of irregular arrangement, inclosing large, coarse, nodular masses of breccia-like rock, hard, compact, cherty, red stained, some portions apparently silicious, some nearly pure dolomite. Thickness, 4.35 feet.

7. Thick, uniform bed of moderately hard, compact texture, the upper portion marked with greenish silicious sand, iron stained. Thickness, 2.75 feet. Total, 21.15 feet.

North of this, in Dodge county, this formation shows an occasional limited exposure, similar to the preceding.

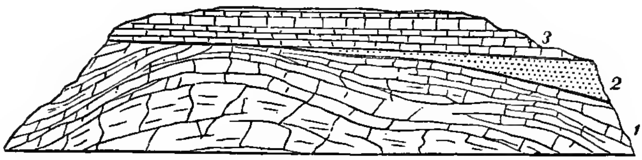
In **Green Lake County** it has already been remarked that the Lower Magnesian strata crown several of the prominent hills. These are the lower layers of the formation, and constitute the small patches lying west of the serrated edge of the main body of the formation, as represented on the accompanying maps.

The extensive prairies of Manchester and Dayton townships are underlaid by this rock, while those to the eastward repose on the Trenton and Galena limestones. It is in this county that we first find a clear demonstration of what constitutes the most remarkable feature of the Lower Magnesian limestone, viz.: the undulatory nature of the upper face of the formation already mentioned. North of Lake Maria, in the town of **Mackford**, are several conical mounds, partially covered with earth, which rise nearly to the level of the base of the Trenton limestone, which occurs a few rods to the east, while in the town south, at least 23 feet of sandstone intervene, and in the town north, at least 82 feet, and near Ripon, over 100 feet. So far as exposed, the strata forming the mounds dip away from the center. But we need not linger upon so poor an exposure.

In the S. E. qr. of Sec. 7 of the same town is a conical hill surmounted by a turret of massive breccia, which needs to be noted in this connection, though there is nothing except its elevated position to show that it indicates any irregularity in the surface of the formation. But in the N. E. qr. of Sec. 15 of the same town, at the point where the road crosses a small stream, there is a most satisfactory demonstration of this in *the rise of an arch of Lower Magnesian strata into actual contact with the Trenton limestone, causing the thinning out of the St. Peters sandstone to absolute zero.* This is illustrated by the accompanying figure.

The layers of the Lower Magnesian at this point, especially as seen down the stream a few rods, consist of two classes, thin undulating beds and thick brecciated ones; the two alternating, in a measure, with each other. The latter are very hard and crystalline in texture. Some of the angular cavities that constitute the interspaces between the fragments of the breccia are filled with calcite and pyrites, but most of them are empty, giving the impression that the rock had been crushed. But this, with one or two other similar cases, is exceptional. The breccias that are so common a feature in this lime-

FIG. 28.



1. Lower Magnesian Limestone. 2. St. Peters Sandstone. 3. Trenton Limestone.

stone cannot, in my judgment, be satisfactorily explained by any form of crushing after deposition. In this instance the undulatory nature of the thin beds, and the hardness and crystalline character of the brecciated rock lend some plausibility to the idea of compression, or forcible upheaval, as the cause of this apparent flexure of the Lower Magnesian strata. But we shall have occasion to consider a large mass of facts not in consonance with such a view.

The figure, which exhibits an east and west section, shows that the strata dip in both those directions, and by following down the stream to the northward, they are seen to slope rapidly in that direction also. To the south they are concealed, but judging from analogy, they descend also in that direction within a short distance, thus forming a dome supporting the Trenton strata above.

The character of the sandstone, which will be considered more fully under its appropriate head, makes it evident that the sides of this dome were subject to the action of the waves while the St. Peters sandstone was being deposited, demonstrating that whatever cause produced the arch, acted before the sandstone was formed.

In sections one of this town and thirty-six of the town north, the Lower Magnesian and Trenton strata are found at the same level and very near each other, leaving no doubt that here is another instance of the lower formation rising into the horizon of the upper. This is shown by Fig. 19, *ante* p. 251.

Six miles to the west of this, on the shores of the **Little Green Lake**, the same peculiarity is again manifested. At the southeast angle of the lake, a low arch is partially exposed, while on the north shore a more decisive instance occurs. A precipitous bluff, crowned with Trenton strata, skirts the lake on that side. At the west end of this bluff, there are fifty-four feet of St. Peters sandstone between the Trenton layers and the water's edge, and how much is concealed beneath is unknown. But within eighty rods to the east, the Lower Magnesian strata rise above the water's edge, and approach within eighteen feet of the Trenton above, if, indeed, they do not come into actual contact, as the nature of the slope seemed to indicate, but which could not be observed on account of the talus covering the side of the bluff. In the opposite direction, within a half mile, the Lower Magnesian strata may be found arching upwards to elevations of thirty and forty feet, or more, above the lake level.

About half a mile to the northwest, a valley reveals the arcuate nature of the strata most clearly. On entering the gorge below, the layers are found to dip southward at an angle of 20° and upwards, but as the crest is mounted, the inclination becomes less and less until they are lost beneath the soil, within twenty feet of the Trenton horizon.

Toward the top, there are to be found some very sandy layers that appear to rest, in a measure, unconformably upon a worn surface beneath, and probably represent the St. Peters sandstone, which would naturally be calcareous in such a situation.

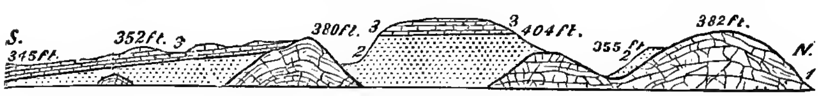
A portion of the rock of this dome is a coarsely brecciated, very hard crystalline dolomite, but the greater part belongs to the more common class of coarse, impure magnesian limestone that characterizes this formation.

Passing by a number of minor exhibitions of the same phenomena, we find, in the vicinity of **Ripon,** this peculiarity developed to a wonderful extent. Just west of the Ceresco Mills, in the lower part of the city, there rises a rock hill, having an elongated oval contour, somewhat enlarged and curved at the eastern extremity. Its base is skirted on the east and north by streams above which its crest rises to an average height of about one hundred feet. Its axis lies east and west, and does not much exceed one-fourth of a mile in length. It is terminated at the west by a deep ravine, beyond which rises a second ridge of similar form and height, and somewhat greater length, but which is less conspicuous because of its connection with the plateau on the south. The ridge first mentioned is nearly isolated by a deep ravine on the south, which reveals its form, though the rock exposures are chiefly confined to the eastern end. On the northeast slope, thick, heavy, rough beds of Lower Magnesian limestone show a dip of 15° to 18° to north of east. On the easternmost point, the dip is 18° to the eastward, while on the southeast curve a slant of 25° to 30° to the southeast is observed, and farther along the south side of the hill, a more southward and southwestward dip seems to be indicated, though the exposures are very unsatisfactory. A small quarry above the limekiln, and near the top of the hill, shows within itself dips of 3° E., 12½° N. E., and 7° N. W., with all intermediate inclinations. This irregularity is not caused by the folding or contortion of even bedded layers, so much as by the thickening and thinning of irregular ones. Great lumps, as it were, occur at certain points, swelling two or three fold the thickness of the layer, or causing it to disappear entirely in a structureless mass. The rock is greenish blue, somewhat argillaceous, and contains a few fossils.

Down the slope from this quarry, and within six rods of it, a bed of St. Peters sandstone lies immediately against the flank of the Lower Magnesian arch, *the top of the sandstone being 30 feet below the crest of the ridge.* The actual junction of the sandstone with the limestone was not visible at the time of either of my visits, but I was credibly informed that in a filled portion of the sand pit it had been previously exposed.

Wells in the vicinity show that the surface of the limestone descends to at least 100 feet below the top of the hill. *There is here then within a horizontal distance of less than one quarter of a mile, a rise and fall of the upper limits of the Lower Magnesian limestone of not less than 100 feet.*

Fig. 29.



North and South Section, near Ripon.

1. Lower Magnesian limestone. 2. St. Peters sandstone. 3. Trenton limestone.

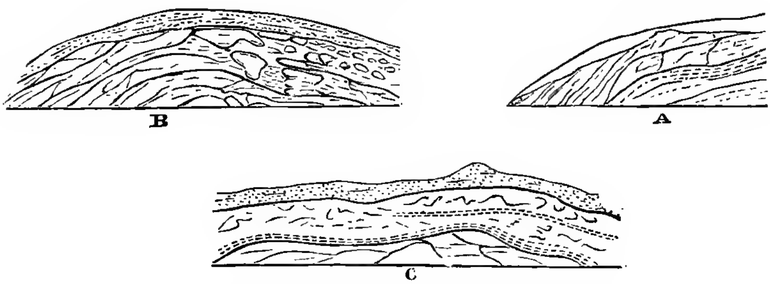
Within less than a half mile south of this arch, the Lower Magnesian strata again mount into the Trenton horizon, more than 100 feet above the intervening depression, and again to the south, less than half a mile, another arch appears, but passes under the bluff to the west before attaining so great an altitude as the two preceding ones. The rock forming this one is unusually irregular in hardness, and weathers out into the most fantastic shapes, so that the loose worn masses are much admired as lawn ornaments.

The accompanying figure will assist in illustrating the foregoing facts. The irregularity is unquestionably due chiefly to the undulation of the upper strata of the formation; but there is evidence that the sides of these prominences were somewhat worn by wave action during the deposit of the St. Peters sandstone and a portion of the rock incorporated in that formation. Near the west line of the township of Ripon, on the lowlands, near the ledge that marks the limit of the Trenton plateau, the upper portion of one of these swells is finely shown. It is only a few rods in extent, and attains but a meager elevation compared with those just described. It is oval and symmetrical in outline, and has its greater axis, which is about twice its transverse diameter, east and west, in harmony with the general rule. The surface rock, which alone is exposed, is rather even bedded and homogeneous for this formation, in which irregular structure is the prevalent form.

West of **Rush Lake,** at several points, the billowy character of this face of the formation is shown by variously dipping strata and half exposed domes of rock.

In the railroad cut adjacent to the lake shore, near the center of section 15, Nepeuskin, something of the nature of the interior of these mounds is revealed, though the cut does not exceed six feet in depth. The surface of the rock is irregularly undulating, consisting of hummocks and hollows; notwithstanding which, it is interesting to note that it is polished and covered with glacial striæ, bearing westward. It might be supposed that the present surface is due to erosion, were it not for a sandy layer, covering a portion of the surface, that seems to belong to the sandstone subsequently deposited. The rock is very irregular in bedding and stratification. The layers thicken and thin, enter and disappear, in a very remarkable way, and that within the space of a few feet. At the same time they curve and dip in various degrees and directions. The accompanying cuts, from sketches made on the spot, will serve to show this imperfectly.

FIG. 30.



SKETCHES FROM SECTION 15, NEPEUSKIN.

Showing irregular structure of Lower Magnesian limestone.

The irregularity is such that it seems necessary to attribute it to the conditions of deposition and not to subsequent disturbance. During the process of deposition there appears to have been more or less of loosening, breaking up, rounding and rearranging of the somewhat indurated sediment and its redeposit, intermixed with finer material, but after the final deposition there is no evidence of subsequent disturbance beyond that common to all formations. Northwest of **Winneconne** these mounds become so prevalent that the surface of the formation may very fittingly be termed billowy. They seldom exhibit a greater length than forty rods, nor an elevation of more than thirty or forty feet, and are usually much less than this. Of course mention is here made only of that portion which protrudes above the drift, and not of the actual dimensions. Their greatest length here, as elsewhere, is east and west. The dip in all cases, so far as could be determined, was quaquaversal, being greatest on the sides and perceptibly less at the extremities. The greatest dip observed in this vicinity was 20°. In most cases apparently only the crest of the arch was exposed and the dips were low.

One of these hills, situated near the center of the east line of section 15 of the town of Winneconne, presents some special features deserving mention. The uppermost layer, where still preserved, contains a large ingredient of quartzose sand, or is incrusted with sand, or in other cases, consists of a conglomerate or breccia whose matrix is quartzose sand. This layer is also sometimes oölitic. As similar facts were observed at several other widely separated localities, this sandy portion is believed to be the transition layer to the St. Peters sandstone, and if so, it indicates, where preserved, the original form of these mounds, and that in these instances the drift forces have only removed the incoherent sandstone above. This is rendered the more probable by the fact that usually this sandy layer was found on the *southwestward* side of the prominence, where it would be protected from the more forcible action of the glacier, while the northeastern corner, which sustained the full force of the ice mass coming from that direction, was often conspicuously abraded.

Another interesting fact observed at this point was the presence of distinct *mud-cracks* and *ripple marks*. The latter are far less common on limestone than on sandstone, and the former are more abundant in shales. Both occur here together on the gentle slope of one of these peculiar mounds. *The dip*, here, varies from 0 to 8°, conforming as usual to the shape of the hill, which in this case departs somewhat from the usual symmetrical contour. The rock structure is very irregular. Some portions are a well marked conglomerate, both matrix and pebbles being, however, dolomitic. A layer near the surface is very fossiliferous, over the small space exposed, but the casts are so obscure as to preclude satisfactory specific determinations. They consist of the internal casts of an *Ophileta* and two undetermined species of *Raphistoma*.

While our attention has thus been fastened upon the peculiarities of the superior face of the Lower Magnesian formation, we have been led northward along the eastern margin of the outcrop, where alone the upper portion has escaped erosion, and have passed by some noteworthy outcrops belonging to the middle and lower parts of the formation. If we now return to the vicinity of the village of **Eureka** we shall be introduced to a feature that characterizes the submedian portion of the formation. The ledge southwest of that place presents the following section in descending order:

1. Heavy irregular beds of impure dolomite, containing many cavities, more or less filled with quartz crystals of the transparent and milky varieties; texture varying; bedding uneven and somewhat undulatory; rock weathers to a very rude ragged aspect. Thickness, 10 feet.

2. Reddish shale, variegated with gray and green, the lower portion mostly soft, breaking and crumbling easily; some parts quite arenaceous; the upper portion more calcareous or dolomitic, and containing many aggregations of quartz crystals, usually of the opalescent variety. The layers are irregular and somewhat undulating. Thickness, 15 feet.

3. Very heavy beds, nearly uniform in thickness, and horizontal in bedding. The rock contains many almond-sized but irregular cavities, only a small proportion of which are filled with crystals. It is uneven but distinctly granular crystalline in texture, medium in hardness, and dirty gray or buff on the exterior, but mottled bluish on the interior. It is well adapted to heavy masonry, as foundations, piers and locks. It is used for the latter purpose in the construction of the adjacent locks on the Fox river. Thickness exposed, 6 feet.

Attention is here called to the shale which constitutes the middle member of the section. What appears to be the stratigraphical equivalent of this, occurs at several points to the northward, the most remote being over one hundred miles distant. From this fact it has a value as a guide in fixing the position of the subordinate divisions of the formation.

In speaking of the sandstone below, mention has already been made of several localities in Green Lake county, where the lower strata of this formation are visible chiefly in the position of protecting caps covering sandstone hills.

Mt. Tom, in the township St. Marie, while affording another example of this, exposes a considerable group of the bottom layers of the Lower Magnesian limestone as follows, in descending order:

1. Rough, silicious, conglomeritic dolomite, of dirty gray aspect, weathering to a very ragged surface, which develops prominently its conglomeritic character, and also the many aggregations of white quartz crystals that abound in it; rather thick bedded. Entire thickness of original stratum not known, as it forms the apex of the hill. 28 feet.

2. Light bluish gray, thin bedded dolomite of even, fine grained texture, and easy, regular, earthy fracture, which would render it very excellent for building purposes if the courses were thicker, as they probably would be found to be where less affected by surface agencies. 4 feet.

3. A thick, rough, brecciated bed similar to No. 1 above. 2 feet.

4. Shelly, magnesian limestone and calcareous shale. The layers are thickest and most calcareous at the top, becoming thinner and graduating into the more shaly portion below, which is grayish buff and purple, and appears to be quite arenaceous, though not so in fact. 8 feet.

5. Coarse, rough, thick bedded, dirty gray, hard, granular, silicious dolomite, containing small inconspicuous geodes; irregularly cracked and fissured, and frequently forming over-hanging ledges from the removal of the softer sandstone below. 15 feet.

On the slope below the limestone occasional slight exposures of red and yellow Potsdam sandstone are visible.

In sections 11 and 14 of **Brooklyn**, in this county, the beds exposed are unusually geodiferous. Nearly or quite half the volume of the rock in some cases is formed of cavities lined with quartz crystals. These are chiefly red, brown and pink, sometimes forming very handsome, though small and irregular geodes. At numerous other points in Green Lake county, there are slight outcrops of this formation, which do not merit special description, but which may be readily identified by the characteristics already given, or by reference to the accompanying maps.

In the town of **Poygan**, Winnebago county, the western limit of this formation is marked by a line of bluffs, along the face of which occasional outbreaks of the strata occur, but no conspicuous escarpments.

In the N. W. qr. of Sec. 26, a quarry has been opened and a kiln constructed for the purpose of manufacturing hydraulic and quicklime. At the top of the quarry, three feet of thin-bedded undulatory layers of magnesian limestone are burned for the latter purpose. Below this is a layer exhibiting very unequal deposition, whose irregularities seem to give rise to the wave-like nature of the beds above. This is underlaid by sixteen feet of a rather soft, granular, argillaceous, magnesian limestone of a slightly olivaceous gray color, which disintegrates readily when acted on by the elements. The beds are below medium thickness, and, in some cases, furnish good flagging, and the material from which the waterlime is prepared, At the base is one foot of a yellowish-gray rock, eight inches of decomposed rotten stone, reposing on the common hard dolomite of the formation, which is very slightly uncovered.

In the erosion of the Wolf river valley, in **Caledonia, Mukwa and Hortonia**, the sandstone below was readily removed and the more resisting ledges of dolomite left projecting in vertical cliffs of moderate height. By combining the facts exhibited at several points along this line of ledges, chiefly those in Hortonia, the following section, representing about 60 feet of the base of the formation, was obtained.

Earth.

1. Curved strata of hard, compact, flint-like, bluish dolomite. 18 inches.
2. Compact bluish white dolomite. Purest layer. 13 inches.
3. White compact dolomite, with quartz in layers, at the bedding planes. 28 inches.
4. Compact whitish dolomite, similar to the above, but less silicious. 20 inches.

Unexposed. 6 to 7 feet.

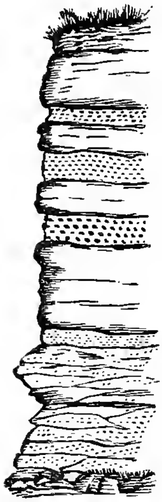
5. Blue compact hard dolomite, somewhat silicious. 9 inches.
6. Yellow, fine-grained dolomite, softer than the above. 3 feet.
7. Thin sandy, argillaceous layer. 1 inch.
8. Thin bedded dolomite, suitable for lime. 12 inches.
9. Fine grained, but rough bedded dolomite. 3 feet.
10. Thinner bedded, compact dolomite. 3 feet.
11. Thin, shelly, sandy layer. 10 inches.
12. Unexposed. 3 feet.
13. Mottled brecciated dolomite. 18 inches.
14. Very rotten, chippy layer. 18 inches.
15. Brecciated mottled layer, as above. 18 inches.
16. Thick bedded, rough, uneven-textured dolomite. 6 feet.
17. Shelly rotten layer. 3 feet.
18. Not exposed. 3 feet.
19. Rough, uneven-textured dolomite. 1 foot.
20. Flinty layer. 4 inches.
21. Somewhat sandy, dolomitic limestone. 4 inches.
22. Rough, irregular dolomite. 3 feet.
23. Sandy layer. 1 foot.
24. Light colored, slightly silicious and moderately hard dolomite. 2 feet.
25. Broken rotten layer. 14 inches.
26. Silicious, dolomitic limestone, very hard and flint-like. 2 feet and 9 inches.
27. White sandstone, marked with green. 4 inches.
28. Sandy layer. 3 inches.
29. Similar to No. 26. 3 feet and 3 inches.
30. Oolitic layer. 4 inches.
31. Coarsely brecciated layer, chiefly sandstone, but with some quartz and quartzite-like rounded and angular masses. 4 feet and 2 inches.
32. Coarse friable sandstone of uniform grain, and containing nodules of iron ore. Quartzite-like layer near the top. 3 feet and 8 inches.

Unexposed.

In tracing the layers along the face of these natural walls, they show much tendency to change, and it is only by close observation and great care that an accurate correlation of different sections can be made, and considerable variation is to be expected where much distance intervenes.

This changeableness will be manifest by comparing the preceding section with the two following, both taken from the same quarter section (S. W. qr. Sec. 25, Mukwa).

FIG. 32.



1. Earth.
2. Magnesian limestone. 20 inches.
3. White sandstone. 3 inches.
4. Magnesian limestone. 8 inches.
5. Oolitic silicious limestone. 7 inches.
6. Magnesian limestone. 9 inches.
7. Sandstone. 8 inches.
8. Thick even-bedded magnesian limestone. 24 inches.
9. Oolitic silicious limestone. 5 inches.
10. Sandy magnesian limestone of irregular bedding and texture. 20 inches.
11. Irregularly bedded sandstone, marked with iron. 22 inches.

Total thickness, 10 feet and 6 inches.

FIG. 33.

1. Earth.
2. Yellow sandy and oolitic magnesian limestone. 18 inches.
3. Green sandstone. 4 inches.
4. Oolitic magnesian limestone, as above. 20½ inches.
5. White sandstone. 3 inches.
6. Oolitic magnesian limestone, as above. 9 inches.
7. Yellow sandstone. 4 inches.
8. Sandy silicious limestone. 13 inches.
9. Oolitic layer. 3 inches.
10. Sandy and Oolitic limestone. 13 inches.
11. Yellow sandstone, marked with green. 15 inches.

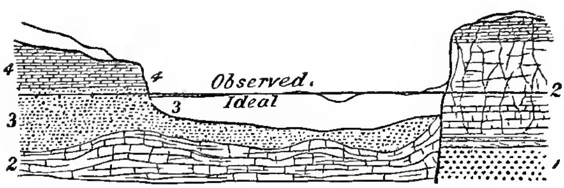
Total thickness, 8 feet and 6½ inches.

The increase of silicious matter in the latter is very noticeable. This is perhaps due to the fact that the ledge from which the section is taken here approaches within a half mile of the Archæan outcrop of granite in this town, previously described. As it arose into the Lower Magnesian horizon, it might perhaps rationally be supposed to produce such a modification of the limestone in its vicinity. But the fact of changeableness is nevertheless a general one.

Through Hortonia the course of the ledge is eastward, in which direction the formation slowly dips, until in the town of **Ellington** it is covered by the St. Peters sandstone and Trenton limestone, which, standing out in a similar escarpment, seem to form a continuation of the Lower Magnesian ledge.

It has already been remarked that the course of the streams in this vicinity is peculiar. The Wolf river, when it arrives opposite this rock barrier, turns sharply to the west, while a little stream traverses the township of Ellington in an almost direct line parallel to this ledge, and enters the Wolf river at the point of its sudden flexure. This little stream lies in the level bottom of a valley averaging about a mile in breadth. On its south side, in sections 25 and 26 of the town of Ellington, highly fossiliferous limestone of the Trenton period reaches from near the flood plane of the valley upwards, 35 feet or more. On the opposite side of the valley, in section 24, there arises from the same flood plane, a mural cliff of Lower Magnesian limestone to the height of more than 50 feet. The accompanying figure presents the relations of these formations:

FIG. 34.



1. Potsdam sandstone. 2. Lower Magnesian limestone. 3. St. Peters sandstone. 4. Trenton limestone.

The rock forming this Lower Magnesian cliff is a very hard, silicious dolomite, of almost flinty texture, striking fire readily from impact of the hammer, and yielding a resonance and fracture more like quartzite than ordinary limestone. Its distant bedding joints are very obscure, in the main body of the cliff, while irregular vertical fissures are numerous and conspicuous. Geodes of limpid and opalescent quartz are scattered through it. These characteristics pertain in full only to the cliff in question. To the east a lower ledge of the more usual coarse, silicious limestone extends some distance into the next township, and a similar ledge on the west, curves to the north, and is lost under the drift. But it soon reappears and extends with insignificant interruptions onward to the vicinity of the Wolf river. The strata, like those on the south side of the valley, rise in that direction, so that near the river the upper face of the Potsdam sandstone is brought considerably above the flood plane, and a profile section across the valley at Stephensville would show a very unequal elevation in the Lower Magnesian strata.

Still further to the westward, within about two miles of New London, two conspicuous mounds, known as North and South **Musquito Hill**, rise about 200 feet above the R. R. grade at the depot. Their main mass is sandstone, but they are crowned with calcareous strata. On the western brow of the south hill the uppermost layers exposed are thin, banded, arenaceous and oölitic, and are succeeded below by two feet of shelly, rotten, mottled layers, underlaid by sixteen inches of thin-bedded, flag-like rock, under which again lies a foot of hard, broken, chippy rock, which in turn rests upon quartzose sandstone beds of 6 inches to 24 inches in thickness. The actual exposure of the sandstone is confined to a few feet, but the precipitous slope indicates its presence in considerable thickness. On the south face an exposure exhibits the same section, with something of the usual tendency to variableness.

On the north hill, near the crest, a quarry has been opened in straw colored, calciferous strata, whose bedding, as exposed, ranges from 2 inches to 12 inches in thickness. Certain layers are somewhat greenish, and green spots abound in others. The slope below affords occasional glimpses of gray and green sandstones.

It may be stated incidentally, as an interesting fact, that a loose block of Trenton limestone was found on the summit of this hill.

The character of the magnesian limestone reposing on the summits of these hills differs somewhat, it will be observed, from that of the lower beds of the Lower Magnesian limestone on the opposite side of the Wolf river, and may not belong to precisely the same horizon, but it is evident that it cannot belong to a higher, and if it does not belong to the same geological level, must constitute an intercalated band in the Potsdam sandstone. But the elevation of the junction of the sandstone and limestone on Musquito Hill was estimated to be 100 feet higher than the junction of the sandstone and limestone on the opposite side of the valley. It appears then that for a distance of about twenty miles (how much more is not known), the formations on the north side of the valley are notably higher than on the south side. While it is possible that all this may be due to a southward dip of no great magnitude in itself, but quite unusual in these formations in this region, especially in that direction, it seems more consonant with all the facts of the case, to suppose that the valley represents the line of a fault with a downthrow on the south side.

It is in this region that the *stair-like border* of this and the higher formations is most conspicuous. From the eastward-bearing ledge just under discussion, the western limit of the formation runs in its irregular zigzag way, almost due north to Lake Shawano, where it turns again nearly due east along the south side of the Oconto river.

Passing by for want of space several ledges that occur in the towns of *Black Creek*, *Cicero*, *Lesser* and *Hartland*, which will have value as the country develops, we find at the angle made south of **Lake Shawano**, the following beds forming the summit of a bluff 133 feet high, the lower portion of which is Potsdam sandstone. (Sec. 34, S. E. qr., T. 27, R. 16 E.)

1. Earth.
2. Rather thin bedded, shaly arenaceous magnesian limestone, 4 feet.
3. Bluish irregular magnesian limestone, containing geodes of quartz, 3 feet.
4. Compact silicious limestone, 1 foot.
5. Grayish white magnesian limestone, 8 inches.
6. Cherty magnesian limestone, 1 foot and 6 inches.
7. Light gray magnesian limestone, 3 feet.
8. Oölitic layer, 2 feet.
9. Concealed, 3 feet.
10. Oölitic layers, 3 feet.
11. Light colored magnesian limestone, partially exposed.
12. Slope. concealing sandstone.

At Oconto Falls the following section is shown:

1. The uppermost portion exposed consists of grayish buff, silicious dolomite, of medium hardness, somewhat uneven texture, being in part minutely granular crystalline, and in part earthy, containing frequent cavities varying from the size of a pea to that of a walnut. These cavities are sometimes partially lined with quartz crystals, but these miniature geodes are so much less prevalent than in the layer below, which is studded with them, and with clusters of quartz crystals, as to make this a distinguishing feature. The bedding is irregular, but as exposed in the face of the gorge, the layers are from one

foot thick downwards. The rock weathers to a granular, sandy surface, much pitted from unequal resistance to the elements, and showing lines of deposition, 5.1 feet.

2. A group of beds very similar to the above, but characterized by a much greater abundance of crystalized quartz, lining the numerous small cavities, or forming small clusters. There is no distinct line of demarkation between these and the above layers. 11.7 feet.

3. Below the above lies a thick bed of impure conglomeritic dolomite, the component fragments having an almost flinty hardness and fracture. It presents the appearance of having been formed of fragments of silicious dolomite imbedded in a matrix of dolomitic sand and mud, which afterwards cemented, and in a measure, coalesced. On weathering, the constituents are brought out conspicuously. The more compact fragments seem to contain a considerable percentage of silica disseminated through them, while segregations of quartz, much oftener in the crystalline than the nodular form, are very numerous, and, standing out upon the weathered surface, give it a very rough aspect. This layer by its hardness offers great resistance to erosion from the volume of water pouring over it, but when undermined by the removal of the softer rock below, it falls in huge masses, sometimes 20 feet in maximum diameter, which lie in the channel for ages before complete removal. The prevailing color of the rock is dark gray, mottled by the white quartz, and the variously colored fragments of which it is composed. The thickness of the bed is varying, that measured as an average being 4.7 feet.

4. Underlying the above is a very hard, impure dolomite of a dark gray color, mottled with lighter hues, and of more uniform texture than that above, but still not homogeneous, while some portions are studded with small geodes and clusters of quartz crystals. It is not subdivided into regular beds, but is much fissured vertically. 9.7 feet.

5. Still lower lies a stratum of less hardness, much finer and more uniform crystalline grain, and more distinctly laminated, so as to present a horizontally banded appearance. It has a bluish gray cast on the fresh, somewhat conchoidal fracture, distantly stained with dark purplish brown iron spots, but weathers to a dirty gray. The quartz segregations descend from above into the upper layers of this. 4.7 feet.

An analysis of this stratum by Mr. G. Bode gave:

Carbonate of lime	49.414
Carbonate of magnesia	39.784
Silica	7.638
Alumina	1.473
Oxide of iron	1.691
	100.000

6. Below this follows a bed of green and purple shale and argillo-arenaceous dolomite, having the following composition:

Carbonate of lime	29.370
Carbonate of magnesia	18.860
Silica	37.798
Alumina	9.621
Oxide of iron	4.351
	100.000

This shale very closely resembles that of the Eureka section, and probably belongs to the same horizon. It is to the softness of this shale and the ease with which it is eroded, that the falls are due. 2 feet.

7. A yellowish or grayish dolomite of very rough, irregular, granular crystalline and earthy texture, containing geodes and almost devoid of bedding lines. 6 feet.

8. At the base of the above, are two thin layers that present a virescent hue, caused by small green spherules imbedded in a gray rock. Associated with these are a greater or less number of oölitic spherules, some ocherous, and others in which the center is yellow and the exterior green, which suggests that the coloring matter may be a ferrous compound of iron which oxidizes to the hydrated ferric form. On the weathered portion of the rock these little spherical bodies are wholly or partially dissolved out, giving a harsh, minutely pitted surface. Those that are partially dissolved, show a radiating structure somewhat resembling some of the Foraminifera, but the rays are not reducible to any definite numerical system. Aggregations of similar problematic forms, not green, but usually white, occur in and upon the surface of the layers, disposed precisely as the white oölitic masses are in the layers below, some of which show clearly a concretionary structure, making it probable that all are so. They deserve more study than it has been possible yet to give them. The same layers contain many illy preserved remains of what appear to be an undescribed species of Salterella and also an undetermined Gasteropod having a low broad coil. The gray portion of the rock is a mixture of earthy and crystalline granular material, rather soft, and has an easy regular fracture. 6 inches.

9. This fossiliferous layer graduates below into a very peculiar dolomitic and silicious rock, in which the concretionary structure attains an unusual development. Almost the whole mass is formed of variously sized concentric segregations of chert and dolomitic material. They are not unfrequently two or three feet in diameter, and resemble coarse, gigantic Stromatopora. 2.2 feet.

10. This rests upon a dark gray dolomite, similar to that immediately above the concretionary layer, but contains aggregated masses of white oölite, and is itself somewhat oölitic from the presence of yellowish and dark gray spherules. The white ones are of large size, and upon fracture and abrasion show their concentric structure. They are aggregated so as to form flat or nodular masses similar to those usually assumed by chert in this and the higher Silurian formations. 16 inches.

11. Closely associated with this below is a layer of a pistachio-green cast formed by abundant green spots, with which are mingled a less number of yellow, orange and reddish ones, the rock mass being gray. Aside from the colored spherules, it is slightly oölitic and rather soft, possessing a regular easy fracture. The Salterella occurs here also. 3 inches.

12. The base of the exposure is formed by a dark gray, very impure, and for the most part oölitic dolomite. The oöliths are generally darker than the mass of the rock, and the larger ones are seldom perfectly spherical, but incline to the forms usually assumed by chert nodules. Ocherous spherules occur, and occasionally red hematite ones. In some layers, quartzose sand is abundant, forming seams or lenticular masses. Geodes, both of quartz and calcite occur. The bedding is very irregular. 5 feet.

Total exposure, 53.2 feet.

The falls have a vertical descent of 22 feet, with a fall of 10 feet on the rapids above, and a greater amount below.

A few miles north of **Stiles**, on Jones creek, a thinner band of shale, very similar to that described above, gives rise to a diminutive imitation of Oconto Falls, though the layers are not specifically identifiable with those of the preceding section. The dip is undulating, so that though shown for some distance along the stream, but a small vertical thickness is exhibited.

The upper portion of the formation is displayed at several points between Angelica and the Oconto river; at Ordway's ledge and vicinity, about five miles north of Stiles; and on the south side of the main Peshtigo river, from above the mouth of the Little river to near the bend above Potato rapids. At these several points the uneven nature of the superior face of the formation is shown to be still a prominent fact. The last mentioned point is 120 miles from that at which this feature was first described, showing that this is not a local or exceptional character, but one that attaches to the formation throughout this portion of the state, and to some extent, at least, beyond.

As the formation passes across the **Menomonee** river into Michigan, it affords us a parting glimpse at the Grand Rapids. The section is closely similar to that at Oconto Falls, and will not be here repeated. A full description is given by Dr. Rominger in his report on the Paleozoic Rocks of the Upper Peninsula of Michigan, p. 72.

Economic Considerations. — Many portions of this formation furnish stone well suited for heavy masonry, as locks, piers, foundations, etc. Its heavy beds, somewhat silicious character, and freedom from shaly matter, render it enduring, while it is wrought without difficulty. Other portions are adapted to ordinary construction, and exceptional portions are fitted for cutting.

The rock is burned at numerous points for *quicklime*, and when a judicious selection is made, which is not always the case, with good results. The mass of the formation is not adapted to this purpose, but some parts are exceptionally pure dolomites, and properly burned, produce a most excellent lime. Selection becomes a matter of much importance, and as it is equally so with other formations, and other portions of the state, the volume on the general geology of the state will contain specific information and directions that will assist in choosing a suitable stone.

Some of the less pure portions produce a lime that forms a slightly hydraulic mortar, suitable for general construction, but whose inferior whiteness reduces its value for finishing purposes. In some cases, where the rock is burned at a low heat, the hydraulic property becomes sufficiently marked to be very serviceable in many cases where common quicklime will not answer, and where the more expensive cement is too costly. I am informed by Hon. Wm. Starr, of Ripon, that formerly, lime of this class from the Lower Magnesian limestone at that place was used for cisterns with success, and that in removing the foundations of a mill that had stood many years exposed to water, the mortar made from this lime was found in excellent condition.

An analysis of the rock which constitutes a portion of one of the mounds previously described, taken from the N. W. ¼ of the N. E. ¼ of Sec. 20, Ripon, gave the following result:

Carbonate of lime	51.68
Carbonate of magnesia	40.93
Sesquioxide of iron	0.60
Alumina	3.09
Silica	3.16
Water	0.70
	100.16

Insoluble in acids, 6.17 per cent., or nearly the entire amount of silica and alumina.

Messrs. Blish & Barlow manufacture a hydraulic lime from rock belonging to this formation, found in the N. W. ¼ of Sec. 26, town of Poygan, Winnebago county.

The following analysis by Prof. W. W. Daniells, shows it to be an impure dolomite:

Carbonate of lime	49.747
Carbonate of magnesia	38.189
Insoluble in acid	9.442
Sesquioxide of iron and alumina	1.587
Water	1.190
	100.155

The insoluble residue consisted of silica, 5.803, and alumina, 3.639. The manufactured product is used in the vicinity, and in the neighboring cities.

Some of the argillo-arenaceous dolomites, associated with the shale belt of this formation, have a composition approaching very near that of some of the well known cement rocks of the country, as will be seen by reference to the analysis of Layer 6, at Oconto Falls, previously given, which was made with this fact in view, and which deserves consideration, though the stratum at that point is unfavorably situated.

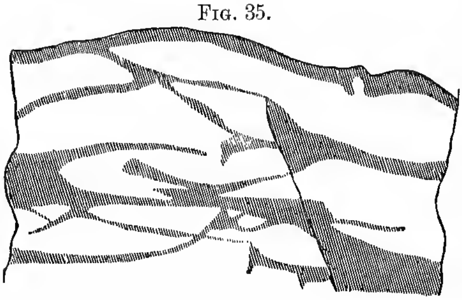
ST. PETERS SANDSTONE.

Upon the billowy surface of the Lower Magnesian limestone, filling up its troughs, and in most cases surmounting the crests of its prominences, lies the St. Peters sandstone. This formation has usually been described as a very uniform deposit of purely quartzose, incoherent, pebbleless, non-fossiliferous sandstone. All these characteristics fail in eastern Wisconsin.

Owing to the unequal surface of the Lower Magnesian limestone previously described, *its thickness*, instead of being remarkably uniform, is precisely the opposite. It is known to vary within the district under description from two hundred and twelve feet down to a single layer of sand grains. It ranges from zero to one hundred feet or more — within a quarter of a mile, in one case, at least, and changes in a similar rapid and remarkable manner at many other points. In the instances of its entire disappearance, its thickness is not sufficient to overtop the prominences of the lower formation, and *the Trenton limestone above rests directly upon the Lower Magnesian limestone,* while in the immediate vicinity, observed depths of sandstone of fifty-four feet, eighty-two feet, and one hundred feet have been noted. This irregularity appears to be greatest from Dodge county northwards. In the southern part of the district, and, so far as the Artesian wells enable us to judge, in the lake shore region, a greater degree of uniformity prevails. In other words, the unevenness of the Lower Magnesian surface seems to have been greatest near its margin, or near the shore line of the ocean at the time of its deposit; and as it recedes to the eastward and southward, it becomes more uniform.

Setting aside, for the moment, a large number of exceptional cases, arising chiefly from the foregoing peculiarities, the rock may be described essentially as it is found to be elsewhere, being composed of well rounded, rather uniform, transparent, incoherent grains of quartz, forming a very friable rock. Calcareous and argillaceous matter are almost entirely absent. White, yellow and gray are the most prevalent colors, but red, brown, pink and green are not uncommon. Sometimes the rock is beautifully variegated and in other cases it is banded in a disjointed and irregular way, producing a very interesting and unique effect. This is imperfectly illustrated in the accompanying figures. In the upper part of the formation, irregular concretions of iron ore occur, which, on weathering, present a dark brown, glazed surface, which leads to the popular impression that they are of volcanic or meteoric origin.

Fig. 35.



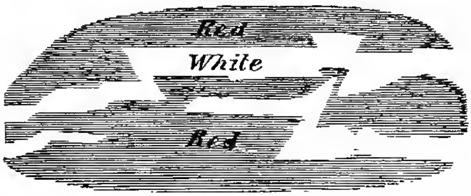
Showing Coloration of St. Peters Sandstone at Ripon.

The shaded portion represents brown sandstone; the remaining portion is white, lined and flecked with pink.

In structure, the St. Peters sandstone is finely laminated, frequently in oblique and cross lines, and shows at some points fine examples of ebb and flow structure. The bedding is usually obscure. Vertical, oblique and irregular fissures frequently traverse the formation, cutting it into huge, irregular masses.

The exceptions to these general characteristics arise chiefly from the relation of this sandstone to the irregularities of the underlying formation. Where it adjoins the sloping sides of the limestone mounds, it has derived from them ingredients not possessed elsewhere. More or less of calcareous matter would necessarily become mingled with the sand during its deposit. The amount observed is not so great as might be expected, and sandstone within a few feet of limestone dipping under it at an angle of 25°, and rising thirty feet above it, has been observed to be almost perfectly free from calcareous matter. It is to be remarked, however, that the arching form of these limestone mounds, and the concentric nature of the external layers are most admirably adapted to resist erosion, and that by the nearness of these domes to each other, they would afford mutual protection from violent wave action. Conglomeritic and brecciated rock, formed by fragments of the limestone imbedded in the sandstone, have been observed at several points, but only in very close relation to the limestone.

Fig. 36.



SHOWING THE COLORATION OF ST. PETERS SANDSTONE AT RIPON.

A much more prevalent modification, especially to the northward, consists of thin seams of white argillaceous material interlaminated with the sand and, to some extent, diffused through it, giving it a schistose character. It then possesses considerable coherence, and is found in large firm masses on the slope below the ledges of Trenton limestone. At some points, *ferruginous matter* mingles with the calcareous and argillaceous ingredients, forming a variegated rock not unlike the red and purple shales of the Mendota beds.

In addition to the modifications arising from the Lower Magnesian limestone, the Archæan rocks contribute others, which have perhaps been sufficiently described in connection with the quartzites of Portland and Waterloo.

At several points in Rock county, *the passage* of the St. Peters to the formation above is attended by an alternation of sandstone and calcareous rock. The sandstone just below the calcareous bed is marked with fucoidal impressions and the base of the calcareous layer contains abundant Scolithus tubes. The calcareous bed is of a greenish gray cast containing a large percentage of insoluble, argillo-arenaceous material, in addition to the evident quartzose grains that are more or less freely scattered through portions of it. This has not been observed to attain a thickness of more than four or five feet. The upper portion is usually shaly and appears at some points to have been eroded before the deposition of the stratum of sandstone above. This latter is thin and mixed with argillaceous material on which sometimes supervenes a thin seam of carbonaceous matter followed by the fossiliferous Trenton limestone. At the most northern point at which the junction was seen, the sand mingles freely with the calcareous layers of the Trenton, for several feet above their base. At most other points the usual abrupt transition was observed.

Organic Remains. Previous to the present year (1876) there has been no published announcement of the existence of fossils in this formation. In the Fourth Annual Report of the Geological Survey of Minnesota, Prof. N. H. Winchell describes a Lingulepis, found near Fountain in that state, in the upper beds of the formation.

In my unpublished report of 1873, Scolithus borings were described as occurring in rock in the town of Waterloo, referred to the St. Peters sandstone. In 1874, this was confirmed by finding well preserved tubes of the same in the town of Beloit, in strata belonging to the upper part of the formation. Fucoidal impressions were also found at the same locality. In 1875, Scolithus tubes were seen in sandstone referred doubtfully to the base of the formation.

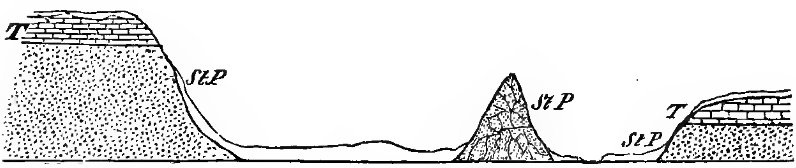
In a synopsis of my report for these years, three hundred copies of which were printed and distributed at private expense, in the early part of January, 1876, the existence of organic remains in this formation was announced. This form of announcement will not probably be regarded as sufficient to justify a claim to priority, in this interesting discovery. The organic remains so far have been found exclusively where the sandstone was compacted by some cementing material, which justifies the belief that the absence of fossils throughout the greater part of the formation is due to want of preservation and not to original absence of life in the depositing sea.

Method of formation. The existence of the remains of marine life demonstrates that the fossiliferous portions at least are submarine deposits, while the well rounded character of the grains, the ebb and flow structure, the shaly laminations, the conglomeritic portions and its relations to the adjacent formations leave no doubt that it belongs to the common class of oceanic sand deposits.

Extent and Local Descriptions. The St. Peters sandstone enters this district from Illinois and from the Lead Region at the southwestern corner of *Rock county.* Owing to the ease with which the sandstone is eroded, it usually occupies only a narrow belt close under the protecting ledges of the overlying Trenton limestone, and appears on the map as a narrow border to that formation. In some places, as in Rock county, where it is represented as occupying more ample areas, it is quite probable that if the drift could be removed the sandstone would be found absent at some points. The preglacial rivers undoubtedly cut entirely through it, but their position cannot now be accurately mapped.

In Rock county it may be readily identified, since it seldom shows itself except under a protecting shelf or crown of Trenton limestone, whose characteristic fossils are easily recognized, and by the simpler fact, that it is the only sandstone exposed in the county. Its upper portion is amply displayed in the western portion of the county, where the drift is light, but presents so great similarity that it will be unnecessary to enter into local details. A feature occurs in the north part of the township of Magnolia, of this county, deserving notice. A small stream, known as Allen's creek, flows westward along the line separating sections 4, 5, and 6, on the north, from sections 7, 8 and 9, on the south. On each side there is a range of bluffs capped with Trenton limestone and underlaid with St. Peters sandstone. The junction of the two formations on the south side is, by aneroid measurement, 155 feet above the stream, and on the opposite side, in section 6, 32 feet, showing a difference of 123 feet. This superior elevation of the south bluff is maintained as far to the east as the two can be compared. In section 7, about midway between the two bluffs, there is a very sharp east and west ridge of hard sandstone, intersected in every direction by a network of silicious seams that stand out prominently on the weathered surface, as though the rock had been extensively fractured and subsequently reunited by silicious cement. This ridge rises 50 feet above the junction of St. Peters and Trenton on the north side of the stream. These facts are illustrated by the accompanying figure.

FIG. 37.



SHOWING THE RELATIONS OF THE ST. PETERS SANDSTONE AND TRENTON LIMESTONE, MAGNOLIA.

In this quiet region of gentle southeastward dips, these phenomena are unusual, though insignicant in general geology. They are equally explainable by supposing a flexure of the strata or a fault.

At the railroad cut near **Magnolia station,** the transition from the St. Peters sandstone to the Trenton limestone is well shown. The main cut consists of the limestone, the lower 3 or 4 feet of which are more or less sandy. Below this lies 8 inches of sandstone containing seams and nodules of iron oxide and sulphide, doubtless all originally pyrites. This layer of sandstone rests upon 4 feet 4 inches of impure sandy conglomeritic limerock, full of Scolithus(?) tubes. Below this, continuing to the base of the exposure, is an incoherent sandstone, mottled and banded with yellow, orange and green colors, and exhibiting oblique and horizontal lamination. A similar transition may be seen at numerous other points in Rock county. From this county onward, the general course of the formation is due north for about sixty miles, and then east of north for more than one hundred miles. Its irregularity of thickness in tracing it northward first becomes pronounced in the western part of Dodge county, and it is first known to be entirely cut off by the contact of the limestones, below and above, in the southern part of Green Lake county, notwithstanding which, and frequent subsequent interruptions, it maintains an existence for more than 120 miles to the northward. It was last observed within about four miles of the Michigan line, where it had a thickness of 20 feet. Beyond that point it is concealed by the drift.

The formation is not recognized at all in the recent geological report of Michigan, although the foregoing facts offer a strong presumption that it exists there. Under the impression that has formerly prevailed concerning the uniformity of this deposit, the finding of the Trenton limestone on the Escanaba river, resting directly upon the Lower Magnesian, would justify the inference that the St. Peters sandstone was essentially wanting in the Upper Peninsula of Michigan, but with the light now possessed, the fact of contact at that point has little significance in relation to the question of the presence or absence of the formation in question.

Economic Considerations. The greatest prospective value of this formation is doubtless its *water-bearing capacity*, it being, as has already been shown, the great source of Artesian fountains in this portion of the state. In view of this fact, the foregoing developments in respect to its nature possess eminent practical importance.

For some years geologists have habitually recommended the sand of this formation for *the manufacture of glass.* Its value for that purpose is now being put to the practical test. A factory has recently been established at Omro for that purpose. The sand is derived from near Waukau. A six pot furnace has been erected having a capacity per month of 800 boxes of 100 feet each. At present the manufacture is confined to window glass and shades. The results thus far attained are reported as highly satisfactory.

In the town of Waterloo the sandstone has sufficient compactness to serve as *a building stone*, but usually it is too soft. This latter fact, however, permits its extensive use as sand for mortar, and similar purposes. At most localities it can be dug with pick and shovel, the mere handling being sufficient to reduce it to sand. On account of its cleanness and sharpness, it is much superior to most drift sand.

TRENTON GROUP.

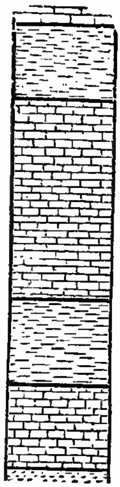
Upon the St. Peters sandstone there lies an extensive series of limestones and shales, which represent the Trenton period. It consists of three main divisions, which are recognized in geological history as epochs. The lowest member is known as the Trenton limestone, the next in order as the Galena limestone, and the uppermost as the Cincinnati shales and limestone. These are firmly linked together by fossils common to the three horizons, and in the northeastern part of the state it is exceedingly difficult to discern any satisfactory line of demarkation between them. In the southern portion, however, they are well distinguished, and will receive consideration in the order named.

TRENTON LIMESTONE.

Subdivisions. The Trenton limestone proper, as it is developed in the southern portion of the district under consideration, consists of four subdivisions sufficiently well characterized to be valuable aids in the study and discussion of the formation, and in the practical application of the results of the survey.

Adhering as closely as the nature of the case will admit, to the terms already in use, these will be distinguished as follows:

FIG. 38.



I. UPPER BLUE BEDS, thickness, 15 feet.

II. UPPER BUFF BEDS, thickness, 55 feet.

III. LOWER BLUE BEDS, thickness, 25 feet.

IV. LOWER BUFF BEDS, thickness, 25 feet.

It has been customary to divide the Trenton limestone of this state into the "Buff limestone" and the "Blue limestone," and in the Lead region the latter and some higher beds form the "Glass rock," "Brown rock," and "Green rock." These latter terms are based upon lithological characters that do not prevail in southeastern Wisconsin, and hence the use of these terms would be undesirable even if their application within the Lead region was sufficiently well defined to justify their extension to other localities.

To continue the unmodified use of the terms Blue and Buff limestone, and to rest with this twofold subdivision, is open to serious objection, as experience has shown.

In the first place, *the color distinction* made between the two is not applicable without qualification, since more than half of the upper portion usually designated Blue limestone is quite as persistently buff as the lower division. The unleached interior of the thicker beds, in all the subdivisions, is blue, and that was doubtless the original color of the whole formation, but the two divisions designated in this report as Buff are habitually leached to much greater depths than the remaining two, and are less associated with bluish green shales, which give to the latter a bluish or greenish aspect. Applied as now suggested, the terms blue and buff become reasonably appropriate and very convenient.

In the second place, *the chemical distinction*, viz.: that the lower division is a dolomite, and the remainder a limestone, does not hold good. An analysis of chippings from unweathered layers, representing the whole thickness of what has heretofore been called Buff limestone, and is now called the Lower Buff beds, exclusive of the argillaceous layers at the base, shows 36.41 per cent. of carbonate of magnesia. A similar analysis of the Lower Blue beds shows 38.39 per cent. of carbonate of magnesia. A like analysis of the lower 13 feet of the Upper Buff beds gives 43.30 per cent. of magnesic carbonate, and one of a higher stratum, 34.86 per cent. These analyses were all made from rocks whose exposure to leaching and weathering was as nearly as possible equal, and from adjacent, where not identical, localities, all being from the vicinity of Beloit.

From these it appears that the quantity of magnesia varies but slightly, and that the entire amount is large, so that the term dolomite is applicable here as well as to the calcareous formations above and below, while the Blue limestone of the Lead region is a true limestone, containing but little magnesia.

In the third place, *the paleontological distinction* heretofore drawn does not hold good. The Buff limestone has been regarded as characterized by great numbers of Gasteropoda, Cephalopoda and Lamellibranchiata, especially by species referable to *Tellinomya*, *Cypricardites* and allied genera. But this is at least equally true of the Upper Buff beds of this report.

The following species catalogued in the report of 1862, as belonging to the Lower Buff limestone, have been found in the Upper Buff beds of this report:

Cypricardites Niota, *C. rotundatus*, *C. ventricosus*, *Modiolopsis superba*, *Tellinomya nasuta*, *T. ventricosa*, *Murchisonia helicteres*, *Pleurotomaria* (*Raphistoma*) *Nasoni*, *P. subconica*, *Trochonema umbilicatum*, *Raphistoma lenticularis*, *Cyrtoceras annulatum*, *C. eugium*, *Oncoceras Lycus*, *O. Pandion* and *O. plebium*.

Only one of the list given in the report of 1862 as from the Buff is known to me as occurring exclusively in the Lower Buff, while three have been found in the Upper Buff that have not been observed in the Lower. The majority are common to the two subdivisions, and to this number several allied species have now been added. *Columnaria alveolata*, also regarded as peculiar to the Lower Buff, is found in the upper beds.

The strata at Rockton, which belong to the Upper Buff beds, are referred to the Buff limestone of previous authors,[1] and a similar pardonable confusion of the two members has undoubtedly been experienced by other writers on the geology of this region.

These facts are dwelt upon to this extent to demonstrate the necessity for the introduction of a new classification, and of new terms

[1] See pp. 89, 90, Vol. V, Geol. Rep. of Ill.

in lieu of those that have already found a place in the literature of western geology.

It is not presumed that the distinctions here made have any wide geographical application, and hence the terms in common use have only received such qualification as the geology of this region demands.

The term *beds* has been substituted for *limestone*, since, in the opinion of the writer, these divisions do not rise to the dignity of what are technically known among geologists as epochs, to which grade the more significant term should be confined, unless there are special lithological reasons for its use otherwise. While it is very much in the interests of science, and its practical application, to subdivide the several formations as far as the facts will permit, and thus give to our discriminations and descriptions as much of exactness as possible, much confusion is introduced into the general literature of the science, if each of these minor members is clothed with a formal title.

1. The Lower Buff Beds. It has already been observed in connection with the St. Peters sandstone, that a slight alternation of sandstone and calcareous layers occurs in the transition to the Trenton limestone, there being above the main body of sandstone a calcareous layer of about four feet thickness, overlaid by a bed of sandstone two feet or less in thickness. Above this there follow the Lower Buff beds. Their usual thickness is from eighteen to twenty-five feet. At some points the formation seems to be made up of three main strata, the lower one, more or less shaly toward the bottom, of about four feet thickness, the middle one seven feet, and the upper, twelve. These are less distinctly subdivided into beds from two feet in thickness downwards. When these distinctions are not observable, the layers are of a similar heavy bedded character, except when affected by the action of the elements. The texture is somewhat irregular, arising from an uneven association of earthy and crystalline material. The general aspect is earthy, but crystalline particles compose the greater part of the mass. The color, as seen in natural ledges and superficial quarries, is a light yellowish buff or gray. The interior of thicker and less exposed layers frequently has a bluish cast.

The rock is composed of carbonate of lime and magnesia, a considerable percentage of silicious and aluminous material, and an insignificant ingredient of iron and the more common salts. Crystals of calcite and occasionally those of pyrite occur in cavities.

The fossils of this division are abundant, although less so than in the upper divisions, especially the blue beds.

The following is a partial list of the species that lived during the deposition of these strata:

Buthotrephis succulens, *Streptelasma* (*Petraia*) *corniculum*, a new species of *Stictopora* and one of *Trematopora*, a *Lingula*, resembling *L. obtusa*, *Orthis disparalis*, *O. perveta*, *O. subquadrata*, *O. tricenaria*, *Streptorhynchus deflectum*, *S. filitextum*, *S. deltoideum*, *S. planumbonum*, *Strophomena alternata*, *S. camerata*, *S. camura*, *S. incrassata*, a new species of *Rhynchonella*, *Tellinomya nasuta*, *Cypricardites Canadensis*, *C. rectirostris*, *C. rotundatus*, *C. subtruncatus*, *C. ventricosus*, *C.*, *n. sp.*, *Modiolopsis superba*, *Helicotoma planulata*, *Raphistoma lenticularis*, *R. Nasoni*, *Pleurotomaria subconica*, *Trochonema ambiguum*, *T. umbilicatum*, *Murchisonia tricarinata*, *M. bicincta*, *Subulites elongatus*, *Bucania bidorsata*, *Bellerophon bilobatus*, *Pterotheca attenuata*, *Orthoceras anellum*, *O. junceum*, *O. vertebrale*, *O.*, *n. sp.*, *O. Beloitense*, *Oncoceras Pandion*, *O. plebeium*, *Gyroceras convolvans*, *Lituites occidentalis*, *Illænus taurus*, *Ceraurus pleurexanthemus* and *Leperditia fabulites*.

It is impossible in the present state of our knowledge to name any single fossil of common occurrence that is peculiarly characteristic of this geological horizon The abundance of Lamellibranchiates, Gasteropods and Cephalopods, and the fewness of the Corals and Bryozoans sufficiently distinguish it from both of the Blue beds above, but not from the Upper Buff beds to which this division bears a strong resemblance paleontologically as well as lithologically. At some points the Lower Buff beds develop something of a shaly character at the base, and are highly fossiliferous, in which cases the facies of the fauna strongly resembles that of the Blue beds, which are likewise shaly. It appears from all the facts that there was an alternation of conditions in the depositing Trenton seas, and that when the conditions were such as to favor the formation of limestone simply, the life above characterized predominated, and that whenever the conditions changed so as to cause a deposit of shale interleaved with layers of limestone, the brachiopodous and coralline fauna prevailed. These subdivisions then signify rather physical mutations of a more or less local nature, than wide spread changes in the life-character of the period.

2. *The Lower Blue Beds.* The upper surface of the preceding division is at most points well defined, and upon its thick beds rest an alternating series of thin, impure limestone layers and thinner shaly leaves. These are usually grouped into more massive beds, and where removed from the action of surface agencies, the shaly portions often possess sufficient coherence to bind the limestone layers into beds of respectable dimensions.

The average thickness may be put down at from twenty to twenty-five feet. The limestone is varying in texture. Usually it is a mixture of earthy material and minute crystals, but sometimes has a compact crystalline structure, and occasionally a coarse granular one. Some layers are little else than a mass of fossils. The color is bluish, or grayish, weathering to light gray or buff.

The shale is a bluish green, and aside from mingling with the limestone somewhat, it forms seams and partings between the layers. These are seldom over two inches thick in the southern part of our province, but attain more considerable dimensions at the north. A notable amount of carbonaceous material is sometimes associated with this shale. It is usually very highly fossiliferous.

In chemical composition the limestone layers do not essentially differ, so far as tested, from the Buff already described, being an impure magnesian limestone. The analysis previously referred to included only the limestone layers, the shaly partings being excluded. Including these, probably one-third of the whole mass would be found to be silicious and aluminous material.

Besides the bluish green cast that the shale gives to the mass, it has served to protect the limestone from the leaching action of percolating water, so that it also oftener retains its original bluish hue than the beds below and above, and renders the name applied to it not inappropriate. It is characterized by a much greater abundance of fossils than the beds below. These differ from those below in the much greater abundance of Corals, Bryozoans and small Brachiopods, especially the Orthidæ. *Murchisonia gracilis* appears in great abundance near the base of this division. It is not found in my somewhat extensive collections from the Lower Buff, which indicates its rarity, though perhaps not absence, from that horizon. *Bellerophon bilobatus* is very abundant, though not confined to this horizon. This division comprehends, in greater or less numbers, a large proportion of all the species found in the Trenton limestone of this region.

3. The Upper Buff Beds. This is the thickest and most important subdivision of the group in the Rock river valley, reaching a vertical dimension of fifty-five feet. It is less uniform in its several parts than the two preceding, and is less easily described in general terms, and the reader will perhaps find the detailed description of the section at Beloit, given subsequently, under the head of local descriptions, more satisfactory than the general statements here made. The most prevalent kind of rock is a rather heavy bedded limestone, obscurely banded and mottled with light gray and buff, giving the whole a light, yellowish buff aspect. The gray portions are more compact and crystalline than the buff, which are porous and earthy although beautifully bespangled with glistening crystalline facets. These characters apply more particularly to the lowest and uppermost members; the latter is distinguished by the presence of nodules of chert. A portion of the intermediate layers, while retaining something of the nature above described, becomes much more irregular in texture, and possesses a very rough fracture, which gives the ledges in the quarry a brecciated appearance that is increased by the presence of cavities.

Another portion is more homogeneous in structure than either of the preceding kinds, and has a very noticeable conchoidal fracture, resembling in this respect the glass rock of the Lead region, from which, however, it differs in having a less compact and more earthy texture, caused by the presence of from 12 to 15 per cent. of aluminous and silicious material. It is lined with obscure reddish stains, probably of fucoidal origin. This constitutes two bands, two to four feet thick, lying near the center of the division and separated seven or eight feet from each other. They thus constitute reliable landmarks in correlating partial exposures at distant points, and, if intelligently used, will prove a serviceable guide to the quarryman.

The life at this stage was, as has been remarked, very similar to that at the time of the deposit of the Lower Buff beds, but was more prolific and varied. Nearly sixty species are known to occur in these beds, and it is presumable that the actual number is much larger.

Of these, between fifteen and twenty have not been found in the Lower Buff beds, but until more thorough search has been made it would not be wise to regard them as diagnostic. The occurrence of *Halysites* at this horizon is especially worthy of remark, as being the lowest point at which it has yet been authentically reported in the western series.

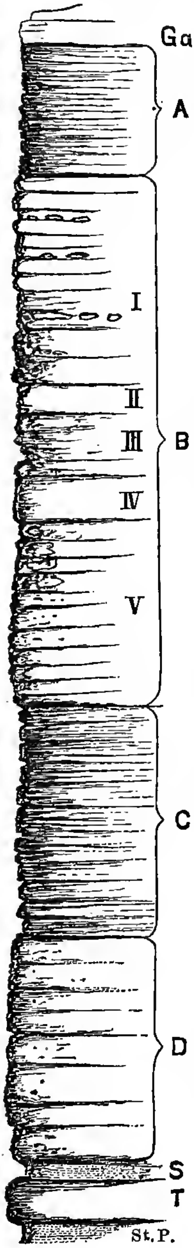
4. The Upper Blue Beds. These are so similar in general character to the Lower Blue Beds. as not to need extended description. They differ from them chiefly in those cases where they take on a coarse granular character, approaching that of the Galena limestone above, to which they constitute the transition. The degree in which they are thus modified varies with the locality. At several points there are only four or five such transitional beds, and at other points the whole division shows something of this character.

An abundance of *Brachiopods*, *Bryozoans and Chætetoid corals* form the leading feature of the life of this period. Its general aspect is more manifestly similar to that of the Cincinnati shales above the

Galena than that of the beds below. *Leptæna sericea* is a very abundant fossil, which has not been observed to be true below.

Local Descriptions. In the vicinity of **Beloit** are a number of natural and artificial exposures that are so fortunately situated at different elevations as to exhibit the entire thickness of the formation, and yet, an equally fortunate circumstance for the students of geology of that locality, their correct correlation is attended with something of difficulty, and is only accomplished by careful and industrious study. By combining the partial series shown at the various points, the following general section for that vicinity may be constructed:

FIG. 39.



UPPER BLUE BEDS.

A. A greenish blue impure limestone, chiefly earthy and subcrystalline, but in part granular, beds thin and separated with shale, very fossiliferous. Estimated thickness, fifteen feet.

UPPER BUFF BEDS.

B. I. In general a fine grained, impure limestone, of earthy or subcrystalline texture, the former a light buff, the latter gray, combined so as to give an obscure banded and mottled appearance quite peculiar. Nodules of chert are present, which distinguish it from the rock below. Beds, thick and uniform, fracture, easy and regular in the upper two-thirds, while that of the lower part is very rough and angular, as though from a brecciated structure; more impure than the upper portions. A shaly layer, 7 feet from the base, contains carbonaceous seams with Graptolite markings. Twenty-two feet.

II. Layer of homogeneous structure, conchoidal fracture, and earthy texture, but sparkling with minute crystals; lined and spotted with obscure reddish fucoidal stains. Two and one half feet.

III. Combines to some extent the character of the layers above, being less homogeneous than the last, and more so than the proceding. Some layers, very fossiliferous, the remains being grouped more or less in colonies. Horizon of the Halysites. Seven to eight feet.

IV. Similar to II, but the characters more marked. Three to four feet.

V. Similar to I, but not cherty. Texture toward the upper part more irregular than below. Nineteen feet.

LOWER BLUE BEDS.

C. Thin-bedded impure limestone of varying earthy and crystalline texture, interleaved with shaly partings, the whole having a bluish-green or gray color. Very fossiliferous. Twenty-three feet.

LOWER BUFF BEDS.

D. Thick-bedded, buff limestone, of rather coarse texture, somewhat shaly at the base. Fossils not very abundant except in the shaly portions, Twenty-three feet.

Transitional layer of sandstone, 2 feet.

Transitional layer of impure limestone, 4 feet.

St. Peters sandstone.

At Clute's point, near the east line of Sec. 10, town of Beloit, about four miles north of the city, the upper portion of the St. Peters sandstone and the lower part of the calcareous transition bed is shown. About a quarter of a mile southeast of this, in Sec. 11, N. W. qr. of S. W. qr., the transition stratum is better shown, together with the layer of sand above and the bottom layers of the Lower Buff beds. About an equal distance further south, near the high bluff that overlooks the river, cherty layers, B, I, and a portion of those above are shown. The latter partake quite decidedly of the characteristics of the Galena limestone, and are less shaly than usual. Passing over the high hill to a ravine on its southwest flank, the Galena limestone and some of the upper transitional layers may be found. Nearly a mile further south, at the large quarry near the C. & N. W. R. R., a portion of the St. Peters sandstone, the calcareous transitional layer, the interstratified layer of sand, the shaly layers of the Lower Buff limestone, one of which is especially crowded with *Leperditia fabulites*, the heavy Lower Buff beds in full, and the Lower Blue beds, may be seen in magnificent vertical exposure.

A partial analysis of chippings from the entire thickness of the Buff and Blue layers at this point, exclusive of the thin ones at the base, shows the following composition:

	Buff.	*Blue.*
Insoluble residue	5.74	10.29
Soluble silica	1.96	1.75
Sesquioxide of iron and alumina	3.27	1.60
Carbonate of magnesia	36.40	38.39
Carbonate of lime, etc., by estimate	52.63	47.97
Total	100.00	100.00

In a ravine a little south of this the upper part of the Lower Buff and the lower part of the Lower Blue beds are shown in a small quarry. Still further south along the railway, another large quarry exhibits a considerable portion of the Lower Buff and Blue beds, and below, near the track, the St. Peter sandstone is slightly exposed. Several minor openings along this line of bluffs display limited sections. A mile or more to the southeast, at Carpenter's quarry, on the line between sections 26 and 27, the lower portion of the Upper Buff beds — B. V, IV, III and a portion of II, of the preceding section — are extensively wrought, the lower beds especially being a desirable building-stone. The ravine below this quarry has gullied into the Lower Blue beds, and shows their character wherever subjected to the full action of atmosphere, frost, and water.

A partial analysis of the strata B. V and B. IV, at Carpenter's quarry, shows their chemical nature to be as follows:

	Upper Buff.	
	B. IV.	B. V.
Insoluble residue	12.50	3.42
Soluble silica	1.87	1.99
Sesquioxide of iron and alumina	2.23	1.42
Carbonate of magnesia	34.86	43.87
Carbonate of lime, etc., by estimate	48.54	49.30
Total	100.00	100.00

A mile and a half farther southwest, Hess' quarry appears to lie across the layer marked B. II, in the section, and to include some of the layers above and below, the latter being especially prolific in fossils heretofore classified as characteristic of the Buff. At Hanchett's quarry, a short distance south of this, the present exposure reaches from about three feet below the bed marked B. IV, to about the top of B. II. A little over a half mile northwest of this point, at Smith's quarry, the junction of the Upper Blue beds and the Galena limestone with a few feet above and below is shown, completing the series. This junction may also be seen between Turtleville and Shopiere.

The quarries at Rockton, Illinois, present a magnificent section of the Upper Buff beds from layer B. IV upwards to the lower portion of the Upper Blue beds.

These statements are given thus specifically that there may be the fullest opportunity for verifying and utilizing the statements of this report, and that there may hereby be furnished a basis for the more accurate study of the vertical, and, to some extent, horizontal range of the exceedingly interesting fossils of these beds, which it is hoped will be prosecuted by the geologists of the region. A series of collections carried on for years under the favorable opportunities afforded by continuous quarrying, in which the exact locality and horizon should be carefully noted, could not fail to show valuable results.

Over one hundred species of fossils are known to occur in these beds, among which the following identifications have been made:

Buthotrephis succulens.
Steptelasma corniculum.
Chætetes lycoperdon.
Chætetes discoideus.
Stictopora elegantula.
Stictopora, n. sp.
Schizocrinus nodosus.
Ptilodictya recta.
Lingula, sp. und.
Orthis perveta.
Orthis plicatella.
Orthis testudinaria.
Orthis pectinella.
Orthis tricenaria.
Orthis bellarugosa.
Strophomena camerata.
Strophomena alternata.
Strophodonta, sp. und.
Streptorhynchus deflectum.
Streptorhynchus subtentum.
Leptæna sericea.
Rhynchonella, sp. und.
Ambonychia attenuata.
Ambonychia, n. sp.
Ambonychia lamellosa.
Cypricardites Niota.
Cypricardites rotundatus.
Cypricardites ventricosus.
Cypricardites, n. sp.
Tellinomya nasuta.
Tellinomya alta.
Tellinomya Iphigenia.
Tellinomya levata.
Tellinomya ventricosa.
Modiolopsis superba.
Modiolopsis plana.
Raphistoma lenticularis.
Raphistoma Nasoni.
Trochonema ambiguum.
Trochonema umbilicatum.
Trochonema Beloitense, n. sp.
Plurotomaria subconica.
Murchisonia bicincta.
Murchisonia gracilis.
Murchisonia helicteres.
Murchisonia pagoda.
Murchisonia tricarinata.
Cyclonema percarinatum.
Subulites elongatus.
Clisospira occidentalis, n. sp.
Helicotoma planulata.
Maclurea Bigsbyi.
Metoptoma perovalis, n. sp.
Bellerophon bilobatus.
Bellerophon Wisconsinensis, n. sp.
Bucania Buelli, n. sp.
Bucania punctifrons.
Bucania bidorsata.
Pterotheca attenuata.
Hyolithes Baconi, n. sp.
Gyroceras, sp. und.
Cyrtoceras annulatum.
Cyrtoceras corniculum.
Cyrtoceras eugium.
Cyrtoceras Neleus.
Oncoceras abruptum.
Oncoceras Alceus.
Oncoceras Lycus.
Oncoceras Pandion.
Oncoceras plebeium.
Oncoceras, sp. undescribed.
Oncoceras, sp. undescribed.
Orthoceras anellum.
Orthoceras multicameratum.

Orthoceras junceum.
Orthoceras planoconvexum.
Orthoceras Beloitense.
Orthoceras 2 sp. undes.
Orthoceras vertebrale.
Endoceras annulatum.
Endoceras proteiforme.
Gonioceras anceps.
Worm borings.
Illænus ovatus.
Asaphus Barrandi.
Asaphus Iowensis.
Ceraurus pleurexanthemus.
Encrinurus sp. undes.
Leperditia fabulites.

In the vicinity of **Janesville** are a number of extensive quarries and natural exposures that display the three lower members of the formation quite extensively. At the quarry, a mile and a half west of the city we find, at the base, heavy buff layers, containing but few fossils, and representing the Lower Buff beds. The complete thickness is not shown. On these repose thinner bedded, eminently fossiliferous, blue and gray beds attended with shaly layers and seams. These are the Lower Blue beds, in thickness, 22 feet 9 inches. These support about 13 feet of light buff colored limestone, of uneven structure — owing to earthy or soft granular spots and occasional cavities — rather irregular fracture, giving an earthy surface with crystalline spangles, and containing but few fossils. Beds one foot or less in thickness. These constitute the lower portion of the Upper Buff beds. The following species were observed at this point, nearly all belonging to the Blue beds: *Buthotrephis, Chætetes lycoperdon, Crinoid stems, Stictopora* (two new species), *Ptilodictya, Trematopora, Lingula attenuata, Orthis perveta, O. tricenaria. O. sp. new* (like *O. testudinaria*), *Streptorhynchus deflectum, Strophomena camerata, S. incrassata, Rhynchon-aella, n. sp., Ambonychia lamellosa, Tellinomya n suta, Cypricardites rotundatus, C. ventricosus, Modiolopsis plana, Helicotoma planulata, Raphistoma lenticularis, Trochonema umbilicatum, Murchisonia helicteres, M. tricarinata, Pleurotomaria subconica, Bucania, n. sp., Pterotheca attenuata, Hyolithes Baconi, n. sp., Orthoceras junceum, O. vertebrale, O., n. sp., Endoceras, Proteiforme, Cyrtoceras Pandion? Gomphoceras? Asaphus Barrandi, Illænus ovatus, Ceraurus pleurexanthemus, Leperditia fabulites* and *Beyrichia.*

At the lower railroad bridge at Janesville, the whole of the Lower Buff limestone is shown resting upon the St. Peters sandstone, and overlaid by about 30 feet of the higher beds, which are here less fossiliferous than usual. A section of this exposure is given in the report of 1862. About two miles above the city, Rock river cuts through the lower part of the formation and into the St. Peters sandstone, and a ravine coming in on the east, through which the road ascends from the river, exposes a large part of the higher strata, so that by combining the sections, nearly the whole of the series may be studied. Fossils are abundant in the usual layers.

Farther up the river, above **Fulton Center**, the lower strata crown the bluffs with weather-worn outliers, while nearer the water's edge the St. Peters sandstone discovers itself. They become somewhat cavernous at one point, a rare feature in this region. The following fossils were collected along the ledges on the west side of the river: *Chætetes, Streptelasma corniculum, Stictopora, n. sp., Orthis perveta, O. tricenaria, Streptorhynchus deflectum, Strophomena camerata? S. incrassata, Rhynchonella, Tellinomya nasuta, Cypricardites Canadensis, C. rectirostris, C. rotundatus, C. ventricosus, Modiolopsis superba, Raphistoma lenticularis, Trochonema ambiguum, Pleurotomaria subconica, Murchisonia tricarinata, Bucania bidorsata, Pterotheca attenuata, Orthoceras junceum, O. vertebrale, Ormoceras, Illænus taurus, Leperditia fabulites.*

The lower beds are also exposed at the outlet of **Lake Koshkonong.** In the western part of Rock county there are numerous outcroppings of this formation, most frequently of the lower beds; but occasionally also of the higher ones. The railway cut near **Magnolia** station exposes the Lower Buff beds, and furnishes an excellent opportunity for studying its character and fauna, which is very similar to that already given. The uppermost layers of the Trenton, and its junction with the Galena limestone above, may be seen satisfactorily in the N. E. ¼ of Sec. 31, and in the S. E. ¼ of Sec. 19, town of **Union**, where a new species of *Stictopora*, and one of *Trematopora*, *Ptilodictya recta*, *Orthis perveta*, *O. testudinaria*, *O. tricenaria*, *Leptæna sericea*, and *Ceraurus pleurexanthemus* indicate the character of a fauna very abundant in individuals, though not especially so in species. At the lower quarry belonging to Mr. Krump near **Ft. Atkinson**, the upper portion of this formation is again shown, though the layers are somewhat lower than the above. About two miles below Jefferson, on the west side of Rock river, a little stream has cut down to dark mottled, fine grained, rather thick beds that are capable of receiving an excellent polish. Their lithological affinities are with the upper half of the formation.

Near **Aztalan** are several quarries showing the junction of the Lower Buff layers and those above. The fossils collected were chiefly Buff species. The surface of the rock is beautifully polished and striated by glacial action.

On the north side of **Red Cedar Lake** in the town of Oakland, and in the vicinity, on the west, the lower beds are displayed, showing a somewhat less firm rock than usual. The first mentioned locality affords *Schizocrinus*, *Stictopora*, *Orthis perveta*, *O. plicatella?* *O. tricenaria*, *Streptorhynchus felitextum*, *Strophomena incrassata?* *Zygospira modesta?* *Raphistoma lenticularis*, *Pleurotomaria*, *Subulites elongatus and Cyrtolites.* To which the others add *Buthotrephis succulens*, *Strophomena camerata*, *Cypricardites rotundatus*, *Orthoceras vertebrale*, *Ormoceras* and *Gonioceras anceps.*

The most interesting exposure of the Trenton limestone in the town of **Waterloo** is at the quarry of Mr. David Crump in section 35. The lower four feet are of thick bedded, very serviceable rock, above which lies one foot of thin shaly stone, succeeded by six feet of somewhat irregular layers of medium thickness, upon which are two feet of even bedded stone overlaid by two and a half of thin, greenish, shaly material. The lower portion is to be regarded as representing the Lower Buff layers, and the upper ones the Lower Blue limestone. The following species were collected in a limited time at this locality: *Buthotrephis succulens*, Graptolite-like bodies; *Chætetes*, *Streptelasma corniculum*, *Orthis tricenaria*, *Streptorhynchus deflectum*, *S. planumbonum*, *Strophomena incrassata*, a new species of *Rhynchonella*, *Tellinomya ventricosa* (young) *Cypricardites rotundatus*, and a new species, *Raphistoma lenticularis*, *Pleurotomaria subconica*, *Murchisonia bicincta*, *M. helicteres*, *Orthoceras annellum*, *O. vertebrale*, and fragments of *Ormoceras and Cyrtoceras.*

The Trenton formation outcrops in the towns of *Shields*, *Portland*, *Elba*, *Lowell*, *Calamus*, *Beaver Dam*, *Westford*, *Fox Lake* and *Trenton*, in Dodge county; but the exposures in all cases are slight, and for the most part belong to the base of the formation. While they subserve a very useful purpose in supplying their respective regions with building material, they add little to our knowledge of the formation, and possess but small interest to the geologist or general reader.

In the townships of **Mackford** and **Green Lake**, in the county of Green Lake, more frequent and extensive exposures, both natural and artificial, occur, particularly in the vicinity of the lakes that beautify those towns. According to the general rule already observed, they are chiefly the lower beds, and are caused to stand forth by the easy degradation of the sandstone below.

In the vicinity of **Ripon** the Lower Buff limestone is well displayed. One of the noticeable peculiarities in this neighborhood is the unequal elevation of the base of the formation. While resting, so far as observed, conformably upon the St. Peters sandstone, the junction is found at varying altitudes. One of the lowest points is at "The Falls," within the city. These falls are caused by the waters of Silver creek pouring over the lower ledges of the Trenton limestone and excavating the softer sandstone below. By following up the stream, a strong dip to the north of east may be observed. Fossils are not abundant here, and but few species were collected, although the quarrying and natural exposures afforded ample opportunities. A few rods west of the business center of the city, the lowest layers of the formation are about 40 feet higher than at the falls. Along the bluff, in the western part of the city, the same layers are 25 to 30 feet higher still, from which point they dip to the south until they disappear beneath Crystal creek at a lower point than that at which they occur to the east in the southern part of the city. To the west of this, toward Green Lake, the base of the formation is more nearly horizontal. In section 5 of the township of Ripon, about three miles northwest of the city, the junction in question occurs at a lower elevation, if an aneroid measurement is to be trusted, than at any of the preceding points.

All these variations may be readily accounted for by supposing a changeable dip of a few degrees; but they are nevertheless unusual in this formation. As the floor of the formation has its greatest elevation at and in the vicinity of the point where it rests upon the domes of Lower Magnesian limestone previously described, and has a lower elevation as it recedes from this point, it is reasonable to suppose that the phenomena may be due to that relationship.

The following species representing the fauna of the lower beds of the formation were collected in this vicinity, the quarries of Mr. Coombs and Mr. Corlis proving most prolific: *Buthotrephis succulens, B. gracilis, Chætetes, Streptelasma corniculum, Retepora, Trematopora, n. sp., Lingula,* like *L. obtusa, Stictopora, Orthis perveta, O. tricenaria, O. subquadrata, Streptorhynchus deflectum, S. deltoideum, S. filitextum, S. planumbonum, Strophomena alternata, S. camura, S. incrassata, S. tenuistriata, Rhynchonella, n. sp., Tellinomya nasuta, Cypricardites rotundatus, C. subtruncatus, C. ventricosus, C., n. sp., Modiolopsis superba, Helicotoma planulata, Raphistoma lenticularis, Trochonema ambiguum, T. umbilicatum, Pleurotomaria subconica, Murchisonia bicincta, Holopea, Subulites elongatus; Orthoceras annellum, O. junceum, O. vertebrale, O. planoconvexum, O., sp. new, Cyrtoceras (Oncoceras) plebeium? C. Pandion, C. or Gyroceras* (outer chamber only), *Ormoceras, Gyroceras convolvans, Lituites, Illænus taurus, Encrinurus, Leperditia fabulites, Ceraurus pleurexanthemus.*

North of Ripon, the formation soon becomes doubly covered with drift, being overlaid not only by the original glacial deposit of rubbish, but also by the later lacustrine clays, and hence it presents itself at the surface even more rarely than before, so that our attention is not again demanded by the meager and scattered exposures until we reach the vicinity of **Neenah** and **Menasha**, where a cluster of interesting quarries occur. Leaving out of consideration those directly south of Neenah and north of Menasha, which are referred to a higher horizon, we find a belt of quarries beginning with Thompson's in Sec. 29, Neenah, and extending north to the county line, which possesses the general lithological characters of the Upper Buff beds, which have already been fully described. The following *list of species*, however, collected from this belt, shows several forms not observed in that horizon in the southern part of the state, but which are common in a higher position and which therefore give special interest to the fauna of these localities: Two new species of *Chætetes, Streptelasma corniculum, Columnaria,* a new species of *Stictopora, Schizorinus nodosus, Lingula quadrata? Orthis lynx, O. plicatella, O. subquadrata, O. testudinaria, O. pectinella, Streptorhynchus deflectum, S. filitextum, Strophomena alternata, S. incrassata, S. camerata, Leptæna sericea, Zygospira recurvirostris, Rhynchonella Anticostensis, Raphistoma lenticularis, Pleurotomaria subconica,* a new species of *Murchisonia*, having a lofty spire, *Endoceras proteiforme*, an undetermined *Gyroceras* and *Leperdita alta?* were secured in the limited time that could be devoted to collection.

In the vicinity of Mr. Verbeck's residence, near the southeast corner of section 18, Menasha, are several small quarries that possess interest from their position and character. At the quarry just east of his house, the rock consists of thick bedded, light greenish blue, or gray limestone containing some argillaceous material distributed through the mass in thin leaves, forming a rock quite similar to that which prevails in the bed of the Lower Fox river. Between the heavy beds are greenish blue argillaceous shales containing fossils, the small Brachiopods of the Blue beds predominating.

Opposite this, on the south, a few feet of rock of a similar nature but more fossiliferous, are underlaid by a partially exposed bed of dark blue crystalline rock. About forty rods west of this is another shallow quarry displaying apparently a lower horizon. The mass of the rock here has a rather brittle, compact, crystalline texture of dark, slightly bluish gray color, and irregular or sometimes vitreous or conchoidal fracture. In the lower strata there is much chert, distributed in layers of nodules which are white or flint colored and fossiliferous. The rock also contains frequent small geodes, the cavities being lined with calcite and occasionally pyrite, or rarely by zinc blende. The walls of fissures are also sometimes lined with calcite and pyrite. A short distance to the northwest of the quarry first mentioned the beds present the more usual characteristics of the argillaceous portions of the Blue limestone as seen farther south. The strata at these several quarries dip at an angle of about 2° to the southeast.

Passing on to the north about ten miles we find in the S. E. qr. of section 28 of the town of **Center,** a partially exposed low dome of rock, reminding us forcibly of the Lower Magnesian mounds previously described, the more so because that formation lies about two miles distant. The beds are exposed on the east and south sides, in which directions they dip, but it is not certain that the uncovering of the other sides would bear out the impression of a mound with quaquaversal dip, given by an approach from the east and south. It may be here remarked that the dip of the Trenton in this region is greater and more varying than in the southern part of the state, though even here the inclination rarely exceeds 7° or 8°. The rock at this point is a bluish gray argillaceous limestone, with shaly partings and very fossiliferous, the following species, many of them represented by a large number of individuals, being gathered by the writer in a half hour: *Buthotrephis succulens, Spongoid bodies Astylospongia?* a new species of *Chætetes, C. discoideus, Streptelasma corniculum, Schizocrinus nodosus,* a new species of *Stictopora, Orthis lynx, O. subquadrata, O. testudinaria,* a new species of *Orthis, Streptorhynchus, Strophomena alternata, Leptæna sericea, Zygospira recurvirostra,* a new species of *Rhynchonella, Raphistoma lenticularis,* an undetermined cast of *Murchisonia,* containing a fragment of *Subulites,* resembling *S. brevis, Bellerphon bilobatus, Bucania* (fragment), *Orthoceras* and *Illænus taurus.*

In describing the Lower Magnesian limestone in the region just west of the last locality, its relations to the Trenton were dwelt upon, and in view of that relationship, it may be profitable to here record the occurrence of the following species in Secs. 25 and 26, town of Ellington, immediately over against the escarpment of Lower Magnesian limestone: *Paleophycus cæspitosum, Schizocrinus nodosus, Orthis lynx, Streptorhynchus deflectum, Strophomena alternata, S. incrassata* and an undetermined species of *Rhynchonella.*

By reference to the maps it will be seen that the formation passes north through the townships of *Freedom, Osborn, Seymour, Maple Grove, Lesser, Angelica, Little Suamico, Pensaukee, Stiles, Oconto, Peshtigo* and *Marinette,* as those townships are now constituted. The exposures in these towns are scattered and meager, and represent chiefly the lower member of the formation. They possess much local value as a source of building material, but in their present undeveloped condition they add but little of knowledge or interest to what has already been said, although they indicate that the characteristic peculiarities of the formation at the south undergo something of modification.

It is the barrier interposed by this formation, that causes the Peshtigo river to make a detour to the eastward in range 31, and gives rise to *Potato and Place's Rapids*, where the river crosses it, the former due apparently to the more resisting Lower Buff beds and the latter to the Upper.

The second series of rapids encountered in ascending the *Menomonee river* are attributable to a similar cause. It is much to be regretted that at this extremity of our district, two hundred miles from the point where our study of the formation began, there is not an equally extensive and fortunate exposure of its several members, that comparisons might be made which would exhibit the changes it has undergone in thickness, lithological character and organic contents. Instead of this we have only a few feet poorly exposed in the banks of the Menomonee river. A portion of the rock at the rapids is a deep blue, heavy, crystalline limestone, weathering smooth and breaking into rectangular blocks, while other portions are quite irregular in texture, being composed of combined earthy, crystalline and shaly material, with partings of the latter material. The bedding is thin and the layers for the most part uneven. On the whole, while not differing essentially from the general characters of the formation as seen elsewhere, it presents an exceptional aspect in harmony with the suggestion already made, that this formation in common with the accompanying ones below and above has changed, in a subordinate degree, its peculiarities. The following species indicate the character of the fauna: A new species of *Cruziana*, *Buthotrephis succulens*, undetermined *Fucoids*, *Chætetes lycoperdon*, *Monticulipora* allied to *M. frondosa*, *Crinoidea (Cyathocrinus?)*, columns of *Schizocrinus nodosus*, a new species of *Stictopora*, *Ptilodictya recta ? Orthis testudinaria*, *O. tricenaria*, and an undetermined species, *Streptorhynchus filitextum*, *S. planoconvexum*, *Stryphomena incrassata*, *Rhynchonella*, *Zygospira recurvirostra*, *Pentamerus hemiplicatus*, and Trilobitic remains (*Asaphus*).[1]

Industrial Considerations. This rock is extensively quarried for the purposes of common masonry. At the great majority of places the quarries are only superficial and the layers thin, and associated with much chipstone. As greater depths are reached a better class of building stone is usually found, because the rock has been less subject to surface action. It is to be observed, however, that with the same amount of exposure the layers in the interior of a hill, which appear firm and solid, would become split and broken, like those that outcrop. The change that is seen in tracing a layer back into the hill is brought about by the atmosphere, frost, percolating water, and similar agencies, and is not due to the original nature of the rock. This fact affords a means of judging of the endurance of the rock, and, applied to most of the beds of this formation, shows that their power of resisting the elements is limited. This is especially true of the Blue limestone, which is inferior to the Buff, and which is to be avoided as far as circumstances will permit. It is a matter of experience that two quarries may be opened with what appears to the proprietors an equally good prospect, one of which will soon reach regular, even courses, with little waste material, while the other only develops thin layers with much shale and chipstone. Such would be

[1] Compare list from the same locality in the Michigan Report, Paleozoic Rocks, 1872, p. 62.

the case if one were located in the horizon of the Buff beds, and the other in that of the Blue. The facts here given should assist in avoiding mistakes of this kind. The Upper Buff beds furnish the best quality of building stone, unless thick layers for heavy masonry are desired, when the Lower Buff also furnishes good material. Very little of this formation is well adapted for cutting, though the lower portions of the Upper Buff, and some parts of the Lower, are well suited to rough-dressed, course-work, its soft color, when tastefully relieved by appropriate pointing, cappings, and cornice, producing a very grateful effect. It is a significant fact in this connection, that in the vicinity of Beloit, where, as stated in the local descriptions, quarries have been opened at nearly every horizon of this formation, none are now habitually worked, *except those lying in the lower two-thirds of the Upper Buff beds.*

This limestone is burned at some localities for quick lime, but except as a source of local supply when communication is poor, such use is not to be recommended. The ten to twenty per cent. of impurities which it usually contains are not only so much waste material, as ordinarily manufactured, but if the heat is allowed to become excessive, the impurities unite with the lime, producing a neutral product. Burned at a low temperature, this difficulty is in a measure avoided. Some of the more impure, yet homogeneous portions, would probably produce a water lime that would fall into the class known as "limes slightly hydraulic," or perhaps a grade higher.

GALENA LIMESTONE.

Reposing on the Trenton beds just described, lies the Galena limestone; so named from the double fact that in the southwestern part of the state, where it has its most characteristic development, it is the chief formation that bears the lead ore, Galena or Galenite, and that in the vicinity of the city of Galena, it is extensively displayed.

General characteristics. In chemical constitution, the rock consists essentially of carbonate of lime and carbonate of magnesia, united, molecule to molecule, and hence it is, strictly speaking, a dolomite. In addition to these main ingredients, there is always present a variable quantity of silicious and aluminous material, and also some iron. Iron pyrites, calcite, zinc blende and galenite are not unfrequently associated with it in the district under consideration, while in the Lead region these exist in great abundance, and others than those named are associated with them.

The dolomite of this formation exists usually in an imperfectly crystallized granular form, while the silicious and aluminous material has an earthy texture, and when abundant, gives the rock a shaly structure. These earthy ingredients are usually distributed in seams or partings between the layers, and in thin leaves in the mass of the bed. These being insoluble are left as a clay when the lime and magnesia are dissolved away, giving rise to a clayey soil, or crevice filling according to circumstances. When the rock is ground up by glacial action more of the soluble parts are retained and a most excellent marly clay soil results. In its more manifest characters and typical form, this deposit may be described as a heavy bedded, irregular, coarse textured, gray or buff dolomite, containing frequent cavities lined or filled with the minerals already mentioned, and weathering in a very irregular, fantastic way, owing to inequalities of structure. Nodules, and occasionally continuous sheets of chert or flint are a prominent feature of some portions of the formation. When exposed at or near the surface, the rock usually presents a decayed, rotten appearance.

As a general description, this is applicable in eastern Wisconsin as far north as Dodge county. At that point the formation begins *to undergo a change.* The modification consists mainly in the introduction of more clayey material in the form of shaly leaves and partings. The effect of this has been to render the rock more impervious to water and atmospheric agencies, and hence, its original blue or gray color is more generally preserved, and to this is added the greenish or bluish hue of the shaly material, so that the rock, instead of being light yellowish gray or buff, is usually greenish or bluish gray. With the increase of argillaceous material there is also an increase of fossils. This may be partly due to the more perfect preservation that was afforded by the nature of the rock, but it is probable that the change in the oceanic conditions that caused the increase of clayey material also had its effect upon the life of the period.

Without entering into a full discussion of the causes that produced this modification in rock and fauna, it may be observed that the typical Galena limestone, viewed as a whole, arches over the low broad anticlinal axis, which stretches southward from the more ancient rocks that form the elevated country in the northern part of the state, and that, whatever may be true of the western horn of this arched crescent, as it enters the trough between the Wisconsin and Minnesota axes, the eastern horn becomes depressed and modified as it reaches the margin of the great basin occupied by the Lower Peninsula of Michigan and adjacent regions. It will be subsequently shown that there is, and was at the time of deposit, a marked depression of all the formations in this region, and that they were all modified by the change of conditions which this depression caused, aided by the protection which the projecting axis above mentioned and its associated reefs afforded. The change in the Galena limestone is gradual and progressive for 40 or 50 miles, beyond which its nature as modified becomes constant for nearly a hundred miles to the limits of the state.

Organic Contents. For a complete list of the fossils found in the progress of the survey in this formation, the reader is referred to the general table of fossils of the Trenton, Galena and Cincinnati formations, where may also be obtained a convenient view of their distribution, and for a knowledge of their special distribution and associations, reference may be had to the lists given in the local descriptions that follow. In addition to these, only a few general remarks need here be made. The "Lead Coral," *Receptaculites Oweni*, is the most characteristic fossil, and, from the ease with which it can be distinguished, furnishes a most convenient and reliable guide. It is not, however, always to be found in limited exposures of the formation, though it is very widely distributed. A large coiled shell, having a high spire, known as *Murchisonia bellicincta* is almost equally characteristic in this region and is more abundant. This species is regarded as identical with *Murchisonia major*, whose typical locality lies in this horizon in the Green Bay region. Two somewhat similar fossils, *Fusispira ventricosa* and *F. elongata* are, so far as yet determined in this region, confined to this formation. *Lingula quadrata*, a phosphatic shell, is also regarded as characteristic, though it is not strictly confined to this horizon. Several other species, so far as present knowledge goes, are found only in these beds, but their distribution is not sufficiently general and well ascertained to justify regarding them as distinguishing species. The majority of the species, as we should expect, are also found in the adjacent formations. Of the 75 species collected from this formation, setting aside doubtful forms, 19 are confined to it, 42 are also found in lower strata, but not above, and 14 are found both below and above. These statements relate only to the collections made, and it is to be considered that owing to practical difficulties, the collections from the adjacent strata above are léss full than from those below, and that from the immediately superjacent beds there are no collections, because no exposures in this region.

Thickness. The average of several estimates gives this formation a thickness of about 160 feet, with a variation from about 125 feet to 200 feet.

Industrial value. While this is the formation which is so productive of lead and zinc in the southwestern part of the state, there is little reason to expect that it will prove so in the region under consideration, for, although the ores of those metals occur not unfrequently in small quantities, no indications of valuable deposits have yet been developed.

Analysis shows that much of this formation from Dodge county southward is a comparatively pure magnesian limestone, and is well adapted to the manufacture of quicklime. It is used for this purpose at Watertown, Ft. Atkinson, Whitewater and elsewhere. It is estimated that 40,000 to 50,000 barrels are burned annually. It is much to be preferred to the Trenton beds which are sometimes burned in the immediate vicinity.

In the southern portion of the district it furnishes an inferior building stone, owing to its granular character, but as it undergoes modification farther north, it becomes better suited to the purposes of construction. At Waupun, Oshkosh and other localities, it is rough-dressed for course-work with very satisfactory results. At other points, especially Duck Creek and Kaukauna, the heavy beds are well suited to the more massive kinds of masonry, and have been used in the construction of the government works in that region.

Distribution and Local Details. The more exact surface distribution of the Galena limestone is shown on the maps of the accompanying atlas. Viewed in a comprehensive way the formation may be said to constitute a broad, nearly north and south belt, having a jagged, irregular outline, and forming the floor of the great Rock river and Green Bay valley.

Beginning at the south, according to our habit, we find on the west side of Rock river, in **Rock county**, about a dozen small areas of this formation, capping the higher prominences. Only a few feet of the base of the formation are present at these points.

In the eastern part of Rock county, and the western part of Walworth county, the Galena limestone has a more ample development, though largely concealed by drift. The rock in this region has essentially the same characteristics that distinguish it in the Lead region, being a rather heavy bedded, coarse, uneven textured, granular, buff dolomite, containing more or less of chert, and weathering to a very rough exterior. Fossils are not abundant, and are usually in the condition of obscure casts. The most extensive exposures are found where the westward flowing streams have formed gorges in crossing the strata.

The Western Union Railway passes through one of these, in the town of **Turtle,** about midway between Beloit and Clinton Junction, and has added several fine cuts to the natural exposures made by the stream.

In the town of **Bradford**, the Turtle creek has excavated a passage through this formation, leaving vertical escarpments of moderate altitude, surmounted by steep slopes, rising from 80 feet to 100 feet above the stream. Fissures analogous to those of the Lead region occur here, but no trustworthy indication of valuable lead deposits were seen. A few fossils were collected here, including *Receptaculites Oweni*, an undetermined species of *Streptelasma*, a new species of *Lingula*, *Orthis lynx*, *O tricenaria*, a *Strophomena*, *Cypricardites rotundatus*, *C. subtruncatus*, *C. ventricosus*, *Raphistoma lenticularis*, *Trochonema umbilicatum*, a new species of *Murchisonia* and *Orthoceras junceum*. The most southerly exposure of this formation, seen in Walworth county, was near **Sharon Mills.** Between this point and **Whitewater**, deep drift conceals it. Near the latter point, several quarries bave been opened, from which a supply of building stone and lime are derived. The rock here is of a more decided buff color than is common, and is marked with peculiar concentric wavy lines of a redish hue. It is soft, porous, granular, uneven in texture, and much decomposed on the surface, but is more cohesive and enduring than its appearance would indicate. There is evidence of a considerable fauna at this point, though the preservation of the fossils is usually poor.

The following identifications have been made, a portion of them based on specimens from the private collections of Mr. L. C. Wooster:

Receptaculites globosus, *R. Oweni*, *Astylospongia*, casts of the cup of a *Zaphrentis*, *Cornulites-like tubes*, *Lingula quadrata*, *a Monomerella*, *Orthis lynx*, *O. perveta*, *or equivalvis*, *Streptorhynchus deltoideum*, *Strophomena alternata*, *S. camerata*, large form, *S. camerata?*, small ventricose form, *Atrypa bisulcata*, *Rhynchonella capax*, *Ambonychia erecta?*, *A. lamellosa*, *Cypricardites ventricosus*, *Raphistoma lenticularis*, *Trochonema umbilicatum*, *Pleurotomaria*, resembling *P. Occidentalis*, *Murchisonia bellicincta*, or *M. major; M. bicincta*, and a new species, *Holopea paludiniformis*, *H.* near *H. obliqua*, *Fusispira elongata*. *F. ventricosa*, and a new species of *Ecculiomphalus*, *Maclurea Bigsbyi?*, and two n. sp. *Conularia Trentonensis*, *Orthoceras planoconvexum*, and two undetermined species, *Cyrtoceras (Oncoceras) plebeium*, and two undetermined species.

Passing by several minor exposures, we find about two miles southeast of **Fort Atkinson**, quarries situated in the lower portion of this formation, and a little to the north (Sec. 10, S. E. qr., T. 5, R. 14), a quarry in the Upper Blue limestone. The rock from the former furnishes a good lime and an ordinary building stone. On the west side of Rock river, in the towns of **Jefferson** and **Oakland**, are several patches of Galena limestone, forming the nucleus of the prominent hills of that region. On the east side of the river, the heavy drift accumulations effectually conceal the formation.

About two miles north of **Watertown**, in the S. E. qr. of Sec. 20, town of Emmet, Dodge county, is an extensive quarry displaying this formation, which still maintains the characteristics already described. Cavities in the rock are rather more than usually abundant, and are usually lined with calcite, or more rarely dolomite, and occasionally with zinc blende or galena. Iron pyrites also occur in nodular crystallizations, many of which are desulphurized in whole or in part.

Chert, as usual, is abundant, more particularly in the upper layers. Fossils are rare. An analysis by Mr. Bode of chippings from the several layers representing a thickness of fifteen feet, shows the following composition:

Carbonate of lime	54.051
Carbonate of magnesia	44.139
Silica	1.564
Alumina	0.072
Oxide of iron	0.174
	100.000

From which it will be seen to be a nearly pure dolomite, aside from the chert, which was excluded from the specimens analyzed.

As far north as this point, the rock of this formation has maintained a very constant character, and, as remarked before, closely resembles the Galena in its more typical localities. To the north of this point it begins to undergo a change. For twenty-five miles northward the change is slight. The rock becomes somewhat more firm, compact, and serviceable as building material and of a gray or blue cast rather than buff. It is also somewhat more argillaceous.

In the vicinity of **Fox Lake** and at **Waupun**, this change has become quite pronounced, resulting in a rock, much superior to that farther south, for purposes of construction, though less serviceable for quicklime. If the formation be traced along its western margin, that is, along its base, the modification of its characteristics is found to be very gradual. Along the upper margin, there are but few opportunities for examination.

At **Seven Mile Creek** there is a flat weathered exposure that reveals little, save the fact of change in the direction indicated. Moore's quarry in the western part of the city of **Fond du Lac** displays a rough, coarse, thick bedded rock of irregular texture, containing cavities lined with calcite and pyrite, and somewhat, though not remarkably, argillaceous. While different from the rock at Watertown and southward, it still retains a noticeable resemblance to it. *Receptaculites Oweni* and *Murchisonia bellicincta* (*major*) occur here, as well as at Waupun and other points in this region, and leave no doubt as to the horizon to which these beds belong. At Moore's quarry the strata have been forced up into a sharp anticlinal axis, from which the beds dip equally in both directions at an inclination of upwards of 10.° The trend of the axis is northwest and southeast. It is manifestly a case of disturbed strata, but the extent of the distubance is unknown, as the excavation is very limited. It is interesting chiefly because such features are very rare in this quiet region. While sloping and undulating beds are not at all uncommon, they almost invariably carry with them evidences that they were so deposited rather than folded or tilted by subsequent force.

Beyond this point, so far as known to me, the Galena formation has not been mapped by previous investigators, and most, if not all of the rocks north of this point, now referred to that horizon, have heretofore been placed either in the Trenton series below, or the Cincinnati above, and lest the position now taken should be misapprehended, it must be borne in mind, that it is simply claimed that the beds in question belong to the Galena horizon, and are a continuation of the unquestioned strata of that formation as found to the southward, and since they are the exact stratigraphical equivalents of the lead-bearing beds, they are mapped and described as being a modified form of that subdivision of the Trenton group. Whether the term Galena limestone should be applied to this group of strata as far as they are directly traceable, or whether it should be limited to the lead-bearing portion, or whether it should apply to that portion which has the same lithological character as the lead-bearing portion, but is not itself productive, as for instance, that portion now described, or whether it should be extended as far as a similarity of organic remains is found, which would include a portion whose lithological characters differ from the typical Galena limestone, is not here discussed, and is a matter of little practical importance, except as a means to a clear understanding of the facts.

But it is a matter of much importance to ascertain precisely what becomes of the lead-bearing formation as it recedes from the productive area in southwestern Wisconsin, since it adds to our knowledge of the conditions under which the formation had its origin, and which, it is commonly held, determined its metalliferous character. About two miles southwest of **Oshkosh** are quarries that possess unusual interest, on account of their relation to this question. Two kinds of rock are displayed by the excavations. *The lower portion*, consisting of an exposure of 15½ feet, is formed of regular, uniform layers from 4 to 10 inches in thickness, rarely more or less, of a crystalline, compact, hard, brittle, subtranslucent, magnesian limestone, marked at intervals with irregular argillaceous seams of a deep blue color, occasionally tinged with green. These shaly partings are usually clustered about the bedding joints, to which they probably stand in the relation of cause. Aside from these seams, the mass of the rock is a dark bluish gray. The specific gravity is high. Geodes are common, and are usually filled with calcite in a great variety of forms of crystallization, and with pyrite, also in unusual variety of forms and colors. Zinc blende is also quite common, and more rarely, Galena. This combination often gives to these geodes a very beautiful and interesting appearance. Sheets of iron pyrites, filling vertical fissures, sometimes traverse the quarries. Zinc blende is sometimes found in small lumps in the interior of the beds. Fossils are somewhat rare in this portion, *Receptaculites Oweni* being most frequent. Columns of *Schizocrinus*, and a fragment of an *Endoceras* were also found by diligent search.

The upper portion of the quarry consists of alternating beds of limestone and shale, the whole having a greenish gray color. The limestone is much more impure and less crystalline than that below, and of a less firm character. These beds, and more especially the associated shales, are quite fossiliferous. Among the species represented are the following:

Small spherical bodies (sponges?), *Chætetes lycoperdon*, *C. discoideus*, a new species of *C.* (branching form), *Zaphrentis* (res. *Streptelasma multilamellosum*), *Schizocrinus nodosus?* (large size column), *Homocrinus*, a new species of *Stictopora*, a new species of *Trematopora*, a new species of *Lingula*, *Crania scabiosa* on *Streptelasma*, *Orthis lynx*, *O. plicatella? O. testudinaria*, *O. tricenaria*, *Streptorhynchus deltoideum*, *Strophomena alternata*, *S. camerata*, *S. incrassata*, *Leptæna sericea*, *Zygospira recuvirostris*, a new species of *Rhynchonella*, *Ambonychia radiata? Cypricardites* (internal cast), *Tellinomya* (internal cast) *Euomphalus*, *Murchisonia bellicincta* = *M. Major*, *Bellerophon bilobatus*, *Illænus taurus* (pygidium), *Calymene senaria*, *Harpes?* (fragment of cheek spine), *Ceraurus pleurexanthemus*.

A specimen of *Receptaculites Oweni* was found in the rock pile, adjacent to the quarries, and was believed to have come from the upper layers.

It will be best to reserve a discussion of the interesting facts here presented until the data furnished farther north are before us, and while noting on the map the position and stratigraphical relations of these quarries, pass on along the strike of the formation to the vicinity of **Neenah.**

About a mile southeast of this place, the rock comes to the surface and is quarried to the depth of a few feet. Like the upper portion of the quarries at Oshkosh, there is an alternation of impure limestone and shale. There is also present a coarse, granular crystalline rock of firmer texture than the remaining layers. The dip is irregular, varying from 8° downwards. Some layers, especially the shaly ones, are quite fossiliferous. The following species occur here:

Buthotrephis succulens, *Graptolites*, *Chætetes lycoperdon*, and a new species having a branching form, discs of *Schizocrinus*, plates of *Crinoids*, two new species of *Trematopora*, two new species of *Stictopora*, a *Ptilodictya*, *Lingula quadrata*, *Orthis lynx*, *O. pectinella*, *O. testudinaria*, and a new species, *Hemipronites Americanus*, *Streptorhynchus deltoideum*, *Leptæna sericea* (small one) *Zygospira modesta*; a new species of *Rhynchonella*, an undetermined species of *Ambonychia*, and of *Euomphalus*, *Raphistoma lenticularis* (small), *Helicotoma planulata*, *Murchisonia bellicincta*, *M. Gracilis*, *Conularia Trentonensis*, an *Orthoceras*, a *Cyrtoceras*, *Leperditia fabulites*, *Illænus Iowensis*, *I. taurus*, *Calymene senaria* and *Dalmania callicephalas*.

The facies of this fauna, as well as the nature of the beds, show a somewhat wide departure from the character of the typical Galena limestone, and a close alliance with the Upper Blue beds of the Trenton; but the facts yet to be given will, it is believed, justify the position to which they are assigned.

Three miles north of this, in the town of **Menasha** (Sec. 11, E hf. of S. W. qr.), are two quarries only a short distance apart, but owing to the irregular nature of the dip, it is not clear precisely what relation they sustain to each other. The quarry south of Mr. Hunt's house consists of impure argillaceous greenish blue limestone, alternating with shaly layers and partings, closely resembling the upper beds at the Oshkosh quarries, and carrying about the same fossils.

The more recently opened quarry north of this, so far as developed at the time of my visit, showed a more granular rock, abounding in chert. It is important to note that here, *Receptaculites Oweni*, *R. Iowensis* and *Murchisonia bellicincta*, fossils that characterize the Galena horizon, occur, associated with *Chœtetes lycoperdon*, a new species of *Chœtetes* having a large branching form, *Streptelasma corniculum*, *Schizocrinus nodosus*, a new species of *Stictopora*, *Orthis lynx*, *O. testudinaria*, *O. disparalis*, *O. pectinella*, *O. tricenaria*, *Strophomena incrassata*, *Leptœna sericea*, a new species of *Rhynchonella*, *Raphistoma lenticularis*, a *Helicotoma*, resembling *H. planulata*, two species resembling *Murchisonia bellicincta*, one resembling *M. gracilis*, and one like *M. percarinata*; a *Bellerophon*, a doubtful form of *Holopea paludiniformis*, and an undetermined *Orthoceras*.

From Appleton to De Pere, the **Lower Fox river** forms a succession of rapids over the heavier and more resisting ledges of this formation. A description of the beds at Kaukauna will sufficiently indicate the general character of the whole. At that point the layers vary from 6 to 30 inches in thickness, and have a dip of from 1½° to 2° to the S. of E. The rock is of a dull bluish green or gray hue, and is characterized by very thin, shaly partings between some of the layers, and by thin, irregular, argillaceous laminæ through the body of the rock, not sufficient however to notably impair its strength or powers of resisting atmospheric influences, since bowlders, that have apparently been exposed since the drift period, are still sound. Aside from these laminæ, the rock has a crystalline character, impervious, and compact in general, though it contains a few cavities, some of which are lined with calcite, and occasionally, pyrite. The beds are vertically fissured at intervals, affording facilities for easy quarrying. Some of these fissures are lined with calcite or pyrite.

These layers contain comparatively few fossils. The most conspicuous and characteristic are *Marchisonia bellicincta* (*major*), *Lingula quadrata*, and *Fusispira ventricosa*. With these are associated several other species, already mentioned as occurring at Oshkosh, Neenah and Menasha. At Little Chute, a *Climacograptus*, nearly allied to *C. typicalis*, occurs, and also north of this, in equivalent strata on Duck creek, but is not known to be found at any other horizon. An analysis shows this rock to be a dolomite, with about 8 per cent of impurities, consisting chiefly of silica, alumina and iron.

Duck creek, which runs nearly parallel to the Fox river, has also cut away the drift and displayed this formation. At the village of Duck Creek, near its mouth, the massive beds are strikingly similar to those at Kaukauna, both in lithological characters and in organic contents. *Murchisonia bellicincta*, *Fusispira ventricosa* and *Lingula quadrata* are again the most noteworthy fossils. Farther up the stream, the beds are more argillaceous and alternate with shaly, very fossiliferous layers, closely resembling those already described. The leading fossils are graptolitic remains. *Chœtetes lycoperdon* and a large new species of the same genus, *Streptelasma corniculum*, *Pleurocystites*, *Glyptocystites Logani*, a *Trematopora*, *Lingula quadrata*, and a species resembling *L. attenuata*, *Orthis pectinella*, and a new species, *Strophomena alternata*, *S. incrassata?* *Rhynchonella capax*, *Raphistoma lenticularis*, *Trochonema umbilicatum*, *Murchisonia bellicincta* and *Dalmania callicephala*.

Duck creek, as well as the Fox river, runs along the line of drift movement, but in the opposite direction. The glacier moved *up* these valleys and planed, polished and grooved the surface of the rock in the most beautiful manner, as may be observed at any favorable locality. In this planing process, the softer portions of the rock were doubtless excavated deepest, leaving the more resisting portions prominent, and these portions form the rapids on these streams, and are the parts chiefly observed. The more shaly portions are not observed at all on the Fox river, and at but few localities on Duck Creek.

The Big Suamico river has likewise denuded this formation at a few points. The most noteworthy of these is at **Flintville**, and as the section here best illustrates the peculiarities which the formation has assumed, it may be described in some detail.

1. The lowest rock seen is a bed of soft, bluish-green, disintegrating shale, only partially exposed.

2. Above this, is a three-inch layer of coarse, blue, granular, half crystalline limestone, mixed with earthy, argillaceous material, and at all points very full of *Orthis testudinaria*.

3. Upon this, rest 10 inches of soft, bluish-green, decomposed shale, containing numulitic forms of *Chœtetes* and *Streptelasma corniculum*.

4. Above this, lies a four-inch bed of deep blue, coarse-grained, crystalline magnesian limestone, mixed with more or less of yellowish, earthy matter, the whole having a high specific gravity. This layer is characterized by the presence in unusual numbers of *Receptaculites Oweni*, the characteristic fossil of the Galena limestone, while other fossils, except minute crinoidal discs, are rare.

5. Upon this, repose 2 feet 10 inches of shale and impure limestone, easily decomposing on exposure, and containing many branching forms of *Chœtetes*, *Streptelasma corniculum*, *Orthis lynx*, *O. plicatella*, *Leptœna sericea*, and other fossils.

6. Next above, occurs a 10 inch layer, similar to No. 4, but more massive, and marked by irregular laminæ of a dark, dirty greenish, argillaceous, and apparently carbonaceous material, giving a somewhat fetid odor under the stroke of the hammer.

7. Five inches soft shale, similar to No. 3.

8. A four-inch layer, similar to No. 5, but more markedly blue.

9. An irregular layer, about 2 inches thick, that is little else than a mass of the stems of the branching *Chœtetes*. The numulitic forms, as also *Brachiopods* and *Trilobites*, are present.

10. About 1 foot 6 inches of shale, containing *Chœtetes* in abundance, especially the more hemispherical forms.

11. Above this, lie about 3 feet of thick bedded, massive dolomite, very similar to that previously described at Kaukauna and Duck Creek. It contains *Receptaculites Oweni*, besides *Orthis plicatella*, *O. lynx*, *Leptœna sericea*, *Strophomena alternata*, *Raphistoma lenticularis*, and fragments of trilobites and crinoids.

The entire collection made at this locality, which is given below, shows an interesting mingling of those species that are characteristic of the Galena limestone in its typical localities, with an abundant Trenton fauna not found at this horizon in the Lead region. *Cruziana ? Receptaculites Oweni*, *Chœtetes lycoperdon*, and three new species, *Streptelasma corniculum*, two new species of *Stictopora*, *Lingula attenuata ? Philodops truncata*, *Orthis lynx*, *O. plicatella*, and a form with bifurcating ribs like *O. fissicosta*, *O. testudinaria*, *Hemipronites Americanus*, *n. sp.*, *Strophomena alternata*, *S. incrassata ? Leptœna sericea*, *Zygospira recurvirostris*, a new species of *Rhynchonella*, *Pentamerus (Camerella ?) hemiplicatus*, *Raphistoma lenticularis*, *Murchisonia bellicincta* (slender form), *Murchisonia* (slender form like *M. gracilis*, round volutions), *Fusispira elongata*, *Bellerophon bilobatus*, *Cyrtolites Dyeri*, *Endoceras proteiforme*, *Illœnus taurus*, *I. Iowensis*, *Asaphus*, *Calymene senaria*, *Ceraurus pleurexanthemus*, *Dalmania callicephala*, *Spherocoryphe*, *sp. ?* and *Proëtus ?* (fragment only).

This formation, without noteworthy modification, is again exposed by the Little Suamico river, and outcrops along the shore of Green Bay, south of Pensaukee, and, although largely concealed by drift, borders the bay northward into Michigan.

Its last appearance in the state is at the lower rapids of the Menomonee river, a little above **Marinette**, where a few feet are exposed in the channel of the river. It is here a bluish or greenish gray, impure dolomite of rather coarse, uneven, partly crystalline and partly earthy texture, containing some cavities lined with calcite. Fossils are not abundant. Dr. Rominger, in the Michigan report, cites the following: "Lingula quadrata, Leptæna camerata, Streptorhynchus filitextus, Murchisonia major, Bucania expansa, Trochonema umbilicata, Maclurea (large casts, three inches in diameter), Conularia Trentonensis, Dictyonema (a species with very delicately reticulated fronds expanding from a transversely-wrinkled hollow cylindrical stem, with a shining carbonaceous surface); also indistinct specimens of Chætetes frondosus and Crinoid stems are included in the rock," p. 57; to which may be added a new species of Stictopora, Raphistoma lenticularis, a Murchisonia allied to M. gracilis, but larger, a Pleurotomaria, and an Orthoceras.

In the way of recapitulation, it may be observed that a comparison of the fossils that have now been enumerated, in connection with the several localities, shows, (1) that there are a considerable number that range throughout the whole Trenton period, including the Cincinnati epoch, and are, therefore, of no service in discriminating between its subdivisions; (2) that there is another portion whose occurrence is chiefly confined to the strata below; and (3) that there are a few that are not authentically known to occur either above, or below, the horizon under consideration, and may be regarded as characteristic of it. Of this latter number, *Receptaculites Oweni* and *Murchisonia bellicincta*, or *major*, are the most constant and reliable. *Lingula quadrata*, although rare in other beds in this region, does not appear to be strictly confined to this subdivision. *Fusispira ventricosa*, *F. elongata*, and an intermediate form, are, perhaps, to be added to the list, as they range from Walworth to Oconto county, and are not found in the collections of the survey in any other stratum.

It will be seen that the change in the nature of the rock commenced in Dodge county, and was essentially completed in Winnebago county, being gradual and progressive through 40 or 50 miles; and that it consisted mainly of the addition of shaly or argillaceous material; and that the increase in the variety and number of the fossils accompanied the increase of the clayey ingredient.

By a comparison with the formations already described, and those remaining to be treated, it will further be seen, that they also undergo some modification at essentially the same latitude, the cause of which can be better understood when all the facts are before us.

THE CINCINNATI SHALES AND LIMESTONES.

The Galena limestone is succeeded by a series of shales and limestones, constituting what will be known in this report as the Cincinnati group, a name now quite generally adopted for this geological horizon, although there is still some difference of opinion as to the lower limits which should be assigned to the application of the term. It here includes all the beds known to lie between the upper surface of the Galena limestone, and the upper limits of the Lower Silurian formation.

General Character. The shales that form so prominent a member of this group are of a varied character. One kind is little else than a slightly indurated green or blue clay, often very fine in texture, containing but little sand, or other hard material, and being, chemically, little else than silicate of alumina. This graduates, by the addition of fossils, iron pyrites, calcareous and silicious matter, and, occasionally, crystals of gypsum, into a variety of impure and changeable shales. Another class has a more slaty structure, having been deposited in delicate laminæ of fine sediment, not so largely clay as the above. These split with great ease and regularity into thin, brittle plates. Still another kind has a more arenaceous character and regular bedding, giving it somewhat the appearance of a fine grained sandstone. These three general classes include many minor varieties.

The associated limestone is also varying in nature. A portion has a coarse, granular, crystalline texture, mingled with earthy, or ocherous matter, while another portion is compact, crystalline, with leaves of argillaceous matter variously distributed through it; and still other portions are silicious or cherty. These several forms often give place to, or graduate into shale. The limestone occurs at all observed horizons, but, except at the northern extremity of the exposure, is much less in quantity than the shale. Near Little Sturgeon Bay, the calcareous material is much increased, and limestone predominates.

The upper part of the formation is chiefly composed of the clay-shales and limestone.

The slaty and arenaceous shales are found at lower horizons. Their special positions and distribution may be found among the local details.

The thickness of the formation may be placed at 200 feet, with an ascertained variation from 165 feet to 240 feet. There are reasons for believing that the extreme range is somewhat greater.

Life. Sea weeds represented the plants, and Radiates, Mollusks, and Articulates, the animals.

The most noteworthy feature is the remarkable abundance of Chætetoid Corals and Bryozoans at certain localities. Upwards of 30 species were collected from the shale thrown out of two shafts of no considerable depth. Other Corals, than those related to Chætetes, are far less abundant. Brachiopods are next in prevalence, the genera *Orthis* and *Strophomena* predominating. Lamellibranchs and Gasteropods are rare, and Crustaceans and Crinoids limited to a few species. More specific facts will be given with the local details, and a full list, except some new or doubtful species, may be found in the table of fossils of the Trenton period.

Industrial value. This formation makes two notable contributions to the soil derived from it, either directly, or through the medium of the drift. The one arises from the clayey members of the formation, and furnishes an argillaceous constituent to the soil. They usually contain, also, some lime, which, with the interstratified limestone, adds a calcareous ingredient. The other has its origin in the arenaceous shales, which give rise to a somewhat sandy soil. The two mingle for the most part, producing an intermediate and excellent soil. In portions of the towns of Ottawa, Eagle, Palmyra, and La Grange, however, the sandy element is objectionably prevalent.

The decomposing shales are used in the manufacture of brick, of which they make an excellent quality. Some of the clays of this formation possess an exceptionally fine texture, and are much freer from sand, or grit, than most drift clays, and hence are to be recommended for those purposes that require such a clay. These chiefly lie in the upper part of the formation.

It may be remarked, in view of the unwarranted expenditures that are likely to be made under false advice, or superficial knowledge, that, however much any portion of this formation may resemble, in general aspect, any portion of the Coal Series, there never has been, and there is no likelihood that there ever will be, any workable deposit of coal found either in, or beneath it. No reliance whatever is to be placed on the physical nature of the rock. The fossils found in it, which, in this and other formations, are given with unusual fullness, demonstrate the utter folly of enterprises looking to the discovery of coal in or beneath this formation.

Distribution and Local Details. The most southerly point at which the Cincinnati beds have been observed in outcrop is near the middle of the south line of Sec. 9, in the town of **Eagle**, Waukesha county. The exposure at this point is very slight, and consists of impure limestone, a portion of it having an earthy and a portion, a granular crystalline texture, full of small cavities, and speckled with ocherous spots. A sufficient number of imperfect fossils are present to determine the position of the rock, which is near the upper face of the formation, but not immediately beneath the Niagara limestone, there being a bed of clay or clay-like shale between. In this vicinity the drift contains many blocks of a fine-grained, dark clay shale, and a lighter colored, olivaceous gray, arenaceous rock, having a somewhat shaly structure. The two kinds are not uncommonly united in one bowlder, but the former soon disintegrates on exposure. The slaty portion also contains many comminuted fragments of *Lingula*, provisionally identified as *Lingula Maquoketa*, and of indistinct graptolitic remains, similar to *Climacograptus*. As this is a very soft rock, and the blocks are little worn, and are essentially confined to this vicinity, where the glacial moraine crosses the Cincinnati belt, it is safe to conclude that it forms one of the members of the Cincinnati group at this point. This is confirmed by the fact that precisely similar rock occurs between 150 and

175 feet below the base of the Niagara limestone, on the east side of Lake Winnebago, and is found at other points, constituting a portion of the series.

In the adjoining section (Sec. 10, N. W. qr.), the Niagara limestone, which constitutes Hinkley's quarry, rests upon a dark blue, hard clay, constituting the upper member of the formation. The transition is abrupt, as is befitting the junction of the Lower and Upper Silurian formations.

North of this, the formation is concealed by drift, and, except as occasionally struck by a well, is not again accessible to observation until Roberts' quarry, on the south side of **Pewaukee Lake**, is reached. This quarry, like the last, is in the lower beds of the Niagara limestone, and has for its floor the clay.like shale of the formation under consideration. Fortunately for the geologist, however unprofitable for the owner, some "experienced miner," in his "practical" wisdom, had discerned in this the Coal formation (!), and expressed the belief that coal would be found beneath the shale; so a shaft was sunk, from which was thrown a remarkable abundance of beautifully preserved Lower Silurian fossils, but, it is needless to say, no "fossil fuel." The shaft and boring together reached a depth of 50 feet, and showed an alternating succession of blue shale, and gray, yellow, and blue limestone, associated with some crystalized quartz, and with considerable iron pyrites. Among the fossils collected from the material thrown out of this shaft, there were found no less than *sixteen* species of Chætetes, nine of which are regarded as new. With these are associated two species of *Stellipora*, one of *Dekayi*, two of *Stictopora*, several new species of *Trematopora*, a *Fenestella*, a *Retepora*, an *Alecto*, and two of *Callopora*, making nearly thirty species of Bryozoans and Corals. Of other forms, there were found five species of *Orthis*, six of *Strophomena*, *Crania setigera*, *Zygospira modesta*, *Pterinea demissa*, *Calymene senaria*, an *Illænus*, a new species of *Beyrichia* and one of *Ortonia*. *These all came from the upper 10 feet of the shaft.*

Passing onward, the formation is again effectually concealed, till the town of **Ashippun** is reached. In Sec. 6 of this town, and Sec. 1 of the adjoining town of Lebanon, small streams have denuded arenaceous beds identical with the rock described as occurring in the drift in the town of Eagle. At other points in this vicinity the presence of the formation is sufficiently indicated, even though it does not display itself in actual outcrops.

At **Hartford**, these shales underlie the iron ore bed, and are penetrated by cellars, wells, and other excavations.

The portion here exposed is the upper stratum, and has its usual characteristics, being a blue, clay-like, fossiliferous shale, containing some limestone.

The following list of fossils will be of local interest: Several species of *Chætetes*, among which are *C. annuliferus*, *C. rhombicus*, and a new species, *Stictopora fragilis*, *Orthis testudinaria*, *O. subquadrata*, *O. occidentalis*, *Leptæna sericea*, *Strophomena unicostata*, *Rhynchonella capax*, and some undetermined forms. With more favorable exposures, this locality would doubtless prove prolific in interesting species. It may be remarked as a practical suggestion, that the iron ore beds, when present, always lie above this formation, except where disturbed by the drift.

Beneath the mines at **Iron Ridge**, and in the vicinity of the upper portion of the formation, is a light greenish blue, scarcely indurated clay, not very fossiliferous. Below this the shale is darker and more full of fossils. As usual, interstratified beds of limestone are present. The upper surface of the clay mingles with the iron ore above for one or two feet, rendering it too impure for use.

The following interesting collection was made at this point: *Chætetes rhombicus*, *n. sp.*, *C. briareus*, *C. punctatus*, *n. sp.*, and several other new or undetermined species, *Alveolites*, *n. sp.*, *Aulopora arachnoidea*, *Alecto inflata*, *Stellipora antheloidea*, *Stictopora fragilis*, a *Helopora*, a *Lingula*, *Orthis testudinaria*, *O. lynx*, *O. subquadrata*, and an undetrmined species, *Strophomena unicostata*, an undetermined *Strepto-*

rhynchus, *Leptæna sericea*, *Rhynchonella capax*, and a new species, *R. perlamellosa*. Beneath the ledges in this region, the Cincinnati beds approach near the surface, but are rarely exposed on account of their soft nature. It is to this fact, chiefly, that the vertical ledges owe their origin. The soft clays and shales were easily carried away during the drift period, leaving the firmer Niagara limestone projecting above. Since the drift period, the springs that issue so numerously at the surface of these clays have worn them away still farther, and the limestone from above has fallen in huge blocks and covered the slope at the base of the cliff. So that not only in the region we are now speaking of, but for a hundred miles northward, the Cincinnati formation will chiefly manifest itself by a slope, covered with debris, at the base of vertical walls of limestone, known in all this region as "The Ledge." Occasionally streams cut through this loose, concealing material, and display portions of the formation. An interesting case of this kind occurs in the town of **Herman**, where a beautiful brook tumbles over the step-like layers of Niagara limestone, and finally plunges into a gorge excavated from the shales under consideration. Only a few feet of blue clay and a yellow arenaceous shale are, however, exhibited. A similar instance occurs in the N. W. qr. of Sec. 21, **Taycheedah**. The falls at this point wash out of the clay large numbers of aggregations of crystals of iron pyrites. These are usually globular, but sometimes take varied and fantastic forms. A considerable deposit of travertine, of modern origin, occurs at this point.

South of **Clifton**, on the east side of Lake Winnebago, upwards of 175 feet are occupied by this formation, above the level of the lake. How much it extends below is not known. The upper portion is chiefly concealed with fallen blocks from the cliff above and other debris. At the lake level there appears a dark chocolate brown shale, alternating with impure limestone and shale of lighter color. The dark shale contains many comminuted fragments of Lingulas.

Above this, lies a bed of limestone, about eight inches thick, of mingled crystalline and earthy structure. Upon this, rests a dark chocolate brown, slate-like shale, splitting with facility into soft, brittle plates. Many water-worn fragments of this stratum are heaped up by the waves on the beach below, and present an exaggerated illustration of the difference between the rounding effects of beach action and of running water. In the former case, the effect of the waves is, to cause the fragments to move up and down the sloping beach, and if they were originally flat, as in this case, their tendency is to slide, rather than roll, and the result is a round, disk-like, but not globular, form, and this is very markedly the case at this point. On the other hand, the effect of running water is to roll, rather than silde, the fragments, and hence, to produce spherical pebbles. This distinction, may be studied with profit, in connection with the drift deposits. Above the slate-like beds, lies a yellowish gray shale of homogeneous, somewhat arenaceous texture, and having a conchoidal fracture, giving the rock the appearance of having an obscure concretionary structure.

Beds higher than these, and lower than those previously described, are slightly exposed in Lot 59, Stockbridge, where shales and limestones constitute the section and *Orthis occidentalis*, *O. tricenaria*, *Strophomena alternata*, and *Rhynchonella capax*, the chief features of the fauna. An extraordinarily large specimen of the last named species was found, by Mr. King, at this locality. In **Brown county**, several of the streams that come down from above the ledge denude, to some extent, the Cincinnati beds. One of these forms the beautiful Cascade Falls, east of De Pere, where the shales underlie the iron ore deposit, and will be again mentioned in connection with that formation, and another, east of Green Bay, forms a succession of rapids over greenish blue shales and limestones.

On reaching Green Bay, the formation is better exposed in its upper portion, but its base here, as elsewhere, is concealed. The escarpment of limestone that forms **Whit-**

ney's **Bluff** is underlaid by about 65 feet of this formation, consisting, so far as exposed at the time of examination, mainly of blue shale, but including, also, some beds of limestone. A portion of the shale consists of a bluish, drab-colored, scarcely indurated, clay, of very fine texture, nearly free from sand and similar impurities, and is, in this respect, much superior to most drift clays, and is worthy of attention, as an excellent clay. Crystals of gypsum, of the variety *Selenite*, are found at this locality.

North of this, the formation is quite changeable in nature. This may be well observed along the cliff that lines the shore of **Green Bay**, south of Little Sturgeon Bay. On the western curve of the point, at the mouth of the latter bay, where the formation last displays itself in force, the entire exposure, 15 feet, is of a hard, compact, fine grained, laminated limestone, showing mud cracks.

Following along the shore southward, a most interesting series of minor changes and fine exhibitions of the manner in which this class of rocks are deposited, is presented for study, and is worthy of note here for the benefit of students of geology, since nowhere else in the state are equally good opportunities for the study of shale deposits afforded. Degrees of induration, from that of ordinary clay, to rocks of almost flint-like hardness, varieties of lamination, from that which is so delicate and uniform as to indicate the most quiet depositing waters, up through various degrees of undulation and irregularity, to ripple marks, eight inches from crest to crest, and an inch high; together with mud cracks, so pronounced and regular as to sometimes cause the surface to resemble a pavement of octagonal bricks, may be observed, while the cliffs are banded and variegated with various shades of blue, green, gray and purple, the whole indicating great variety of conditions and of material, within a limited area.

The formation is here much more calcareous and more firm and resisting in its nature, and, at the same time, less fossiliferous than at any point observed to the southward. In some of the lower layers exposed, there is much chert in large nodular or lenticular masses.

The following section is perhaps as nearly typical as any that could be selected to represent the formation at this extremity of its area:

1. Hard, fine grained, compact, argillaceous limestone, in beds 10 inches or less in thickness, some of them weathering rough and irregular. About	9 ft.
2. Similar, but harder limestone, marked with undulating and contracted laminations; some shaly layers interstratified; bluish gray in color, lined with red	7 ft. 6 in.
3. A group of shales of varying color and texture, the most prominent of which are finely laminated and slaty, splitting up on exposure into scales and plates, while some are more clay-like. The group includes limestone layers	16 ft. 8 in.
4. Thick bedded, blue, cherty limestone, with some argillaceous impurities in the form of laminæ and partings	5 ft. 8 in.
5. Very similar to the above, but harder	1 ft. 1½ in.
6. Thin bedded, broken, irregular, nodular, quite cherty, calcareous layers. Exposed	3½ ft.
Total, about	44 ft.

At the point west of Little Sturgeon Bay, the formation sinks beneath the waters of Green Bay.

FOSSILS OF THE TRENTON PERIOD.

GENERA AND SPECIES.	Lower Buff.	Lower Blue.	Upper Buff.	Upper Blue.	Trenton Epoch.	Galena proper.	Galena modified.	Cincinnati.
PLANTÆ.								
Palæophycus cæspitosum					*			
P. gracile	*				*			
P. tubulare					*			
P. und. sp					*			*
Cruziana, und. sp					*		*	
Buthotrephis succulens	*	*	*		*		*	
B. und. sp					*		*	
Phytopsis tubulosa					*			
FORAMENIFERA.								
Receptaculites globularis						*		
R. Iowensis							*	
R. Oweni						*	*	
PETROSPONGIA.								
Astylospongia? und. sp					*	*	*	
GRAPTOLITIDÆ.								
Buthograptus laxus					*			
Climacograptus typicalis?						*	*	
C. und. sp							*	*
Dictyonema Neenah					*			
Diplograptus Peosta					*			
Graptolitic bodies, gen. and sp. und					*		*	
CORALS.								
Chætetes annuliferus, n. sp								*
C. atritus								*
C. briareus								*
C. discoideus				*	*		*	
C. Jamesi								*
C. lycoperdon			*	*	*	*	*	*
C. mammulatus								*
C. Ortoni								*
C. pavonius								*
C. polyporus, n. sp								*
C. pulchellus					*			
C. punctatus, n. sp								*
C. rhombicus, n. sp								*
C. ramosus								*
C. rugosus								*
C. n. and und. sp			*	*	*		*	*
Monticulipora Dalei					*			
M. und. sp					*			
Stellipora polystomella								*

FOSSILS OF THE TRENTON PERIOD — *continued.*

GENERA AND SPECIES.	Lower Buff.	Lower Blue.	Upper Buff.	Upper Blue.	Trenton Epoch.	Galena Proper.	Galena Modified.	Cincinnati.
CORALS — con.								
Stellipora, n. sp.	....	....	....	....	....	..	....	*
Alveolites, n. sp.	....	....	....	....	....	....	....	*
Dekayi, sp. res. D. aspera	....	....	....	....	....	....	....	*
Streptelasma (Petraia) corniculum	....	....	*	....	*	....	*	*
S. (Zaphrentis) multilamellosum	....	....	....	....	....	....	*	....
S. profundum	....	....	....	....	*	....	....	....
S. und. sp.	....	....	....	....	*	*	....	....
Columnaria alveolata	....	....	....	....	*	....	....	....
C. und. sp.	....	....	....	...	*	....	....	....
Zaphrentis, und. sp.	...	....	....	....	*	....	*	....
Coral resemb. Calceola	....	....	....	....	*	....	...	....
Favosites,	....	....	....	....	*	....	....	....
Cornulites-like tubes, gen. and sp. und.	....	....	....	....	....	*	....	....
CRINOIDEA.								
Schizocrinus nodosus	....	*	*	....	*	....	*	....
Poteriocrinus, und. sp.	....	...	....	....	*	....	....	....
Cyathocrinus, n. sp. ?	....	....	....	....	*	....	....	....
Homocrinus, und. sp.	....	....	....	....	...	....	*	....
Lichenocrinus, sp.?	....	....	....	....	....	....	....	*
Crinoids, gen. and sp. und.	....	....	....	....	*	....	....	*
CYSTIDÆA.								
Pleurocystites squamosus?	....	....	....	....	....	*	*	....
Glyptocystites Logani,	....	....	....	....	....	....	*	....
BRYOZOANS.								
Trematopora sp. res. Gorgonia perantiqua	....	....	....	*	*	....	....	....
T. new and und. species	*	....	....	....	*	....	*	*
Stictopora elegantula	....	*	*	....	*	....	*	*
S. fragilis	....	....	....	....	....	....	....	*
S. ramosa	....	....	....	....	*	....	....	....
S. n. sp. No. 1	*	....	....	*	*	....	*	....
S. n. sp. No. 2	....	....	....	....	*	....	*	....
S. n. sp. No. 3	....	....	....	....	*	....	*	....
Ptilodictya recta	....	....	*	*	*	....	....	....
P. und. species	....	....	....	....	*	....	*	....
Clathropora flabellata	....	....	....	....	*	....	....	....
Callopora und. sp	....	....	....	....	....	..	..	*
Fenestella, und. sp.	....	....	....	....	....	....	....	*
Retepora, und. sp.	....	....	....	...	*	....	...	*
Alecto inflata.	....	....	....	....	....	....	....	*
Aulopora arachnoidea	....	....	..	....	....	....	....	*
Helopora, und. sp.	....	...	....	...	....	....	....	*
Paleschara? und. sp	....	....	....	...	....	....	....	*
BRACHIOPODA.								
Lingula alternata	....	....	...	....	*	*	....	....
L. maquoketa	....	....	....	...	....	....	....	*
L. quadrata	....	....	....	....	*	*	*	....

FOSSILS OF THE TRENTON PERIOD — *continued.*

GENERA AND SPECIES.	Lower Buff.	Lower Blue.	Upper Buff.	Upper Blue.	Trenton epoch.	Galena proper.	Galena modified.	Cincinnati.
BRACHIOPODA — (con.)								
Lingula, sp. res. L. obtusa	*				*			
Lingula, two new species						*	*	
L. und. sp			*		*			
Lingulella? n. sp								*
Pholidops truncata							*	
Crania scabiosa							*	
C. setigera								*
C. n. sp					*			
Schizocrania filosa					*			
Monomerella sp. undes						*		
Orthis bellarugosa				*	*			
O. disparalis	*				*		*	
O. Ella					*			
O. equivalvis					*	*		
O. Kankakensis								*
O. lynx				*	*	*	*	*
O. occidentalis								*
O. pectinella				*	*		*	*
O. perveta	*	*	*	*	*	*		
O. plicatella				*	*		*	
O. subequata					*			
O. subquadrata	*				*			*
O. testudinaria		*	*	*	*	*	*	*
O. testudinaria var					*	*		*
O. tricenaria	*	*		*	*	*	*	*
O. sp. res. O. hybrida					*			
O. sp. res. O. borealis					*			
O. new species					*		*	*
O. und. species						*	*	
Hemipronites Americanus, n. sp							*	
Streptorhynchus deflectum	*	*	*		*			
S. deltoideum	*?				*	*	*	
S. filitextum	*?				*			
S. planoconvexum					*			
S. planumbonum	*?				*			*
S. rectum					*			
S. sinuatum					*			
S. subtentum			*		*			
S. two n. sp								*
Strophomena alternata	*	*	*	*	*	*	*	*
S. antiqua								*
S. camerata	*				*	*	*	*?
S. camura	*				*			
S. n. sp								*
S. incrassata	*	*	*		*		*	
S. meridionalis, n. sp								*
S. nitens								*
S. recta								*
S. tenuistriata					*			
S. tenuilineata					*			
S. Thalia								*
S. n. sp					*			
S. und. sp						*	*	
Strophodonta			*		*			
Leptæna sericea				*	*	*	*	*

FOSSILS OF THE TRENTON PERIOD — *continued.*

GENERA AND SPECIES.	Lower Buff.	Lower Blue.	Upper Buff.	Upper Blue.	Trenton Epoch.	Galena proper.	Galena modified.	Cincinnati.
BRACHIOPODA — (con.)								
Zygospira modesta	....	....	....	....	*	....	*	*
Z. recurvirostra	....	....	..	....	*	....	*	....
Atrypa bisulcata	....	....	....	....	....	*	....	....
Rhynchonella Anticostensis	....	....	....	....	*	*	*	....
R. capax	....	....	....	....	*	*	*	*
R. Janea?	....	....	....	....	....	....	....	*
R. n. sp., No. 1	*	....	....	....	*	....	*	....
R. perlamellosa, n. sp	....	....	....	....	....	....	....	*
Pentamerus hemiplicatus	....	....	....	....	*	....	*	....
LAMELLIBRANCHIATA.								
Pterina demissa	....	....	....	....	....	....	....	*
Ambonychia attenuata	....	....	*	....	*	....	....	....
A. erecta	....	....	....	....	*	*	....	....
A. lamellosa	....	*	*	...	*	*	....	....
A. planistriata	....	....	....	...	*	....	....	....
A. radiata	....	....	....	....	*?	*	*	....
A. n. sp.	....	....	*	....	*	....	....	....
Tellinomya Iphigenia	...	*	*	....	*	....	....	...
T. alta	....	....	....	....	*	....	....	....
T. lirata	....	....	....	....	*	....	....	...
T. levata	....	....	....	....	*	....	....	....
T. nasuta	*	*	*	....	*	....	....	....
T. ventricosa	....	*	*	*	*	....	....	....
T. n. and und. sp	....	....	....	....	*	....	*	....
Cypricardites Canadensis	*	....	....	....	*	....	....	....
C. Niota	....	*	*	*	*	....	....	....
C. rectirostris	*	....	....	....	*	....	....	....
C. rotundatus	*	*	*	*	*	*	....	....
C. subtruncatus	*?	....	....	...	*	*	....	....
C. ventricosus	*	*	*	*	*	*	....	....
C. n. sp.	*	....	*	*	*	....	....	....
C. sp?	....	....	....	....	....	....	*	....
Modiolopsis faba	....	...	....	....	*	....	....	....
M. plana	....	....	*	....	*	...	...	....
M. superba	*	....	*	*	*	....	....	....
M. und. and n. sp	....	....	....	....	*	....	....	....
GASTEROPODA.								
Euomphalus, n. sp?	....	....	...	....	....	....	*	....
Ecculiomphalus, und. sp.	....	....	...	....	....	*	....	....
Raphistoma lenticularis	*	*	*	*	*	*	*	....
R. Nasoni	....	*	*	....	*	....	....	....
Helicotoma planulata	*	*	*	....	*	....	*	....
H. n. sp.	....	...	....	....	*	....	...	....
H. sp. und	....	....	....	....	....	*	*	....
Trochonema ambiguum	*	*	....	...	*	....	....	....
T. Beloitense, n. sp	....	....	*	....	*	....	....	....
T. umbilicatum	*	*	*	....	*	*	*	....
T. res. T. lapicidum	....	....	....	....	....	*	....	....
T. und. sp	....	....	....	....	....	*	*	....

FOSSILS OF THE TRENTON PERIOD — *continued.*

GENERA AND SPECIES.	Lower Buff.	Lower Blue.	Upper Buff.	Upper Blue.	Trenton Epoch.	Galena proper.	Galena modified	Cincinnati.
GASTEROPODA. — (con.)								
Eunema? pagodum					*			
Pleurotomaria depauperata					*			
P. Niota					*			
P. subconica	*	*	*		*			
P. und. sp.							*	
P. sp. res. P. occidentalis						*		
Cyclonema percarinatum			*		*			
Murchisonia bicincta	*?		*		*	*		
M. bellicincta=M. major						*	*	
M. gracilis		*			*		*	
M. helicteres		*	*		*			
M. pagoda		*	*		*			
M. percarinata?						*		
M. serrulata			*		*			
M. tricarinata	*	*	*		*			
M. three n. sp.						*		
Holopea obliqua	*?				*		*	
H. paludiniformis					*	*	*	
H. und. sp.						*		
Subulites elongatus	*	*	*		*			
Calisospira occidentalis, n. sp.		*			*			
Fusispira elongata						*	*	
F. ventricosa						*	*	
F. n. sp.							*	
Maclurea Bigsbyi		*			*	*?		
M. camerata, n. sp.						*		
M. subrotunda, n. sp.						*		
Metoptoma, sp. res. M. patelliformis								*
M. ? perovalis, n. sp.		*			*			
HETEROPODA.								
Bucania bidorsata	*	*	*		*			
B. Buelli, n. sp.		*	*	*	*			
B. expansa					*			
B. punctiformis			*		*			
B. und. sp.						*		
Bellerophon bilobatus							*	
B. Wisconsinensis, n. sp.	*	*	*	*	*			
B. und. sp.		*			*		*	
Cyrtolites compressus					*			
C. Dyeri							*	
PTEROPODA.								
Conularia Trentonensis						*	*	
Hyolithes Baconi, n. sp.		*	*		*			
Pterotheca attenuata	*	*	*		*			
Ecculiomphalus undulatus					*			
E. n. sp.						*		

FOSSILS OF THE TRENTON PERIOD — *continued.*

GENERA AND SPECIES.	Lower Buff.	Lower Blue.	Upper Buff.	Upper Blue.	Trenton Epoch.	Galena proper.	Galena modified.	Cincinnati.
CEPHALOPODA.								
Orthoceras amplicameratum						*		
O. anellum	*	*	*		*			
O. capitolinum					*			
O. junceum	*	*	*		*	*		
O. planoconvexa	*?	*	*		*	*		
O. multicameratum			*		*			
O. vertebrale	*	*	*		*		*	
O. n. sp?	*				*			
O. und. sp		*			*	*	*	
O. (Ormoceras) Beloitense, n. sp	*	*	*		*			
Ormoceras tenuifilum?					*			
O. und. sp	*	*	*		*			
Endoceras annulatum?			*		*			
E. proteiforme		*			*		*	
E. und. sp							*	
Cyrtoceras annulatum			*		*			
C. camuum					*			
C. corniculum		*	*		*			
C. eugium		*	*		*			
C. loculosum					*			
C. macrostomum					*			
C. Neleus			*		*			
C. und. sp						*	*	
C. und. sp		*			*			
Oncoceras Alceus			*		*			
O. abruptum			*		*			
O. Lycus		*	*		*			
O. Pandion	*	*	*		*			
O. plebeium	*?	*	*		*	*		
O. und. sp		*			*			
Ascoceras or Cryptoceras, und. sp							*	
Gyroceras convolvans	*				*			
G. duplicostatum n. sp					*			
Gonioceras anceps		*	*		*			
G. occidentale					*			
Lituites occidentalis	*				*			
L. Robertsoni					*			
Gomphoceras, und. sp					*			
CRUSTACEA.								
Leperditia fabulites	*	*	*		*		*	
Illænus crassicauda?					*			
I. Iowensis							*	
I. ovatus		*	*		*			
I. taurus	*				*		*	
I. und. sp			*		*	*		*
Asaphus Barrandi		*	*		*			
A. gigas					*			
A. Iowensis		*			*		*	
A. n. sp					*			
A. sp. und							*	
Calymene senaria					*		*	*
Harpes, und. sp							*	

FOSSILS OF THE TRENTON PERIOD — *continued.*

GENERA AND SPECIES.	Lower Buff.	Lower Blue.	Upper Buff.	Upper Blue.	Trenton Epoch.	Galena proper.	Galena modified.	Cincinnati.
CRUSTACEA — (con.)								
Dalmania callicephala	....	....	....	....	*	....	*	....
D. meta	....	....	....	....	*	....	....	....
Ceraurus pleurexanthemus	*	*	....	*	*	....	*	...
Encrinurus, n. sp. ?	*	....	*	....	*	....	....	....
Sphærocephalus ? und. sp	....	....	....	....	....	....	*	....
Proëtus, und. sp	....	....	....	....	....	....	*	....
Beyrichia, und. and n. sp.	....	....	....	....	*	....	....	*
ANNELIDA.								
Ortonia, n. sp.	....	....	....	....	....	....	....	*
Serpulites-like tubes	....	....	....	....	....	*	....	....

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IRON RIDGE MINE.

CHAPTER VIII.

UPPER SILURIAN.

CLINTON IRON ORE DEPOSIT.

It has already been incidentally stated, that, at certain points, the Cincinnati shales were overlaid by an iron ore deposit, while much more frequently it was observed, that the Niagara limestone rested directly upon them. Wherever the iron ore occurs, it is found to be capped by Niagara limestone. The phenomenon presented, then, is that of a separation of the shales and limestone, at some points, by a bed of iron ore, coming in between them, and growing thicker till its maximum is reached, and then thinning out and disappearing again, forming an irregular lens-like mass.

As yet there seems no authentic instance of organic remains having been found in this deposit, although I was shown fossils, said, with undoubted truth, to have been taken from the ore, but they were probably found in the disturbed drift ore, as they were Cincinnati species, specimens of which were ascertained to have been driven up by glacial forces into the mixed mass overlying the Mayville ore bed. We are left, then, without the valuable criterion which fossils afford for determining the age of this important formation. But there is, nevertheless, no occasion for doubt on this subject. Its stratigraphical position fixes its age within very narrow limits. The limestone above belongs to a very low horizon in the Niagara group, and, indeed, it has been regarded by some eminent geologists as belonging to the Clinton epoch, and it probably is the approximate equivalent of the upper portion of the Clinton beds of New York, but as will be seen hereafter, there is no good reason for separating this limestone from the great mass of the Niagara group, with which it is intimately connected. There is a sharp line of demarkation between the ore and the limestone, at most points, so that there is no reason for assigning the ore a higher position than the Clinton epoch.

While, as already stated, the clay below mingles somewhat with the lower layers of the iron deposit, the ore "takes on" layers at the bottom, so that its beds are in a slight degree unconformable to those below, which constitutes a reason for not grouping the iron beds with the Cincinnati series.

Within the limits to which stratigraphical evidence thus confines this formation, there can be no hesitancy in referring it, on lithological grounds, to the Clinton epoch, since that epoch is characterized from Ohio as far eastward as Nova Scotia, and as far southward as Alabama, by a similar deposit of oölitic iron ore.

As this formation is developed only at certain localities, we may profitably omit further general remarks, and give place to detailed local descriptions.

By far the most important development of this formation occurs at **Iron Ridge,** in the township of Hubbard, Dodge county. The main deposit is included in Secs. 12 and 13 of that town. The locality is characterized by a north and south ledge facing the west, and overlooking the lower land in that direction, from a height of about sixty feet. The upper twenty feet or more of this ledge is composed of heavy, rough beds of Niagara limestone. Beneath this lies the ore bed having a varying thickness, the average of which is perhaps fifteen to eighteen feet.

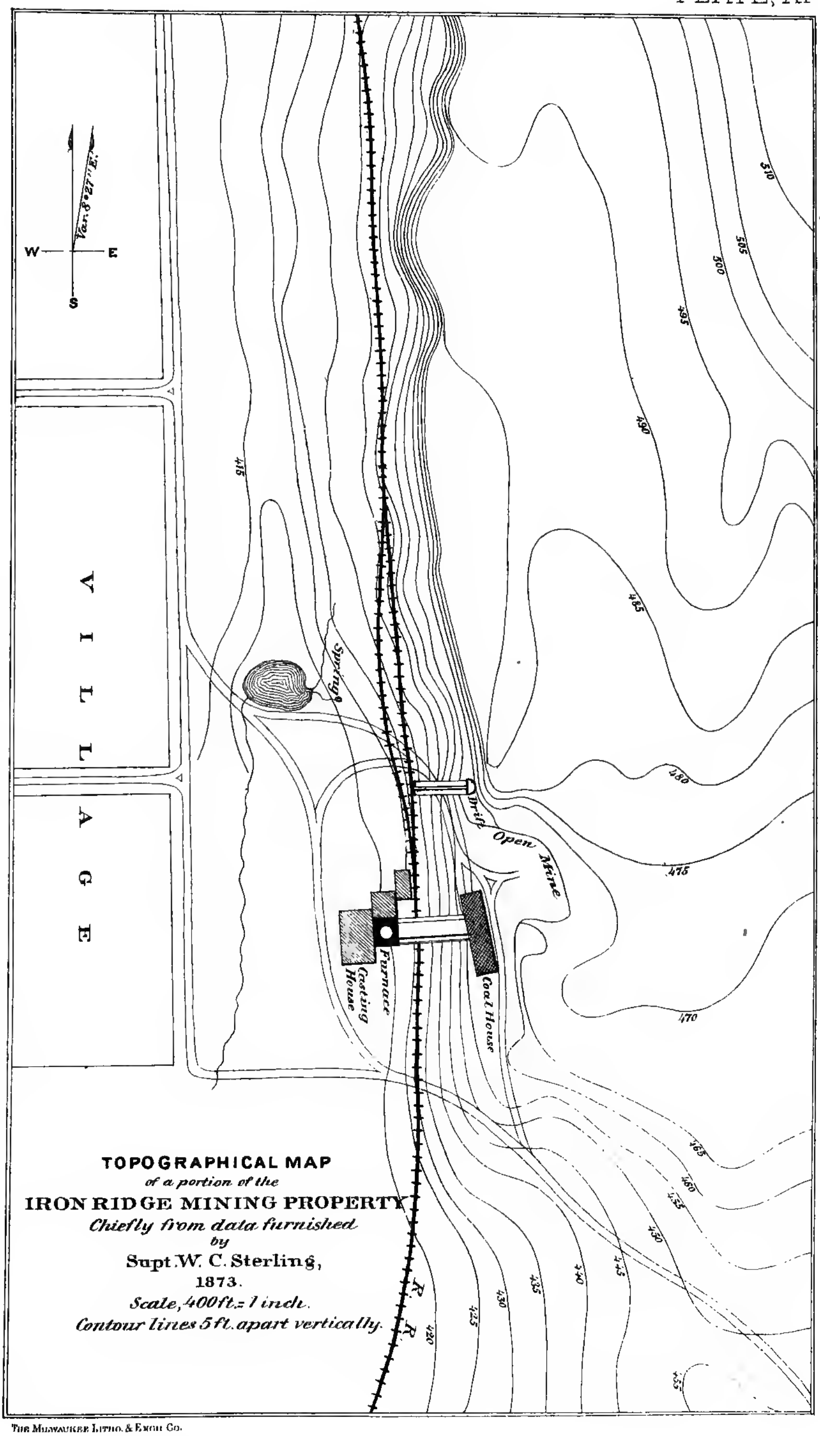
This leaves the base of the ore at a most convenient elevation above the lower land adjoining on the west, giving the most ample facilities for drainage, loading the ore into cars, or supplying the adjacent furnace. The accompanying topographical map, for the data of which, as well as many other favors, I am indebted to the kindness of Supt. W. C. Sterling, will show the situation more precisely, and the chromo-lithograph (Pl. X), which has been accurately sketched from a photograph, will give a more vivid conception of the relations of the ore and the method of mining, than can be conveyed by description. The mine, of which only a small portion is shown in the plate, is situated a short distance west of the center of Sec. 13.

Near it is the furnace, and a little further west is the village. Three-quarters of a mile north of this, is the Mayville mine, on what is known as the Mayville Ore Bed, though the village of Mayville is four miles and a half distant. The working force at this point, at the time of my investigations, was in charge of G. R. Hood, to whom I am indebted for various favors.

Having thus before us the essential geographical features of the location, and the general situation of the ore bed, we may give our attention more specifically to the deposit itself.

The ore occurs in regular horizontal beds, varying from about 3 to 14 inches in thickness. The dip is slight and varying in direction. Near the furnace, it is northward; at the Mayville Ore Bed, it is south-

PLATE, XI



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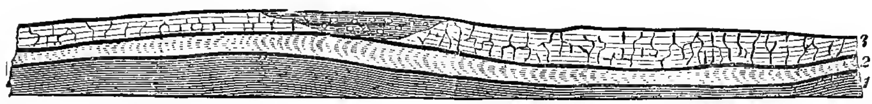
eastward; and north of this, it is again northward. This, in connection with the fact that the thickest portion of ore occurs at the highest elevation, near the center of the deposit, seems to indicate that appreciable, though slight, flexures of the strata have taken place at this point since their original deposition.

FIG. 40.



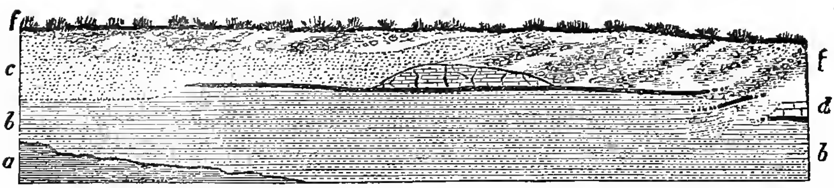
NORTH AND SOUTH SECTION THROUGH THE IRON ORE DEPOSIT, IRON RIDGE.
1. Cincinnati Shale. 2. Iron Ore. 3. Niagara Limestone.

The ore, as a whole, must be classed with the hematites, although it contains a notable amount of water in combination, and gives a streak varying from a dirty red to a yellowish brown, and, except the upper layer, which differs from the main body, seldom gives a bright scarlet streak or powder. The hydration is not uniform, however, and is most marked where the ore is most exposed, and seems to be a process in progress, rather than an original characteristic. The water collected in, or issuing from, the mines is colored to a bright scarlet, although a spring issuing beneath is almost free from indications of iron, as indeed are all the springs in the vicinity. They cannot be relied upon, then, to indicate the presence of this iron deposit. The ore consists chiefly of small lenticular concretions, whose average diameter is about one twenty-fifth of an inch. They are less uniform in size than would appear to casual observation, being of all dimensions, from one tenth of an inch in diameter to those that are very minute. There occur also in all of the layers, but more numerously in the lower ones, larger concretions which are usually more or less lenticular in form, though frequently otherwise. These seem to be largely composed of argillaceous material. From this concretionary or oölitic structure, the ore receives its popular names, "seed ore," and "shot ore." The concretions are bound together by just enough of adhesive ore powder to give the mass a somewhat firm coherence, and the result is a soft, granular rock. The little lens-shaped concretions lie, as would naturally be anticipated, chiefly upon their sides, giving to the rock a ready cleavage in a horizontal direction. These facts, together with the vertical joints and frequent bedding lines, render mining remarkably easy. The prevailing color is a dark reddish brown. At certain points it becomes purplish and even bluish, as at the Mayville Ore Bed, where the term "blue ore" is applied.

The top layer, from 3 to 8 inches thick, differs markedly from the rest of the deposit. It is dark purple in color, much harder and more compact than the oölitic ore, and is not lenticular, though sometimes incorporating a few concretions. It gives a bright scarlet streak and powder, has an irregular or conchoidal fracture, and much higher specific gravity than the main mass. It contains, as noted by Dr. Percival, scales of specular ore.

At the mines, the bedded ore varies from 15 to 25½ feet in thickness. To this, at the Mayville Ore Bed, there is added a considerable depth of drift ore increasing the thickness to 40 feet or more.

FIG. 41.



PROFILE SECTION AT THE MAYVILLE ORE BED.

a. Cincinnati Shale. *b.* Bedded Ore. *c.* Drift Ore. *d.* Niagara Limestone, Capping Ore. *f.* Mixed Drift.

The accompanying section (fig. 41) shows very inadequately the arrangement of the undisturbed and drift ores, and of the ocherous drift, gravel, bowlders, and disturbed and undisturbed limestone, as seen at the time of my visits. It was taken just when the drift, in the progress of mining, was giving place to undisturbed limestone, a point most favorable for study. It will be noted that the various bands of drift material extend from the left (north) obliquely upwards to the right, and that at the left, the upper dark layer of ore is swept away, and at the right, it is broken up in a peculiar way very imperfectly illustrated in the figure.

The force that produced the disturbance and intrusion of the ore into the common drift seems to have come from the west of north, and to have been massive in character. It is but another characteristic instance of glacial action.

What may have been the original extent of the ore deposit to the westward cannot now be ascertained. That portion has been swept away by the denuding agencies which formed the valley lying in that direction. To the southward and south-westward, the same agencies have limited our knowledge. To the eastward, the deposit thins out. To the northeastward, there rises a high ridge, underlaid by a considerable depth of limestone, which has thus far limited explorations in that direction, since the immense quantities of ore already developed leave no necessity for further exploration at present by the company owning the land. The deposit may be traced a mile and a quarter to the northward from the furnace, where it is lost under the hills that rise in that direction. It has been found in a thin deposit, two miles farther on to the west of north, in the town of Williamstown. It has also been found a mile to the east of the furnace. Though it is difficult to give even an approximate estimate of the amount of ore here deposited, it is at least safe to say that it is to be reckoned by millions of tons, and, though not absolutely inexhaustible, is at least adequate to all anticipated wants for a long period to come.

Both open and underground mining have been made use of, but the former method has been found the most economical.

The position of the ore, outcropping along the face of a terrace, at a convenient elevation, rendering drainage, "stripping," loading into cars, or the furnace, convenient, the soft character of the ore, its horizontal bedding of medium thickness, the ease with which it may be bored and blasted, its situation in a rich agricultural and heavily timbered region, and its railway connections, combine to render this locality unsurpassed in the advantages it presents for mining, reducing and shipping the ore.

The following table of analyses shows the chemical nature of the ore:

Analyses of Iron Ridge Ore.	By C. T. Jackson.	By Chilton, Native Ore.	By Chilton, Soft Ore.	J. S. Cassels. Partial Analyses for Owen's Report.	By Cassels. Best Upper Bed.	By Cassels, Best Lower Bed.	By Cassels, Upper Ore.	By Cassels, Washed Ore.
Loss by heat at 212°	...	....	....	....	2.00	3.00	2.00	....
Specific gravity	....	....	.. ..	....	2.94	3.07	2.99	3.03
Peroxide of iron	72.50	74.40	79.25	76.74	77.34	78.75	41.67	76.51
Carbonate of lime	0.56	6.72	6.81	....	0.55	2.00	15.48	0.75
Carbonate of magnesia	0.64	0.41	0.14	....	6.64	trace.	8.25	trace.
Oxide of manganese	1.40	....	....	1.05	3.50	3.30	2.56	3.10
Alumina	8.40	2.26	2.49	4.00	5.00	4.50	12.74	5.21
Silica	7.75	9.11	6.18	10.09	8.57	6.40	15.12	10.13
Water and loss	8.75	3.10	4.00	....	2.65	....	2.65	....
Water	....	....	....	6.00	....	3.00	....	4.30
Loss	....	....	....	2.22	....	1.30	....	....
Phosphoric acid	....	1.00	1.13	....	2.75	0.75	1.53	....
	100.	100.	100.	100.	100.	100.	100.	100.
Metallic Iron	....	....	....	....	54.14	54.13	29.17	53.56

In his report, Dr. Jackson says, that the lime and magnesia are combined with the silica and not with carbonic acid, so that the above table should read, lime, for carbonate of lime, and magnesia, for carbonate of magnesia, so far as his anslysis is concerned.

I am indebted to the kindness of Supt. Sterling, for the following relating to the iron interest at this point. The whole amount of ore shipped from July 1, 1869, to January 1, 1872, was 173,842 tons; the amount in 1872, 82,371 tons; in 1873, 48,706 tons; total for the three and a half years, 304,919 tons. This ore was shipped to Chicago, Joliet and Springfield, Ill., St. Louis, Mo., Wyandotte and Jackson, Mich., Appleton, Green Bay and Milwaukee, in our own state, and Zanesville and Newburg, Ohio, as well as to various other points in small quantities.

The cost of mining the ore (1873) is from 50 to 75 cents per ton. The value of the ore, delivered on the cars, is from $1.50 to $2.00 per ton.

The average furnace-yield of metal, from the ore, is 45 per cent.

The furnace at this point is 40 feet high, 9½ feet across the boshes, uses 4 or 5 tuyeres, as occasion may require, makes use of the hot blast, blown by steam power, burns charcoal — the average cost of which is 11½ cents per bushel — and has a capacity of about 3,500 gross tons yearly. No flux is used.

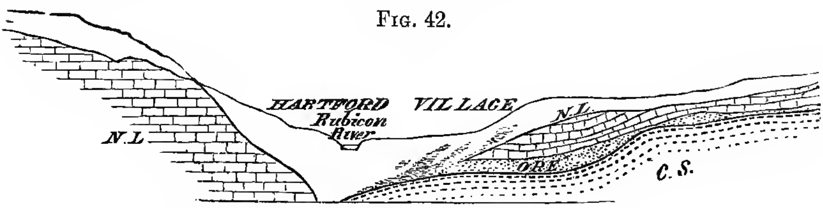
The composition of the pig-iron product is shown by the following analysis, by E. T. Sweet, kindly furnished by Prof. Irving:

	Per cent.
Iron	95.784
Phosphorus	1.675
Graphite	1.379
Combined carbon	0.849
Silicon	0.491
Sulphur	0.108
Manganese	Trace.
	100.286

In 1849, a blast furnace was established at the village of Mayville for the reduction of this ore. I am indebted to Mr. James Scoular for the following facts concerning its present capacity and workings (1873): Height, forty feet — nine feet in the boshes; uses four tuyeres, the hot air blast, charcoal as fuel, and steam and water combined, as power. The charge is seven hundred pounds of ore and sixteen bushels of charcoal. The ore used is from the north opening at the Mayville Ore Bed. Limestone and lean ore have sometimes been used as a flux. *Sandstone* was being tried. The yield is thirteen or fourteen tons of iron per day, being about forty-two per cent. of the ore.

Hartford. The deposit at this place is altogether similar to that at Iron Ridge. It is, however, much inferior in both vertical and lateral extent, and if the numerous statements collected concerning the wells of the place, with such observations as were possible, can be trusted, much more uneven. The bed underlies the southeastern portion of the village. In the southwestern portion, the denuding agencies have swept away the overlying limestone and the ore, if it ever existed there, and have substituted a drift deposit. On the north side of the Rubicon, the horizon of the ore has been depressed by an apparent fault, so as to occur at a considerable depth below the surface of the river. There seems good evidence that the deposit reaches ten or twelve feet in thickness at some points, but rapidly thins out, so that the average thickness for the area over which it occurs probably does not exceed two feet. The accompanying section will show the general nature of the deposit and its relations.

FIG. 42.

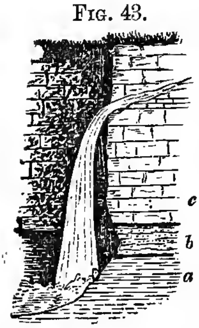


POSITION AND RELATIONS OF THE IRON ORE AT HARTFORD.
N. L. — Niagara Limestone. *C. S.* — Cincinnati Shale.

Besides the deposits at Iron Ridge and Hartford, and their vicinity, drift ore, of precisely similar nature, occurs in the town of Stockbridge. The deposit is small and lies upon the west side of a ridge of moderate height, the exterior of which, at least, is drift. A well in the vicinity is said to have reached iron ore, eighteen inches in thickness, beneath limestone.

At the Cascade Falls, east of De Pere, the formation again appears. Its situation beneath the Niagara limestone and above the Cincinnati shales is shown in the accompanying figure. The fall is caused by the fact that the iron ore is more easily worn away by the action of the stream than the limestone above. The shale is somewhat more resisting than the ore. The maximum thickness of the ore is five feet. On the east side of the gorge, its base was concealed at the time of examination, and it was only at the fall, and to the west of it, that full measurements could be made. Just east of the fall, the thickness, measured as accurately as the nature of the case would admit, is four feet, eight and one-half inches. Just west of the fall it is four feet nine inches. A little farther on where the wall of the gorge curves toward the north, it reaches its maximum of five feet.

FIG. 43.

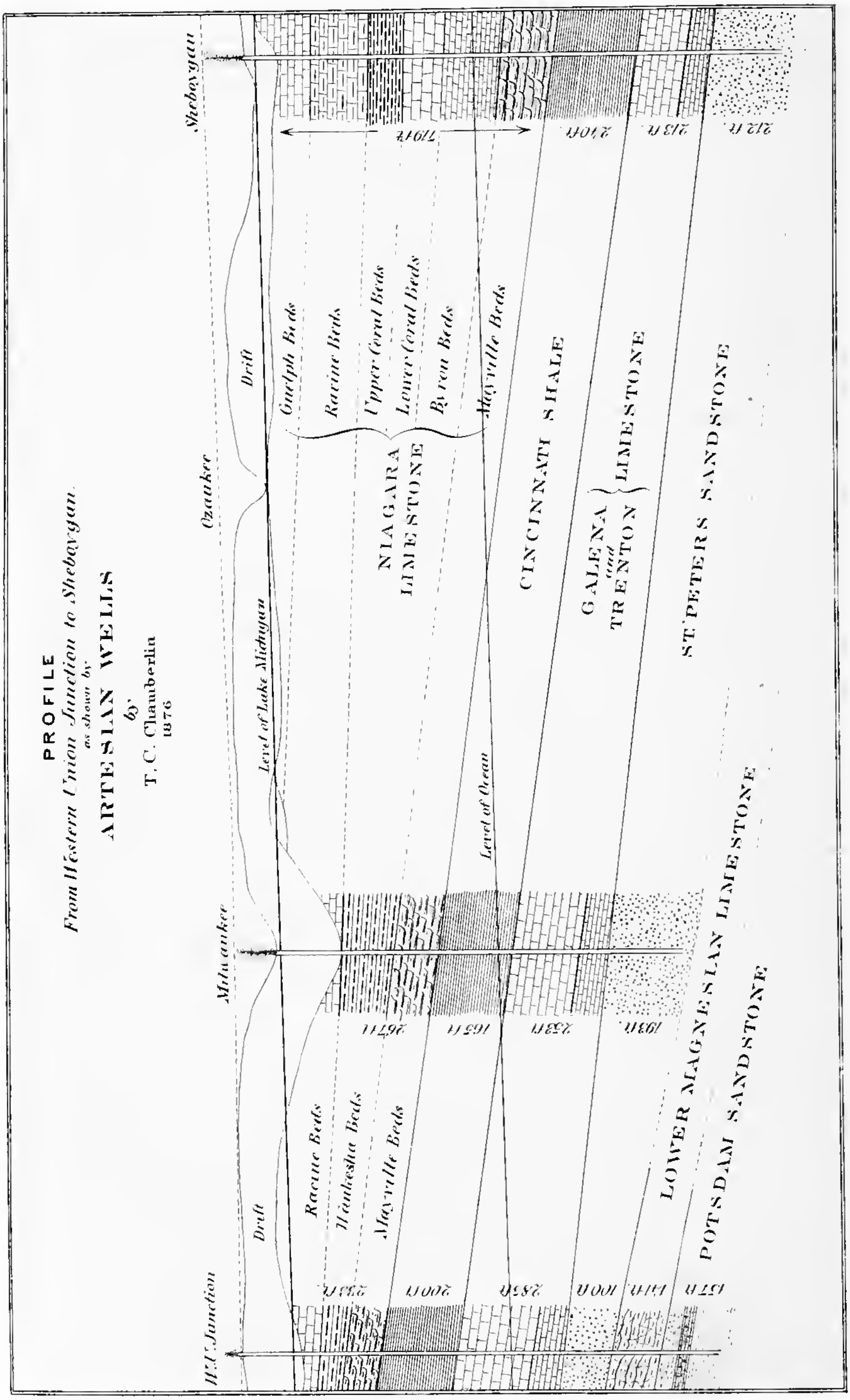


CASCADE FALLS, NEAR DE PERE.
a. Cincinnati shale.
b. Clinton iron ore.
c. Niagara limestone.

and still farther on, it is reduced to four feet six and one-half inches. Near the point of greatest thickness, there are slight indications of "taking on" layers. The ore at this point is very similar to that at Iron Ridge. The oölitic concretions are somewhat larger on the average, and of a slightly duller color, and there is a greater amount of argillaceous material present. Upon the bed of lenticular ore, there is a highly pyritiferous layer that seems to represent the dark layer at Iron Ridge. Along the shore of Green Bay, south of Little Sturgeon Bay, this geological horizon is marked by a somewhat continuous bed of ore, or ocherous rock, of a few inches thickness. It very rarely presents an oölitic structure, or other characteristic of the deposits already described, but it is identical with them in geological position, and must be regarded as their stratigraphical equivalent.

It appears, then, from the foregoing facts, that this iron ore occurs at widely separated points, and that between these it is entirely wanting, or is represented only by a rusty seam between the limestone and shale. There can be no doubt that it was a marine deposit, for in addition to the evidence of the beds in this state, the equivalent formation elsewhere contains the remains of marine life. It appears altogether probable that the ore was deposited in detached basins, over which, and over all the intervening region, the Niagara limestone was afterwards laid down, enclosing the detached deposits between it and the shale below in the form of lenticular masses. This ore is to be sought for *only* between the Cincinnati shales and the Niagara limestone. The line along which the junction of these two formations comes to the surface will be found traced with much care on the accompanying maps. To the east of this line, the horizon of the ore lies beneath the Niagara limestone, and, so far as geological evidence goes, is as likely to be found at the base of that formation, at any point over the broad area occupied by it, as at the points where its base has come to be exposed at the surface by denuding agencies. Of course the value of a bed of ore, found at any considerable depth below the surface, would be very seriously affected by its unfavorable position.

While it is probable that beds of this ore do exist at points not yet discovered, it is prudent to bear in mind that deposits of the thickness of that at Iron Ridge are very rare, there being but a single known instance of a thicker deposit in all the wide range of the Clinton formation, though beds of less depth are profitably mined; and while it is legitimate to hope that further profitable discoveries may yet be made, it is the part of wisdom to exercise due caution in the expenditure of time or funds in exploration, and to be guided by an



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intelligence derived from careful study of the geological facts relating to this interesting formation.

NIAGARA LIMESTONE.

The shales and iron ore deposits, that have last been described, lie along the eastern margin of the great Green Bay and Rock river valley, and are to a large extent overhung by beetling cliffs of craggy limestone that form the western projecting edge of the Niagara formation.

The strata, that thus jut out along this border, form the lower member of an extensive and important limestone group, that occupies nearly all the region between this border and Lake Michigan. The strata dip to the eastward, so that the higher members of the series appear in succession in that direction. All these members are magnesian limestones, or dolomites, some of them being among the purest known.

The belt occupied by this formation has a north and south extent of about two hundred miles. In the course of this extension, its character undergoes a change, so that its nature at the two extremities is quite different. And it is a most interesting fact to note that this change takes place at the same latitude as that at which the changes that we have previously noted in the lower formations, especially the Galena limestone, take place. At the north, there are six subdivisions, sufficiently well marked and persistent to justify their being named, described, and mapped separately. At the south, there are four such subdivisions. It should be observed that these are denominated *subdivisions* of the Niagara limestone. They are not regarded as distinct formations, or as having the grade of epochs, as that term is usually understood, but they are nevertheless well characterized subordinate divisions of a formation of more than ordinary importance, and it is believed to be of much value to industry, as well as science, to give all the exactness and precision possible to its investigation and description. The names given to the subdivisions are as follows, placed opposite to each other for convenience of comparison:

NIAGARA GROUP.

At the South —	*At the North* —
1. Guelph Beds.	1. Guelph Beds.
2. Racine Beds.	2. Racine Beds.
3. Waukesha Beds.	{ 3. Upper Coral Beds. 4. Lower Coral Beds. 5. Byron Beds. }
4. Mayville Beds.	6. Mayville Beds.

The term *Guelph* has been applied to the uppermost beds on account of a similarity of fossils to those of the Guelph limestone of Canada, to which the Wisconsin formation is probably equivalent. The recognition of this equivalence is due to Prof. Whitfield.

The *Racine* beds are the equivalent of what has been known as the Racine limestone,[1] except that the upper portion is now separated as Guelph, and the reefs and associated rocks west of Milwaukee, which have been referred to a lower horizon, are included in it.

The lowest strata of the Niagara series are named *Mayville* beds because they have their maximum development and finest exposure south of that village. For the strata that lie between these and the Racine beds, in the southern part of the state, the term Waukesha limestone, which has been previously applied to a portion of them, has been adopted with modifications. The white limestone, that lies upon the Mayville beds, in the northern portion, receives its name from the township of Byron, where it is extensively utilized for lime, building stone, and flagging, and where occurs the only fossil yet found abundantly in it. The Upper and Lower Coral beds have been thus designated from the preponderance of coralline forms among the fossils found in them.

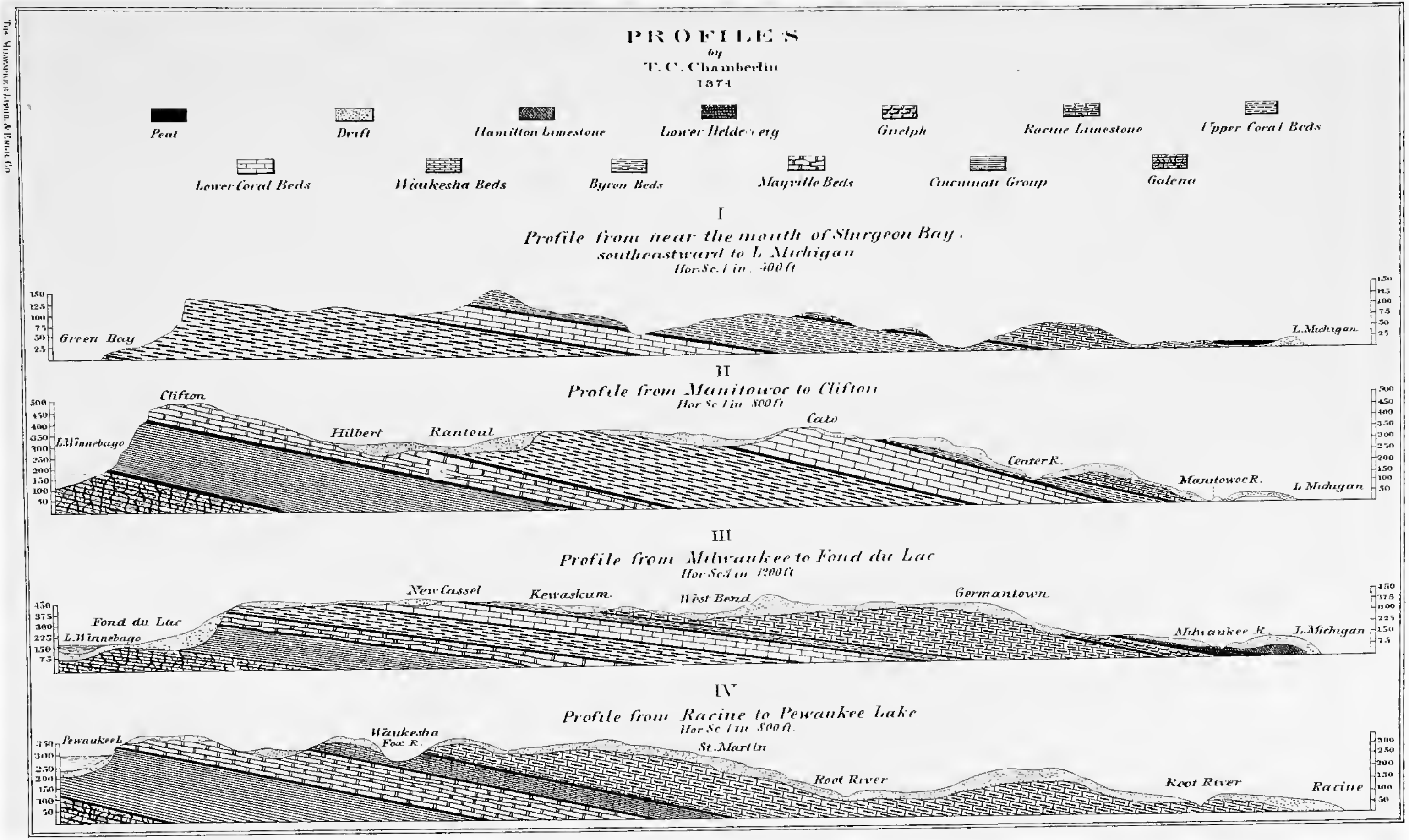
The accompanying plates (Plates XII and XIII) will show the position and relations of these subdivisons very satisfactorily. Plate XIII is based upon the facts developed in sinking the Artesian wells at Sheboygan, Milwaukee and Western Union Junction. They were sunk after my investigations upon this formation, and confirm in a most satisfactory manner my conclusions. The plate also illustrates a number of other interesting geological facts, among which is the northward dip of the strata. It also furnishes valuable data in reference to Artesian wells.

MAYVILLE BEDS.

As already indicated, these beds form the lowest member of the Niagara series throughout its whole extent. They possess the same general character throughout their entire area, and, in this respect, differ from the rest of the group. The rock of this member is, in general, a rough, coarse, gray, magnesian limestone. There is considerable difference, however, among the several layers that compose it, and some of these maintain their peculiarities with great persistency, so that it is possible to distinguish them at points one hundred miles or more apart. This makes it possible to describe a section which

[1] Geology of Wisconsin, 1862, p. 67.

PLATE, XII



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will be applicable in a general way to the formation at all points, and will be of practical service, as some layers are valuable and others comparatively worthless. It will, however, be impossible to readily distinguish all these layers at every point.

The lowest stratum consists of from four to ten feet of shaly, impure limestone, usually of a yellowish gray, but sometimes of a greenish hue. The beds, at some points, attain sufficient thickness and soundness to be serviceable as building stone. At Iron Ridge, this stratum either disappears or loses its characteristics.

Upon this lies a stratum of hard, heavy-bedded magnesian limestone, usually gray in color, and generally characterized by prominent vertical fissures and obscure and distant bedding joints. It does not make good quicklime, and is of comparatively little value as a building rock. It varies from six to twelve feet in thickness. The third general stratum is composed of three parts, as found in most places. The lower one consists of broken fragments of limestone imbedded in a greenish, bluish or yellowish, marly clay. More or less of chert is present. The middle portion consists of compact, sometimes cherty limestone, in even beds, from four to fourteen inches thick, and serviceable for building stone. The upper portion is a repetition of the lower. The three portions are not to be distinguished, however, at all points. The chert is sometimes almost entirely wanting, as in Oakfield, and sometimes is a very prominent feature, as in Ottawa. The entire stratum varies from five to thirty-five feet in thickness. In the town of Taycheedah, there occur at the bottom of this stratum a few regular beds that are marked by an abundance of Stromatopora, very imperfectly preserved. They should probably be grouped with the above, as Stromatopora extends into its layers.

This stratum is overlaid by an even bedded limestone, usually quite hard, compact, fine grained, white or light gray, often nearly a pure dolomite, and a valuable rock. At the same horizon, or just above it, in Taycheedah, Empire, Ashippun, and less distinctly at some other points, there occurs a reddish yellow, granular crystalline dolomite, called by the workmen and residents "sandstone." It is, in fact, an unusually pure dolomite, so that if the term is understood to imply that the rock is silicious, it could scarcely be more erroneous, since the amount of silica is not more than about *one-fourth of one per cent.* It is, however, a fine example of calcareous sandrock. The grains are chiefly minute crystals, that show no evidences of wearing action, and have evidently not been disturbed since their crystallization. The interstices between the crystals are to a considerable extent unfilled by any matrix, making the stone highly porous, and, in some cases, rendering it liable to disintegrate to a calcareous sand. It occurs in heavy beds, is easily quarried, cuts with the greatest facility, and is much used at Fond du Lac for cappings, etc. It is probable that this and the preceding rock are to be referred to the same horizon, as they seem to graduate into each other at some points, and to replace each other, mutually, at others.

Upon this rests a stratum similar to the second in being characterized by thick beds and vertical fissures, but differing from it in being less hard, and in possessing a highly brecciated structure in some localities. To the position just above this is to be referred a layer containing many obscure casts of a *Pentamerus* (*Gypidula*), very similar to the species *occidentalis*. This stratum is succeeded above by the white, even-textured limestone of the Byron and Waukesha beds.

As a whole, the Mayville beds may be readily recognized by their thick bedding, uneven structure, and the rough, craggy, pitted surface of the weathered ledges, when taken in connection with their position. It is the best exposed member of the Niagara group, as it forms a chain of craggy cliffs, upwards of a hundred miles in length, though broken down and concealed at frequent intervals. The greatest observed thickness is one hundred feet. The average thickness is probably not more than sixty feet. The chemical composition of some of the more important of these beds is shown in the following table:

ANALYSES.

	I.	II.	III.	IV.	V.	VI.
Carbonate of lime	50.52	50.54	53.95	55.03	54.91	55.18
Carbonate of magnesia	40.97	40.37	44.28	44.34	42.77	41.70
Sesquioxide of iron	0.77	1.02	0.30	0.31	0.43	0.57
Sesquioxide of alumina	3.49	2.67	0.10	.....	0.46	0.18
Silica	3.57	4.52	.....	.....	.....	.....
Insoluble residue	.....	.....	1.23	0.26	1.35	1.73
Water	0.48	0.70	trace.	0.29	0.26	0.45
Total	99.80	99.82	99.86	100.23	100.18	99.81
Per cent. of impurities	7.83	8.21	1.63	0.57	2.24	2.48

The rock for the first analysis was from the shaly beds, at the base of the formation, that are used for making waterlime in Williamstown (N. W. ¼ of N. E. ¼ of Sec. 27, T. 16 N., R. 12 E.), and the second was from similar beds found in Stockbridge (N. E. ¼ of Sec. 11, T. 19 N., R. 18 E.). The third was from the limestone used at the Appleton iron furnaces for flux, and obtained from the lower 20 feet of the formation at Clifton, on Lake Winnebago. The fourth was from the so-called sandstone near Taycheedah. The fifth, from the upper layer, and the sixth from the lower layer, at Andley's quarry, in the town of Delafield (Sec. 20, S. E. ¼). The limestone in the last named instance included many nodules of chert, which were excluded from the samples analyzed, one object of the analysis being to ascertain the chemical nature of limestone associated with well-defined concretions of chert. The above analyses were executed by Prof. Daniells.

It appears that in all cases, the carbonates of lime and magnesia exist essentially in the proportions necessary to form dolomite, so that these beds may be said to be true sedimentary dolomites, and the remaining constituents may be regarded as impurities, and are so summed up for convenience, the water being disregarded. It will be observed that the Taycheedah "sandstone" is remarkably pure. This will be again noticed in the discussion of economic considerations.

Life. The remains of the life of the period are very illy preserved, and it is only rarely that fossils can be found sufficiently well-defined to be satisfactorily identified. In most cases, only obscure casts remain. It is not to be inferred from this, however, that the life of the period was actually meager. On the contrary, it was probably abundant. The conglomeritic character of a portion of the beds shows that the material was subjected to much grinding action by the waves of the depositing seas, and makes it probable that the greater portion were comminuted in the process of deposit, while the crystalline nature of the rock suggests, that the process of crystallization may have obliterated some that escaped comminution, and cavities having the form of fossils show that some others have been removed by solution. From the nature of the material, some of the identifications are necessarily doubtful, and are so indicated.

In the following table, the occurrence of the several species, at the more important localities, will be found systematically and compactly arranged. Students and collectors will find this a convenient form. A table will be found at the close of the description of the Niagara group, in which the fossils of this member are compared with those of the other beds, which will also be found instructive.

FOSSILS OF THE MAYVILLE BEDS OF THE NIAGARA GROUP.

GENERA AND SPECIES.	Hartford (Blodgett's).	Williamstown.	Taycheedah.	Ashippun.	Near Little Sturgeon Bay.	Eagle (Hinckley's).	Iron Ridge.
PETROSPONGIA.							
Stromatopora concentrica	*	*	*	*	*	*	....
CORALS.							
Favosites Niagarensis	*	....	....	*	*	*	*
F. favosus	....	....	*	....	....	....	....
Astrocerium venustum	....	....	....	....	*	....	....
Halysites catenulaatus	....	....	....	*	*	....	*
Heliolites pyriformis	....	....	*	....	*	....	....
Diphyphyllum cæspitosum	....	....	....	....	..	....	*
Zaphrentis, und. sp	*	....	....	....	*	*	....
Cyathophyllum, und. sp	*	....	*	....	*	....	....
Chonophyllum Niagarense	....	....	....	....	*	....	....
Amplexus, und. sp	....	....	....	....	*	....	....
BRACHIOPODA.							
Orthis flabellula	*	*	*	....	*	....	....
O. res. O. hybrida	....	....	*	....	....	*	....
Strophodonta striata	*	....	....	....	....	....	....
Strophomena rhomboidalis	...	....	....	....	*	....	...
Meristina, res. M. cylindrica	....	....	....	....	*	....	....
Retzia aprinis=Rhynchospira aprinis	....	*	....	....	....	....	....
Atrypa, n. sp	....	....	....	....	*	....	...
Pentamerus fornicatus	....	*	....	....	....	....	....
P. oblongus	*	...	....	....	....	....	....
Gypidula, res. G. occidentalis, H. but smaller	....	*	...	....	....	....	....
Stricklandinia, und. sp	....	*	....	....	....	....	....
Leptocœlia planoconvexa	*	....	....	....	....	*	....
GASTEROPODA.							
Euomphalus Racinensis	...	....	....	....	*	....	....
Bucania, und. sp	....	....	....	....	*	....	....
CEPHALOPODA.							
Ormoceras, prob. O. vertebratum	....	....	....	....	*	*	*
CRUSTACEA.							
Illænus, res. I. Barriensis	*	....	....	....	....	....	....

Economic Value. From the analyses already given, it will be seen that some portions of this formation are remarkably pure dolomites, while others are notably impure. From the description already given, and, more especially, from the local details that follow, it will appear that these several portions occur in such a way as to require some discrimination, if the best quality of rock is to be chosen; and it is hoped this report will furnish some assistance in making a suitable selection.

Kilns for the reduction of lime have been established along its entire length. These vary in construction, from mere rude domes of bowlders to approved patent kilns. And yet some of each class were found abandoned, while others were doing a profitable business. It was observed that, in many cases, an impure rock had been burned. In some instances, this was pardonable, as no better was exposed in the vicinity, and the local demand warranted the use of such as was accessible, until improved means of communication supplied a superior article from other sources; but in other instances, it is evident that the failure was due to the use of inferior rock, when a superior ore existed in the immediate vicinity.

Properly selected, a very excellent lime may be made from this formation. A considerable quantity of stone may be selected, in which the impurities are *less than one per cent. of the whole;* much additional may be found, in which they are less than two per cent., and an inexhaustible quantity, in which they do not exceed three per cent. The large percentage of magnesia is an advantage, for it is a well established fact that dolomite makes a stronger cement than simple limestone. At many localities, the better class of rock is used, and an excellent product obtained. Practical suggestions in relation to selection will be found in Vol. I, where they are given to save constant repetition. Numerous statistics relating to the industry were taken; but they could not be made sufficiently complete, accurate, and uniform to justify publication here.

At some localities, it is claimed that the lower beds of this formation are suited to the manufacture of hydraulic lime, and analyses I and II, given above, were made to ascertain upon what basis this claim was founded. The composition, it will be seen, is quite differfrom that of the celebrated hydraulic cements, and would not justify an expectation that this rock would produce an hydraulic lime that would have more than a local market. It will doubtless furnish a serviceable substitute for the more expensive cements, for certain purposes, where common fat lime will not answer.

Rock obtained from Clifton is used at Appleton as a flux for Lake Superior iron ores, and is said to work satisfactorily. The rock is obtained from the fallen masses on the slope below the cliff, which consist of a mingling of the several strata. The analysis above given represents the better quality found in the rock pile at the furnace. By comparison with that from Taycheedah, it will be seen that the limestone used is not the purest that is accessible to Lake Winnebago, and this fact may be worthy of the attention of those interested.

For the purposes of ordinary masonry, this formation furnishes an abundance of readily accessible material, and it is extensively used for such purposes. The granular stratum furnishes an excellent stone for cutting. Its rich cream color gives it a very pleasing effect. Rock obtained east of Horicon marsh is wrought at the State Prison, at Waupun, and quarries have been opened upon this stratum, east of Found du Lac, from which a supply of cut stone, for that city and other points, is obtained.

Distribution, and Local Descriptions. By consulting the maps, it will be seen that these beds occupy an irregular belt, stretching in a nearly north and south direction, from the Illinois line, in Walworth county, to near the extremity of the peninsula east of Green Bay, where it dips beneath the surface of that body of water. Most of the localities here mentioned lie on the extreme western margin of this belt, and show the projecting edge of the formation.

The point at which the formation enters this state from Illinois, or leaves it in that direction, if you please, is deeply concealed by drift, but there is abundant reason for believing that it crosses the line from the towns of Walworth and Linn, as represented on the map.

On the north side of Lake Geneva, the limestone approaches the surface, but does not actually outcrop. The most southerly point where the western limit of these beds is accurately determined by outcrop is in the S. W. qr. of Sec. 10, town of **Eagle** in Waukesha county. South of this point, the outline, as mapped, is based upon topographical and drift evidence, and can only be regarded as approximate. At Hinckley's quarry, in the above-named section, four feet of thin bedded, impure magnesian limestone, having an even fracture and light, yellowish gray color, blotched with green in places, especially between the layers, form the base of the quarry, and rest upon the Cincinnati shale. Above these are nine feet of thicker bedded limestone of coarser and more irregular texture, and marked by walnut-sized cavities, lined with yellow granular matter.

These beds, when exposed in natural ledges, as they are in the vicinity, weather to a very rough, ragged exterior, due to the irregularities of their structure.

In this region, the great drift moraine, previously described as the Kettle Range, overlies this formation, and it is only here and there that it displays itself. Near Hinckley's quarry, the ledge swings round to the east, and disappears beneath the drift ridges. It emerges again in Secs. 11 and 14 of the town of **Ottawa**. The rock here is characterized by conspicuous nodules of white chert, which are very abundant in some layers.

At Hunter's quarry (Sec. 11, S. E. qr.), the lower three feet exposed is a moderately hard, compact, gray, magnesian limestone, marked with iron stains. Upon this lies a somewhat peculiar shaly layer, which may be described as chipstone imbedded in a clayey material. Above this are two and a half feet of more solid rock, the upper portion of which is cherty. This is overlaid by another shaly, or chipstone layer, similar to that below, but cherty; and this in turn is surmounted by a few rotten buff layers that complete the exposure. The two chipstone layers are worthy of note, as they may be recognized more than a hundred miles to the northward.

In **Delafield**, the next town north, notwithstanding the drift, the formation discovers itself at several points, though nowhere in great force. Its character is essentially as in Ottawa. At the quarry near the village, the two shaly layers are observable.

At Audley and Graham's quarry (S. E. qr., Sec. 20), a few layers of dark, gray crystalline limestone, containing much chert, are burned for lime. The analysis of this has already been given. At Roberts' quarry, south of Pewaukee Lake (S. W. qr. of S. W. qr., Sec. 24, Delafield), the beds are more close-textured and silicious than at the points previously described, and the chert is more distinctly arranged in layers along the bedding joints. The exterior of the layers is buff, while the interior is blue, the latter sometimes appearing as a well-defined rectangle, surrounded by a border of buff, when a block has been broken across. The whole was undoubtedly once blue, and the buff has been caused by leaching, and the peroxidation of the iron present.

The formation again disappears beneath the drift, and is next seen in the town of **Ashippun**, in Dodge county, where it forms a few ragged outlying ledges. The most noteworthy of these lies in the west half of Secs. 6 and 7. It rises about fifty feet above "the grade," at its base, though the vertical ledge only presents a face of about twenty feet.

The bedding joints are very obscure, and the layers are traced with difficulty, so that the rock presents a very massive appearance, but a general section, somewhat as follows, may be made out. Six feet exposed at the base consist of a hard, but porous, dolomite of uneven texture, made up of fine and coarse grained patches, mottled gray and buff correspondingly. This is overlaid by from 4 to 6 feet of very hard, compact, flintlike limestone, much fissured vertically. Upon this rest 7 to 8 feet of a reddish buff, granular, somewhat friable, magnesian limestone, the granules consisting of small crystals of dolomite, the spaces between which are mostly unfilled, giving a porous structure. Chemically, this is a very pure dolomite, and should be burned for lime instead of either of the other layers exposed at this point, as it would not only produce a superior quality of lime, but would burn easier. This is undoubtedly the equivalent of the "sandstone" layer near Taycheedah, and is the most valuable portion of the beds under consideration. This is overlaid by 6 feet or more of brecciated rock, consisting of subangular fragments of a gray magnesian limestone, imbedded in a yellow, granular matrix of similar chemical nature.

North of this, the margin of the main body of the formation recedes to the eastward as far as **Hartford**. Near this place are several limited exposures of these beds, one of which, on the farm of Mr. Blodgett, is interesting on account of the fossils it contains, a list of which has already been given. The rock is a light colored, granular dolomite of irregular texture.

Passing by several outcrops in Herman, we find at **Iron Ridge**, reposing on the ore beds, 6 feet 8 inches of buff magnesian limestone, in beds of 8 to 16 inches thickness. Upon this, lies a layer 6 feet 8 inches thick, the bedding planes of which are very obscure, so that it appears like a single layer, while vertical fissures are frequent. This is overlaid by 2 feet 10 inches of thin bedded magnesian limestone, which gives place above to a shaly layer, composed of rotten chipstone, mingled with a greenish blue clay. The whole is capped by about 6 feet of broken, frost-riven limestone. As the mining progresses backward from the face of the ledge, the thinner beds will doubtless be found uniting into thicker and more solid ones, and the disintegrated rock will give place to that which is more firm, with corresponding changes in color and general aspect.

From this point northward, there is no dearth of outcrops. The Kettle Range has receded to the eastward, and there is left only the usual drift deposit, through which the formation boldly thrusts its jagged edge.

About two miles south of the village of **Mayville**, there is a precipitous cliff 100 feet in hight, exhibiting the full extent, and more than the usual thickness of this subdivision of the Niagara group. Owing to the difficulties of measuring on the vertical face of the cliff, the thickness of the beds is only approximately given from aneroid measurement.

At the base, are 5 feet of the usual thin bedded, shelly, light colored layers, disintegrated back from the face of the ledge.

Overhanging this, is 12 feet of hard, semi-translucent dolomite, not separated into distinct beds, but rifted with vertical fissures, which do not, however, extend into the beds above or below. This supports 7 feet of shaly and cherty rock, lying beneath 4 feet of thick bedded limestone, which is in turn overlaid by 23 feet of shaly and cherty layers, the three forming the shaly or chipstone group, previously described.

Upon this, lies another stratum of about 23 feet, in which the vertical fissures are much more pronounced than the bedding lines.

This is surmounted by a somewhat thicker group of soft, white, granular, crystalline dolomite, some layers of which contain many casts of fossils, particularly of *Gypidula*. The top of the ledge is formed of white, fine-grained, crystalline dolomite, closely resembling the rock of the next group above, to which it probably belongs.

In crossing the east branch of Rock river, the boundary again swings to the eastward as in the case of the Rubicon, and in the course of this detour, manifests itself in several low ledges.

Returning from this deviation, the formation enters upon a succession of precipitous ledges that extend to Little Sturgeon Bay. These are all so like each other, and so similar to those already described, that it will not be necessary to repeat the details of their structure. From near the village of Kekoskee, the ledges succeed each other in stair-like order, shifting westward till the margin of **Horicon Marsh** is reached, when they stretch northerly to its extremity, where, forming a continuous rampart, the line curves rapidly to the eastward through the corner of **Oakfield**, and onward in crenate outline through the town of **Byron.**

The direction of the ledge is now in the line of dip, and the beds under consideration rapidly drop down and are soon surmounted by the white walls of the Byron beds. Turning abruptly northward, in the northwest corner of the town of **Eden**, the chain of ledges extends through the western part of **Empire**, the Mayville beds again emerging and forming the rocky rampart, while the white Byron beds retire to the eastward. Opposite the southern extremity of **Lake Winnebago**, the crown of the cliff, at some points, is formed by a very pure, granular crystalline, cream colored dolomite, locally known as a sandstone. The constituent grains are small crystals of the carbonate of lime and magnesia, usually quite firmly compacted, but sometimes loosely aggregated, leaving numerous interspaces, which render the rock very porous and disposed to crumble to a calcareous sand, whence the local name. It is probably due to the misapprehension of its real character, growing out of the use of the name sandstone, that it has not been more extensively used for the manufacture of lime, instead of the much inferior rock that has been employed. Aside from this important stratum, the formation continues essentially as previously described. The chain of cliffs skirts at a little distance the east shore of Lake Winnebago, rising more than 200 feet above it. Toward the northern extremity, the ledge approaches the lake and directly overlooks it.

Between Lake Winnebago and Green Bay, the formation is more broken down and covered, but on reaching the eastern shore of the latter, it reappears in bold relief, crowning and protecting the more perishable Cincinnati shales, and giving a picturesque outline to the bay shore as far north as Little Sturgeon Bay. It forms the rocky summit of **Whitney's Bluff**, where it is wrought for various purposes. The most northern place where it is extensively used is on the shore west of **Little Sturgeon Bay**, where a pier and kilns have been constructed. At this point, many of the general features noted in Waukesha county are still discernible though the texture and composition here are superior. North of this point these beds drop down to near the level of the waters of Green Bay, and alternately appear and disappear with the undulations of the strata, as far north as the Light House point opposite Chambers' Island, where they finally disappear beneath the waters of the bay.

BYRON BEDS.

Reposing upon the coarse textured Mayville beds last described, lies a somewhat thicker series of beds, bearing a strong contrast to them in color, texture, stratification, and general character. The ledges of the former are rough in aspect and dull in color, those of the latter are usually smooth and white. The texture of the former is generally coarse, and often very uneven, that of the latter is always fine, and sometimes so close and compact as to be lithographic in character. The transition from the one to the other is usually abrupt and well defined. These facts eminently justify the distinction here adopted.

To describe somewhat more precisely, it may be remarked, that the color, where not white, is a light gray or cream tint, sometimes lined or mottled with pink in a very handsome manner. The texture is usually either very close and compact, or very fine grained. In the former case, it is hard and has a somewhat glassy fracture, and the edges of the fragments often appear translucent. Such portions often have a grayish water hue. The other class usually has a regular or conchoidal fracture, and is opaque. Some portions are finely laminated, and where these laminæ are colored, as sometimes occurs, a beautiful effect is produced.

The bedding is either thin, producing excellent flagging, or attains more considerable dimensions, and furnishes cutting and building stone. Some of the strata are habitually undulating, and some, in the weathered ledges, are excessively fractured in a conchoidal manner, while others are vertically fissured.

Argillaceous partings are occasionally present, and the rock, though rarely, becomes shaly. *Mudcracks* and *ripple marks* were observed.

The following analysis of rock taken from Butler's quarry (Sec. 10, Byron), made by Prof. Daniells, for the survey, shows it to be a nearly pure dolomite:

	Per Cent.
Carbonate of lime	54.25
Carbonate of magnesia	44.48
Sesquioxide of iron	0.26
Sesquioxide of alumina	0.10
Insoluble residue	0.67
Water	0.11
Total	99.87

Fossils. These are very rare. At Butler's quarry, in the town of Byron, *Leperditia fonticola* is abundant, this being its typical locality. Fucoidal impressions are occasionally met with, and an undetermined *Zaphrentis* was found near Sturgeon Bay.

Thickness. The greatest observed thickness, not including the transition beds above, is 110 feet; including that portion of the transition beds most allied to this division, its maximum thickness would reach perhaps 140 feet.

Distribution. The formation presents so great a degree of uniformity that local sections and descriptions will be unnecessary.

In delineating the outcroppings of the beds below, we were carried northward to near the extremity of the peninsula east of Green Bay. We may secure continuity of thought and save ourselves mental transportation by taking up the distribution of this division at that point.

It was stated that at Little Sturgeon Bay, the Mayville beds dipped down to near the water's edge. On doing so, they are at once surmounted by the Byron beds, in full force. These form a series of bold, picturesque cliffs, extending to the extremity of the peninsula. Two of these cliffs stand like pillars of Hercules, at the mouth of Big Sturgeon Bay, and each of the harbors north of this, on the west side of the peninsula, is guarded by at least one such Cyclopean sentinel, and one stands by Death's Door at the extremity. South of Little Sturgeon Bay, this formation lies a little back from the rocky escarpment that faces the Green Bay valley, and its strata are beveled down to the general surface of the country, so that it displays itself less conspicuously. The belt which it occupies at the surface lies next east of the Mayville beds as far south as Washington county. Southeast of Fond du Lac, it again comes out to the margin of the valley above referred to, and forms the white cliffs in the towns of Empire, Eden, Byron and Oakfield. In this region, the base of the formation is thin bedded, while in the upper portion, the beds are thicker. South of this, the formation again recedes from the chain of ledges, and, at a very unfortunate point is lost beneath the drift of the Kettle Range. This drift moraine crosses the strata under question obliquely, and effectually conceals them from view for thirty miles. On the other side of the range, the beds at Pewaukee are the nearest exposed rock east of the Mayville beds.

The upper strata at this point are very similar to the Byron beds in color, texture and composition, but in fossils, they are closely related to the Racine limestone, while the Byron beds contain but few remains of any kind, and are separated from the Racine by the Coral beds, containing an abundance of fossils, less closely related to the

Racine fauna than those of the Pewaukee beds, so that there is here presented a novel and interesting question of equivalency, that will be more fully appreciated when all the facts are before us.

The strata under consideration are designated Byron beds in this report, only so far south as they maintain their distinctive character. They have been regarded by some geologists as the equivalents, in part, of the Clinton strata of New York. In reference to this question, the attention of geologists is called to the fauna of the Mayville beds, which lie between these and the Clinton iron ore beds, which shows that there is no good reason for separating these from the Niagara group.

Economic Considerations. The purity of the rock of the Byron beds admirably fits it for the manufacture of lime. It makes a strong and white article, that sustains an excellent reputation. In selecting for this purpose, the granular variety is generally to be preferred, from its superior purity, and because its somewhat porous nature allows the carbonic gas that is discharged in the burning to escape readily, thus facilitating an easy and complete calcination.

In the towns of Oakfield and Byron, kilns have been established, that manufacture an excellent lime, some of which is shipped to the Chicago market. To the northward, where the formation is so abundantly displayed, it is but little burned, as the local demand is as yet small, and shipment by water is attended with risk.

The thicker beds furnish an excellent building stone, either rough dressed, for ordinary masonry, or cut, for the finer classes of work. In some instances a color as white as statuary marble may be obtained.

In the town of Brillion, and less notably at some other localities, the strata are beautifully mottled and banded with pink, producing a handsome ornamental stone. It is fine grained and close textured, though not entirely free from minute pores, and possesses sufficient hardness to be capable of taking a fair polish. It will not take rank as a high grade of marble, but should find a place as an ornamental stone.

As considerable sums have been expended on this series of limestones, in search of marble, it may be well to remark here that this is an undisturbed sedimentary formation, lying very much as it did when deposited by the ocean, and, while it has crystalized to a large degree, there is no evidence that it has undergone any unusual degree of heat or pressure, and there is no reason to expect that any portion of it will present that indurated and perfectly crystallized character that is shown by metamorphic rocks, to which class the better grade of marble belongs.

The thinner beds of this formation furnish an excellent flagging. The compactness and fine grain of some layers fit them for lithographic purposes, but they are apt to be marred by occasional small cavities or other flaws.

Transition Beds. Above the Byron beds, as they are developed in the Green Bay peninsula, there lies a series of alternating, coarse and fine grained strata, that are transitionary in character, and mark the passage from the fine textured Byron beds to the coarse textured Coral beds above. They may be briefly described as follows, in descending order:

Beginning at the base of the Lower Coral beds, there occurs first, a hard, tough, conglomeritic dolomite, of bluish color, mottled with lighter hues, which weathers into creases, rather than pits. It has a close, but uneven texture, and contains some argillaceous partings, and a few cavities. No fossils were seen except in the upper layer, and here only one, not observed elsewhere. This consists of minute, vertical, cylindrical canals, somewhat regularly interspersed through the rock, but separated from each other by several times their own diameter. The general appearance is similar to that which would be given if a small, distant-tubed Syringopora were to be entirely removed by solution, leaving only its external cast in the rock. It seemed to be confined to a single layer, which was traced 2,000 feet, for the purpose of securing the dip, which was found at this point — southwest shore of Sturgeon Bay — to be nearly 80 feet per mile, southwestward.

Below this portion, the rock is uniform in texture, close, compact, fine grained, regularly bedded, smooth on the weathered exterior, even in fracture, and is of grayish or white color. No fossils were observed in this portion.

Below this, there are thick, heavy, granular beds of coarse, crystalline texture, and irregular hardness, in general, quite similar to the Lower Coral beds in lithological characters, but containing few or no fossils. The observed thickness of these, taken together, is about 30 feet.

Below this, there is more or less of alternation between the thin bedded, compact rock, that characterizes the Byron beds below, and the thick-bedded, coarse-grained rocks that represent the formations above. The conglomeritic layer is the only one that is not, in its nature, allied either to the Lower Coral beds above, or to the Byron beds below.

LOWER CORAL BEDS.

A considerable portion of the transition beds just described are to be regarded as belonging to this division. The rock of this formation is a rough, heavy-bedded dolomite, not unlike the Mayville beds, The layers are sometimes very massive, 12 to 15 feet intervening between distinct bedding joints. In one case, a brecciated reef-like outlier, 18 feet in height, showed no bedding lines. This massive structure is an occasional feature of this formation.

In texture, the rock is coarse, crystalline, granular, and usually rather soft. Occasional layers are marked by argillaceous seams and partings, and by bands or scattered nodules of chert or flint, or by silicified fossils. The softer portions usually contain frequent cavities, doubtless formed by the removal of fossils. These, together with the irregular hardness of the rock, give to the weathered outliers a very rough, craggy, pitted exterior. The prevailing color is gray, verging toward blue, white, and yellow, at times occasionally enlivened by markings of red, pink, and purple.

Much of the rock is a nearly pure dolomite, admirably adapted to the manufacture of lime. Some portions are, however, quite silicious or argillaceous, and the discrimination recommended in reference to the Mayville beds is to be observed here; indeed, the economic remarks made with reference to that subdivision are generally applicable here, and need not be repeated.

Organic Remains. These are abundant and consist very largely of corals, among which the genus *Favosites* predominates. Brachiopods are next in abundance, among which *Pentamerus* is most prevalent.

The following table shows the leading species and local distribution in a compact form:

FOSSILS OF THE LOWER CORAL BEDS OF THE NIAGARA GROUP.

GENERA AND SPECIES.	R. R. cut, Sec. 11, Ashford.	R. R. cut, Sec. 2, Ashford.	Cooperstown.	Cato (Mendhks).	T. 16, R. 20, Sec. 18, S. E. ¼.	Cato.	Kewaskum.	New Cassel.
PETROSPONGIA								
Stromotopora concentrica	....	*	....	*	....	....	....	*
CORALS.								
Favosites favosus	*	*	*	*	*	*	....	....
F. Niagarensis	*	*	*	*	....	*	*	*
Astrocerium venustum	....	....	....	*	....	*	....	....
Halysites catenulatus	*	*	....	*	*	*	....	*
H. catenulatus var., microporus, n. var	....	....	....	....	*	....	....	....
H. catenulatus var., macroporus, n. var	....	....	....	*	*	....	....	....
H. agglomeratus	....	....	....	*	....	....	....	....
Diphyphyllum cæspitosum	....	....	....	*	....	*	....	....
Syringopora Dalmani	....	....	....	....	*	....	....	....
S. und. sp	....	*	....	....	....	....	....	....
Cystostylus typicus, n. gen. and sp	....	....	....	....	....	*	....	....
Cyanthophyllum, und. sp	....	....	....	....	*	....	....	....
Amplexus, und. sp	....	*	....	....	....	....	....	....
Zaphrentis, und. sp	....	*	*	....	*	*	....	....
Aulacophyllum, und. sp	....	....	....	....	*	....	....	....
Chonophyllum, und. sp	....	....	....	*	*	....	....	....
BRACHIOPODA.								
Dinobolus Conradi	....	*	....	....	....	....	....	....
Trimerella, res. T. grandis	....	*	....	....	....	....	....	....
Meristina, und. sp	....	....	....	....	....	*	....	....
Pentamerus bisulcatus	....	....	....	....	*	*	....	....
P. oblongus	*	....	*	....	....	....	*	*
P. ventricosus	....	....	*	*	....	....	....	....
Stricklandinia	....	....	*	*	*	....	....	....
GASTEROPODA.								
Straparollina, und. sp	....	*	....	....	....	....	....	....
Trochonema, und. sp	....	*	....	....	....	....	....	....
Pleurotomaria, n. sp	....	*	....	....	....	....	....	....
P. und. sp	....	*	....	....	*	....	....	....
Murchisonia Hercynia	....	*	....	....	....	....	....	....
Bucania trigonostoma	....	*	....	....	....	....	....	....
CEPHALOPODA.								
Orthoceras alienum	....	*	....	....	....	....	....	....
O. und. sp	....	*	*	....	....	*	....	....
Discosorus conoideus	....	*	....	....	....	....	....	....
Cyrtoceras	....	*	....	....	....	....	....	....
Phragmoceras labiatum, n. sp	....	*	....	....	....	....	....	....
CRUSTACEA.								
Illænus, und. sp	....	*	....	....	....	....	....	....

It is difficult to state definitely the thickness of this subdivision, for, as already seen, its lower limit is not well defined, and it is equally difficult to fix precisely its upper boundary.

The greatest thickness, directly observed, was 48 feet, but this does not include any of the transitional beds, and probably not all others, as the section was incomplete. If we include that portion of the beds of passage below and above, which is most nearly allied to this division, the maximum thickness will be about 70 feet.

This formation is very closely related to the Upper Coral beds, and the distinction between the two is less marked than that between the other subdivisions of this group. It will therefore be a matter of convenience to describe the Upper Coral beds, and then consider their extent and local developments conjointly.

UPPER CORAL BEDS.

These beds directly underlie the Racine limestone at the north, and are separated from them by a sharp line of division, readily distinguishable wherever observed.

The rock is a rather thin bedded dolomite, generally of a buff color, as seen in exposures, but, in its unweathered condition, often grayish or bluish. It is usually subcrystalline, of fine grain, compact, and hard, but occasionally earthy. It shows a tendency to split into irregular rudely lenticular flakes. It contains much silicious material in the form of chert, flint or silicified fossils. The chert is usually white, and in the form of nodules, but graduates into dark, translucent varieties, which pass into flint, resembling that of the chalk beds of England. The carbonate of lime, that originally constituted the material of the fossils, has been replaced in many cases by a whitish, chert-like material, and in others by translucent and transparent forms of cryptocrystalline silica, while the cavities are drusy with quartz. Silicified fossils are more common than the unchanged form, and on weathering, these project from the surface, giving the rock a very rough, harsh exterior. The stone is of little value for construction or lime. Some layers make a tolerable flag.

Organic remains are exceedingly abundant in this formation, among which corals mostly predominate. About thirty species were collected, and many of these occur in great number. The state of preservation is often very fine, owing to silicification. The more important localities are tabulated below, and a full list of species and their range will be found in the general table of fossils of the Niagara group.

FOSSILS OF THE UPPER CORAL BEDS OF THE NIAGARA GROUP.

GENERA AND SPECIES.	Cato, S. 27, N. E. qr.	Cato, Clark's Mills.	Cato Falls.	Cato, S. 5, N. E. qr.	Gibson, Smith's ledge	Kewaunee, S. 14.	Scarboro Creek, T. 24 R. 24, S. 30.	T. 24, R. 24, S. 28.	Forrestville, S. 17.	Sturgeon Bay, T. 27, R. 26, S. 9.	Bailey's Harbor.
PLANTÆ.											
Buthotrephis, und sp										*	
PETROSPONGIA.											
Stromatopora concentrica	*		*	*	*			*			
S. und. sp.							*			*	*
CORALS.											
Favosites favosus	*		*		*			*	*	*	
F. Niagarensis		*	*			*			*	*	
F. favosus, var. with larger cells								*	*	*	*
F. und. sp	*		*			*	*	*	*	*	
Astrocerium venustum				*						*	
A. und. sp		*									
Michelina? undcs. sp											
Alveolites, und. sp.								*	*		
Halysites catenulatus					*					*	*
H. var. macroporus	*	*	*		*		*	*		*	*
H. var. microporus				*							*
H. agglomeratus		*									
H. und. sp.										*	
Heliolites pyriformis								*?		*	
Thecia, und. sp. with small cells					*				*	*	*
Aulopora, und. sp											*
Cladopora reticulata									*	*	*
C. und. sp.									*		
Syringopora compacta								*			
S. Dalmani	*				*			*	*	*	
Cyathophylluu, und. sp			*				*			*	
Zaphrentis sp. res. Z. gigantea						*			*		
Z. und. sp.	*		*	*	*		*	*		*	
Aulacophyllum, und. sp								*			*
Amplexus fenestratus, n. sp	*										
A. und. sp.			*		*						
Streptelasma calyculum				*?			*				
Chonophyllum, und. sp		*				*		*	*	*	*
Cystiphyllum Americanum		*									
C. Niagarense										*	
C. und. sp.										*	
Strombodes pentagonus								*	*		*
S. n. sp.							*				
S. und. sp.								*		*	
Diphyphyllum cæspitosum											*
Cystostylus typicus, n. sp	*									*	
Cœnites lunatus									*		

FOSSILS OF THE UPPER CORAL BEDS OF THE NIAGARA GROUP — *continued.*

GENERA AND SPECIES.	Cato, S. 27, N. E. qr.	Cato, Clark's Mills.	Cato Falls.	Cato, S. 5, N. E. qr.	Gibson, Smith's ledge	Kewaunee, S. 14.	Scarboro Creek, T. 24 R. 24, S. 30.	T. 24, R. 24, S. 28.	Forrestville, S. 17.	Sturgeon's Bay, T. 27 R. 26, S. 19.	Bailey's Harbor.
BRACHIOPODA.											
Orthis flabellula	....	....	....	*	....	....	....	....	*	....	....
Strophomena, n. sp.	....	....	....	....	....	*	....	....	....	....	....
Atrypa reticularis	....	....	*	....	....	....	....	....	....	....	....
Pentamerus bisinuatus	....	....	....	*	*	*	....	....	*	....	....
P. oblongus	....	....	*?	....	....	....	*	....	....	*	....
P. ventricosus	....	....	*	....	....	....	....	....	....	....	....
P. n. sp.	....	....	....	....	....	....	*	....	....	....	....
Stricklandinia, n. sp	....	....	....	....	....	....	*	....	....	....	....
S. und. sp.	....	....	....	....	....	....	....	*	....	....	....
Rhynchonelloid shell	....	....	....	....	....	....	....	....	....	*	....
GASTEROPODA.											
Loxonema	....	....	*	....	....	....	....	....	....	....	....
CEPHALOPODA.											
Orthoceras, und. sp.	....	....	....	....	....	....	....	*	....	*	...
CRUSTACEA.											
Illænus, pygidium of an und. sp.	....	....	....	....	....	....	....	....	....	....	*
Bronteus Acamas	....	*?	....	....	....	....	....	....	....	....	....
INCERTA SEDES.											
Huronia annulata	....	....	....	....	....	....	....	....	*	*	....

The greatest thickness of this formation actually observed is 75 feet. Its maximum thickness is estimated at 90 feet.

Distribution. Beginning at the north, we find the central, and, to a great extent, the eastern portion of the Green Bay peninsula occupied by the Coral beds, the lower division, of course, lying to the westward. Extending southward, they constitute an irregular belt, occupying a median position on the Lake Michigan slope, and ceasing to be traceable as distinct subdivisions in the southern portion of Fond du Lac county.

Local Details. Near the eastern entrance of **Porte de Morts,** the coral beds present themselves in vertical cliffs, facing the lake. The exposure belongs chiefly to the upper division, and presents, in certain portions, more than the usual amount of cherty material. In general, the beds are highly fossiliferous. Silicified specimens of *Pentamerus oblongus*, of rare beauty, are occasionally met with.

At **Bailey's Harbor,** the Upper Coral beds are exposed in nearly their entire thickness, constituting three terraces, rising in succession from the lake shore. The ledges here are extremely fossiliferous, and this locality is already known in the literature of the science. The uppermost ledge is capped by a few layers of the Racine limestone. South of **Jacksonport**, along the lake shore, the Upper Coral limestone is again exposed, presenting a thickness of twenty feet, with its usual characteristics and abundance of fossils.

In the vicinity of **Sturgeon Bay**, several exposures, both of the Upper and Lower beds, occur. In Sec. 9, there are several slight outcrops of the upper strata, which are here, as usual, quite cherty and contain an abundance of silicified fossils, among which the coralline forms predominate. In Sec. 5, near the village of Sturgeon Bay, the upper portion of the Coral beds have a slight exposure, overlaid by a few of the Racine beds. The junction between the two is here sharp and well defined, the uppermost layers of the Coral beds being highly fossiliferous, a fact which does not seem to be universally true, as at several other points the beds lying immediately beneath the Racine limestone are comparatively free from fossils. North of the village, near the mill, the Lower Coral beds are shown imperfectly, but in considerable thickness. Still farther north, along the cliffs facing the bay, at various points, partial sections of the same beds are exposed. On the opposite side of the bay are numerous partial exposures of the Lower Coral beds overlying the Byron beds. Following the outcrops of the formation southward, Greening's ledge, in the town of **Forrestville** (S. W. qr. Sec. 17), is worthy of note for the remarkable abundance of fossils which it presents. Passing by several minor exposures, we find, on Scarboro creek, in the town of **Casco**, and in Sec. 28 of the town of Pierce (T. 24, R. 24), the Upper Coral strata presenting their usual thin, irregular, cherty outcrops, and characterized by an unusual abundance of well preserved silicified fossils. The latter locality is remarkable for the great number of Favositoid corals, large masses of *Syringopora*, and frequent specimens of *Strombodes*, in association with an abundance of the more usual forms. In Sec. 14, in the town of **Kewaunee**, at the mill of Mr. Stramsky, the uppermost layers of the Coral beds are found immediunderlying the Racine limestone. They are here more homogeneous and less cherty than at most localities to the northward, and much less fossiliferous than the corresponding beds at Sturgeon Bay, only five or six species being observed. In the valley of West Twin river, several notable exposures of this formation occur. In Sec. 28, town of **Gibson**, a vertical thickness of about forty feet, belonging to the lower division, is exposed. The upper portion of the ledge consists of very heavy beds of coarse, rather soft dolomite, characterized by fine specimens of coral. The lower portion of the ledge consists of a harder and more compact rock of finer texture, very prolific in *Pentamerus*. In the vicinity of the junction of Mud creek with the West Twin river, particularly in Sec. 13, **Cooperstown**, ledges that appear to represent the transition from the Lower Coral beds to the Byron beds find ample exposure. The following section is observed near the center of Sec. 13.

1. At the top, a broken, grayish white dolomite, mottled with pinkish red, of porous, rather hard, brittle, crystalline texture and uneven fracture, in beds of 18, 11½, 15 and 13½ inches, respectively. The lower layers are more compact than those above..................	4 ft.	10 in.
2. Harder laminated dolomite, of slightly porous texture, gray, lined with pink...	1 ft.	5½ in.
3. Similar to No. 1, but more coarse and porous in texture, and rougher in general aspect...	2 ft.	2½ in.
4. Similar to No. 2, but not distinctly laminated. In beds of 7½, 12 and 11 inches respectively...	2 ft.	6½ in.
5. Rather soft, granular dolomite, of sandy appearance, streaked with white and yellow, and distinctly blotched with copper red		6 in.

6. Rather hard, compact dolomite, mottled with purplish, pink and white, containing a few very small drusy geodes. Weathers smooth,	1 ft.	6 in.
7. Coarsely porous dolomite, of uneven texture, prominently mottled with scarlet, pink and purple, and containing corals and drusy geodes. Marked with stylolites..................................	2 ft.	3 in.
8. Rather hard, firm, laminated dolomite, rather thin bedded, having a brittle, uneven fracture. In successive beds of 9¾, 13, 9, 13, and 5½ inches..	4 ft.	2¼ in.
9. Very fine grained, compact, flint-like dolomite, of smooth, hard, semi-conchoidal fracture, and bluish and yellowish gray color. In beds of 11, 7½, 4½, 5, 3½, 4½, 9, 6¼, and 7 inches respectively.......	4 ft.	10¾ in.
10. Compact, but more granular crystalline than the above, of whitish gray color. In beds of 9, 6, 9, 8½, 2½, and 11 inches, the lowest of which is banded with purple................................	3 ft.	10 in.
Total	28 ft.	2½ in.

In the vicinity, higher and more fossiliferous beds find limited exposure. In Sec. 25 of this town, there is a peculiar outlier of 18½ feet vertical exposure, presenting no well-defined bedding. The rock is a rather hard, coarsely brecciated, light colored dolomite, weathering very rough, and containing few fossils. It resembles some of the brecciated portions of the Lower Magnesian limestone previously described, but more especially the reef structure of the Racine limestone, yet to be considered.

Passing by a number of minor outcrops in this vicinity, in Sec. 5, of the town of **Cato**, is a notable ledge arising to the height of 46 feet, which consists of heavy, irregularly bedded dolomite, of coarsely brecciated structure for the most part, but, to some extent, coarsely granular, and containing abundant cavities of various sizes, often filled with calcite, many of which are evidently the result of the entire or partial removal of fossils. Corals are present in abundance. In the N. W. ¼ of the N. W. ¼ of the same section is an isolated ledge of somewhat similar character, but rather more thin-bedded and compact, and differing from the former in the presence, in some layers, of much chert, in which fossils, most beautifully silicified, are abundant, *Pentamerus oblongus* being the predominating form. In Sec. 6 of the same town, on the farm of Mr. J. Mendlik, is a conspicuous ledge, consisting of very heavy bedded, rough, irregular dolomite, of varying hardness, usually rather soft, brecciated for the greater part, white or gray in color, and variously mottled and streaked with pink. The structure is very irregular. The rock contains many corals, especially those belonging to the genus *Favosites*, and a few other fossils.

Another noteworthy ledge occurs near the middle of the south half of Sec. 36, town of **Richland.** The following section, in descending order, was noted at that point:

1. Hard, white, compact, somewhat cherty dolomite, containing occasional cavities, and showing a slight tendency to separate on the weathered surface into thin beds....................................	10 ft.	
2. Hard, grayish white dolomite of uneven texture, and subcrystalline, irregular fracture, marked by numerous argillaceous, lamellar partings, and a few geodes. Weathers irregularly into deep pits. In layers of 3 feet 4 inches, 2 feet 6 inches, and 3 feet................	8 ft.	10 in.
3. A softer and more granular stratum, containing Cyathophylloid corals, which were not observed in the upper beds.......................	3 ft.	2 in.
4. A stratam of irregular, grayish white, shaly dolomite of uneven texture, which weathers into rough creases........................	4 ft.	

5. White, rather soft, granular crystalline dolomite, of more even texture than the above, and better suited for cutting. Weathers smooth. In layers of 10 to 13 inches	2 ft. 11 in.
6. Thin, regular bedded, white, granular crystalline, rather soft, somewhat shaly dolomite, in layers from 3 to 9 inches in thickness, partially concealed	3 ft. 9 in.
7. Pure, opaque white, saccharoidal dolomite, of medium hardness and even texture, weathering comparatively smooth. In layers of 13, 16, 17, 36, 16, and 10 inches, which occasionally unite or subdivide.	9 ft.
8. Granular crystalline dolomite, of medium hardness, somewhat uneven texture, white and pale orange color, mottled and mingled. Layers not always well defined	6 ft. 6 in.
Total	48 ft. 2 in.

At **Cato Falls**, on the Manitowoc river, thinner and more homogeneous beds, belonging to a higher horizon, appear in undulating stratification. At **Clark's mills**, two miles below, similar thin beds, in broken ledges, form a wall along the bank of the river, rising from 10 to 15 feet in hight, and are characterized by abundance of corals of the genus *Favosites*. Near the old mill, a short distance below Clark's mills, on the left hand side of the river, occurs a slight outcrop, the top of which is very cherty, and contains silicified fossils, the most conspicuous of which is the remarkable Cyathophylloid coral, *Amplexus fenestratus*, n. sp., which attains a foot or more in length, and two or three inches in diameter. A short distance down the river, from 20 to 25 feet of impure, brecciated limestone is overlaid by about 12 feet of cherty rock containing the above mentioned coral, the whole, from its hardness, giving rise to the rapids. It is worthy of note that these two localities are the only ones at which the above fossil has been found. South of the Manitowoc river, the formation is overlaid for a considerable distance with the glacial accumulations of the Kettle Range, and effectually concealed from observation.

In Secs. 2 and 11 of the town of **Ashford**, Fond du Lac county, the railroad excavations again bring the formation to our notice. In the former section, the rock is a soft, yellowish dolomite of irregular texture and bedding, and is specially interesting for the variety, abundance and peculiarity of its fauna, as will be seen by reference to the table. The cut in Sec. 11 presents a rock whose lithological characters are not essentially different from the preceding, but which contains a very great abundance of *Pentamerus oblongus*, in great variety of size and form, and an almost entire absence of the fossils which characterize the preceding location. At the village of **Elmore**, in the same township, a quarry exhibits a heavy bedded rock of much more firm and homogeneous texture, the sole, but abundant, fossil of which is *Pentamerus oblongus*, in unusually large and fine specimens.

In the N. W. ¼ of Sec. 6, in the town of **Kewaskum**, at Kuhn's quarry, is a porus, granular, crystalline dolomite, containing an abundance of Favositoid corals and *Pentamerus oblongus*, and probably represents the horizon of the Lower Coral beds. Southward from this point, the formation is lost under the Kettle Range, and we do not again see it, or what may be supposed to be its equivalent, until we reach the vicinity of Pewaukee. On the Sheboygan river, at the village of **Rockville**, there is a slight exposure of the upper portion of the Upper Coral beds, presenting a more than usually dark gray color, with more or less of chert, and containing but very few fossils. The drift in the vicinity, however, is prolific in those species which are so abundantly present farther to the north.

WAUKESHA BEDS.

The term Waukesha limestone was selected many years since by Dr. Lapham, to designate the thin bedded strata that occur at Waukesha, and their equivalents elsewhere.[1] This term was also adopted by Prof. Hall, in the report of 1862.[2] It seems therefore desirable to retain a name that has already become fixed in the literature of the subject, although we shall be compelled to restrict its application, and to entertain, to some extent, different views as to its relations.

There are at Waukesha three classes of limestone. In the quarry near the college, the upper fourteen feet consist of a soft, yellowish, coarse-textured dolomite, that has been identified with unquestioned correctness, as the equivalent of the Racine limestone. This reposes upon regular, even beds of a hard, compact, fine-textured, crystalline dolomite, of gray color and conchoidal fracture. It is characterized by the presence of much chert in the form of nodules, distributed chiefly in layers, coinciding with the bedding joints. These strata abound in Orthoceratites, but contain few other fossils. They constitute the type of the Waukesha beds. The transition to the Racine beds is quite abrupt, but does not correspond to a bedding joint. From three to four inches of the base of a thick layer are of compact rock, like that below, while the remainder has the open texture and fossils of the Racine beds.

Passing by several intermediate quarries, for the moment, we find at the lime kilns, two miles above Waukesha, a fine display of the Racine limestone reposing upon similar cherty flags, which form the sole of the quarry. The transition is accomplished in a manner precisely similar to that above described.

In the road, south of this quarry, the porous Racine rock appears, but one hundred yards beyond, and *at the same elevation*, occurs a light colored, hard, compact, close-grained, subcrystalline dolomite, resembling closely the Waukesha flags, except that chert is absent. A few rods further, a quarry has been opened, exposing these strata more satisfactorily. In addition to the close textured rock, there are layers of mottled blue and white color, and irregular, lumpy structure, such as are associated with the even-bedded rock in the vicinity of the Niagara reefs near Milwaukee. Several openings follow at short intervals, including the main quarry of Mr. Hadfield, all of which exhibit the same character. This is also true of the several quarries on the opposite side of the Fox river. I have elsewhere dem-

[1] See Owens' Geological Survey of Wisconsin, Iowa and Minnesota, p. 455.

[2] Geology of Wisconsin, 1862, pp. 56–64; also note on pp. 446–448.

onstrated that the coarse, open-textured Racine limestone graduates horizontally into a precisely similar compact rock, and am therefore inclined to consider the weight of evidence as favoring the conclusion that such is the case here. In this view, the flags and thicker even-bedded rock, on either side of the Fox river above Waukesha, would be regarded as belonging to the Racine beds, being the stratigraphical equivalents of the coarse-grained Racine layers. The only undoubted members of the Waukesha beds are, then, the cherty flags near the college and at the kiln.

Farther up the stream, in Sec. 31, Menomonee, similar cherty flags make their appearance, and they also occur in the drift at intermediate points.

At Pewaukee, the upper strata consist of a white, fine-grained, but porous crystalline dolomite, having a conchoidal fracture. In this portion occur the crinoids *Caryocrinus ornatus*, *Eucalyptocrinus crassus*, *E. cœlatus*, *E.*, *n. sp.*, and the trilobites, *Illænus Ioxus* and *I. pterocephalus*, *n. sp.*, in association with several Orthoceratites and other fossils, thus manifesting a noticeable affinity to the Racine fauna.

The lower layers at this point are more argillaceous and silicious, and of more irregular texture, with patches of cherty material. *Halysites*, *Favosites* and *Pentamerus* occur in these beds. In one portion of Mr. Pelton's quarry a layer is almost entirely composed of a large *Pentamerus oblongus*, imbedded in white dolomitic material, forming a rather heavy bedded rock of uneven texture. It lies near the base of the quarry, but from its situation and the undulating nature of the strata, its relation to the impure layers above mentioned are not apparent. It is quite possible that, as suggested by Prof. Whitfield on paleontological evidence, the upper portion belongs to the Racine, and the lower to the Waukesha horizon. The list of fossils, collected at this ponit, is as follows: *Stromatopora concentrica*, *Favosites favosus*, *Astrocerium venustum*, *Halysites catenulatus*, *Zaphrentis*, *Omphyma*, *Caryocrinus ornatus*, *Eucalyptocrinus crassus*, *E. cœlatus*, *E.*, n. sp., *Streptorhynchus subplanum*, *Strophomena rhomboidalis*, *Spirifera nobilis*, *Meristina Maria*, *Atrypa reticularis*, *Pentamerus oblongus*, *P. ventricosus*, *Orthoceras annulatum*, *O. alienum*, *O. medulare*, *O. crebescens*, *Gyroceras Hercules*, *Gomphoceras nautilus*, n. sp., *Illænus Ioxus*, and *I. pterocephalus*, n. sp.

An interesting feature of this locality is a mound of rock lying a short distance west of the main quarries which rises ten or twelve feet above its base, and has a diameter of only a few rods. It consists of very irregular beds, coalescing promiscuously with each other and dipping irregularly in all directions. The rock is, for the most part, hard, compact, white, and, in some portions, cherty, and contains a few Brachiopods. It evidently owes its origin to irregularities of deposition and not to upheaval.

Johnson's quarry in the town of Genesee, presents a vertical exposure of more than 25 feet, of a beautiful white, fine-grained dolomite, in beds of 20 inches thickness and less, having an eastward dip of one foot in sixty. Near the base a layer possesses the mottled color and uneven texture above decribed. Fossils are rare in this location. A few rods distant on the opposite side of the road, a quarry displays very similar beds, but they are rather more porous in general and abound in chert in certain layers which is rare or absent at the former locality. They are also more fossilferous, though not abundantly so. The following species were collected: Of Crinoids, *Caryocrinus ornatus*, *Eucalyptocrinus crassus*, *and E. cœlatus;* of Brachiopods, *Orthis flabellula*, *Spirifera plicatella*, *Atrypa reticularis*, *Rhynchonella Indianensis;* the Gasteropod, *Platyostoma Niagarense;* of Cephalopods, *Orthoceras annulatum*, *O. alienum*, *O. columnare*, *O. medulare*, *O. n. sp.*, *Cyrtoceras Orcas*, *Gyroceras Hercules*, and the Trilobite, *Illænus ioxus*; a a fauna very closely resembling that of Pewaukee.

In the rise of the hill, immediately to the east, the typical, yellow, coarse-grained Racine limestone appears, as it also does in the adjacent ridge on the south. It is probable that many of the prominent hills in this region contain a core of Racine limestone; though deeply overlaid by the almost universally prevalent drift.

Closely allied strata occur at Castleman's quarry, in the town of East Troy, but no distinct fossils were found. The locality is widely separated by deep drift from all other outcrops.

Returning to the vicinity of the typical locality in Waukesha county, we find in Sec. 34, of the town of Lisbon, a formation that may be said to be identical in character with the upper strata at Pewaukee. To the east and northeast, in that and the adjoining town, are numerous openings upon white, or light colored, fine-grained, even bedded dolomite, with few or no fossils, which renders their place in the series somewhat doubtful.

As the horizon of the Waukesha beds is traced northward, it plunges beneath the deep drift of the Kettle Range, and on emerging beyond, the Byron beds and the Upper and Lower Coral beds are found to occupy the space between the Racine beds above and the Mayville below. The cherty flags at Waukesha most closely resemble the upper portion of the Upper Coral beds, which occupy the same stratigraphical position beneath the Racine strata, but nowhere in the southern counties is there manifested that abundance and variety of coralline forms that distinguish the formation to the northward. The Pentamerus beds at Pewaukee bear a closer alliance to certain members of the Lower Coral beds than to any other member of the northern Niagara series, while the white, compact, chertless beds bear so striking a lithological resemblance to the Byron beds, that they have been sometimes regarded as equivalents. But to satisfy all these affinities would be to impose incredible, if not impossible, demands upon the stratigraphical relations of the southern members, besides, the affinities are not by any means unequivocal.

The facts seem to be that in this case, as with the lower formations, the deposits in the southern counties differ from the corresponding ones in the northern counties, and that the Waukesha group of strata is the equivalent of the three more ponderous northern members that lie, like it, between the Mayville and Racine horizons.

On Plate X of the accompanying atlas, white lines have been used to designate, in a general way, the surface area of each of the subdivisions of the Niagara group. Within the spaces included between these lines are often limited — and occasionally considerable — areas of a higher member occupying the summit of prominences, or of a lower member, reached by deep erosion. Within the general area of the Waukesha beds, patches of Racine limestone occur, as already cited in Genesee. The white lines for this subdivision were drawn so as to include all of the known cherty flags belonging to this horizon.

RACINE BEDS.

Overlying the Waukesha beds at the south, and the Upper Coral beds at the north, is a magnesian limestone to which the term Racine has been applied, from its important development at that point.[1] It has an extent of about 200 miles, reaching from Illinois to near the extremity of the Green Bay peninsula, and attains a surface width of thirty miles. In its southern portion, where it rests upon the Waukesha limestone, it consists of reef-like masses of conglomeritic rock, which, on the denuded surface, appear as mounds or ridges, and which graduate into various kinds of porous, granular, irregularly bedded rock, or into fine grained, compact, even-bedded strata, the whole constituting a formation of exceedingly irregular structure. In its northern portion, where it reposes on the Upper Coral beds, it possesses a much more uniform character. On account of these pecu-

[1] Report of 1862, p. 67.

liarities, it is thought best to depart from our usual order of description, so far as to consider, first, the local peculiarities of the formation, after which we may, with more satisfaction, indulge in generalizations and draw conclusions.

Local details. At **Racine,** whence the formation takes its name, as exposed at the rapids of Root river, it is a blue, gray or buff, brittle dolomite, having a somewhat glassy fracture, subcrystalline structure in part, and earthy in part, and contains many geodic cavities, filled with calcite and pyrite, and sometimes mammillary deposits. Its texture is uneven, being sometimes granular and again brecciated, usually coarse and porous, but sometimes fine and compact. It is frequently stained with iron oxide, and, in places, is quite pyritiferous, especially in the fissures. The bedding is also irregular, but usually rather heavy, ranging from five feet downwards. In the south quarry at this point, belonging to Mr. Horlick, there is a small mound of highly porous blue rock, without visible bedding, full of fossils, from which it doubtless had its origin, after the manner of reef formation. It is surrounded on all sides by bedded rock. The dip at this point is varying in amount and direction, as shown by the following record of observations in different parts of the three quarries near the rapids:

EAST QUARRY.

Dip 8°.	Direction	N. 47° W.
Dip 7°.	"	N. 40° W.
Dip 1°.	"	N. 55° W.
Dip 3½°.	"	W. 45° S.

WEST QUARRY.

Dip 5°.	Direction	N. 65° W.
Dip 1½°.	"	N. 11° W.
Dip 2°.	"	N. 30° W.
Dip 1°.	"	N. 63° W.

NORTH QUARRY, WEST SIDE.

Dip 0°.	Direction	....
Dip 1°.	"	S. 80° E.

NORTH QUARRY, EAST SIDE.

Dip 0°.	Direction	....
Dip 1°.	"	N. 30° E.

It is understood, of course, that these measurements were made in different parts of the quarries, and on different layers, and they doubtless do not in all cases represent the true dip; i. e., the maximum inclination, as the exposure often did not render the demonstration of this possible. But the general fact of irregularity is sufficienty shown, and it is to be noticed that the average dip is to the N. W., a direction opposite to the general dip of the formation.

Fossils are very abundant, in the form of imperfect casts. At Vaughn's quarry, less than two miles distant, the first six or eight feet, as it lies in the beds, is deep yellow in color, verging to orange and red on the one hand, and to pale buff on the other. Below this the color varies from ashy-gray to grayish-blue. The upper layers are apparently thinner bedded than those below, though this is probably only the effect of the elements. The lower layers are heavier, but do not often exceed a foot in thickness. The beds are but obscurely defined, so that it is difficult to trace a given one for any considerable distance, or to ascertain the dip with any precision. There is an almost entire absence of shaly partings or laminæ of clay, so that the chipstone are comparatively free from the marly or clayey matter common in quarries. This is only true of the lower layers that have not been affected by inwashing from above, and by the immediate action of the surface elements.

The vertical joints are prominent, and in some portions frequent, and are usually smooth, and coated with calcareous and pyritiferous deposits.

The rock is porous and geodiferous; the former condition being largely due to crinoidal remains imperfectly preserved, and the latter perhaps in part to the same cause, also, the portion removed being the calyx. The material filling the geodes is chiefly calcite and pyrite, both of which appear in abundant and beautiful forms. The pyrite takes the tabular form of crystallization to a large extent, and the calcite seems to prefer the form known as dog-tooth spar. Crystals of this an inch or more in length are not uncommon.

The rock is quite brittle and sonorous, and presents a saccharoidal appearance on the freshly fractured surface of the unweathered layers. A bluish green, argillaceous material is found in obscure, irregular partings.

In fossils, it is far less prolific than the rock at the Rapids.

At the quarries belonging to Mr. Trimbone, in the town of **Greenfield**, Milwaukee county, the rock is chiefly a light buff, porous, granular, brittle dolomite, rather soft, and in some cases almost friable, and at points disintegrating to a calcareous sand. A little calcite in crystals, but no pyrite was seen. The fracture is rough, but usually along the line indicated by the application of the force, the manner in which the force is applied, rather than the nature of the rock, determining the line of fracture.

But in the southeastern quarry, the rock differs considerably from the rest, being harder, finer, more compact, less brittle, and bluer.

In general, the beds are from 1½ to 3 feet in thickness, but readily split into thinner layers. The beds, though in general regular and somewhat uniform, not unfrequently thicken, and curve, or undulate. Indeed, the last feature seems to be a common characteristic when any considerable area is considered, so much so as to render any attempt to get the general dip, by local observations, utterly futile. These undulations are not regular, nor do they present a system, as though due to some common cause, as contraction or upheaval, but are in a sense inharmonious with each other. The phenomenon arises, doubtless, in irregularities of deposition, and not in subsequent folding or other disturbance. A little careful study is decisive on this point. One of the clearest illustrations of this is to be found in the southeastern quarry, where the lower bedding joints can be traced in a straight line beneath the apparent folding. The next ones are lost in a thick unbedded mass, over which the upper layers pass on a considerable curve.

Passing by the Milwaukee region for the moment, we find near **Cedarburg** and **Grafton**, excellent examples of the irregular nature of this deposit. At the village of Cedarburg, most of the rock is a soft, porous, granular, minutely crystalline, dolomite, varying in color from white to light cream. Occasionally, cavities of the size of a walnut or larger appear, but they are not frequent. The beds are from 2 feet to 4½ feet thick, but not well defined, nor are vertical fissures regular or prominent. The local dip varies from 1° to 3½° in a southwesterly direction, but is changeable.

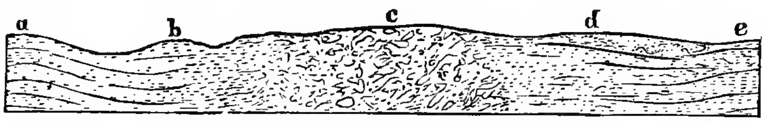
Other portions are harder and more compact, some of which, however, when mined back from the exposed surface, become softer and more granular, at variance with the usual fact.

A half mile to the east, near the center of Sec. 26, a very soft crystalline rock, called sandstone, from its friable and granular nature, occurs, having a strong dip to the westward. Following down the stream a short distance, we find a hard, brecciated and geodiferous rock of bluish cast without apparent stratification.

This gives place almost immediately to a granular rock similar to the preceding, but the bedding joints become entirely lost, and, in an exposure of 20 feet, none are visible. Vertical seams occur at intervals, which are disposed to change to an angle of 45° with the horizon, and to pass obliquely across to the neighboring fissure.

If we pass on eastward about half a mile, we find a rock, at a somewhat higher elevation, of a more earthy structure, belonging to the Guelph horizon, but when we reach the Milwaukee river, below the rapids, we again find the granular rock, as before, but distinctly bedded and dipping northward. In a few rods, the layers become harder and are almost as soon lost in a brecciated, unstratified mass, whose superior hardness has given rise to the rapids. This mass is made up of fragments of rock cemented by comminuted debris of a dolomitic character, which renders the distinction of the fragments from the matrix often obscure. This breccia graduates almost imperceptibly into hard, compact layers, as we proceed up the river, and these in turn soon give place to granular rocks again, the strata dipping northward for a distance, and then rising, as illustrated in the accompanying figure.

FIG. 44.



PROFILE SECTION ALONG THE MILWAUKEE RIVER, BELOW GRAFTON, SHOWING THE CHANGEABLE NATURE OF THE RACINE LIMESTONE.

a. Soft and granular; *b.* Close-grained and hard; *c.* Brecciated; *d.* Hard and compact; *e.* Granular.

At the dam near the south line of the S. E. qr., Sec. 24, Grafton, the granular dolomite is developed in its most characteristic form, becoming a well marked calcareous sand-rock.

Above the dam, a harder rock of closer but irregular texture ensues, but at a somewhat higher level, and belongs to the Guelph horizon.

Near the center of the east line of Sec. 33, Cedarburg, there is an outlier of rough, coarse brecciated dolomite of light gray color. It is composed of fragments of compact rock, the spaces between which are filled with a yellow pulverulent material. As the rock of the vicinity has been swept away, leaving it about 30 feet higher than its base, it is probable that it was surrounded by the softer granular beds that are prevalent in this neighborhood.

Throughout **Ozaukee** and **Washington** counties, this formation is chiefly represented by rocks similar to those already described, but to this remark there are conspicuous exceptions.

Near the south line of the S. W. ¼ of Sec. 35, **Germantown**, there is a quarry of considerable lateral extent, though it exposes but about 8 feet vertically. In the western portion of the quarry, the upper 13 inches consist of a hard, close-textured rock, but full of rough, irregular cavities. Below this, and not definitely separated from it, are 23 inches of porous, granular rock of the Racine type, showing, on the weathered edge, *oblique and cross lamination.* (*e* of Fig. 45.) Below this, are 5 feet of bluish white, very fine grained, compact dolomite, in beds averaging 6 inches in thickness. (*f* of Fig.) The distinction between this and the rock above is sharp and clear, so that it may be accurately traced, even where the bedding joint does not correspond to the junction. Traced to the northeast, the porous layer of the Racine type is reduced to 18 inches within 25 paces. It has also lost much of its porous character, having changed so as to be less different from the upper portion, and being now broken up into irregular layers. Five paces farther, this layer is reduced to six inches, and has still farther changed in character. (*g.*) Ten paces farther, it is no longer recognizable, both it and

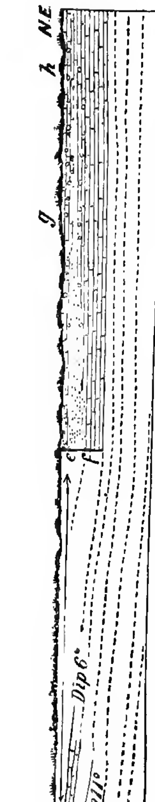


FIG. 45.

SHOWING PECULIAR STRUCTURE DESCRIBED IN THE ACCOMPANYING TEXT.

the layer above having changed so as to be scarcely distinguishable from the compact rock below. Farther on, the difference becomes still less, a few cavities, and a slightly greater irregularity in the subordinate layers, being all that distinguishes them from the layers below. (*h.*) At the farthest point to which these layers can be traced, no geologist would think of separating them from the layers below, thus making it a clear case of thinning out and transformation. These layers are essentially horizontal.

If we now return to the point in the southwestern part of the quarry, whence we started, and take 69 paces to the southwest, we find the rock exposed in the road as follows:

First, a compact limestone, similar to that in the quarry, dipping eastward at an angle of 6°. The upper layer is 8 inches thick, underlaid by one of 4 inches. (*d.*) The rock for 5 paces is then covered, beyond which it again appears. The upper 22 inches of this are divided irregularly into beds, the superior portion of which is as compact as any seen at the quarry, but the lower is somewhat more porous. This dips 11° N. of E. Under this lie 5 inches of porous rock, but not of the most pronounced class. Under this, again, lie 2 inches of similar kind; beneath which, again, there are 5½ inches of limestone, containing many cavities of the size of an almond, and similar to the upper layer described at the quarry. Under this lie 18½ inches of the more pronounced and typical, porous, granular rock. (*c.*) Here again the section is interrupted by 8 paces of unexposed surface, when a porous, granular rock succeeds, having a dip of 14° N. of E. (*b.*) There are about 26 inches of this, the irregularity of the structure making it difficult to measure exactly. Below this come 6 to 8 inches of a rough, irregular, brecciated, rather hard and tough, but somewhat porous, rock, containing large and small crinoid stems, like those common in the Racine beds. The section is again interrupted for 4 paces, when a rough, very irregular, brecciated, porous rock follows, constituting a confused mass, similar to the rock mounds near Milwaukee and Wauwatosa, yet to be described. (*a.*) In this, *Illænus ioxus*, fragments of *Atrypa* and *Rhynchonella*, crinoid stems, and an *Orthoceras*, were found. This exposure continues 18 paces. The whole situation is imperfectly represented by the accompanying figure.

It seems to be possible to draw but one rational conclusion from the foregoing facts, viz: (1) That the last mentioned irregular mass stood as a reef in the depositing sea; and (2) that the alternating layers were deposited on its slope, while (3) these, in the more quiet waters at a little distance from the reef, were replaced by a deposit of finer silt, which formed the compact layers. The unusual phenomena of cross and oblique lamination in limestone harmonizes with this view.

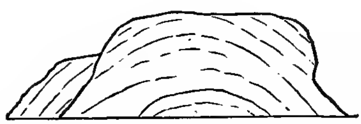
Within a mile from this point, there are several exposures of the compact rock. In the south half of Sec. 36, this even textured, compact variety is associated with a layer of the same general color and composition, but having a sort of lumpy structure, a kind of conglomerate, in which the pebbles and matrix were of the same material, and blended in solidification. This association here is an important link in the chain of evidence, as we have a precisely similar association with even textured layers, near Milwaukee, which have been heretofore excluded from the Racine group.

The position of these beds is also to be taken into account. To the northeast, northwest, southwest and southeast, are outcrops of the characteristic granular rock, within from one to four miles, with nothing in the topography to favor any other view than that taken.

About four miles to the southeast (middle N. line Sec. 29, **Granville**, Milwaukee county), we find a mound of confused, unstratified rock, having a north and south axis. The rock is dirty buff in color, and soft, granular, and almost pulverulent in texture. Eighty-five paces to the southeast of this, is a similar, but much smaller, mound, on the north side of which a quarry has been opened in even bedded, rather soft and porous dolomite, the layers of which dip into, or under, the mound at an average angle of about 4°. *Pentamerus (Gypidula) multicostata* abounds in these layers, and, in the larger mound, is associated with other Niagara fossils.

Near **Milwaukee** there are three mounds or ridges of rock that have attracted much attention, and which seem to be regarded as exceptional phenomena, but which, I think, in the light of preceding and subsequent facts, should cease to be so regarded. One of these, known as Moody's quarry, is located in the Fourth ward of the city of Milwaukee, in the side of the bluff facing the Menomonee river. Another is situated in the grounds of the National Military Asylum, and the chief and most noted at the station Raphu, near **Wauwatosa**, and commonly referred to the latter locality in the literature of the subject. The distance from the first to the second, on an air line, is 2¼ miles; from the second to the third, a little more than two miles, and from the first to the third, less than 3¼ miles. Lines joining them thus would form an obtuse-angled triangle. Within this triangle are two quarries of regularly bedded, horizontal limestone. One of these, Storey's quarry, is about two-thirds of a mile northeast of the outcrop in the Asylum grounds, and the other, about the same distance from the Raphu or Wauwatosa mound. Only a few rods west of the last, there are similar horizontal beds, having a very close relationship to the mound. These mounds are similar in character. The most striking peculiarity, aside from their external form and stratigraphical relations, is the great irregularity of their structure. The stratification is obscure, and sometimes apparently wanting. The rock has an irregular texture and varying, but frequently glassy, fracture, and contains many cavities of varying size and very irregular form. These are sometimes drusy with crystals, sometimes coated with stalagmite, or, again, filled with pulverulent material. The color is also varying, but usually bluish or yellowish. In composition, it is nearly a pure dolomite, and that from Schoonmaker's quarry is used successfully as a flux for iron at the Bay View furnaces.

FIG. 46.



SHOWING THE STRATIFICATION AT MOODY'S QUARRY, MILWAUKEE.

As the quarries near **Wauwatosa** furnish the best exposures, are the most fossiliferous, and have been the subject of most discussion, it is desirable that we should enter somewhat into particulars in reference to this interesting locality. If we place ourselves at the extreme western exposure, known as **Busack's** quarry (see Fig.), we shall find a section showing heavy, well defined, nearly horizontal, slightly argillaceous beds, of a rather fine, uniform, compact grain, medium hardness, smooth conchoidal fracture, and bluish gray color. Interstratified with these, are layers having the lumpy nature previously described as occurring in Sec. 36, Germantown. The layers dip eastward to about the middle of the quarry, from which they rise, but not uniformly, for at this point an east and west axis occurs, having the general trend of the ridge farther east, and with which it probably has a definite connection. An east and west section in this part of the quarry would show a dip to the westward, and a north and south section would exhibit the layers curving gently over this axis. But as we trace the rock eastward, it changes in nature. Near the eastern extremity, the upper layer becomes slightly irregular in bedding, and rather soft, and granular in texture.

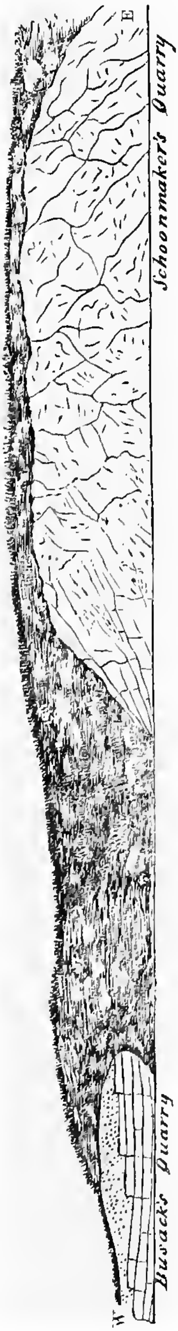


Fig. 47.

Relation of the Mound and Horizontal Limestone near Wauwatosa.

Below this is a layer from 22 to 24 inches thick, divided into sublayers, somewhat irregularly, and occasionally showing lines of deposition. To casual observation, it appears to be a compact, fine-grained, even-textured dolomite, but closer inspection shows it to contain many small cavities, that are angular and sharply defined, and are the result of the removal of minute fossils, in which the rock abounds at this point. Aside from these, the rock is as previously described, with occasional seams of argillaceous material. Below this, the rock is similar to that in the western part of the quarry. In the extreme southeastern portion exposed in connection with this quarry, the rock becomes quite irregular in structure.

There ensues at this point, unfortunately, an interruption of several rods in the exposure, so that this incipient change in structure cannot be traced to its consummation.

Passing this interval, we find at the western extremity of **Mr. Schoonmaker's** quarry, at the surface, a cellular, even textured, regularly bedded rock, similar to the last described, but of lighter color, and more distinctly granular nature. This dips southward at an angle of about 15°. As the face of the quarry curves round to the south, the whole section is composed of similar rock down to and beneath the water that occupies the bottom of the quarry at this point. But these lower layers dip less and less, until they become horizontal, and even slightly incline *toward* the irregular mass. If we trace these lower layers toward the ridge, their inclination somewhat increases *as well as their thickness* — this latter sometimes markedly — until they are lost in the obscure structure of the reef, or disappear at the surface.

As we pass eastward along the face of this ridge, now well exposed by quarrying, the dip of the ill-defined layers increases gradually to 54°, when the stratification can no longer be clearly distinguished. This obscurity continues for 80 paces. There are some indications of horizontal bedding in this space, and also some that the dip is to the south, and that the exposure is along the strike of the strata, but neither observation is altogether trustworthy.

East of this, blue and lighter colored bands indicate a dip of about 30° eastward. This continues for about 35 paces, the observation at the eastern extremity showing a dip of 31° in a direction E. 10° to 15° S., this being the dip *as exposed*, not necessarily the full amount of the true dip. The same qualification is true of the other observations made on dip along the face of this exposure.

Ten paces of unexposed face succeeds, followed by 90 paces uncovered, which shows an obscure dip of about 30° E. of S. Again 30 paces are concealed, beyond which a face 40 yards in length succeeds, whose dip is 33° E. of S. After another interruption of 60 paces, we find the last exposure of about 10 paces length, whose very obscure stratification indicates a dip to the S. W. The ridge reaches a hight of about 45 feet above the sole of the quarry.

Near the summit of the ridge, at its western extremity, is a slight outcrop apparently in place, and seeming to dip to the northwestward (20°, N. 30° W.). If this be reliable, we should infer that the ridge was comparatively narrow, as the exposure lies only 17 paces back from the face of the quarry.

The trend of the ridge, as estimated from the exposures, is a little to the north of east.

The rock at **Storey's** and **Schwickhart's** quarries, within the triangle before mentioned, is closely similar to that in the western part of **Busack's** quarry, and the same remark may be made of the fossils, which consist mainly of *Orthoceratites*. But in **Busack's** quarry, where the strata approach the reef, the fauna is much amplified, and we find *Halysites catenulatus*, an undetermined *Trematopora*, *Streptelasma* and *Fenestella*, *Stephanocrinus gemmiformis*, *Orthis biloba*, *O. elegantula*, *Strophomena rhomboidalis*, *Streporhynchus subplanum*, *Atrypa reticularis*, *Rhynchonella neglecta*, *Platyceras Niagarense*, *Orthoceras annulatum*, a new species of *Phragmoceras*, found also in the adjoining reef, a *Gomphoceras*, *Calymene Niagarensis*, *Encrinurus ornatus*, and a new species found also at Zimmerman's quarry, *Illænus Ioxus*, and *Bronteus Acamas*.

From all the foregoing facts, it may be regarded as fairly demonstrated that theso horizontal beds were laid down simultaneously with the formation of the mounds. The cellular nature of the rock of the latter, and the uncompressed condition of fragile fossils, are fatal to any theory of upheaval, or other violent action.

About five miles northwest of this, at **Zimmerman's** quarry, in Section 7, N. E. qr., Wauwatosa, there is an even-bedded limestone of compact or minutely cellular texture, very similar to that of some layers in the eastern part of Busack's quarry already described, and to which they are equivalent, as shown by the contained fossils. As quarried, the layers are thin, but the true beds are of more considerable thickness, a statement which is true of most or all the flags and apparently thin-bedded strata of this region. A few miles farther to the northwest, at **Howard's** quarry, and at several other points in **Menomonee**, quarries of white and gray flags, and even-bedded, compact, fine-grained, chertless limestones occur, that seem to belong to this horizon. At Howard's are found *Halysites catenulatus*, *Atrypa nodostriata*, *Orthoceras annulatum*, *O. medulare*, *Phragmoceras Nestor*, *Illænus Ioxus*, *Calymene Niagarensis*, and several undetermined forms. At other points, fossils are rare. In the adjoining town of **Lisbon**, as already mentioned, are similar strata, whose exact stratigraphical position is somewhat doubtful. From the fact that the compact, even-bedded rock that unquestionably belongs to the Racine horizon is everywhere, so far as known, free from chert, while the strata immediately underlying the undoubted Racine beds at Waukesha are highly cherty — and the same is true of the layers beneath the Racine in all the northern counties — the presence or absence of chert is entitled to some consideration as a distinguishing feature. From its nature, however, I am disinclined to rigidly apply it as a diagnostic character, and, besides, such application would, in some cases, lead to stratigraphical difficulties. It may be best, however, to provisionally regard the chertless beds as belonging to the Racine horizon. and the cherty flags to the Waukesha beds. If this rule be followed, most of the rock exposed in the town of Lisbon, and a portion of that in Pewaukee, would be regarded as Racine. In justification of the fact that any doubt remains, it is to be remarked that this is a region of almost universally prevalent drift, and that exposures of the rock are few and of limited extent, and it is further to be remembered that these are distinctions between *subordinate divisions* of the same epoch, and involve discriminations not often attempted with equal detail.

In the northern counties, the formation is much more uniform, both in the character of the rock and of its organic contents. As a type, or at least standard of comparison, we may select a limited but characteristic section from the town of **Kewaunee** (T. 23, R. 24, Sec. 14, S. hf).

1. Top Layer. A hard, compact, rather fine-grained, grayish white, even bedded dolomite, of somewhat uneven texture, weathering into creases, rather than pits, and quite fossiliferous, especially abounding in Brachiopods	1 ft 10 in.
2. Somewhat similar to the above, but coarser, softer, more uneven in texture, more inclined to be granular, and containing fewer fossils. It weathers into pits rather than creases	1 ft 2 in.
3. Similar to the last, but still more soft and granular, and more irregular in bedding and texture	2 ft 4 in.
4. Similar to the above	3 ft 6 in.
5. Thin layers, belonging to the Upper Coral beds	11 ft.

Although some of these layers are described as soft and granular, they do not possess these qualities in the same degree as that at Cedarburg and similar localities.

At **Wilmot**'s quarry S. E. qr., Sec. 32, Pierce (T. 24, R. 24), about five miles from the above, we find a rather soft, somewhat granular dolomite of subcrystalline structure, irregular fracture, rather thick, scarcely even beds, of bluish and grayish white color, with occasional stains of yellow and red, weathering to a yellow or buff.

All of the rock referred to this formation in Kewaunee county is very similar to the above.

One more example, from near **Sturgeon Bay**, Sec. 9, S. E. qr., T. 27, R. 26, will suffice for this portion of the formation. This outcrop consists of a whitish, somewhat granular, porous dolomite, of subcrystalline structure. It is heavy bedded and weathers into pits and creases, but not conspicuously so. The weathered surface shows white lines about one-half inch in width that are usually parallel to the bedding. These correspond to thin laminæ of a more compact, homogeneous, cryptocrystalline rock, apparently of essentially the same chemical composition as the rest. Some portions of the rock instead of being granular, are close and flintlike in texture, although enclosing numerous small cavities. On the average, the rock is of medium hardness and irregular fracture.

The formation throughout **Door county** does not essentially differ from this, except that at some points it verges more toward the coarse-grained saccharoidal marbles.

Speaking in general terms, the formation is possessed of quite constant lithological characters *north* of Sheboygan county.

Summation. It appears, then, that in the southern counties there are three well marked classes of limestones, with intermediate gradations, one class, consisting of very irregular, often brecciated or conglomeritic dolomite, forming masses that usually appear as mounds, or ridges of rock, of obscure stratification, a second class, formed of pure, soft, granular dolomites, a part of them calcareous sandrock, and a third class, consisting of compact, fine grained, regular, even beds. *We have demonstrated that the three forms change into each other when traced horizontally. They were therefore formed simul-*

taneously. The view that best explains these facts is, (1) that the mounds and ridges were ancient reefs, and (2) that the granular sand rock was formed from calcareous sands, derived by wave-action from the reef, and (3) that the compact strata originated from the deposit of the finer calcareous mud that settled in deeper and more quiet waters, the whole process being analogous to, if not identical with, the coral formation of the present seas. But before pursuing this analogy farther, it will be well to consider the evidences of life found in these rocks. While some of *the reefs*, or at least that portion of them that happens to be exposed to examination, present only a few fragments of fossils, others are prolific in organic remains, and some of them are remarkable for the richness and variety of their fauna. The reef near Wauwatosa (Schoonmaker's quarry), is a striking instance of this. There have been collected from it, chiefly by Dr. Day, probably not less than two hundred species. Of these there have been identified 28 Corals, 8 Bryozoans, 4 Crinoids, 19 Brachiopods, 11 Gasteropods, 9 Lamellibranchs, 24 Cephalopods, and 16 Trilobites. And an exhaustive examination of the collections would doubtless much increase the number. The specific character of these will be seen by consulting the accompanying table. This locality is especially notable for its Trilobites. At the quarry in Milwaukee, Corals are proportionately more abundant in number of individuals. At Noessen's quarry near Saukville, where there is a mingling of Racine and Guelph faunas, some portions of the rock are little more than a mass of coral remains imbedded in calcareous sand.

Of the granular varieties of rock, that which is nearest allied to the reef rock is peculiarly notable for an abundance of Crinoids. The locality near Racine is preëminent in this respect. Upwards of thirty species have been identified from this one locality. These are associated, as will be seen by consulting the table, with a large number of Corals, Brachiopods, Gasteropods, Cephalopods, Trilobites and a lesser number of other forms. Very similar faunas are displayed at Greenfield, Waukesha, and elsewhere. The more purely granular sandrock seldom contains many fossils.

The fauna of the compact strata is distinguished for the conspicuous presence of the straight and curved Cephalopods with comparatively few associates. The Cephalopods are abundant, as already noted, in the reefs and crinoid beds, but are overshadowed by the number and variety of other forms, while in the compact rock, they greatly predominate.

It appears then, (1) that upon the reefs there swarmed a vast variety of life; (2) that upon certain banks or shoal areas there was also great abundance and variety, among which the crinoid family attained unusual prominence; (3) that over areas of submarine sand-flats there either was little life present, or, from the porous nature of the rock, it has been illy preserved, and (4) that over the deeper areas, that deposited fine calcareous mud, the gigantic Cephalopods held sway. The counterpart of all this is to be found among the coral reefs of to-day. Vivid descriptions, almost specifically applicable to the formations in question, save in the modern aspect of the life, may be found in the writings of Prof. Dana and Mr. Darwin on recent coral formations. A few quotations from the excellent work of the former on Corals and Coral Islands, may find a place here by way of illustration and confirmation.

"Generally the barren areas much exceed those flourishing with zoöphytes, and not unfrequently the clusters are scattered like tufts of vegetation in a sandy plain. The growing corals extend up the sloping edge of the reef, nearly to low tide level. For ten to twenty yards from the margin, the reef is usually very cavernous, or pierced with holes or sinuous recesses, a hiding place for crabs and shrimps, or a retreat for the echini, asterias, sea-anemones and mollusks; and over this portion of the platform the gigantic Tridacna, sometimes over two feet long and five hundred pounds in weight, is often found, lying more than half buried in the solid rock, with barely room to gape a little its ponderous shell, and expose to the waters a gorgeously colored mantle. Further in are occasional pools and basins, alive with all that lives in these strange coral seas. The reef rock, when broken, shows commonly its detritus origin. Parts are of compact, homogeneous texture, and solid white limestone, without a piece of coral distinguishable, and rarely an imbedded shell. But generally the rock is a breccia, or conglomerate, made up of corals cemented into a compact mass, and the fragments of which it consists are sometimes many cubic feet in size." "Besides corals, the shells of the seas contribute to it, and it sometimes contains them as fossils, along with bones of fishes, exuvia of crabs, spines, and fragments of Echini, Orbitolites (disk-shaped foraminifers), and other remains of organic life inhabiting reef grounds."

Speaking of the masses of coral rock thrown upon the beach by the waves, he says:

"On moving these masses, which usually rest upon their projecting angles, and have an open space beneath, the waters at once became alive with shrimps, crabs and fish, escaping from their disturbed shelter; and beneath appear various Actiniæ, or living flowers, the spiny echini and sluggish biche-de-mar, while swarms of shells, having each a soldier crab for their tenant, walk off with unusual life and stateliness. Moreover, delicate corallines, Ascidiæ and sponges tint with lively shades of red, green and pink, the under surface of the block of coral which had formed the roof of the little grotto."

In other portions of the same work, there are frequent descriptions or references to sandrock, solid limestone, and various conglomeritic forms, that might almost have been embodied as a portion of the lithological description of this exposure of the Racine limestone. It does not appear, however, that Corals played so conspicuous a part, relatively, in the formation of these ancient reefs as they do in modern ones. In the northern counties, the Racine strata present no indications of this reef formation, but in Ozaukee and Washington counties it becomes pronounced and extends thence southward until, south of Racine, the formation is concealed completely beneath the drift. The line of reefs is unquestionably sixty miles in length, and may be much more. From their position they must be regarded as of the nature of barrier reefs. It is worthy of remark here that the reefs terminate at the north at that point at which the underlying formations undergo the modifications previously described, and it is particularly worthy of notice that this is the point where the Waukesha beds give place to the Byron and Coral beds, from which it appears that the discrimination of these subdivisions has an historical and dynamical importance. The consideration of the industrial value of this formation will be found following the treatment of the Guelph beds.

Dr. F. H. Day, of Wauwatosa, through years of industrious accumulation, has gathered, from the several localities of this formation in the southeastern part of the state, a very extensive collection, that is exceedingly rich in new, interesting, and typical forms. He has very kindly furnished the survey a list of species found at the several localities, which is incorporated in the following table. The species given on the authority of Dr. Day are marked thus †, those of the survey, thus, *.

FOSSILS OF THE RACINE BEDS OF THE NIAGARA GROUP.

Genera and Species.	Burlington.	Racine.	Greenfield.	Waukesha.	Wauwatosa. (Zimmerman's.)	Wauwatosa. (Schoonmaker's.)	Milwaukee. (Moody's.)	Menomonee Falls.	Grafton.	Kewaunee. (Sec. 14.)	Kewaunee. (Wilmot's.)	Sturgeon Bay.
PLANTÆ.												
Arthophycus		†										
Buthotrephis, und. sp.	*		†		†	†	†					
B. gracilis					†							
B. flexuosa					†							
FORAMINIFERA.												
Receptaculites hemisphericus		†	†	*								
R. infundibuliformis			†	*		†						
PETROSPONGIA.												
Stromatopora concentrica			†	*	†	*†	†	*		*		
CORALS.												
Favosites favosus		*†	†		†	*†	*†					
F. Gothlandicus			†		†	†	†					
F. Niagarensis		*†	*†		†	*†	†	*		*		
F. striatus			†									
Astrocerium constrictum			†		*†	†	†					
A. venustum			†		†	†	*†	*		*		
Halysites catenulatus		*†	†	†	†	*†	*†	*	*	*		
H. var. microporus		*										
H. var. macroporus		*										
H. agglomeratus						†					*	
Heliolites pyriformis		*				*†	*					
H. macrostylus						†						
Thecia, und. sp			†			†	†					
Cladopora reticulata						†						
Cœnites lunatus		†				†	†					
Syringopora compacta						*†						
S. Dalmani						†						
S. infundibula, n. sp.						*	*					
S. verticillata						*				*		
Diphyphyllum cæspitosum		*				†	†					
D. sp., with larger col's		*				†	*					
D. sp., with smaller col's		*				†						
Eridophyllum, und. sp		*										
Cyathophyllum, und. sp		*				*†	*	*	*			
Omphyma, und. sp		*			*		†					
Amplexus Shumardi		*†					†					
A. und. sp		*†				*					*	
Zaphrentis, und. sp		†	†	†	†	†	†	*		*		
Z. sp. res. Z. gigantea											*	
Streptelasma calyculum		†	*		*	†	†	*				
Aulacophyllum, und. sp						†	†					
Cyathoxonia Wisconsinensis, n. sp		*										
Chonophyllum Niagarense			†			†	†				*	
Cystiphyllum Niagarense						†	*			*	*	
Strombodes pentagonus						†						

FOSSILS OF THE RACINE BEDS OF THE NIAGARA GROUP — *continued.*

GENERA AND SPECIES.	Burlington.	Racine.	Greenfield.	Waukesha.	Wauwatosa. (Zimmerman's.)	Wauwatosa. (Schoonmaker's.)	Milwaukee. (Moody's.)	Menomonee Falls.	Grafton.	Kewaunee. (Sec. 14.)	Kewaunee. (Wilmot's.)	Sturgeon Bay.
CRINOIDEA.												
Saccocrinus Christyi	....	*†	*†	†	....	†	....	....	....	....	....	....
S. semiradiatus	....	*†	†	*†	....	....	....	....	....	....	....	....
Marcrostylocrinus striatus	....	*†	†	*†	....	....	....	....	....	....	....	....
Melocrinus Verneulii	....	*†	†	*†	....	†	....	....	....	....	....	....
Glyptocrinus armosus	....	*†	†	*†	....	....	....	....	....	....	....	....
G. nobilis	....	*†	*†	†	....	....	....	....	....	....	....	....
Glyptaster occidentalis	....	*†	†	*†	....	....	....	....	....	....	....	....
G. pentangularis	....	†	†	†	....	†	....	....	....	....	....	....
Lampterocrinus inflatus	....	*†	†	....	....	....	....	....	....	....	....	....
Eucalyptocrinus cœlatus	....	*	....	*	....	....	....	....	....	....	....	....
E. cornutus	....	*†	†	†	....	†	....	....	....	....	....	....
E. cornutus, var. excavat's	....	†	†	†	....	....	....	....	....	....	....	....
E. crassus	....	*†	*†	†	....	....	†	....	....	....	....	....
E. obconicus	....	*†	†	†	....	....	....	....	....	....	....	....
E. ornatus	....	*†	†	†	....	....	....	....	....	....	....	....
E n. sp	....	*†	†	†	....	....	....	....	....	....	....	....
Platycrinus, und. sp	....	*†	†	....	....	....	....	....	....	....	....	....
Rhodocrinus rectus	....	†	†	†	....	....	....	....	....	....	....	....
Cyathocrinus Cora	....	*†	....	†	....	....	....	....	....	....	....	....
C. pisiformis	....	*†	†	†	....	....	....	....	....	....	....	....
C. Waukoma	....	†	†	*†	....	....	....	....	....	....	....	....
Stephanocrinus gemmiformis	....	†	*†	*†	*	*†	....	....	....	....	....	....
Caryocrinus ornatus	....	*†	*†	*†	....	....	....	....	....	....	....	*
Ichthyocrinus subangularis	....	†	†	....	....	†	....	....	....	....	....	....
CYSTIDEA.												
Crinocystites ornatus	....	†	†	†	....	....	....	....	....	....	....	....
C. n. sp.	....	*†	†	†	....	†	....	....	....	....	....	....
Apiocystites imago	....	†	....	†	....	....	....	....	....	....	....	....
Echinocystites nodosus	....	*†	†	†	....	....	....	....	....	....	....	....
Gomphocystites clavus	....	....	....	....	....	†	....	....	....	....	....	....
G. glans	....	*†	†	†	....	*†	....	....	....	....	....	....
Hemicosmites subglobosus	....	*†	†	....	....	....	....	....	....	....	....	....
Holocystites cylindricus	....	*†	†	*†	....	....	....	....	....	....	....	....
H. ovatus	....	....	....	*†	....	....	....	....	....	....	....	....
H. scutellatus	....	*	....	*†	....	†	....	....	....	....	....	....
H. Winchelli	....	....	†	*†	....	†	....	....	....	....	....	....
H. abnormis	....	†	†	†	....	....	....	....	....	....	....	....
H. alternatus	....	†	†	†	....	....	....	....	....	....	....	....
BRYOZOA.												
Lichenalia concentrica	....	*†	....	*	†	†	*†	....	....	....	....	....
Sagenella membranacea	....	....	†	....	†	†	*	....	....	....	....	....
Fenestella, und. sp	....	*†	†	†	....	*†	*	....	....	....	....	....
F. elegans	....	....	....	....	....	†	....	*	....	....	....	....
Retepora, und. sp	....	....	†	....	†	†	*	....	....	....	....	....
Polypora incepta	....	†	....	....	....	†	....	....	....	....	....	....

FOSSILS OF THE RACINE BED OF THE NIAGARA GROUP — *continued.*

GENERA AND SPECIES.	Burlington.	Racine.	Greenfield.	Waukesha.	Wauwatosa. (Zimmerman's.)	Wauwatosa. (Schoonmaker's.)	Milwaukee. (Moody's.)	Menomonee Falls.	Grafton.	Kewaunee, (Sec. 14.)	Kewaunee, (Wilmot's.)	Sturgeon Bay.
BRYOZOA — (con.)												
Stictopora, und. sp.	....	....	....	....	....	†	....	....	....	....	....	*
Chætetes lycoperdon(?)	....	†	....	....	....	†	....	....	....	....	....	....
Trematopora, und. sp.	....	....	..	....	*	*	....	....	....	....	....	....
BRACHIPODA.												
Trematis, n. sp.	....	†	....	....	*	....	....	....	....	....	....	....
Dinobolus Conradi	....	*†	...	....	....	....	....	....	....	....	....	....
Trimerella, sp. res. T. grandis	...	†	†	...	....	†	....	....	....	....	....	....
Orthis biloba	....	....	†	†	*	*†	....	....	....	....	....	....
O. circulis	....	†	†	†	....	†	...	....	....	....	....	....
O. costalis	....	....	....	....	....	†	....	....	....	....	....	....
O. elegantula	...	*†	*†	*	*	*†	....	....	....	....	....	....
O. flabellula	....	*†	†	....	....	*	....	*	....	....	....	....
O. hybrida	...	*†	†	*	....	†	....	....	...	....	*	....
O. lynx	....	*	*†	....	....	†	....	....	....	....	....	....
O. oblata(?)	....	....	†	....	....	†	....	....	....	....	....	....
O. pectinella	....	†	†	....	....	†	....	....	....	....	....	....
Streptorhynchus subplanus	....	*	*	*	*	*	*	*	....	*	....	....
Discina discus	....	....	....	....	....	†	....	....	....	....	....	....
Strophomena patenta	....	*	....	....	....	....	....	....	....	....	....	....
S. profunda	....	*	*	*	....	....	....	....	...	*?	....	....
S. " small var.	....	..	....	....	....	*	*	...	....	....	....	*
S. rhomboidalis	....	*	*	*	....	*	*	....	....	....	....	....
S. semifasciata	....	....	*	...	....	...	....	....	....	....	....	....
Leptæna transversalis	...	†	*†	*†	*	†	†	..	....	....	....	....
Skenidium insignum	....	†	†	†	*	†	†	....	....	....	....	....
Spirifera eudora,	....	†	†	†	....	†	†	....	....	....	....	....
S. gibbosa	....	*†	†	†	....	*†	...	....	...	....	....	*
S. meta	....	*	*†	*	....	....	....	....	....	....	....	....
S. inconstans =	....	*	....	....	..	....	....	...	..	....	....	....
S. nobilis	...	†	†	....	....	....	..	....	....	....	....	....
S. Niagarensis	....	....	†	....	....	....	....	....	....	....	....	....
S. plicatella	....	*†	†	†	....	*†	*†	....	....	....	....	....
S. " var. radiata	*	*†	*†	*†	....	*†	†	....	....	....	....	*
Meristella Hyale	...	..	†	....	....	†	....	..	...	....	....	....
Cyrtia myrtia	....	†	†	....	*	†	....	....	....	....	....	....
Nucleospira pisiformis	..	*	...	....	....	....	*	....	....	....	....	....
Retzia? und. sp.	....	....	....	....	....	*	....	....	....	....	....	....
Meristina Maria	....	*?	*	....	....	...	....	....	....	....	....	....
M. nitida	....	*	*	...	*	....	....	...	....	....	...	*
Pentagonia, n. sp.	....	....	....	....	...	*	....	....	....	....	....	....
Atrypa congesta	....	....	†	....	....	†	†	....	....	....	....	....
Atrypa nodostriata	....	*†	†	†	..	†	*†	....	....	....	....	....
A. reticularis	....	*†	†	*†	*	*†	*†	*	....	....	....	....
A. n. sp.	....	†	†	†	....	†	*	....	....	....	....	....
Rhynchonella cuneata	....	*†	*†	*†	....	*	....	....	....	....	*	....
R. Indianensis	....	†	*	†	....	....	...	....	....	....	....	....
R. pisum	....	†	....	....	....	....	....	....	....	....	....	....
R. neglecta	....	*†	....	*	*	*	....	....	....	....	....	....
Eichwaldia reticulata	....	....	....	*?	....	....	....	....	....	....	....	....
Pentamerus fornicatus	....	....	†	....	....	†	†	....	....	....	....	....

FOSSILS OF THE RACINE BEDS OF THE NIAGARA GROUP — *continued.*

GENERA AND SPECIES.	Burlington.	Racine.	Greenfield.	Waukesha.	Wauwatosa (Zimmerman's)	Wauwatosa, (Schoonmaker's)	Milwaukee. (Moody's).	Menomonee Falls.	Grafton.	Kewaunee. (Sec. 14.)	Kewaunee. (Wilmot's).	Sturgeon Bay.
BRACHIOPODA — (con.)												
Pentamerus bisulcatus						†	†					
P. oblongus		*†	†		*	†		*			*	*
P. pergibbosus						†	†					
P. ventricosus		†	†	*	*	*†	*†			*		*
Anastrophia interplicata		*			*							
Stricklandinia, und. sp.										*	*	
Gypidula occidentalis		†				†	†					
LAMELLIBRANCHIATA.												
Pterinea brisa		*†	†	*†	†	†	†					
Ambonychia acutirostra		†	*†	†		†	†					
A. aphea						†						
A. undata						†						
Palæocardia cordiformis			†			†						
Modiolopsis Dictæus		†	†				†					
M. Nilesi		†	†	*†		†	†					
M. subundata		†	†	†								
M. recta		†				*†	†					
Amphicœlia (Leptodomus) Leidyi		*		*		*						
Leptodomus undulatus, n. sp.						*						
Schizodus? und sp.						*						
Megalomus Canadensis			†			†						
GASTEROPODA.												
Platyceras Niagarense		†	†	*†		*	†	*				
Platyostoma Niagarense		*†	†	*†		*†	†					
Euomphalus (Straparollus) mopsus				*	*							
E. Racinensis, n. sp.		*										
E. und. sp.										*	*	
Straparollus solarioides		*										
Pleurotomaria axion			†				†					
Pleurotomaria Idia		*†	†	†		†	†					
P. Halei		†					†					
P. occidens		*†	†			†						
P. Hoyi		†	†	†								
P. subtilistriata						†						
Xenophora antiqua						*						
X. trigonostoma				*								
Bucania angusta		†	†	†	†	†						
B. trigonostoma		†										
Trochonema Fatua		*										
Cyclonema elevatum		*										
C. pauper		*										
Loxonema Leda		†	†			†						
Metoptoma		†		†								
Bellerophon expansus					†							
Murchisonia bellicincta		†	†			†						
M. Laphami		†	†	†								

FOSSILS OF THE RACINE BEDS OF THE NIAGARA GROUP — *continued.*

GENERA AND SPECIES.	Burlington.	Racine.	Greenfield.	Waukesha.	Zimmerman's.	Schoonmaker's.	Moody's.	Monomonee Falls.	Grafton, S. 25.	Kewaunee, S. 14.	Kewaunee, (Wilmot's.)	Sturgeon Bay.
GASTEROPODA — (con.)												
Murchisonia macrospira...	....	†	†	....	....	†	....	....	....	....	....	....
M. mylitta..............	....	....	†	....	....	†	....	....	....	....	....	....
CEPHALOPODA.												
Orthoceras abnorme......	....	*†	*†	†	....	....	....	....	....	....	....	....
O. alienum	....	*†	*†	*†	....	*	....	....	....	....	....	....
O. annulatum	....	†	*†	*†	*†	*†	†	....	....	....	....	....
O. columnare	....	*†	*†	†	....	†	†	....	*	...	....	....
O. crebescens...........	...	*†	*†	†	....	....	....	....	....	....	....	....
O. Laphami..............	....	†	†	....	....	*†	....	....	....	....	....	....
O. medulare	....	†	...	....	*	*†	....	....	...	....	....	....
O. Niagarense	....	†	†	*†	...	†	†	...	....	....	....	....
O. trochleare	....	...	....	....	....	†	....	....	....	....	....	....
Ormoceras, sp. res. O. vertebrale...............	....	†	....	....	....	†	....	....	....	*	....	....
Gomphoceras septoris ..	....	....	....	....	†	†	....	....	....	....	....	....
G. scrinium	....	*†	†	†	...	†	....	....	*	....	....	....
G. n. sp................	....	....	....	....	....	*†	....	....	....	....	....	....
Oncoceras Orcas	....	*†	†	..	....	....	....	....	....	....	....	....
O. gibosum	....	†	....	†	....	†	....	....	....	....	....	....
Cyrtoceras brevicorne	....	*†	....	†	....	†	...	....	....	....	....	....
C. arcticameratum	....	....	....	....	....	†	....	....	....	....	....	....
C. Dardanum	....	†	†	*†	....	†	....	....	....	....	....	....
C. Fosteri.........	....	†	†	†	....	†	....	....	....	...	....	....
C. laterale	....	*†	....	*	....	†	....	....	....	....	....	....
C. lucillum...........	....	†	....	....	....	†	....	....	....	....	....	....
C. rigidum............	....	*	....	....	....	....	....	....	....	....	....	....
C. n. sp..............	....	*	....	....	....	...	....	...	...	....	....	....
Phragmoceras, n. sp......	....	....	...	....	...	*	....	....	....	....	....	....
Gyroceras Hercules.......	....	*†	†	†	†	....	....	....	*?	....	....	....
Trochoceras Bannisteri ...	....	†	†	....	....	....	....	....	....	....	....	....
T. Des Plainense	....	*†	....	*	...	†	....	....	....	....	....	....
T. Gebhardi.	....	†	....	†	....	†	....	....	....	....	....	....
T. costatum	....	†	....	....	....	†	....	....	....	....	....	....
T. occidentale	....	†	†	†	....	†	....	....	....	....	....	....
Lituites, und. sp.	...	*†	†	†	....	†	†	....	....	....	....	....
CRUSTACEA.												
Illænus Barriensis........	....	†	†	†	....	...	....	....	....	....	....	....
I. corniculus	....	....	....	....	....	†	†	....	....	....	....	....
I. Daytonensis	....	....	....	....	...	....	....	....	....	†	....	....
I. imperator	*	....	....	....	....	....	....	....	....	....	....	....
I. insignis	*	*	....	*	....	*†	*†	....	....	....	....	....
I. Ioxus	....	*†	*†	*†	....	*	....	....	*	....	....	*
Calymene Niagarensis....	*	*†	†	*†	† †	†	*†	....	....	....	....	....
C. Danai	....	....	†		†	...	....	....	....	....	....	....
C. Clintoni...........	....	....	....	....	†	....	...	....	....	....	....	....
Phacops, n. sp.	...	†	†	....	*†	†	...	....	....	....	....	....
Dalmania vigilans	....	....	†	*†	†	†	†	....	....	....	....	....
Ceraurus Niagarensis	....	*†	†	†	....	*†	*†	....	....	*	....	....

FOSSILS OF THE RACINE BEDS OF THE NIAGARA GROUP — *continued.*

GENERA AND SPECIES.	Burlington.	Racine.	Greenfield.	Waukesha.	Zimmerman's.	Schoonmaker's.	Moody's.	Menomonee Falls.	Grafton, Sec. 25.	Kewaunee, Sec. 14.	Kewaunee. (Wilmot's.)	Sturgeon Bay.
CRUSTACEA — (con.)												
Ceraurus					*							
C. n. sp.		†	†			†						
Encrinurus ornatus					*							
E. Nereus												
E. n. sp.					*†							
Lichas breviceps						†						
L. phlyctonodes		†	†	*†		†						
Bronteus Acamas		*†	†	†	†	†						
B. Laphami, n. sp.										*		
Sphærexochus Romingeri		*		*†		*	*					
Leperditia				*								
Acidaspis		†	†		†							
Harpes tringula						†						
Asaphus, und. sp.						†						

THE GUELPH BEDS.

The Guelph limestone constitutes the uppermost subdivision of the Niagara Group in Wisconsin. In its lithological character, it does not differ essentially from the Racine limestone, being in general a rough, thick bedded, irregular dolomite, usually quite free from impurities, and of buff, gray, or blue color. The distinction between the two subdivisions is a paleontological rather than a physical one. In the latter respect there is less difference between these than either of the other members of the group. There was evidently no marked change in the physical history of the region, but the same conditions continued from the beginning of the deposit of the Racine limestone to the close of the formation of the Guelph beds. In the interval, however, the life underwent a change by the introduction of the species that characterize the Guelph horizon. This introduction was gradual, so that many localities show a mingling of the two faunas. The right hand white line on the maps is intended to bound this formation, and is drawn so as to include localities presenting these mingled species. In doing so, however, it was necessary to include some of the reefs and sandrock deposits whose physical history is unquestionably identical with the Racine reefs. The propriety of doing this may be questioned.

Local Details. The mound and quarry in **Granville** and the Guelph beds near **Cedarburg** and **Grafton** have been mentioned in the description of the Racine limestone. In the former case the formation is so similar to the reef structure of the Racine limestone that it is quite possible it should be so grouped, as has been done in description. In the latter case, however, there is a nearer approach to a lithological distinction than elsewhere, the Guelph beds being more regular and compact than the subjacent Racine. Gasteropods predominate among the fossils.

At Noessen's quarry, north of **Saukville**, (Sec. 26, N. E. ¼), there is a limited opening upon an ancient reef, exposing a rock of varying character, a portion of it being very soft and coarsely granular, while other portions are compact and fine grained. Some portions are made up almost wholly of Crinoid stems and Corals, while others are brecciated. In color the rock is buff, weathering to a deeper and more reddish hue. Corals and Crinoids are abundant, and only extensive quarrying is needed to make this locality valuable to the collector. The fauna shows a mingling of Guelph and Racine species. The locality is rather to be regarded as Racine than Guelph.

At the light-house point, near **Sheboygan**, we find a hard, mottled, bluish dolomite of subcrystalline, rather compact, but not uniform texture. A concentric structure, developed in blue and white, is frequent. This and the mottling, brought out by the polishing of the glacier, and swept by the waves, give the surface a unique beauty. The general dip is to the southward, but after passing a low axis north of the point the slope is in the opposite direction. Near **Sheboygan Falls**, the rock is similar, though at a few points, a tendency toward the granular character, so common to the south, is manifested.

At **Roth's** quarry, N. W. ¼ of S. E. ¼ of Sec. 9, Sheboygan, the greater portion of the rock in the main quarry east of the kiln, is a thick bedded, bluish dolomite, quite hard and comparatively free from cavities, but with occasional geodes of calcite and more rarely iron pyrites. Some portions are beautifully laminated. Other portions are more granular and lighter in color, and approach somewhat the granular rock found farther south. In general aspect and lithological character, it somewhat resembles the rock of Vaughn's quarry, near Racine, already described. This and all the rocks of this vicinity, have but a meagre content of fossils. A few rods west of this, there occurs a hard, shaly, bluish, magnesian limestone with argillaceous partings and laminæ. The layers are undulating and the dip various.

At **Rabie's** quarry (middle N. ½ Sec. 7, Sheboygan), occurs a rock that differs from any found elsewhere in the degree of development reached by certain tendencies of this much varying formation. The vertical exposure is but slight. The upper layers are rather even and compact in texture, but below, the rock is highly brecciated with much argillaceous matter associated as a sort of matrix. The dolomite is a deep blue, while the argillaceous matter has a greenish cast, thus giving the rock a much deeper color than that of other portions of the formation. These layers are very geodiferous, the frequent cavities being drusy with calcite. The brilliancy of these, in strong contrast with the deep color of the rock, led an interested party to believe that there was silver present, and a little iron pyrites scattered sparsely through the rock, raised even brighter hopes, which we were seemingly cruel, but really kind, enough to dissipate.

At **Howard's** quarry, on the Sheboygan river, the rock is very irregular, both in bedding and structure. It varies from a soft granular, to a hard, almost flint-like dolomite. It contains many cavities, and weathers to an exceedingly rough, pitted surface. The more granular rock is white, and the more flint-like, bluish. The bedding is too obscure and irregular to give any reliable dip. The rapids here, as in most other cases within this formation, are due to the changeable nature of the rock, and not to the fact that a uniformly soft layer underlies a harder one, as is commonly true of falls.

In the town of **Carlton**, Kewaunee county, we find the most northern exposure of this formation yet recognized. It consists of a soft, granular, disintegrating, cream or buff colored dolomite of irregular bedding and structure. The fauna is peculiar, in the presence of large Gasteropods and Lamellibranchs.

The following table shows the character of the fauna, of the formation, and at the same time the distribution of the species among the several localities:

FOSSILS OF THE GUELPH BEDS OF THE NIAGARA GROUP.

GENERA AND SPECIES.	Granville, Sec. 29.	Grafton, T. 10, R. 21, Sec. 24.	Grafton, T. 10, R. 21, Sec. 25.	Cedarburg, Sec. 26, E. ½.	Cedarburg, Sec. 35, S. W. ¼.	Cedarburg, Sec. 35, N. W. ¼.	Saukville, (Noesen's.)	Sheboygan Falls, (Howard's.)	Carlton, Sec. 28.
PETROSPONGIA.									
Stromatopora concentrica						*	*		*
CORALS.									
Favosites Niagarensis	*		*	*	*			*?	*
F. occidens, n. sp.					*	*	*	*	
Astrocerium venustum							*?	*?	
Alveolites, und. sp.							*	*	
Cladopora, und. sp.								*	
Halysites catenulatus				*	*	*		*	*
H. catenulatus, var. microporus	*								
Cyathophyllum, und. sp.				*	*	*	*		
Amplexus annulatus, n. sp.							*	*	*
Chonophyllum magnificum									*?
Cystiphyllum, sp. res. C. Niagarense							*		
Diphyphyllum, und. sp.			*				*	*	
Zaphrentis, und. sp.								*	
CRINOIDEA.									
Eucalyptocrinus cœlatus							*		
E. ornatus							*		
Glyptocrinus nobilis							*		
BRACHIOPODA.									
Monomerella prisca			*?			*?		*	
Orthis elegantula				*					
Strophomena profunda							*	*	
S. rhomboidalis				*					
Spirifera plicatella, var. radiata							*		
Meristella Hyale=Charionella Hyale							*		
Retzia, und. sp.					*				
Atyrpa, und. sp.				*					
Rhynchonella cuneata						*	*	*	
R. neglecta	*							*	
R. pisum								*	
Pentamerus oblongus								*	
P. ventricosus							*	*	
P. und. sp.					*		*		*
Gypidula (Pentamerus) multicostata	*		*?		*	*			
G. occidentalis					*	*		*	
LAMELLIBRANCHIATA.									
Megalomus Canadensis									*
Ambonychia acutirostra				*					
Rensselæria, n. sp.				*					

FOSSILS OF THE GUELPH BEDS OF THE NIAGARA GROUP — *continued.*

GENERA AND SPECIES.	Granville, Sec. 29.	Grafton, T. 10, R. 21, Sec. 24.	Grafton, T. 10, R. 21, Sec. 25.	Cedarburg, Sec. 26. E. ½.	Cedarburg, Sec. 35, S. W. ¼.	Cebarburg, Sec. 35, N. W. ¼.	Saukville. (Nœssen's.)	Sheboygan. (Howard's.)	Carlton, Sec. 28.
GASTEROPODA.									
Cyclonema? magniventrum, n. sp.	....	....	....	....	....	....	....	....	*
C. sp. res. C. pauper	....	....	....	*	....	....	....	*	....
Holopea elevata	....	....	....	....	*	....	....	....	....
H. Guelphensis	....	....	*	....	....	....	....	....	....
H. harmonia	....	....	*	....	....	....	*	....	....
Loxonema magnum, n. sp.	....	....	....	....	....	....	....	....	*
Murchisonia Boydii	....	....	*	....	*	....	....	....	....
M. gigantea, n. sp.	....	....	....	....	....	....	....	....	*
M. Hyrcina	....	*	*	....	....	....	....	*	*
M. Logani	....	....	....	....	....	....	....	*	....
M. longispira	....	....	*?	....	*	....	....	*	....
M. macrospira	....	....	....	....	....	....	....	....	*
M. n. sp.	....	....	....	....	....	....	....	*	....
Platyostoma Niagarense	....	*	....	....	....	....	....	....	....
Pleurotomaria axion	....	*	....	....	....	....	....	....	....
P. Halei	....	....	*	....	*	....	....	....	....
P. Idia	....	....	*	....	*	....	*	....	....
Straparollus Hippolyte	....	....	*	....	....	....	....	....	....
S. solarioides	....	....	....	....	....	*	....	....	*
Trochonema Fatua	....	....	....	....	....	....	*	....	....
Subulites ventricosus	....	....	....	....	....	....	....	....	*
CEPHALOPODA.									
Orthoceras abnorme	....	....	....	....	*	*	....	....	....
O. annulatum	*	....	....	*	....	....	....	....	....
O. Carltonense, n. sp.	....	....	....	....	*	....	....	....	*
O. crebescens	....	....	....	....	....	....	*	....	....
Gomphoceras, und. sp.	....	....	*	....	....	....	....	....	....
Cyrtoceras arcticameratum	....	....	....	....	*	....	....	....	....
C. laterale	....	....	....	....	*	....	....	....	....
C. rectum, n. sp.	....	....	....	....	....	....	....	....	....
C. rigidum	....	....	....	....	*	....	....	....	....
Phragmoceras, und. sp.	....	....	....	....	....	....	....	....	*
CRUSTACEA.									
Illænus Ioxus	....	....	....	....	*	....	....	....	....
Bronteus Acamas	....	....	....	....	....	....	*	....	....

INDUSTRIAL VALUE OF THE WAUKESHA, RACINE AND GUELPH BEDS.

Lime. Probably the Niagara limestone surpasses all other formations in the interior of the continent, in the amount and excellence of the quick lime produced from it, and certainly the formation no where surpasses the purity and adaptation to lime manufacture that it attains within the region under consideration. The excellence of certain portions of the lower members in this respect has already been considered, and the higher members now claim attention.

The following analyses show that the first great essential, purity, is possessed in a high degree:

	I.	II.	III.	IV.
Carbonate of lime	52.86	52.16	55.23	55.41
Carbonate of magnesia	42.98	45.50	43.52	43.48
Sulphate of lime	.....	0.10	0.05	.....
Phosphate of lime	.....	0.12	0.10	.....
Sesquioxide of iron	0.32	0.82	0.92	0.61
Sesquioxide of alumina	.....			
Silica	.....	.....	.....	0.50
Sulphur	.....	Trace.	Trace.	.....
Water	0.49	0.67	0.25	.....
Insoluble residue	3.44	0.28	0.40	.....
Total	100.09	99.65	100.47	100.00

No. 1 is from the Pentamerus layer at Pelton's quarry, Pewaukee. This layer is not now burned for lime, the upper layers, which are purer, being used exclusively. No. II is from Mr. Horlick's, and No. III from Mr. Beswick's quarries, Racine. All the foregoing analyses are by Prof. Daniells. No. IV is an average of six analyses of as many layers of Mr. J. Druecker's quarry, near Port Washington, by Mr. Bode. It will be observed that the average insoluble residue of those that are used for lime is *less than one-half of one per cent.;* or, if the alumina and iron be included, but little over one per cent. These are not analyses of exceptional specimens, but are believed to be fair averages of the rock used for the market product, and inexhaustible quantities of equally excellent material are readily accessible. The material used by the leading lime-burners at other points is of essentially the same excellent quality.

Aside from chemical purity, a certain degree of porosity is desirable, since it promotes the ready escape of the gases and secures a uniform and complete reduction without an excessive heat and the consequent partial vitrification of the surface and loss of strength. It likewise facilitates complete slacking when used, thus tending to reduce the liability to slack in the wall, which is the annoying habit of some limes when carelessly used. The more minutely and uniformly porous the rock is, the better. The formation under consideration presents abundant deposits that possess this desirable quality in an eminent degree, and this kind of rock is now almost exclusively used, the practical experience of burners having led to this, without, perhaps, fully appreciating the reason for it.

Owing to these excellencies, the Wisconsin limes produced from this formation enjoy a high reputation, and are largely used in the Chicago market, notwithstanding the distance. When visited, the kilns of Messrs. H. & Y. C. Pelton, of Pewaukee, were producing 1,200 barrels per week, which was shipped to Chicago, Grand Haven, Sparta, Des Moines and elsewhere. At the kilns of Mr. Ormsby, of the same place, 2,000 barrels were being burned per week, about one-half of which was shipped to Chicago and the rest mainly to the La Crosse region. Messrs. Colville & Ormsby, of Lisbon, were burning 700 barrels per week. Messrs. Horlick & Sons, of Racine, manufacture from 60,000 to 75,000 barrels per year, which is sent to the west and south, and to Michigan. Their business is so extensive as to require a branch house in Chicago. Mr. Beswick, of the same place, burns upward of 18,000 barrels per year, which is used chiefly at points on the Lake Shore railroad. Mr. Vaughn, of the same place, produces from 600 to 1,000 barrels per week, which is mostly sold at Chicago. At Waukesha, the Messrs. Hadfield burn and ship extensively. Mr. Johnson, in the town of Genesee, burns sufficient to supply the local demand. Mr. Trimbone, of Greenfield, produces from 60,000 to 80,000 barrels per year, which is chiefly consumed in Milwaukee. The kiln of Mr. Druecker, near Port Washington, has a capacity of 250 barrels daily, the product of which is shipped to Chicago. At Mr. Roth's kilns, near Sheboygan, 1,600 to 1,700 barrels per year are produced. At numerous other points, there are kilns of capacity sufficient to supply the local demand. Probably 400,000 barrels may be considered a fair estimate of the total amount of lime burned per year from the Niagara limestone.

Building-Stone. While this district yearly exports large quantities of brick and lime, it continues to import more or less of building stone. This is due less to the necessities of the case than to the want of development of our own resources So far as there may be a demand for silicious sandstone, there will probably continue to be a a necessity for going outside of our district, though not outside of the state, but the formation under consideration is capable of furnishing excellent material for both massive and ornamental construction.

The careful, and in many cases, elaborate descriptions of the texture and bedding of the members of the formation, given under the head of local details, need not be repeated, and our attention may be confined to a few localities that especially deserve mention. The quarries of the Messrs. Hadfield, near Waukesha, afford excellent, compact, fine-grained, white, or light-gray beds, 20 inches or more, in available thickness. The rock has a reliable conchoidal fracture and can be dressed with as much ease and facility, as is attainable in so firm a rock. It is admirably adapted to use as dimension stone of various kinds, particularly for trimmings with white brick, with which its color harmonizes beautifully.

A white and most excellent rock of similar texture is wrought at Johnson's quarry, Genesee, and is worthy of high commendation.

Near Cedarburg, at the quarry of Messrs. Schleifer & Anshuetz, a white, granular, crystalline rock occurs in massive deposit without evident bedding joints, so that blocks of any required dimensions can be obtained. It cuts with great facility and is a beautiful stone. Large quantities are shipped to Milwaukee, and the surrounding country.

At Kuntz' quarry, Manitowoc, a compact, fine-grained, crystalline dolomite of excellent quality has been mined to some exent, and even sawed and polished as a marble. While not suited to polishing, it is excellent for the coarser, ornamental purposes. In Cooperstown and elsewhere very fine dolomites await development.

Gen. Q. A. Gilmore, in his work on Building Stone, gives the crushing strength of a two inch cube of bluish drab limestone, from Sturgeon Bay, as 86,000 pounds on bed, and 66,750 on edge, with the comment, "a remarkably solid, stable stone." That of the white Joliet (Ill.) limestone, sometimes imported, he gives as ranging from 45,000 to 67,000 on bed. In addition to the fine qualities of rock, the formation furnishes unlimited quantities of material suitable for rough-dressed, course work, and the heavier class of masonry.

Flux. The limestone from Schoomaker's quarry, west of Milwaukee, is used successfully as a flux in the Bay View Iron Works, and the limestones from Trimbone's and Druecker's quarries have been also tested with favorable results. The pure, granular limestones in the towns of Cedarburg, Grafton and Germantown, may also be recommended.

FOSSILS OF THE NIAGARA GROUP.

GENERA AND SPECIES.	Author of Species.	Mayville beds.	Byron beds.	Lower Coral beds.	Upper Coral beds.	Waukesha beds.	Racine beds.	Guelph beds.	Not observed.
PLANTÆ.									
Buthotrephis, und. sp.	....	....	....	....	*	....	*	....	....
FORAMINIFERA.									
Receptaculites hemisphericus	Hall	....	....	....	....	....	*	....	....
R. infundibuliformis	Hall	....	....	....	....	....	*	....	....
PETROSPONGIA.									
Stromatopora concentrica	Goldfuss	*	....	*	*	*	*	*	....
CORALS.									
Favosites favosus	Goldfuss	*	....	*	*	*	*	....	....
F. Gothlandicus? (large cells)	Goldfuss	....	....	....	*	....	....	....	*
F. Niagarensis	Hall	*	....	*	*	....	*	*	....
F. occidens	n. sp	....	....	....	*?	....	*	*	....
F. striatus	Say	....	....	....	....	....	....	....	*
F. cells small, chætetes-like	....	*	....	....	*	....	....	....	....
F. clavate form, 2 kinds cells	....	....	....	....	....	....	*	....	....
Astrocerium venustum	Hall	*	....	*	*	*	*	*?	....
A. constrictum	Hall	....	....	....	....	....	*	....	....
Michelina? und. sp.	....	....	....	....	*	....	....	....	....
Alveolites, und. sp	....	....	....	....	*	....	*	*	....
Cœnites lunatus	Mich. & Hind.	....	....	....	*	....	....	....	....
Thecia, und. sp. with small cells	....	....	....	*	*	....	....	....	....
T. sp. with larger cells	....	....	....	*	*	....	....	....	....
Cladopora reticulata	Hall	....	....	....	*	....	....	....	....
Halysites agglomeratus	Hall	....	....	*	*	....	....	....	....
H. catenulatus	Linn	*	....	*	*	*	*	*	....
H. catenulatus var. microporus	n. var.	....	....	*	*	....	*	*	....
H. catenulatus var. macroporus	n. var.	....	....	*	*	....	*	....	....
Heliolites macrostylus	Hall	....	....	....	....	....	....	....	*
H. pyriformis	Guettard	*	....	*	*?	....	*	....	....
H. spinoporus?	Hall	....	....	*	....	....	*	....	....
Syringopora compacta	Billings	....	....	....	*	....	*	....	....
S. Dalmani	Billings	....	....	....	*	....	*	....	....
S. infundibula	n. sp	....	....	....	....	....	*	....	....
S. retiformis	Billings	....	....	....	....	....	*	....	....
S, verticillata	Billings	....	....	....	....	....	*	....	....
S. und. sp.	....	....	....	*	....	....	....	....	....
Diphyphyllum cæspitosum	Hall	*	....	*	*	....	*	*	....
Eridophyllum, und. sp.	....	....	....	....	....	....	*	....	....
Cyathophyllum, und. sp.	....	*	....	....	*	....	*	*	....
Omphyma, und. sp.	....	....	....	....	....	*	*	....	....
Amplexus annulatus	n. sp	....	....	....	....	....	*	*	....
A. fenestratus	n. sp	....	....	....	*	....	....	....	....
A. Shumardi	....	....	....	....	....	....	*	....	....
Amplexus, und. sp.	....	*	....	*	*	....	*	*	....
Streptelasma calyculum?	Hall	....	....	....	*	....	*	....	....
Zaphrentis, sp. res. Z. gigantea	Ed. and Haine	....	....	....	*	....	*	....	....
Z. turbinata	Hall	....	....	....	....	....	....	....	*
Z. und. sp.	Hall	....	*	*	*	....	....	*	....

FOSSILS OF THE NIAGARA GROUP — *continued.*

GENERA AND SPECIES.	Author of Species.	Mayville beds.	Byron beds.	Lower Coral beds.	Upper Coral beds.	Waukesha beds.	Racine beds.	Guelph beds.	Not observed.
CORALS — (con.)									
Aulacophyllum, und. sp.				*	*		*		
Cyathaxonia Wisconsinensis	n. sp.			*			*		
Chonophyllum magnificum	Billings							*	
Chonophyllum Niagarense	Hall	*							
C. compound form					*				
C. und. sp.					*	*		*	
Cystiphyllum Americanum	Hall				*				
Cystiphyllum Niagarense	Hall					*	*	*	
Cystiphyllum, und. sp									
Strombodes pentagonus	Goldfuss				*			*	
S. n. sp					*				
Cystostylus typicus	n. sp.				*				
CRINOIDEA.									
Platycrinus, und. sp.							*		
Stephanocrinus gemmiformis	Hall						*		
Saccocrinus Christyi	Hall						*		
S. semiradiatus							*		
Macrostylocrinus striatus	Hall						*		
Melocrinus Verneuili	Troost						*		
Eucalyptocrinus cœlatus	Hall						*		
E. cornutus	Hall						*		
E. cornutus, var. excavatus	Hall						*		
E. crassus	Hall						*		
E. obconicus	Hall						*		
E. ornatus	Hall						*		
E. n. sp.							*		
Glyptocrinus armosus	McChesney						*		
G. nobilis	Hall						*		
Lampterocrinus inflatus	Hall						*		
Glyptaster occidentalis	Hall						*		
G. pentangularis	Hall						*		
Rhodocrinus rectus	Hall								*
R. sculptilis	Hall								*
Cyathocrinus Cora	Hall						*		
Cyathocrinus pisiformis	Rœmer						*		
C. Waukoma	Hall						*		
Caryocrinus ornatus	Say					*	*		
Cryptodiscus							*		
CYSTIDEA.									
Holocystites abnormis	Hall								*
H. alternatus	Hall								*
H. cylindricus	Hall						*		
H. ovatus	Hall						*		
H. scutellatus	Hall						*		
H. Winchelli	Hall						*		
Gomphocystites clavus	Hall.						*		
G. glans	Hall						*		
Hemicosmites subglobosus	Hall						*		
Apiocystites imago	Hall								*

FOSSILS OF THE NIAGARA GROUP—*continued.*

GENERA AND SPECIES.	Author of species.	Mayville beds.	Byron beds.	Lower Coral beds.	Upper Coral beds.	Waukesha beds.	Racine beds.	Guelph beds.	Not observed.
CYSTIDEA—(con.)									
Echinocystites nodosus	Hall						*		
Crinocystites ornatus	Hall								*
C. n. sp.							*		
BRYOZOA.									
Lichenalia concentrica	Hall						*		
Sagenella membranacea	Hall						*		
Fenestella elegans	Hall						*		
Retepora, und. sp.							*		
Polypora incepta	Hall								*
Stictopora, sp. und.							*		
Trematopora, sp. und.							*		
BRACHIOPODA.									
Trematis, sp. und.							*		
Dinobolus Conradi	Hall						*		
Monomerella prisca	Billings							*	
Trimerella grandis?	"						*		
Orthis biloba	Linnæus						*		
O. elegantula							*	*	
O. flabellula	Sowerby	*			*	*	*		
O. hybrida	Dalman	*?					*		
O. lynx	Eichwald						*		
Streptorhynchus subplanum	Conrad					*	*		
Strophomena patenta	Hall						*		
S. profunda	Conrad				*?		*	*?	
S. rhomboidalis	Wahlenberg	*				*	*	*	
S. semifasciata	Hall						*		
S. sp. new					*				
Strophodonta striata	Hall	*					*		
Leptæna transversalis	Wahl.						*		
Skenidium insignum?	Hall						*		
Spirifera eudora	Hall								*
S. gibbosa	Hall						*		
S. meta	Hall						*		
S. Niagarensis	Hall								*
S. nobilis	Barrande						*		
S. plicatella	Sowerby						*		
S. plicatella, var. radiata	Sowerby						*	*	
S. sp. und.							*		
Meristella Hyale = Charionella Hyale	Billings							*?	
Cyrtia myrtia	Billings						*		
Meristina cylindrica	Hall	*							
M. Maria	Hall						*		
M. nitida	Hall				*		*		
Pentagonia, sp. und.							*		
Nucleospira pisiformis	Hall						*		
Retzia aprinis = Atrypa and Rhynchonella aprinis	Hall	*							
Retzia, sp. und.							*	*	
Atrypa nodostriata						*	*		

FOSSILS OF THE NIAGARA GROUP — *continued.*

Genera and Species.	Author of Species.	Mayville beds.	Byron beds.	Lower Coral beds.	Upper Coral beds.	Waukesha beds.	Racine beds.	Guelph beds.	Not observed.
BRACHIOPODA — (con.)									
A. reticularis	Linnæus	*			*	*	*		
A. sp. new		*					*	*	
Rhynchonella cuneata	Dalman						*	*	
R. Indianensis	Hall					*	*		
R. neglecta	Hall						*	*	
R. pisum	H. & W.							*	
Eichwaldia reticulata	Hall						*		
Pentamerus bisulcatus	McChesney	*		*	*		*		
P. fornicatus	Hall	*							
P. oblongus	Murchison	*		*	*	*	*	*	
P. pergibbosus	H. & W.	*?		*				*	
P. ventricosus	Hall			*	*	*	*	*	
P. und. sp								*	
P. new sp.					*				
Gypidula occidentalis	Hall	*		*				*	
G. multicostata	Hall							*	
Stricklandinia Galtensis?	Billings			*					
S. multilirata	n. sp.						*		
S. undet. sp		*			*				
S. new sp					*				
Leptocœlia planoconvexa	Hall	*							
L. plicatula	Hall					*			
Porambonites punctostriata?= Orthis punctostriata	Hall	*							
LAMELLIBRANCHIATA.									
Pterinea brisa	McChesney						*		
P. emacerata	Hall								*
P. undata	Hall								*
Ambonychia acutirostra	Hall						*	*	
A. aphea	Hall								*
Palæocardia cordiformis	Hall								*
Modiolopsis Dictæus	Hall						*		
M. Nilesi=Edmondia Nilesi	W. & M.						*		
M. recta	Hall						*		
E. subundata	Hall								*
Leptodomus Leidyi= Amphicœlia Leidyi	Hall						*		
Leptodomus undulatus	n. sp.						*		
Schizodus? und. sp.							*		
Cypricardinia arata	Hall								*
Megalomus Canadensis	Hall							*	
Rensselæria, n. sp								*	
GASTEROPODA.									
Platyceras Niagarense	Hall						*		
Platyostoma Niagarense	Hall						*	*	
Euomphalus macroliratus	n. sp.						*		
E. (Straparollus) mopsus	Hall						*		
E. Racinensis	n. sp.	*?					*		
Straparollus Hippolyte	Billings							*	
S. solarioides	Hall						*	*	
S. solarioides?							*		
Straparollina, und. sp				*					

FOSSILS OF THE NIAGARA GROUP — *continued.*

GENERA AND SPECIES.	Author of Species.	Mayville beds.	Byron beds.	Lower Coral beds.	Upper Coral beds.	Waukesha beds.	Racine beds.	Guelph beds.	Not observed.
GASTEROPODA — (con.)									
Xenophora, n. sp							*		
X.? trigonostoma	Meek						*		
Trochonema Fatua	Hall						*	*	
Holopea elevata	Hall							*	
H. Guelphensis	Billings							*	
H. harmonia	Billings							*	
Cyclonema? elevatum	Hall						*		
C. magniventrum	n. sp							*	
C. pauper	Hall						*		
Pleurotomaria axion	Hall							*	*
P. Fatua	Hall							*	
P. Halei	Hall						*	*	
P. Hoyi	Hall						*		*
P. Idia	Hall						*	*	
P. n. sp				*					
P. occidens	Hall						*		
Murchisonia Boydii	Hall							*	
M. Conradi	Hall								*
M. gigantea	n. sp							*	
M. Hyrcina	Billings			*				*	
M. Laphami	Hall						*		*
M. Logani	Hall							*	
M. longispira	Hall							*	
M. macrospira	Hall							*	
M. Mylitta	Billings							*	
M. turritiformis	Hall							*	
Loxonema Leda	Hall						*		
L. magnum	n. sp							*	
Bucania angusta	Hall								*
B. trigonostoma	H. & W.			*					
Metoptoma, sp. und							*		
Trochoceras Gebhardi	Hall							*	
Subulites ventricosus								*	
CEPHALOPODA.									
Orthoceras abnorme	Hall						*	*	
O. alienum	Hall			*		*	*		
O. annulatum	Sowerby					*	*	*	
O. Carltonense	n. sp							*	
O. columnare	Hall					*	*		
O. crebescens	Hall					*	*	*	
O. Hoyi	McChesney							*	
O. Laphami	Hall						*		
O. medulare	Hall					*	*		
O. Niagarense	Hall						*		
Ormoceras, sp. res. O. vertebrale		*							
Huronia annulata	Hall				*				
Discosorus conoideus	Hall			*					
Gomphoceras scrinium	Hall						*		
G. septoris?	Hall					*			
G. und. sp							*	*	

FOSSILS OF THE NIAGARA GROUP — *continued.*

GENERA AND SPECIES.	Author of Species.	Mayville beds.	Byron beds.	Lower Coral beds.	Upper Coral beds.	Waukesha beds.	Racine beds.	Guelph beds.	Not observed.
CEPHALOPODA — (con.)									
Cyrtoceras arcticameratum	Hall							*	
C. brevicorne	Hall						*		
C. Dardanum	Hall						*		
C. Fosteri	Hall								*
C. laterale	Hall						*	*	
C. lucillum	Hall								*
C. rectum	n. sp							*	
C.? rigidum	Hall						*	*	
C. (Oncoceras) Orcas	Hall					*	*		
C. pusillum	Hall								*
Phragmoceras labiatum	n. sp			*					
P. Nestor	Hall					*			
P. n. sp							*		
Gyroceras Hercules	W. & M.					*	*		
Trochoceras costatum	Hall								*
T. Des Plainense	McChesney						*		
Lituites Ortoni	Meek						*		
Nautilus occidentalis	Hall					*			*
N. n. sp						*			
CRUSTACEA.									
Leperditia fonticola	Hall		*						
Illænus armatus	Hall								*
I. Barriensis?	Murchison						*		
I. cuniculus	Hall								*
I. Daytonensis	H. & W						*		
I. imperator	Hall						*		
I. insignis	Hall						*		
I. Ioxus	Hall					*	*	*	
I. pterocephalus	n. sp					*			
I. n. sp					*				
I. und. sp		*					*		
Calymene Niagarensis	Hall						*		
C. Clintoni	Hall						*		
Phacops, n. sp							*		
Dalmania vigilans	Hall						*		
Ceraurus Niagarensis	Hall						*		
C. n. sp							*		
Encrinurus Nereus	Hall								*
E. ornatus	H. & W						*		
E. n. sp							*		
Lichas breviceps	Hall						*		*
L. phlyctonodes	Hall						*		
Bronteus Acamas	Hall				*		*	*	
B. Laphami	n. sp						*		
Sphærexochus Romingeri	Hall						*		

LOWER HELDERBERG LIMESTONE.

Four miles northwest of the city of Milwaukee — Sec. 7, town of Wauwatosa — in the banks of Mud Creek, are two low exposures of a shaly limestone, that differs in *lithological character* from both the Niagara limestone, upon which it rests, and the Hamilton cement stone, by which it is overlaid. The rock is a hard, brittle, light gray, magnesian limestone, distinguished by numerous minute, angular cavities, that give to it a very peculiar, porous structure. It is thin-bedded and laminated, by virtue of which it splits very readily into flags and thin plates, which are, for the most part, too brittle, and too much subject to further splitting, to be serviceable as paving, but which are considered valuable for Macadamizing. A transverse fracture of some of the layers exhibits an alternation of gray and dark colored laminæ, peculiarly characteristic of this formation.

The rock is a nearly pure dolomite, as shown by the following analysis, by Mr. Bode:

Carbonate of lime	54.569
Carbonate of magnesia	43.410
Silica	1.494
Alumina	0.211
Oxide of iron	0.316
	100.000

The two quarries are less than half a mile apart, and lie on a nearly east and west line. On this line, a little less than two miles to the east, along the Milwaukee river, a short distance above the Washington street bridge, the Hamilton cement stone is found to rest upon a dark brown, ferruginous rock, that, to casual observation, bears little resemblance to that above described, but which, upon closer inspection, is found to possess, in a large degree, the same peculiar porous and laminated structure, and to differ from it chiefly, in being a little less shaly and much more ferruginous. Its chemical composition is shown by an analysis, by the above named chemist, to be as follows:

Carbonate of lime	54.693
Carbonate of magnesia	41.818
Silica	1.575
Alumina	0.478
Oxide of iron	1.436
	100.000

From this it appears that it differs from the rock upon Mud creek very slightly, except in its content of oxide of iron, which gives to it its dark brown color. There can be no doubt then that this is to be regarded as constituting the uppermost portion of the formation under consideration, which, therefore, immediately underlies the Hamilton strata. The exposure upon the Milwaukee river is very slight, and it is impossible to determine whether there is strict conformability between the Hamilton rock and that under consideration or not. It can only be said that if any unconformability exists, its amount is very slight, as the dip of the strata do not markedly differ.

Extent. These are all the exposures of this rock at present known immediately adjacent to the Hamilton formation. Unfortunately almost the whole of this region is thickly covered with drift, and exposures of rock are exceedingly rare. All the territory that can safely be regarded as occupied by this shaly limestone will be found indicated by gray checks on the accompanying map. As hereafter stated, it is probable from drift evidences that there is a small patch on the north side of the Hamilton area, but its precise location is unknown. It might be presumed that the formation would occupy a belt surrounding the cement rock, a conjecture which has heretofore found expression. But the following facts forbid such an hypothesis. At Schwartzburg, a mile north of the outcrops on Mud creek, rock was reached in the excavation of a cellar, which presents all the lithological characteristics of the Niagara limestone, and contains *Pentamerus ventricosus*, a Niagara species.

In the N. W. qr. of Sec. 10 and the N. E. qr. of Sec. 9, of the town of *Granville*, we find the most northwesterly known exposure of the overlying Hamilton formation, in the brow of a hill facing to the northwest. Only thirty-six paces down the gentle slope, from the Hamilton beds, a pit has been opened which discloses the Niagara limestone. The vertical distance between the top of the Niagara exposed, and the bottom of the quarry of Hamilton rock is about six feet. The intermediate slope is largely occupied with old pits, now filled, but in the material thrown from them, only Niagara and Hamilton rock was seen. In the gutter of the adjacent road, both the Hamilton and Niagara are shown, with a vertical distance of less than five feet between them, and in the abundant chipstone of the gutter, there was none of the shaly limestone under discussion. But it is a rock peculiarly liable to break up into chipstone, and is abundant in the drift near the known outcrops, and in the line of drift from them.

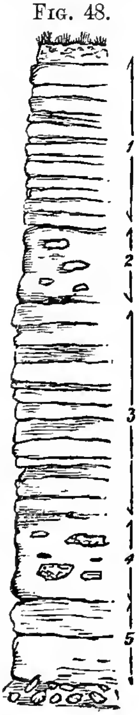
In view of all these facts, the shaly limestone must be regarded as absent at this point. The occurrence of the Niagara limestone along the creek, a half a mile east, near the lower face of the Hamilton formation confirms this view.

We find, however, on the north side of the Hamilton area, some of the shaly rock under discussion in the drift, from which it is probable that there is a concealed area on that side. This harmonizes with the view taken in this report, viz.: that this shaly rock belongs to the Lower Helderberg formation, which is found in Michigan, and absent in Iowa, according to the geologists of those states, and hence, must terminate in the interval, and it would seem that we have here the point of its disappearance. It is certain, at least, that no "narrow circular rim" of the shaly limestone surrounds the Hamilton.

Fossils are very rare in this rock, and I am not aware that any have previously been reported from it. A fair specimen of *Meristella nucleolata*, an *Orthis*, resembling a young *O. oblata*, and an imperfect specimen of *Meristella* or *Pentamerus* were the only reward of repeated and diligent search.

About one mile above the village of Waubakee, in the town of **Fredonia,** Ozaukee county, in the bed of the Milwaukee river, and the vicinity, is a formation that deserves our consideration in this connection. On the north side of the river is a quarry in which the following section is exposed:

FIG. 48.



1. Light gray, thin bedded, shaly dolomite, resembling that above described as occurring at Mud creek, but less porous. The surfaces of some of the layers are covered with large numbers of a *Leperditia*, undistinguishable from *Leperditia alta*	2 ft.
2. A layer of hard dolomite, containing cavities, some 5 or 6 inches in diameter, which are usually filled with large crystals of calcite. *Leperditia* occurs occasionally in this layer	10 in.
3. Alternating thin and thicker beds similar to No. 1 in lithological character, but some layers are marked with a dark, rusty coating	2 ft. 2 in.
4. Similar to No. 2	1 ft. 2½ in.
5. Moderately thick beds somewhat shaly, intermediate in character between the thinner and thicker beds above	1 ft.
Total	7 ft. 2½ in.

The remains of *Leperditia*, found at this locality, are very abundant, literally covering the surface of some layers, and, to a greater or less extent, disseminated through the mass of some of the beds, but unfortunately the state of preservation is poor. A careful examination and comparison of a large number of specimens leaves no doubt that the fossil is *Leperditia alta*, or a very closely related species.

In the bed of the river a little above this locality, very thin beds of a softer, dark dolomite, colored by carbonaceous matter, are found. Some of the layers are marked by numerous black or dark brown carbonaceous laminæ, which give to the rock an appearance quite peculiar. This carbonaceous matter is evidently derived from the remains of plants, many indications of which are present, among them forms resembling *Sphenothallus*. In addition to these, two species of *Orthis* are found, one resembling *Orthis oblata*, and the other closely similar to *Orthis subcarinata*, but smaller. *Pterinea aviculoidea*, or a very closely allied, if not absolutely identical, species, an imperfect *Orthoceras*, and a doubtful *Inocaulis*, are also present.

Farther up the stream, on the opposite side, a quarry has been opened which exhibits a more compact, close textured rock, and one intermediate in lithological character between these and the Niagara limestone. No fossils were found in it, and its relationship is uncertain. Its most striking peculiarity is the strong undulation of its strata, which allies it rather with the Niagara than with the formation under consideration, whose beds have never been observed otherwise than as horizontal and perfectly plane.

The composition of the formation at this point is shown in the following table of analyses by Mr. Bode; No. I being the rock associated with Leperditia; No. II being that in which the cavities filled with spar occur; and No. III being the dark fossiliferous rock from the river bed:

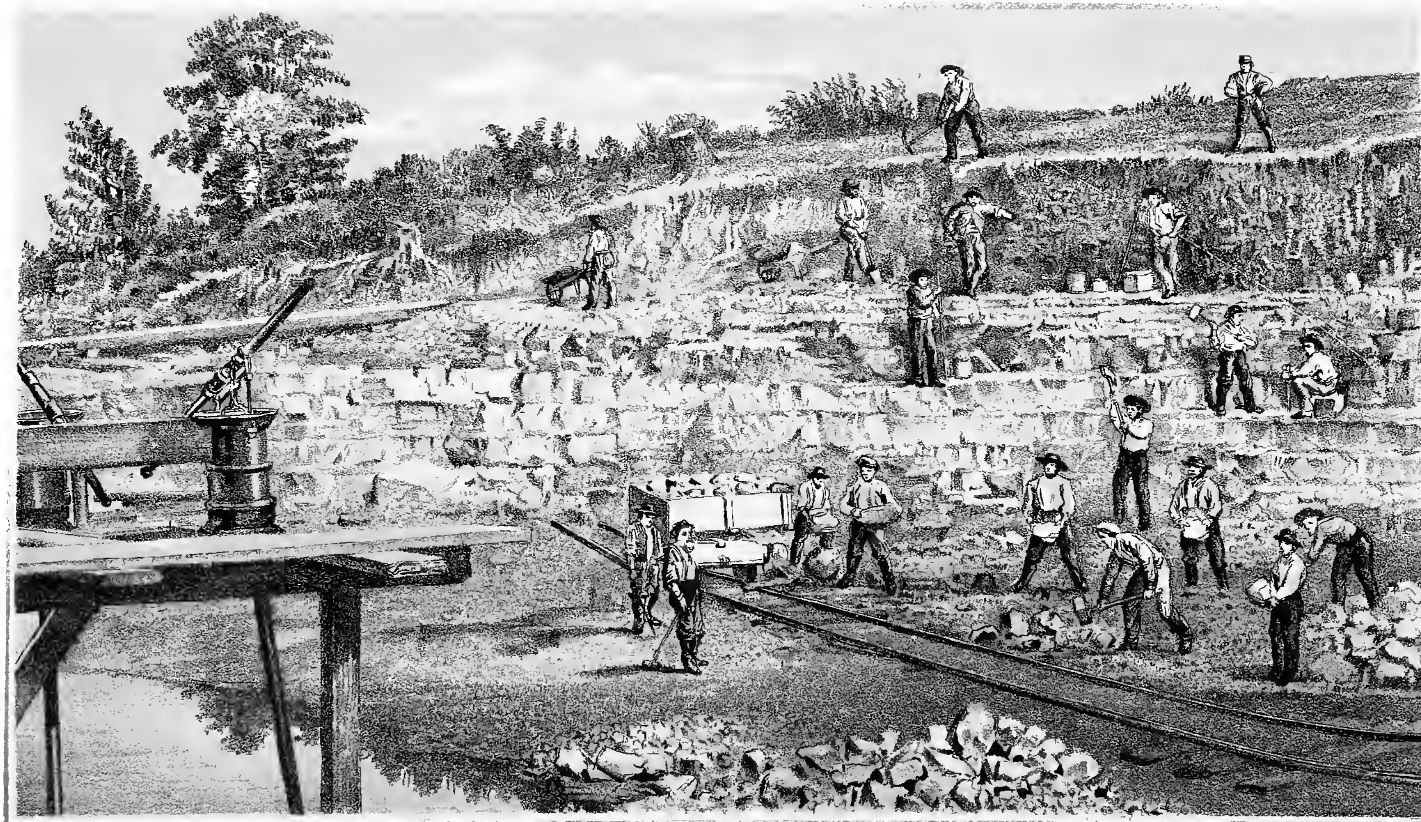
	I.	II.	III.
Carbonate of lime	53.233	56.552	52.786
Carbonate of magnesia	41.573	41.504	43.781
Silica	2.905	1.287	3.094
Alumina	1.462	0.168	0.097
Oxide of iron	0.827	0.495	0.242
Total	100.000	100.006	100.000

It will be observed that they are all essentially dolomites, with a small percentage of impurity, and that in composition they do not essentially differ from the Mud creek rock.

The location of this peculiar deposit adds interest to the problem of its age and relationship. A little more than two miles to the southeast (center E. ½ Sec. 30, Fredonia) is Smith's quarry, where we find a very soft, porous, granular, friable, cream colored dolomite, belonging, undoubtedly, to the Niagara formation. At Newburg, three miles and a half to the northwest, occurs one of the more common varieties of the Niagara limestone. To the south, similar Niagara rocks frequently outcrop. To the northward, there is heavy drift for twenty miles. The deposit under consideration lies at a lower elevation than the rock at Newburg, and at about the same as that at Smith's quarry. It is nine miles distant from the lake, and twenty-six miles distant from the deposit on Mud creek. It is evident from these facts that the stratigraphical relations of the deposit contribute nothing but negative indications, and the question of its *age and equivalency* must rest upon its lithological character and organic contents. While it is evident that neither of these is entirely decisive, yet it is apparent that the weight of their testimony is in favor of referring this formation to the base of the Lower Helderberg group. The same may be said of the formation near Milwaukee. The limited area of these deposits, and their intimate association with the Niagara limestone, taken in connection with the unusual changeableness of the latter formation, both as respects its lithological character, and organic contents, merits consideration however in this connection. On the accompanying maps, the two areas will be found represented by checks of the color of the Niagara formation, at once indicating their relationship to that formation, and their distinction from it.

Economic Considerations. The rock near Waubakee has been burned for lime with fair success. It is not, however, to be recommended for that purpose, since, in the vicinity, dolomites of the Niagara formation of superior quality abound. Certain layers furnish excellent building material, and the thinner beds serve a temporary purpose as flagging, but their tendency to split is detrimental to their durability. The same remarks are true of the formation near Milwaukee. Both are very serviceable for the purposes of Macadamizing, owing to their hardness, and, at the same time, the ease with which they are reduced to the proper form.

PLATE XIIIA



MILWAUKEE CEMENT QUARRY.

CHAPTER IX.

DEVONIAN.

HAMILTON CEMENT ROCK.

The uppermost and newest of the indurated formations of Wisconsin, and the only representative of the Devonian age, is the Hamilton cement rock, near Milwaukee. It occupies a limited area, lying adjacent to the lake, immediately north of the city, and rests in part upon the shaly limestone above described, and apparently upon the Niagara limestone in other portions. In general lithological characteristics, it consists of a bluish-gray or ash-colored, impure dolomite, which weathers, upon exposure, to a yellowish or buff color, owing to the oxidation of the iron which constitutes one of its ingredients. The impurities consist chiefly of silica and alumina. The rock is characterized in certain portions by the occasional presence of cavities, in which occur crystals of iron pyrites and calcite, and, very rarely, zinc blende. Crystals of the two former minerals are disseminated more or less through certain portions of the rock. In texture, it is somewhat varying, being quite homogeneous in some layers, and quite irregular and lumpy in others, while the chemical composition changes much less markedly, though sufficiently to affect the hydraulic properties of the rock. In degree of induration, it ranges from rather soft to moderately hard. The beds are usually thick, with the exception of some portions, which are somewhat shaly. The general aspect of the bedding and stratification is well shown in the accompanying chromo-lithograph.

The chemical composition of the typical portion is very fully indicated by the accompanying table of analyses of cement rocks, in which will be found eight analyses of the rock from the Milwaukee river, the selections and determinations being by different parties.

ANALYSES OF CEMENT ROCKS.

KIND OF ROCK.	Authority for analysis.	Carbonate of lime.	Carbonate of magnesia.	Total carbonates.	Silica.	Alumina.	Oxide of iron, etc.	Total silica, alumina, iron, etc.
Milwaukee, No. 1	Bode	45.54	32.46	78.00	17.56	1.41	3.03	22.00
Milwaukee, No. 2	Bode	48.29	29.19	77.48	17.56	1.40	2.24	21.20
Milwaukee, Layers 2–6	Bode	47.55	30.91	78.46	13.74	3.95	3.85	21.54
Milwaukee, Layers 7–11	Bode	47.09	24.95	72.04	18.77	5.14	4.05	27.96
Milwaukee, Layers 2–11	Bode	45.44	31.27	76.71	15.65	4.60	3.04	23.29
Milwaukee	Doremus	45.57	27.67	73.24	15.60	.12	.38	27.98
Milwaukee, Wash. St. bridge	Bode	41.34	34.88	76.22	16.99	5.00	1.79	23.78
Milwaukee, Wash. St. bridge	Bode	40.05	35.82	75.87	17.00	5.00	1.80	23.80
Milwaukee, average		45.11	30.89	76.00	16.61	4.09	3.25	24.00
Rosendale, New York	Gilmore	46.00	17.76	63.76	27.70	2.34	6.20	36.24
Utica, Illinois	Gilmore	50.42	18.67	69.09	21.60	5.27	4.04	30.91
Utica, Illinois	Reid	58.84	15.38	64.22	25.20	6.16	4.40	35.76
Akron, New York	Gilmore	35.60	19.26	54.86	33.80	3.96	7.38	45.14
Akron, New York	Reid	35.60	19.26	54.86	33.80	3.96	7.38	45.14
Sandusky, Ohio	Reid	40.54	17.98	58.52	19.66	3.14	5.36	40.26
Points aux Roche, L.Champ'n	Reid	53.30	22.60	75.90	20.07	1.70	1.70	23.44
Cumberland, Maryland	Gilmore	41.80	4.10	45.90	21.74	16.74	15.30	56.78
English	Berthier	65.70	0.50	66.20	18.00	6.60	8.80	33.40
Bologne, France	Drapies	61.60	0.00	61.60	15.00	4.80	15.60	35.40
Vassy, France		63.80	1.50	65.30	14.00	5.70	15.00	34.70
Theil, France	Reid	60.00	1.32	61.32	18.20	1.20	11.28	30.68

Organic Remains. The Hamilton period marked a new era in the history of the life of the Wisconsin formations. While multitudes of Protozoans, Radiates, Mollusks and Articulates lived in the Silurian seas, and left their remains embedded and embalmed in the accumulating sediments, whether of sandstone, shale or limestone, no fragment or trace of a Vertebrate has been found. The Hamilton period witnessed the introduction of this highest type of the animal kingdom into the Wisconsin series. In other portions of America, the remains of Vertebrates appear somewhat earlier, in strata wanting in our state, and, in the deposits of Europe, still earlier. The vertebrate remains of this formation are confined to the relics of fishes, and, unfortunately, these are fragmentary and imperfect. They have been submitted to the inspection of Dr. J. S. Newberry, a most eminent authority in this department of paleontology, who finds them to be new and unknown species. They consist of fragments of the teeth of Chimæroids and a plate of a Placoderm. Only one specimen is sufficiently well preserved to justify description, and being thus exceptional in character, may merit the partiality of delineation here. The following is the description of Prof. Newberry:

Rhynchodus excavatus. Newberry.

Tooth small, when entire, perhaps two and a half inches long by one and a quarter inches deep; crown alone preserved. Of this, the external surface is marked vertically with vermicular furrows; superior margin sinuous, terminating anteriorly in a prominent point; the superior surface irregularly excavated and roughened, showing two prominent points, or tubercles, one on the middle of the exterior margin, the other on the inner margin, and near the anterior extremity. The inner surface of the tooth shows a prominent ridge, running up to the anterior point. This tooth is evidently fitted for trituration rather than cutting, and resembles, in its general form, *R. frangens* of the Corniferous limestone. It is, however, much smaller and thinner, and the tubercles of the upper surface are differently situated from what they are in the tooth of that species.

Locality and Formation. Hamilton Group. Brown Deer, Milwaukee county, Wisconsin.

In addition to the fish remains, there are the following invertebrates: Of Bryozoans, a *Fenestella* and a tuberculated *Trematopora* occurring in massive and frondose forms; of Corals, the cast of the cup of a *Cyathophyllum*; of Brachiopoda, a new species of *Lingula*, and also one of *Discina*, *Orthis impressa*, and an undetermined *Orthis*, *Strophodonta demissa*, *S. perplana*, *Chonetes coronata* and a species closely resembling *C. deflecta*, a *Productella*, allied to *P. spinulicosta*, *Spirifera mucronata*, *S. medialis*, *S. granulifera*, *S. fornacula*, *S. pinnata*, a species allied to *S. fornacula*, but larger and one near *S. angusta*, *Spiriferina zigzag*, *Cyrtina Hamiltonensis*, *Trematospira hirsuta*, *Atrypa reticularis*, *A. occidentalis*, *Leiorhynchus*, resembling *L. Kelloggi*; of Lamellibranchs, a *Pteronites*, *Palæoneilo constricta*, *P. emarginata*, a species allied to *P. plana*, *Modiomorpha concentrica*, and an undetermined species; of Pteropods, an *Ecculiomphalus*, closely resembling *Euomphalus laxus;* of Cephalopods, two new species of *Gomphoceras*, and an *Orthoceras;* and of Crustaceans, *Phacops rana.*

These show a preponderance of Hamilton forms, some of which are highly characteristic species, and occur in great abundance. With these are mingled a number of Corniferous species, representing a lower horizon, and a few Chemung forms belonging to a higher series.

Age. The foregoing fossils are entirely decisive as to the age of the formation, and place it in the early portion of the Hamilton period. This is entirely in harmony with its stratigraphical relations and with the general geological structure of the interior of the continent, since, eastward from Wisconsin, there intervenes between the Hamilton strata and the Niagara series, the lower Devonian and the uppermost Silurian formations; while to the westward, in northern Illinois and Iowa, the Hamilton beds rest directly upon the Niagara group. The intermediate formations thin out and disappear, and, as already indicated, the vanishing edge of the Lower Helderberg strata barely reaches the eastern margin of our state. The mingling of Corniferous species from below with Chemung forms from above is not age of the only an interesting fact in itself, but is one whose bearing upon the deposit is most significant and decisive, and establishes the correctness of its reference to the Hamilton period.

Local Descriptions. The most extensive and important outcrop of this formation is found along the Milwaukee river, in the vicinity of **Washington Street Bridge**, extending above and below, in Secs. 4 and 5, T. 7, R. 22 E. The rock nowhere rises to any considerable height above the river-bed, so that no extensive vertical section can be seen, and the frequent interruptions of the exposure, as traced along the river, prevent any trustworthy correlation of the strata. The lithological characters of the rock at this point are essentially those before given as general characteristics, and this locality may be regarded as the typical one of the formation. A portion of the layers found west of the bridge are more shaly than the average rock of the formation, and tend to disintegrate somewhat more readily on exposure. A stratum found below the bridge possesses a more granular character than the rest of the formation, but the chemical analyses that have been made of the several portions, indicate that these variations are largely of a physical nature, and that the chemical composition is less varying. In the drift lying upon this rock, an abundance of black shale is present in thin, fragile, more or less rounded chips, indicating the near presence of the formation from which they are derived, and which may be conjectured to be the overlying black slate, so abundant in other regions. No exposures of this rock have, however, been discovered in Wisconsin, but as this region is extensively covered with drift, it is not impossible that they exist.

Nearly all the species of the foregoing list have been found at this locality, notwithstanding the limited extent of the exposure, and indicate a rich and abundant fauna. The working of the beds, which has been commenced since this collection was made, and the importance and interest which now attaches to the formation will, doubtless, very much increase the number of species now given, and develop specimens which will more fully elucidate the structure of some that are now imperfectly represented.

In section 11, town of Granville, a railroad cut just south of the flag station, known as **Brown Deer,** exhibits a few feet of this formation. The original lithological characters are essentially those already described, but the rock of this locality has been more extensively weathered than that near Washington Street bridge, and presents a buff color, except in the interior of some of the heavier layers, and is also somewhat decomposed in certain portions. This is the typical locality of the Chimæroid fish, *Rhynchodus excavatus*, previously described, and with it are associated the leading forms of the general list above given, prominent among which are *Orthis impressa, Strophodonta demissa, S. perplana, Sperifera pinnata, S. medialis, Speriferina zigzag, Atrypa reticularis, Palæoneilo constricta, Modiomorpha concentrica*, and others. It is stated that in the bed of the Milwaukee river opposite this point, the formation exists in place; but it was not accessible at the time of our investigations.

In **sections 9 and 10** of the same township, occurs the most northwesterly exposure of this formation now known. It occupies the brow of a hill, underlaid by limestone belonging to the Niagara formation. The rock is here a rather soft, granular, buff, impure dolomite, much stained with iron, doubtless due to the decomposition and oxidation of pyrites, originally disseminated through it. *Orthis impressa, Strophodonta demissa, Spirifera pinnata, Atrypa occidentalis*, and *A. reticularis*, show the character of the fauna.

Along the lake shore, on **Whitefish Bay,** the formation rises slightly above the water level in a very limited exposure. The strata at this point have a firmer texture, but more uneven structure, than at the previously named localities. The lines of deposition and bedding are irregular. Angular cavities of moderate size are not unfrequent, some of which are filled with a semi-fluid, tar-like bitumen. An analysis of this rock by Professor Daniells shows it to have the following composition:

Carbonate of lime	49.12
Carbonate of magnesia	38.76
Sulphate of lime	0.07
Phosphate of lime	trace.
Sulphur	trace.
Silica	8.59
Sesquioxides of iron and alumina	3.51
	100.05

From this it will be seen to have much less silica and alumina than the beds on the Milwaukee river.

The following species were collected at this point: *Orthis impressa*, *Strophodonta demissa*, *S. perplana*, *Sperifera medialis*, *S. pinnata*, *Atrypa reticularis*, *Palæoneilo constricta*, *P. emarginata*, *Modiomorpha concentrica*, two new species of *Gomphoceras*, *Phacops rana*, and several imperfect forms belonging to the genera *Cyathophyllum*, *Lingula*, *Spirifera*, *Palæoneilo*, *Modiomorpha* and *Ecculiomphalus*, and the plate of a Placoderm fish.

Economic Considerations. The credit of first calling attention to the hydraulic properties possessed by the rock of this formation belongs to the late Dr. I. A. Lapham, who, some years since, directed attention to it as probably possessing the property of hydraulicity. In an article prepared for Walling's Atlas of Wisconsin, under date of July, 1874, he called attention to the geological relation existing between this rock and the water-limestone of Louisville, Ky., with a suggestion as to its possessing the same useful qualities. The first investigations upon the part of the geological survey were made by the party under my charge, between the 5th and 12th of June, 1874, and specimens were sent to the chemist of the survey for analysis on the latter date, but owing to the crowded state of that department, analyses were not received until the following year. The investigations of Dr. Wight upon the same subject in the year 1875 are fully stated in his Annual Report. The credit of demonstrating by actual tests, the unusual hydraulic excellence of the rock of this formation, is due to the gentlemen constituting the Milwaukee Cement Co., and to Mr. D. J. Whittemore, Chief Engineer of the C., M. & St. P. R. R. To these gentlemen I am under obligations for the following facts, relating to their interesting and important investigations:[1]

The first series of experiments of Mr. Whittemore to determine the quality of this rock as a cement stone, and the strength and value of the product, extended continuously over nearly one year and a half, and embraced about 1,500 individual tests, and perhaps an equal number has been made by him and other competent gentlemen since. These experiments were conducted according to standard methods, with excellent apparatus, and appear to have been characterized by impartiality in selection, and conscientious care in manipulation. The results obtained from the commercial cements with which comparison was made compare very favorably with those obtained by other competent experimenters upon the same products, which indicates that the selection was a fair one, and as the several samples were subjected to the same processes, the results possess much more value than if

[1] See a paper read before the Fortnightly Club of Milwaukee, November 4, 1875, by Don J. Whittemore, of which the following is little more than an abstract.

the data, with which comparison is made, were compiled from trials made at various times, and under varying conditions and manipulation.[1] The Milwaukee cement was prepared by calcination in crucibles with varying degrees of torrification, and, in the absence of experimental knowledge of the peculiarities of the rock, it cannot be supposed that the maximum of good results was secured. Mr. Whittemore expresses the opinion that, with proper care, a better commercial article than the one used might be manufactured.

The commercial cements were obtained as fresh as possible from the stock in the market, a selection being made from large quantities, and only those used, that, upon trial, were found to be of good quality. To secure uniform fineness, only that portion of each product was used that passed through a sieve of 2,704 meshes to the square inch.

The following table shows the tensile strength in pounds per square inch of mortars of clear cement, seven days old, the last six in water; also of mortars composed of equal weights of cement and sand at 90 days, the last 89 in water:

Kind of Cement.	Tensile Strength, in Pounds per Square Inch, of Mortars Composed of	
	Clear cement, seven days old.	Equal weights of cement and sand, ninety days old.
Commercial Cements—		
No. 1	95	194
2	77	185
3	38	152¼
4	97	270
5	107¼	195
7	139⅓	204½
8	44	....
9	36	140
10	94½	182¾
11	95	280
12	98⅓	149
13	90	157
14	70½	196⅔
15	101	190
16	98	202¾
Milwaukee Cement	96	290

In the above table, the result for the Milwaukee cement was ob-

[1] Those who may wish to compare the results obtained by Mr. Whittemore with those of others will find the means of doing so in Gen. Q. A. Gilmore's standard work on Limes, Hydraulic Cements and Mortars.

tained from the average of separate tests of two samples taken from widely different parts of the outcrop on the Milwaukee river, and calcined, one four, and the other three hours, and from a mixture of these calcined for two and a half, three, three and a half, four, and four and a half hours, respectively. The results indicate a convenient latitude in calcination, which is an important consideration in securing a uniformly reliable commercial product.

To ascertain the breaking stength of the cement, rectangular bars one inch square, in cross section, and four inches long, were prepared, from the several samples tested, in a precisely similar manner, and allowed to set under an end pressure of 32 pounds; when they were removed and kept one day in air and ninety-nine in water. They were then broken by resting them upon supports four inches apart and applying weight gradually at the center. The results are given in the following table:

BREAKING STRENGTH OF CEMENT MORTARS.

KIND OF CEMENT.	WHITTEMORE.		YARDLEY.	
	Cement 2 Sand 1	Cement 1 Sand 2	Cement 2 Sand 1	Cement 1 Sand 2
Commercial Cement, No. 1	54	28½	....	....
....do........do... 3	59	44½	....	....
....do........do... 4	98½	44½	64	32
....do........do... 7	100	47	70	33
....do........do... 10	59	44¾	....	....
....do........do... 11	107	56½	62	20
Milwaukee Cement calcined 2½ hours..	119⅓	89½	....	....
....do........do.......... 3 hours...	120¾	75¼	....	....
....do........do.......... 4 hours ..	119½	57½	....	....
....do....... do..mixture (before mentioned)	138	55	....	....
Milwaukee cement, average	124	69		

From the above, it will be seen that the average breaking strength of the Milwaukee cement is 16 per cent. higher than the best result obtained from the six commercial samples tested, when the proportions were two of cement to one of sand, and 22 per cent. when the proportions were one of cement to two of sand. The average of the Milwaukee cement exceeds the average of the commercial cements by 56 per cent. That this difference is not due to inferiority in the commercial cements used by Mr. Whittemore appears from a comparison with the results of tests made by Edward Yardley, C. E., reported in the transactions of the American Society of Civil Engineers for 1872, and given in the table above. Mr. Yardley's specimens were of similar form, composition and age, but were made plastic like mason's mortar, while Mr. Whittemore's were all made stiff. Making all due allowance for this, it still appears evident that Mr. Whittemore used a superior selection of commercial cements.

For determining the crushing strength, cylinders of mortar having a base area of one square inch, and a height of one inch, were formed from the several cements, and kept under a pressure of 32 pounds until set, when they were kept in a dry room one day, and then immersed for 89 days in water, when they were crushed, several samples of each being used. The following table gives the results obtained:

CRUSHING STRENGTH,

In pounds per square inch, of cement mortars, 90 days old, the last 89 in water.

Kind of Cement.		Composition of Mortars.					Aggregate of 1 to 1, 1 to 2 and 1 to 3.	Value.
		Clear Cement.	3 to 1.	1 to 1.	1 to 2.	1 to 3.		
Commercial	No. 1	2,775	1,930	884	299	128	1,311	33
	No. 2	2,200	1,614	794	337	180	1,311	33
	No. 3	2.028	1,661	1,071	417	233	1.721	43
	No. 4	3.302	2,767	1,536	802	524	2,893	70
	No. 5	2,983	2,150	939	742	472	2,153	54
	No. 6	3,479	3.060	1,590	895	615	3,100	77
	No. 7	4,742	3,475	1,737	843	625	3,205	80
	No. 8	2,767	2,396	1,596	1,068	571	3,235	80
	No. 9	3,789	3,156	1,900	955	586	3,441	85
	No. 10	3,247	2,981	2,075	1,208	750	4,030	100
	No. 11	5,019	3,572	2,130	1,192	681	4,003	100
Milwaukee	A	....	....	2.340	1,596	1,083	5,019	125
	B	3,705	3,691	2,146	1,261	1,127	4,534	114
	C	3,887	3,321	2,478	1,467	1,083	5,028	125
	B and C Mixture	3,704	3,469	2,497	1,479	1,135	5,111	128
Portland		5,330	4,630	3,356	1,769	792	5,917	148

By an inspection of the above table, it will be seen that in the strength of the clear cement, the commercial articles Nos. 7 and 11 surpass the Wisconsin product, but as the admixture of sand is increased, the relative superiority of the latter becomes very conspicuous. It appears that the larger the proportion of sand, the greater the *relative* value of the Milwaukee cement. Since cement is usually used with at least an equal quantity of sand, the columns in the above table that give the proportions of 1 to 1, 1 to 2, and 1 to 3, indicate the practical value of the products examined, and they therefore are combined in the sixth column of the table. The last column gives in a more convenient form the value of the several cements for the proportions indicated, the two best commercial cements being taken as a standard of comparison, and expressed by 100. It will be observed that the average of the tests of the Wisconsin product, exceeds the highest of the commercial articles by 23 per cent., and exceeds the average of the eleven, which represent the relative strength of the cement in the Milwaukee market, by 54 per cent. The remarkable imported cement, known as Portland, was included in these tests, and the results are given in the table. As it is extensively used in Europe, and has been submitted to a great many trials, its character and value are well known to engineers and experts, and it therefore furnishes a valuable standard of comparison. Within the proportions named above, the Wisconsin cement surpasses the best of the commercial cements almost as much as it is surpassed by this unrivalled artificial European product.

It remained to test the adhesive strength of this mortar, and for this purpose Mr. Whittemore joined common brick crosswise with mortar composed of equal parts of cement and sand, and kept them under a pressure of five pounds per square inch, until the mortar had set, when the brick were packed in damp sand for seventy days, and then were separated by tensile strain, with the following results:

Commercial cement No. 1	39¾
" " " 2	59
" " " 3	16
" " " 4	27⅔
" " " 6	41¾
" " " 7	54½
" " " 8	41¾
" " " 10	66
" " " 11	63½
Average of commercial cements	45½
Average of three products of Milwaukee cement	75½
English Portland	47½

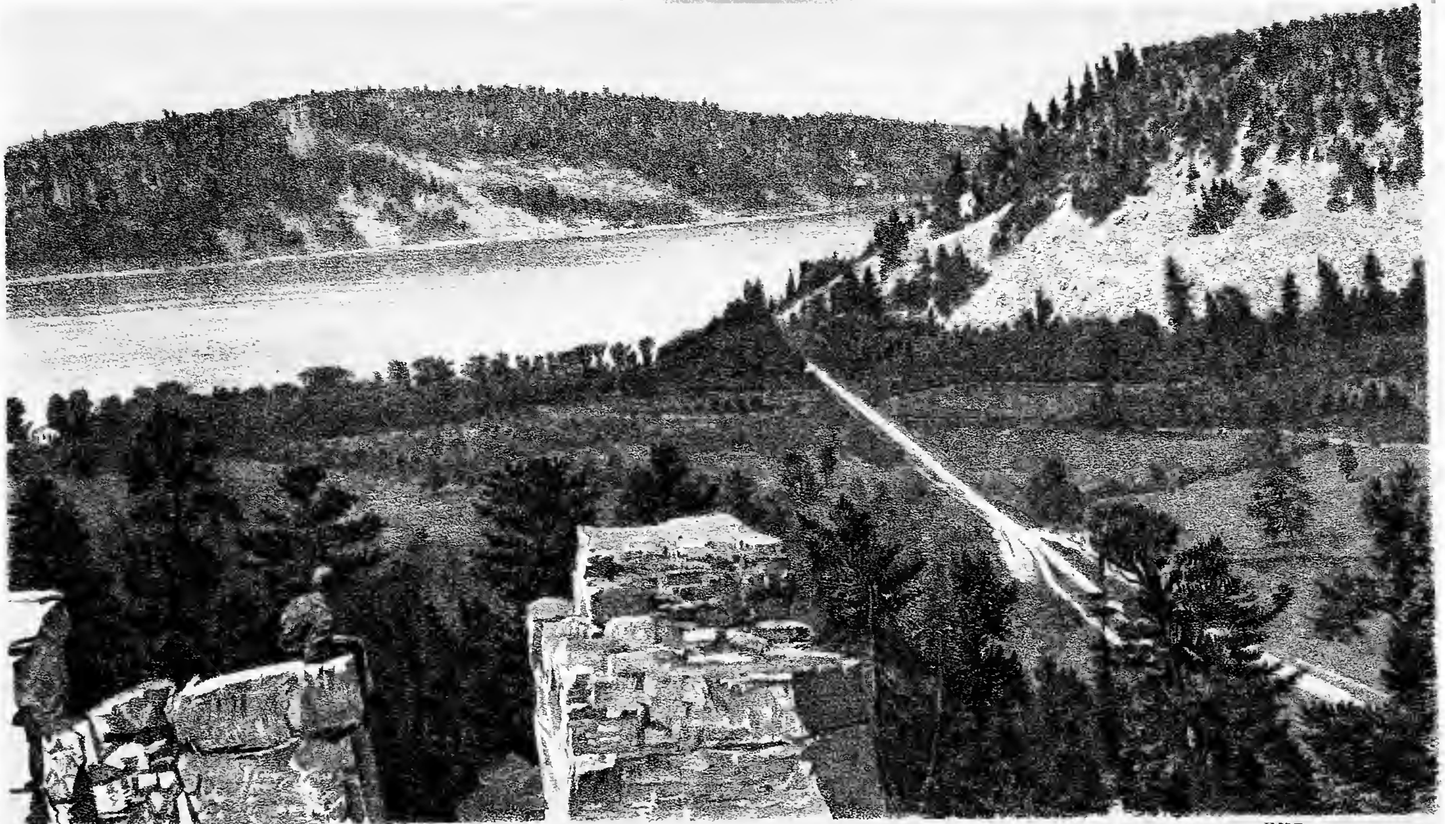
In many instances, the result only shows the cohesive strength of the brick, since after a strain of 60 pounds is reached, the brick is often ruptured instead of the mortar.

Sawn slabs of marble treated in a similar manner showed an adhesive strength of 53¾ pounds, when joined 96 days. The rate of induration was ascertained by crushing cylinders composed of equal parts of cement and sand, at the end of every five days up to ninety. The following series indicates the strength, in pounds, per square inch, attained, beginning at the age of five days and ending at ninety: 403, 837, 1,178, 1,519, 1,953, 2,418, 2,635, 2,759, 2,867, 2,976, 3,068, 3,162, 3,255, 3,332, 3,410, 3,487, 3,571, 3,658.

Gen. Q. A. Gilmore, U. S. A., the highest authority upon this subject in this country, gives as the average tensile strength of the Milwaukee cement, at the end of *seven days*, 64⅛ pounds to the square inch, and that of the standard brands of five of the Rosendale companies at 47 pounds. He also informs me that the commercial product of the Milwaukee stone, used under his direction at Washington city, for making concrete, produced excellent work. Similar testimony is given by others who have used the cement. The excellence of the product may therefore be regarded as established.

Four large kilns, with a mill and accessory works, have been already constructed and put in successful operation. The extent of the deposit is abundantly sufficient for all anticipated wants, and its location is convenient and accessible. The description of so interesting and important a resource forms a fitting close for our discussion of the geology of Eastern Wisconsin.

PLATE, XV



The Milwaukee Litho.& Engr. Co

H.H.Bennett, Photo.

ARCHAEAN,

Devils Lake from the South Bluff, Kirks Bluff on the right 475 ft. high.

PART III.

GEOLOGY

OF

CENTRAL WISCONSIN.

BY ROLAND D. IRVING.

INTRODUCTION.

The following report covers a region having an area of about 10,000 square miles, and is the result of something more than nine months, in all, of field work. The greater part of this was done in the seasons of 1874 and 1875, my work during the other years of the existence of the survey having been in the Lake Superior country, which will be treated of in a subsequent volume.

The district now reported on, including the central counties of Wisconsin, is nearly one-fourth larger than the state of New Jersey, whose third geological survey has been in progress from 1864 up to the present time, and has issued, besides numerous annual reports, a large volume of nine hundred pages, and an atlas of maps. Prof. Geikie, director of the geological survey of Scotland, has recently made the statement, in a public lecture, that the average annual amount of ground gone over by each geologist of that survey is about one hundred square miles, this amount of labor being performed by an average daily walk of ten to fifteen miles, in a year of two hundred days in the field. At the same rate, an examination of the Central Wisconsin district would require over one hundred years of continuous work. These statements are made in order that a fair judgment may be passed upon the results accomplished, as compared with those of the surveys of other states and countries, and in order that it may be understood that no claim is made of having made an exhaustive survey of the district reported upon.

Geological mapping is accurate, *ceteris paribus*, exactly in proportion as the geographical maps used as a basis are accurate. One great advantage enjoyed by the surveys of Great Britain lies in the almost absolute accuracy of the celebrated Ordnance Maps of that country, which are drawn on a scale of six inches to the mile, and show every topographical feature, road, and house, with such faithfulness that the geologist has little more to do than to mark upon them outcrops as fast as found. In the United States, the only maps having any genuine claim to accuracy are those of the coasts of the continent, and of the shores of the great lakes, made by the government triangulation surveys, and even these are, for the most part, on too small a scale to be of much use in geological mapping. Nevertheless, in this regard, we have in Wisconsin a great advantage over most of the older states of the Union, in the possession of the United States Linear Surveys, which have divided the whole state up into townships of thirty-six square miles, and these again into sections of one square mile each. Plats of each township are always to be obtained, drawn to a scale of two inches to the mile, and showing marshes, prairies, streams, and timber land; all of which are pretty closely correct where crossed by the section lines, though elsewhere only roughly approximate. With these maps, a little trouble suffices to locate outcrops with considerable accuracy, and the task becomes still easier in the case of those few counties of which there are atlases showing the locations of roads and houses. Notwithstanding the size of the district, and the shortness of the field work, it is believed that the maps accompanying this report will compare favorably in closeness of detail with those made of any other states in the Union.

The present report is the only comprehensive one ever made on the area included within the Central Wisconsin district, the greater part of which has, indeed, never before been geologically examined, although a number of reconnoissances along certain lines have been made in former years. About 1847, Dr. Randall, one of the corps of the United States survey of Wisconsin, Iowa and Minnesota, under Dr. D. D. Owen, made a trip along Black river from the falls to the Fourth Principal Meridian. His observations occupy two or three pages in Dr. Owen's final report,[1] and are accompanied by one or two colored sections. In the same year, Dr. J. G. Norwood, another of Dr. Owen's corps, made a canoe trip along the Wisconsin from its source to Sauk City. His observations, in the form of an itinerary, cover about fifteen pages[2] of the same volume, which includes also about twelve pages[3] by Dr. B. F. Shumard on the valley of the Wisconsin below Portage. In 1855, Dr. J. G. Percival, then state geologist, spent five months in making a general reconnoissance of the entire state, visiting all but twelve counties. His report on this reconnoissance, printed after his death in May, 1856, covers about fifty pages, in which each formation is taken up in regular order. Whilst this report is tinctured somewhat with the older ideas, and some of its statements have been since proved erroneous, and although Dr. Percival did not have the advantages of the latest discoveries in the science, and of the light now to be obtained from the geological reports of adjacent states, nevertheless his general summary of the geology of the state, so far as my observation goes, is an exceedingly faithful one. The report was published only as a small pamphlet, and has never received the credit it deserved. How far the survey under Mr.

[1] Owen's Geological Survey of Wisconsin, Iowa and Minnesota, p. 151.

[2] *Ibid*, pp. 277–293. [3] *Ibid*, pp. 510–522.

James Hall, in 1858–1861, extended into the Central Wisconsin district, I have no means of knowing, since no reports were ever published, except that on the lead region by Prof. Whitney. The large geological chart of Canada and the northern United States, issued by the Canadian Geological Survey, gives some quite accurate details with regard to the distribution of the Lower Silurian formations of Central Wisconsin, and as these were contributed by Mr. Hall, they would seem to indicate that a good deal of work was done by his survey that was never published.

Future surveys will, beyond doubt, make farther and more detailed observations than now submitted, points now in doubt will be cleared up, and new generalizations, now unthought of, will be made. Amongst those points that now appear especially to need further investigation, may be mentioned the detailed structure of the Archæan terranes of the northern part of the district, and the question as to the existence of two distinct formations within what is now called the the Potsdam sandstone series, the one resting upon the eroded surface of the other. The first of these can be fully attained only by an exhaustive traversing of the unsettled regions on foot, the location of every outcrop, and the microscopic examination of all specimens. The Archæan ranges of the Baraboo valley, too, deserve a more detailed study, and such a one as can only be given by the most thorough traversing on foot.

The general arrangement of this report, by geological formations, seems to be the only logical one. A complete arrangement by counties involves a great deal of repetition, and renders a report far less intelligible to those outside the state. Nevertheless, it has not been thought best to carry the geological arrangement too far, and the local details are, therefore, arranged geographically, so that information with regard to any particular locality may be the more readily found. Moreover, in giving details with regard to the several Silurian formations, these have been grouped together, because in much of the district the areas occupied by them are so interwoven that any attempt to give the details with regard to each separately would result only in confusion. It is a matter of great regret, to me at least, that the small space necessarily assigned to this report has rendered it impossible to print all of the manuscript prepared. The pages thrown out include a detailed topographical and geological description, by townships, of most of the Silurian portion of the district; and the plan of the report is marred by the omission. An Appendix on Artesian Wells and a Chemical Appendix, in which are tabulated, with additions, the analyses cited in the following pages, for the most part the work of Mr. E. T. Sweet, are also crowded out.

The parenthetical numbers of the detailed descriptions of this report are those of specimens representing the rocks described. These specimens will be distributed, according to law, to different institutions in the state, and will be much more valuable for being cited here.

It remains to make acknowledgments for aid received in the prosecution of the field work, and in the preparation of this report.

Mr. E. T. Sweet, M. S., a graduate of the State University, aided me in the field work throughout the season of 1874, and during much of that of 1875. Several of the towns in Dane county were mapped wholly by him, besides which he made many independent observations in other parts of Dane county, and in southeastern Columbia county Mr. Sweet also aided greatly in the chemical work, having been thus employed especially during the winter of 1875–6. With very few exceptions all of the analyses given in this report are Mr. Sweet's work, and full credit is given him here for them.

The late James H. Eaton, Professor of Chemistry and Mineralogy at Beloit College, aided me in the field work during about two months in each season, his services being given for his expenses only. His faithful observations, more especially with regard to the Glacial Drift, have contributed much to the material of this report. It is no exaggeration to say that in Professor Eaton's death the state has lost the best trained and most accomplished, and at the same time one of the most conscientious and painstaking of its scientists.

In the latter part of 1875, Mr. G. C. Synon, B. S., was my aid in the field work. Messrs. Oliver Matthews and W. A. Hover, of the Metallurgical Department of the State University, have both given aid gratuitously in field work, and in making analyses. Analytical determinations have also been made gratuitously by Mr. A. C. Prescott, in the University laboratory. Messrs. J. P. Paine, A. D. Conover, and P. L. Norman have aided me in preparing the cuts and plates for this report. Mr. W. H. Canfield, of Baraboo, for many years a surveyor in Sauk county, furnished me with a map of that county, on which he had marked, from personal observation, the location of quartzite outcrops, thus greatly lessening my own labor. I should also add that Mr. Canfield's topographical map of Sauk county has been of great assistance in outlining the formations. The citizens of the region generally have aided me greatly.

This report has been nearly all prepared, including illustrations, and the examination of between two and three thousand specimens, during the year ending June 1, 1877, for the most part whilst engaged in teaching several hours a day; and the task has not been a light one.

UNIVERSITY OF WISCONSIN, *June 2, 1877.* R. D. I.

GEOLOGY OF CENTRAL WISCONSIN.

CHAPTER I.

SURFACE FEATURES OF CENTRAL WISCONSIN.

The region here designated as Central Wisconsin includes Columbia, Marquette, Waushara, Adams, Juneau, Wood, Marathon, Clark and Jackson counties; all of Dane and Sauk counties except the western tier of towns in each; and also that portion of Green Lake county which lies north of the Fox river. The Atlas plates of Areas D, E, F, and H, apply in part or wholly to this region.

RIVER SYSTEMS AND GENERAL SURFACE SLOPES.

Disregarding the small areas in Clark and Jackson counties which drain into the Chippewa and Trempealeau rivers, the region may be said to include portions of four distinct drainage systems: those of the Wisconsin, Black and Rock rivers, which flow southward and westward to the Mississippi, and that of the Fox river, which flows northward and eastward to Lake Michigan, and is thus tributary to the Saint Lawrence.

The directions and areas of these river systems are more or less directly influenced by the rock structure of the state. Extending into Wisconsin from the Upper Peninsula of Michigan, and forming the central nucleus of the northern half of Wisconsin, is a great mass of ancient crystalline rocks, which is bordered on all sides by newer and undisturbed formations, whose outcropping edges, on the south, east, and west, succeed one another in concentric bands. The central crystalline mass, probably for the most part never covered by later formations, includes the highest land in the state. It has a general slope to the southward, reaching its greatest elevation — 1,000 feet above

Lakes Michigan and Superior — along its northern edge, within thirty miles of the latter lake. The waters which fall upon it are shed in four different directions: to the north, into Lake Superior; to the southeast, into Lake Michigan; to the south, into the Wisconsin — which ultimately reaches the Mississippi; and to the southwest directly into the Mississippi. The northward streams, which interlock on the summit of the divide with those flowing southeast, south, and southwest, and descend in a distance of thirty miles nearly a thousand feet, are entirely without the region at present under consideration. Of the streams flowing southwestward, only the Black river drains any considerable portion of the region, whilst the southeasterly streams are mostly outside of its limits. Some of the latter pass directly to Lake Michigan, whilst others concentrate into the stream known as the Wolf, which, after leaving the area of crystalline rocks, takes a southerly course until it meets the northward flowing Fox. The two, uniting, pass through Lake Winnebago northward to Green Bay. The systems of the upper Fox and of the Rock, though less immediately under the influence of the Archæan watershed of the north part of the state, are still directly affected by the geology of the regions they drain, the waters of the upper Fox being shed to the east by the high sandstone and drift region of western Marquette and Waushara counties, and to the north by the high limestone belt which runs southwestwardly through Green Lake and Columbia, whilst the tributaries of the Rock river are shed southeastward by the same limestone belt. Although traced thus directly to other influences, the drainage areas and general surface slopes of the southern half of the state are still in some degree ultimately attributable to the position and shape of the Archæan nucleus. Whilst the southern region retains the general slope southward of the crystalline rocks in the north, it also shows the same eastward and westward slopes from a central north and south line. This seems without doubt to be due to the continuance, beneath the Paleozoic accumulations, of the Archæan mass with the same surface structure as on its exposed portions, *i. e.*, a central north and south crest line, itself sloping southward, from which there are eastward and westward slants.

Of the whole area of the Central Wisconsin district, the Wisconsin drains about 160 townships, including the eastern part of Clark, nearly all of Marathon, a small part of eastern Jackson, nearly all of Wood and Portage, all of Juneau, nearly all of Adams, all of Sauk, about half of Columbia, and a few towns in northwestern Dane; the Black river drains about 41 townships, including about half of Clark, nearly all of Jackson, and a small area in the western part of Wood; the

Fox drains about 49 townships, including the easternmost part of Marathon and Portage, almost all of Waushara, all of Marquette, southeastern Adams, about four townships in northern Columbia, and all of Green Lake within the district; and the Rock drains about 31 townships, including eastern and southwestern Columbia, and nearly all of Dane.

Much the most important of these streams is the **Wisconsin,** which constitutes, with its valley, the main topographical feature of the region. The total length of this river, from its source to its mouth, is about 500 miles. Rising in Lac Vieux Desert, on the summit of the Archæan watershed, at an elevation of 951 feet above Lake Michigan, it pursues a general southerly course for 300 miles over the crystalline rocks, and then, passing on to the sandstones which form its bed for the remainder of its course, continues to the southward for some eighty miles more. Turning then westward, it reaches the Mississippi within 40 miles of the south line of the state, at an elevation of only 30 feet above Lake Michigan. Like all the other streams which run to the south, southeast, and southwest from the crystalline rocks, it has its quite distinct upper or crystalline rock portion, and its lower or sandstone portion. In the case of the Wisconsin, however, we may conveniently regard the river as having three distinct sections: the first including all that part from the source to the last appearance of crystalline rocks in the bed of the stream, in the southern part of Wood county; the second, that part from this point to the Dalles, on the south line of Adams and Juneau counties; and the third, that portion from the Dalles to the mouth of the stream. The first of these divisions is broken constantly by rapids and falls, caused by the descent south of the surface of the Archæan area, and by the obstructions produced by the inclined ledges of rock which cross the stream. The second and third sections are alike in being almost entirely without rapids or falls, and in the nature of the bed rock, but are separated by the contracted gorge known as the Dalles, which, acting in some sort as a dam, prevents any considerable rise in the river below, the water above not unfrequently rising as much as 50 feet in flood seasons, whilst below the extreme fluctuation does not exceed 10 feet. The total lengths of the Archæan, upper sandstone, and lower sandstone sections of the Wisconsin, are, respectively, 300, 62 and 130 miles, the distance through the Dalles being about seven miles.

For a description of the course of the river more in detail, we may begin with its entrance into the district in the northern part of Marathon county. From here, where the width according to the land office plats is from 300 to 500 feet, the river pursues a general southerly course through towns 29, 28, 27, 26, 25 and 24, of range 7 east, and towns 24 and 23, of range 8 east, in the southern part of Portage county. In this part of its course the Wisconsin flows through a densely timbered country, and has, except where it makes rapids, or passes through rock gorges, a narrow bottom land, which varies in width, is usually raised but a few feet above water level, and is wider on one side than on the other. Above this bottom, terraces can often be made out, with surfaces in some cases one or two miles in width. Above, again, the country surface rises steadily to the dividing ridges on each side, never showing the bluff edges so characteristic of the lower reaches of the river. Heavy rapids and falls are made at Wausau (Big Bull Falls), Mosinee (Little Bull Falls), Stevens Point, and on section 8, town 23, range 8 (Conant's Rapids). All but the last named of these are increased in height by artificial dams. Two miles below the foot of Conant's Rapids, just after receiving the Plover river on the east, the Wisconsin turns a right angle to the west, and enters upon the sparsely timbered sand plains through which it flows for a hundred miles. At the bend the river is quiet, with high banks of sand and a few low outcrops of gneiss at the water's edge. From the bend the course is westward for about nine miles; then, after curving southward again, the long series of rapids soon begins which, with intervening stretches of still water, extend about 15 miles along the river to the last rapid at Point Bass, in southern Wood county. East of the river line, between the city of Grand Rapids and Point Bass, the country rises gradually, reaching altitudes of 100 feet above the river at points ten or fifteen miles distant. On the west the surface is an almost level plain, descending gradually as the river is receded from. At Point Bass the gneissic rocks disappear beneath the sandstones which for some miles have formed the upper portions of the river banks, and now become in turn the bed rock; and the first division of the river's course ends. The main tributaries which it has received down to this point are, on the left bank — the Big Eau Claire, three miles below Wausau; the Little Eau Claire, on the north side of Sec. 3, T. 25, R. 7 E., just south of the north line of Portage county; and the Big Plover, on Sec. 9, T. 28, R. 5 E., just at the foot of Conant's Rapids; on the right bank — the Placota, or Big Rib, about two miles below Wausau; the She-she-ga-ma-isk, or Big Eau Pleine, on Sec. 19, T. 26, R. 7 E., Marathon county; and the Little Eau Pleine, on Sec. 9, T. 25, R. 7, in Portage county. All of these streams are of considerable size, and drain large areas. They all make much southing in their courses, so that their lengths are much greater than the actual distances from the sources to the Wisconsin at the nearest points, and all of them have a very considerable descent, making many rapids and falls over the tilted edges of schistose and gneissic rocks, even down to within short distances of their junctions with the main river. The streams on the west side head on the high country along the line of the Fourth Principal Meridian, about 40 miles west of the Wisconsin, and at elevations from 200 to 300 feet above their mouths; those on the east head on the divide between the Wisconsin and Wolf, about 20 miles east, at elevations not very much less. Reaching back, as these streams do, into a country largely timbered with pine, and having so large a descent, they are of great value for logging and milling purposes.

The second section of the Wisconsin river begins at Point Bass, with a width of from 700 to 900 feet. The next sixty miles of its course, to the head of the Dalles, is a southerly stretch, with a wide bow to the westward, through sand plains, here and there timbered with dwarf oaks, and interspersed with marshes. These plains stretch away to the east and west for twenty miles from the river bottom, gradually rising in both directions. Scattered over them, at intervals of one to ten miles, are erosion peaks of sandstone from 50 to 300 feet in height, rising precipitously from the level ground. Some of these are near and on the bank of the river, which is also in places bordered by low mural exposures of the same sandstone. The river itself is constantly obstructed by shifting sandbars, resulting from the ancient disintegration of the sandstone, which in the vicinity everywhere forms the basement rock, but its course is not obstructed by rock rapids. As it nears the southern line of Adams and Juneau counties, the high ground that limits the sand plain on the west, curving southeastward, finally reaches the edge of the stream, which, by its southeasterly course for the last twenty miles, has itself approached the high ground on the east. The two ridges thus closing in upon the river have caused it to cut for itself the deep and narrow gorge known as the Dalles. In the second section of its course, the Wisconsin receives several important tributaries. Of those on the east, the principal ones are Duck creek and Ten Mile creek in the southern part of Wood county; and the Little and Big Roche à Cris creeks, both in Adams county. The two former head in a large marsh 25 miles east of, and over 100 feet above, the main stream. The two latter head on the high dividing ridge on the west line of Waushara county, at elevations between 150 and 200 feet above their mouths. These streams do not pass through a timbered country, but have very valuable water powers. Of those on the west, two are large and important — the Yellow and Lemonweir rivers. Yellow river heads in township 25, in the adjoining corners of Wood, Jackson and Clark counties, and runs a general southerly course nearly parallel to the Wisconsin for over 70 miles, the two gradually approaching one another and joining in towship 17, range 4 east. The Yellow has its Archæan and sandstone sections, the former exceedingly rocky and much broken by rapids and falls, the latter comparatively sluggish and without rock rapids. The upper portions of the river extend into the pine regions, and much logging is done in times of high water. The water powers are of great value. The Lemonweir is also a large stream. Heading in a timbered region in the southeast corner of Jackson county, it flows southward for some distance through Monroe, and entering Juneau on the middle of its west side, crosses it in a southeasterly direction, reaching the Wisconsin in section 24, township 15, range 5 east, having descended in its length of some 70 miles about 200 feet.

The "Dalles" of the Wisconsin, as already said, is a narrow passage cut by the river through the high grounds which, after bounding its valley on both sides for many miles, have now gradually approached and joined. The total length of the gorge is about seven and one-half miles. At the upper end, about two miles north of the south line of Juneau county, the river narrows suddenly from a width of over one-third of a mile to one of not more than 200 feet. Throughout the whole length of the passage the width does not ever much exceed this, whilst in one place it is only fifty feet. The water in the gorge is very deep, although immediately above it there are broad sand flats with scarcely enough water at low stages to float a canoe. The perpendicular sandstone walls are from fifteen to eighty feet in height, the country immediately on top of them being about 100 feet above the river. From this level, about midway in the passage, there is a rapid rise in both directions to the summit of the high country on each side. In several places branch gorges deviate from the main gorge, returning again to it; these are evidently old river channels and are now closed by sand. The streams entering the river in this portion of its course make similar cañons on a smaller scale.

At the foot of the Dalles the Wisconsin enters upon the last section of its course, and also upon the most remarkable bend in its whole length. From a nearly southerly course it now turns almost due east, in which direction it continues with one or two subordinate turns southward for about seventeen miles, through low sand banks, as far as Portage. Here it bends abruptly south again, and, reaching its easternmost point at the mouth of the Baraboo, soon swerves around into the final southwestward stretch to the Mississippi. The cause of this long détour to the east is sufficiently evident. As the river leaves the Dalles it finds lying directly athwart its course the two bold quartzite ranges which extend east and west through Sauk county for upwards of twenty miles, and, crossing into Columbia, finally unite about eight miles east of the county line, in a sharp and bold, eastward projecting point, which rises 400 feet above the river bottom. Above Portage, where the Wisconsin forms the southern line of the town of Lewiston, the ground immediately north is lower than the water in the river, the heads of Neenah creek, a tributary of the Fox, rising within a short distance of its banks. In times of high water the Wisconsin overflows into these streams, and thus contributes much to a totally different river system. At Portage the Fox, after flowing south of west for twenty miles, approaches the Wisconsin coming from the opposite direction. Where the two streams are nearest they are but two miles apart, and are separated by a low, sandy plain, the water in the Fox being five feet below that of the Wisconsin at ordinary stages. The greater part of this low ground is overflowed by the latter stream in times of high water, and to this is chiefly due the spring rise in the Fox. After doubling the eastern end of the quartzite ranges, as already said, the Wisconsin turns again to the west, being forced to this by impinging on the north side of a high belt of limestone country, which, after trending southwest across the eastern part of Columbia county, veers gradually to a westerly direction, lying to the south of the river along the rest of its course. Soon after striking this limestone region, the river valley assumes an altogether new character, which it retains to the mouth, having now a nearly level, for the most part treeless bottom, from three to six miles in width, ten to thirty feet in height, usually more on one side than on the other, and bounded on both sides by bold and often precipitous bluffs, 100 to 350 feet in height, of sandstone capped with limestone. Immediately along the water's edge is usually a narrow timbered strip — rising two to four feet above the river — which is overflowed at high water. The line of bluffs along the south side of the valley is the northern edge of the high limestone belt just mentioned, which reaches its greatest elevations ten to fifteen miles south of this edge. In front of the main bluff-face, especially in its eastern extension, are frequently to be seen bold and high isolated outliers of the limestone country. On the north bank the bluffs are at first the edges of similar large outlying masses, but further down they become more continuous, the river crossing over the northwestward trending outcrop line of the Lower Magnesian limestone.

In this last section of its course the Wisconsin is much obstructed by bars of shifting sand derived originally from the erosion of the great sandstone formation which underlies the whole region, and to whose existence the unusual amount of obstruction of this kind in the river is due. The peculiar instability of these sand bars, and their liability to form and disappear within a few hours, renders their control very difficult. In view of the enormous quantities of this already disintegrated sand in the region drained by the river and its tributaries, many of which have their entire course through sand districts, the construction of a continuous canal along the Wisconsin river from Portage to its mouth, would appear to be the only way to utilize the natural highway from the lakes to the Mississippi which is offered by this and the Fox rivers. In the last section of its course the Wisconsin receives within the limits of our district only one stream of importance, the Baraboo, which enters the river near the easternmost point of its great bend. Heading in the adjacent corners of Monroe, Vernon and Juneau counties, at an elevation of about 400 feet above its mouth, the Baraboo runs southeastward into Sauk county, where it breaks into the valley between the two east and west quartzite ranges already alluded to, through a narrow gorge in the northern range. Turning then eastward it runs along the middle of the valley between the two ranges for about fifteen miles, and then, breaking again northward through the north range, follows its northern side east to the Wisconsin. The Baraboo is a stream of very considerable size, and yields a number of excellent water powers in the valley between the quartzite ranges, having a fall on this portion of its course of seventy feet. The tributaries on the south side of the Wisconsin, in this section of its course, are of little importance, owing to the nearness of the limestone divide. The most noteworthy is Duck creek, which with its branches drains a considerable area in the towns of Pacific, Springvale and Courtland, in Columbia county, cutting a long way back into the divide.

The following tabulation gives the altitude of the water surface of the Wisconsin at prominent points from the source to the mouth:

Date.	Locality.	Altitudes of Water Surface		Authority.
		Above Sea.	Above Lake Mich.	
....	Lac Vieux Desert	1532	951	Report of I. A. Lapham.
....	Wausau, above Dam	1204	623	Railroad Survey.
....	Knowlton ...... High..	1119	538	Railroad Survey.
....	Knowlton ...... Low ..	1104	523	Railroad Survey.
....	Stevens Point..........	1065	484	Railroad Survey.
....	Conant's Rapids (Sec. 8, T. 23, R. 8)...........	1049	468	Railroad Survey.
....	Grand Rapids Railroad Bridge...............	1001?	420?	Railroad Survey.
....	Kilbourn City Railroad Bridge..........	814	233	Railroad Survey.
Aug. 27, 1867	Portage...............	792	211	Warren's River Survey.
Sept. 9, 1867	Merrimac..............	763	182	Warren's River Survey.
Sept. 17, 1867	Sauk City..............	746	165	Warren's River Survey.
Sept. 27, 1867	Spring Green Bridge	715	134	Warren's River Survey.
Oct. 12, 1867	Muscoda...............	696	115	Warren's River Survey.
Nov. 6, 1867	Mouth of River.........	615	34	Warren's River Survey.

The average velocity of the river below Portage is remarkably uniform and is just about two miles per hour.[1] The daily discharge of of the river at Portage in times of extreme low water is about 259,000,000 cubic feet.[2] The average fall of the water surface of the river below Portage is 1½ feet per mile. General Warrren, from whose report[3] this statement is taken, very truly says that this rapid fall, were it not for the great amount of sand in the river-bed, would make the stream a series of pools and rock rapids; so that, whilst making a great obstruction, the sand really gives the river what navigability it possesses.

In subsequent pages are given a number of geological sections across the valley of the Wisconsin below Portage. The profiles of these sections are reduced from the profiles given in the atlas of Gen. Warren's report, and the geology has been added from my own observations.

Black river rises in townships 31 and 32, on the high drift-covered divide near the Fourth Principal Meridian, at elevations of over 800 feet above Lake Michigan, runs first west into range 2, and then takes

[1] Maj. C. R. Sutter, in Chief of Engineer's Report, 1867, p. 353. [2] The same.

[3] "Report on the Transportation Route along the Wisconsin and Fox River," by Gen. G. K. Warren, U. S. Engineers, Washington, 1876.

a southerly course through Clark county as far as township 24, where it begins a southwesterly stretch towards the Mississippi, which it reaches in town 17, range 8, on the boundary line between Trempealeau and La Crosse counties. Its total length is about 150 miles, and total fall about 750 feet. Like the Wisconsin, it has its upper or Archæan portion, broken constantly by chutes and rapids over gneiss and granite, and its lower or sandstone section without falls. The Archæan section of the river extends to the town of Black River Falls, in township 21, Jackson county, where the gneissoid granite and gneiss cause a long rapid and disappear finally beneath the sandstones, which, however, extend for many miles northward of this point on the immediate banks of the stream, covering the crystalline rocks everywhere except in the river bed. Towards its mouth the valley of Black river is bounded by limestone-capped bluffs like the lower portion of the valley of the Wisconsin. Like the Wisconsin, again, it has its upper waters in a pine covered region, is much used for logging, and affords numberless water powers by its rapid descent and frequent rock interruptions. Most of the branches of the upper Black run over crystalline rocks like the main stream, and have numerous rapids and falls. Some of them, however, as for instance the East Fork, reverse the ordinary conditions of the streams of the region, and have their upper portions in sandstone on the high divide near the Meridian in northeastern Jackson and eastern Clark county, whilst farther down they cut into the crystalline rocks, making the usual rapids and falls.

The main **Rock river** only touches the southeastern corner of our district in the expansion known as Lake Koshkonong, but its branches drain nearly all of Dane and most of eastern Columbia. These branches are everywhere divided from the tributaries of the Wisconsin by the high belt of limestone country already described as running southwestward through eastern Columbia, and then westward through northern Dane. In Dane county are three branches of Rock river, draining three distinct north and south basins. Central Dane is traversed by the Catfish, whose upper waters expand into several large lakes that lie in a series of N. E. — S. W. valleys apparently of glacial origin. Between two of these lies Madison, the capital city of the state. In the western towns of Dane are the heads of Sugar river, whilst on the eastern side the drainage is into Koshkonong creek, except on the extreme northeast, where it is eastward to the Crawfish, as is also the case with the eastern part of Columbia county.

The **Fox river,** the fourth of the main rivers of the district, heads in the northeastern part of Columbia county and the adjoining portions of Green Lake, on the west edge of the high limestone belt previously alluded to. Flowing at first southwest and then due west nearly parallel to the Duck creek branch of the Wisconsin, it approaches the latter stream at Portage. When within two miles of the Wisconsin, separated from it and from Duck creek by only a low, sandy plain, it turns abruptly northward, and, with a sluggish current, continues on this course for twelve miles to the head of Lake Buffalo in the southern part of Marquette county. For some distance below Portage the river has been shortened by cut-offs and slackened by a system of dams and locks. It has already been said that in the spring this portion of the Fox receives a large amount of water from the Wisconsin, much of which reaches it through a branch known as the Big Slough or Neenah creek, which, heading within a mile of the Wisconsin, in the town of Lewiston, reaches the Fox just south of the north line of Columbia county, in the town of Fort Winnebago. At the head of Lake Buffalo the Fox begins a wide curve which brings its direction finally around to due east. Lake Buffalo is merely an expansion of the river, grown up with grass and wild rice, except where the channel crosses it, and is thirteen and one-half miles long and half a mile wide. It runs through a sand plain, which is not many feet above its level. At the foot of the lake, near the village of Montello, a dam has been built which raises the lake-level several feet. From the foot of Lake Buffalo the river for seven miles has an irregular, easterly course, with a somewhat rapid current, to the head of Lake Puckawa, which is eight and one-fourth miles in length and from one to two wide, and is in part grown up with reeds and wild rice. At the foot of the lake there are wide marshes through which the river leaves on the north side, and, after making a long, narrow bend to the west, begins its northeast stretch to Lake Winnebago, keeping along the western edge of the northern extension of the same limestone ridge, to which we have already had occasion so many times to refer, until after it leaves the district. From Lake Puckawa to Berlin the river is wider and deeper, interrupted by but few sandbars, and runs for a considerable portion of the distance between high banks. The main tributaries of the upper Fox enter from the north, and head in the high drift-covered region of southwestern Waushara and northwestern Marquette, at elevations of between 200 and 300 feet above their mouths. The principal ones are the Montello, Mechan and White rivers, each one of which branches many times towards its head. All of these are large, clear, rapid streams, but, running in sand and drift bottoms, are not broken by rock rapids. They are in many places utilized for milling purposes. The eastern side of Waushara county is drained by similar streams, which reach the Fox through Lake Poygan, outside the limits of the district, in Fond du Lac county. The following figures with regard to the Fox are taken from the report of Major Charles Sutter, already referred to:

	DISTANCE. *Miles.*	FALL. *Feet.*
Portage to head of Lake Buffalo	12	7.12
Head of Lake Buffalo to foot of same	13½	1.14
Foot of Lake Buffalo to head of Lake Puckawa	7	5.22
Head of Lake Puckawa to foot of same	8¼	.17
Foot of Lake Puckawa to Princeton	12	3.35
Princeton to Berlin bridge	20¼	8.32
Portage to Berlin bridge	73	25.32

The Fox river, at the foot of Winnebago lock at Portage, is 203.1 feet above Lake Michigan.

The remarkable relations of the valleys of the upper Fox and lower Wisconsin, and the probable former drainage southward of the whole basin of the Fox and Wolf rivers, are alluded to on a subsequent page.

SURFACE RELIEFS.

With the exception of the sand region of Juneau and Adams counties, and portions of the lower Wisconsin valley, no considerable part of the district can be designated as a plain, the surface being everywhere roughened by erosion or heaped up drift. The extremes of elevation are, however, only about 1,100 feet apart, being 1,263 feet for the Rib Hills near Wausau, and 134 feet for the Wisconsin river at Spring Green, both altitudes being referred to Lake Michigan. These are, moreover, at opposite ends of the district, the Rib Hill being itself an isolated ridge 600 feet above the general level. For the most part the region lies between 200 and 900 feet above Lake Michigan, whilst the changes of level in any one vicinity, except in such districts as that of the Sauk quartzite ranges, but rarely reach 300 feet.

The general surface slopes and the extents of the hydrographic basins have already been indicated. The **watersheds** need further remark, those separating the four great basins of the district especially meriting our attention. The high ground which sheds in different directions the waters of the Wisconsin and the Fox begins in township 37, range 11 east, at an elevation of about 900 feet,[1] and trends southward through ranges eleven and ten to the north line of Portage county, where it veers into range nine, which it follows southward to township nineteen, Waushara county, with an elevation gradually lessening from 600 to 500 feet. Thus far the watershed has been between the Wisconsin and the Wolf, the northern branch of the Fox. Its upper end, as far south as Portage county, is on the Archæan rocks, its height being augmented by drift, and its slopes in both directions gradual, although the streams are constantly broken by rock rapids. South of the north side of Portage county, the rock formation is the sandstone. Here also the elevation is increased by drift accumulations, which occur in a morainic condition, of great thickness, and spread over a wide extent of country east and west. The slopes in both directions are very gradual. South of township nineteen this divide, which is now between the Wisconsin and upper Fox, veers again slightly to the west, and, crossing the southern end of Adams county, is cut through by the Wisconsin itself at the Dalles, in township fourteen, range six, having here an elevation of about 400 feet. South of here there is no proper divide between the Wisconsin and upper Fox, both traversing a flat country.

The watershed between the Wisconsin and Black rivers follows nearly the line of the Fourth Principal Meridian from township 31, where it has an elevation of about 900 feet, to township 20, where the elevation is about 400 feet. As far south as township 45 this ridge is on Archæan rocks, much covered by drift, whilst further south the drift soon runs out and the sandstone makes up the ridge. South of township 20, on nearly the same line, the high ground continues, becoming the divide between the Kickapoo, Pine and Baraboo branches of the Wisconsin, and carrying limestone on the summit.

The high limestone prairie belt, separating the systems of the Rock and Wisconsin, has already been several times spoken of. Beginning outside the district, it crosses Green Lake county in a S. S. W. direction, enters Columbia on the north line of the towns of Scott and Randolph, crosses this county in a line gradually veering to the west, and, entering Dane in the towns of Dane and Vienna, turns due west, in which direction it continues to the Mississippi river, breaking down, however, on the line of Black Earth creek in the towns of Middleton and Cross Plains. On the west this divide has an abrupt, serrated face, which increases in boldness and height as followed southward and westward, the watershed itself reaching altitudes of 400 feet

[1] Hereafter all altitudes, unless otherwise stated, are referred to Lake Michigan, which is taken at 578 feet above the sea.

above the adjacent Wisconsin. The eastward slope, on the other hand, is, in Columbia county, very gradual, owing to the general descent eastward of the strata. As the watershed turns westward the direction of the dip changes gradually to the south, its amount at the same time becoming lessened. As a result the slopes towards the Catfish valley are again somewhat more abrupt, but never become like those on the Wisconsin side of the divide.

The western and northern face of this divide, as indicated, forms the eastern and southern side of the Wisconsin valley continuously, from the mouth of the river to the easternmost point of its great bend. Farther north, however, the ridge continues its northeasterly trend, leaving the Wisconsin entirely, and becoming now the eastern boundary of the valley of the upper Fox river as far as Lake Winnebago. This interesting relation, which is very instructive as to the past conditions of the drainage of these valleys, is finely brought out by the colored Atlas Map of Area E, on which the western edge of the main brown-colored (Lower Magnesian) area, together with the brown lime (Mendota base) just west of it, show the position of the western face of the ridge under consideration. The map will suggest at once, what is in every way the truth, that the valleys of the upper Fox and of the lower Wisconsin are really one continuous valley, the valley of the upper Wisconsin being an entirely independent one. As already described, the Fox and Wisconsin at Portage traverse a sandy plain within two miles of one another, and without divide of any kind. A glance at the map will show that the Fox makes towards the Wisconsin exactly as do other small tributaries immediately to the south — and from which there is also no divide — then suddenly turning at right angles, passes northward and eastward through a broad valley, out of all proportion to its size. The whole length of this valley bears testimony to the former presence of a great river. The identity of the two valleys is still further shown by the fact that they constitute one continuous channel of erosion through the same geological formations. The lower Wisconsin is everywhere cut down through the Lower Magnesian limestone, which forms horizontal strata in the upper parts of the high ground on each side. The same formation constitutes the ridge all along the southeast side of the Fox river, and moreover was once spread over the whole country north of that stream, where it is now still found in a few outliers on the very highest ground. The bottoms of both valleys are composed of the Potsdam sandstone.

The natural inference from these facts is that Lake Winnebago, including the whole of the great basin of the Wolf, formerly drained southward, forming a continuous river with the Wisconsin below Portage. This former drainage southward has been suggested by other writers, but most clearly by Gen. G. K. Warren, in his recent report on the Fox and Wisconsin rivers, in which he shows that the lower Fox, through which the entire basin of the upper Fox and Wolf now outlets, is a modern channel, induced to form by a lower position of the continent to the northward than it formerly had. The real identity of the valleys of the upper Fox and lower Wisconsin, now shown, seems to be a convincing proof of the theory. Moreover, in subsequent pages it is shown that the upper Wisconsin has also undergone a change of course, having at one time passed through the Baraboo quartzite ranges, in the gorge now partly occupied by Devil's Lake, and reached the valley of the lower Wisconsin in the region of Sauk Prairie, more than 20 miles below the point at which the Fox and Wisconsin now approach each other. It is shown that this condition held until the Glacial Period, when, the gorge through the quartzite ranges becoming choked with drift, the Wisconsin was forced to find itself a new passage around the eastern point of those ranges. But this passage around the point of the quartzite ranges, and as far southwest as the former junction of the upper and lower Wisconsin, is just as ancient and as deeply eroded as the channel of the lower Wisconsin itself. It follows that even when the upper Wisconsin had its former course, there was still a great river occupying the valley immediately below Portage, and this could only have come from the region of the Wolf and upper Fox.

Of the subordinate dividing ridges we need only mention here the quartzite ranges known as the "**Baraboo Bluffs**;" all others will be described in the chapters on local geology. The Baraboo ranges, however, constitute so striking a feature in the topography of the central palœozoic portion of the state, and present so marked a contrast in direction and outlines to all other relief-forms south of the main region of crystalline rocks, that they deserve especial mention. They are two bold east and west ridges — the southern much the bolder and more continuous of the two — extending through Sauk and eastern Columbia county for twenty miles, and lying within the great bend of the Wisconsin river. Their cores and summits, in some places their entire slopes, are composed of tilted beds of quartzite, metamorphic conglomerate, and porphyry, whilst their flanks are for the most part made up of beds of horizontal sandstone, which, in lower places, sometimes surmounts and conceals the more ancient rocks. On the east and west the two ranges join, and thus nearly completely surround the lower ground between them. The eastern junction, caused by divergence northward of the southern range, the northern retaining its E. W. direction, is a bold, sharp point, rising abruptly 400 feet above the level valley of the Wisconsin. From this point westward the southern range is a continuous ridge of 400 to 700 feet elevation above the low ground on the south, and 600 to 900 feet above Lake Michigan, always bold on both sides, often precipitous, and rising at top into long rounded swells, which not infrequently show the bare, purplish, quartz rocks. The wide, level prairie lying south of the middle portion of this range, known as Sauk Prairie, makes it stand out all the more boldly. It is not, however, only near by that this range is noticeable. It is seen from elevated points forty miles to the north, where its rounded contours distinguish it from the horizontal rock elevations seen on each side of it. Even from points around Madison — which has between it and the Baraboo Bluffs a high limestone divide — by the aid of a telescope, their rounded contours can be distinguished through low places in the divide. At their western ends the two quartzite ranges are a number of miles apart, but are joined by a cross ridge of nearly the same altitude, which has probably a quartzite core throughout. Except, however, over a large rounded elevation about midway in its length, and in other places at its ends, this cross ridge shows only sandstone as the surface rock. On the east the cross ridge descends rapidly to the level of the Baraboo valley. On the west, the high ground descends only gradually, and soon showing the Lower Magnesian limestone as the surface formation, continues many miles westward.

A remarkable feature of all of the paleozoic portion of central Wisconsin is the occurrence of **isolated ridges and peaks,** rising from 100 to 300 feet abruptly, and often precipitously, from the low ground around them, having an area on top of from a fraction of an acre to a square mile, and composed of horizontally stratified sandstone, or of sandstone capped with limestone. Such outlying bluffs lie all along the face of the high limestone country of Columbia and Dane counties, and are generally there capped by the same limestone that forms the elevated land, of which they are themselves fragments. Others again, and these are nearly all entirely of sandstone, occur scattered widely over the central plain of Adams and Juneau counties, often covering but a small area, and showing bare rock from the base to the summit, which not infrequently is worn into jagged pinnacles and towers.

The following tables give the **altitudes** of numerous points throughout the district, referred to Lake Michigan as zero. The railroad elevations were furnished me by the late Dr. I. A. Lapham, who obtained them directly from the profiles in the offices of the several companies. The list is very full, an altitude being given for almost every section line crossed, and of course the figures have a high degree of accuracy. Except where otherwise stated, the railroad grade is always meant. The remaining tables include a number of altitudes, determined by the aneroid barometer, which are, of course, approximations only. These are selected from a list of many thousand, and apply almost wholly to Dane, Columbia and Sauk counties, which have been chosen because in them the conditions of observation were more favorable, reference points having been accessible during nearly every day's work, and because, also, in this part of the district the mapping of the geological formations required that the observations should be much more numerous, and consequently more accurate, than elsewhere.[1] Numerous determinations of altitude were made in the other counties of the district, but, on account of the distance from railroads or other standards, only a few deserve to be listed here. The *general* altitude of any portion of the district can be obtained from the chapters on local details.

MADISON TO ELROY.

Chicago & Northwestern Railway.

Place.	*Altitude.*
East Madison depot	264
Station 65,[1] road crossing	266
" 130	273
" 175, (summit)	305
" 262, (summit)	325
" 277, deep cut, surface	355
" 315, surface Catfish marsh	255
" 315, grade	277
" 400,	285
" 458, grade	323
" 458, surface	310
" 520, Waunakee	341
" 570,	341
" 667, surface	369
" 667, grade	395
" 787, Dane depot	477
" 900,	365
" 1002, surface of creek	233
" 1002, grade	267
" 1039, Lodi depot	267
" 1140,	319
" 1200, grade	265
" 1200, surface	255
" 1300, grade	200
" 1300, surface	175
Station 1360, bridge	215
Station 1360, sur. Wis. riv., low wat.	170
Station 1360, sur. Wis. riv., high wat.	180
" 1380, Merrimac depot	215
" 1460,	250
" 1493, grade	221
" 1493, surface	178
" 1600, grade	292
" 1600, top Devil's Nose	378
" 1696, surface	464
" 1702,	429
" 1783, Devil's Lake, grade	386
" 1908, bridge	276
" 1908, surface	224
" 1950, Baraboo depot	284
Lyons depot	282
Bloom's depot	300
Ableman's depot	297
Reedsburg depot	296
La Valle depot	316
Wonewoc depot	329
Union Center depot	362
Elroy depot	360

[2] Stations 100 feet apart, beginning with East Madison depot as zero.

[1] The aneroid determinations of altitude listed here are believed to have a considerable degree of accuracy. In many cases the same point was visited on different days, from different directions; and in other cases a second barometer was read half-hourly at a fixed point, whilst observations were being made. In this latter way it seems possible to attain great accuracy with the aneroid, especially if such suitable and reliable instruments are used as those made by J. H. Steward, of London. These have a range of only 3.000 feet, and show a variation of 5 feet very distinctly.

ELROY TO MERRILLON.

West Wisconsin Railway.

Place.	Altitude.	Place.	Altitude.
Elroy depot	360	Warren's Mills depot	448
Orange depot	327	Rudd's Mills depot	403
Camp Douglas depot	356	Black River Falls depot	231
Valley Junction depot	354	Wright's depot	353
Lowry's depot	389	Green Bay Junction depot	356

WATERLOO TO MADISON.

Chicago, Milwaukee & St. Paul Railway.

Place.	Altitude.	Place.	Altitude.
Waterloo depot	241	Sun Prairie depot	356
W. line, Sec. 7, T. 8, R. 13 E	260	W. line, Sec. 8, T. 8, R. 11 E	349
W. line, Sec. 12, T. 8. R. 12 E	272	W. line, Sec. 18, T. 8, R. 11 E	341
W. line, Sec. 11, T. 8, R. 12 E	280	S. line, Sec. 13, T. 8, R. 10 E	353
Marshal depot	286	W. line, Sec. 24, T. 8, R. 10 E	355
W. line, Sec. 10, T. 8, R. 12 E	286	S. line, Sec. 23, T. 8, R. 10 E	322
W. line, Sec. 4, T. 8, R. 12 E	278	W. line, Sec. 26, T. 8, R. 10 E	321
Deanville depot	305	W. line, Sec. 34, T. 8, R. 10 E	277
W. line, Sec. 5, T. 8, R. 12 E	295	S. line, Sec. 33, T. 8, R. 10 E	270
W. line, Sec. 6, T. 8, R. 12 E	377	W. line, Sec. 5, T. 7, R. 10 E	286
W. line, Sec. 1, T. 8, R. 11 E	315	East Madison depot	268
W. line, Sec. 2, T. 8, R. 11 E	374	West Madison depot	275
W. line, Sec. 3, T. 8, R. 11 E	393	Lake Monona (3d Lake)	262
W. line, Sec. 4, T. 8, R. 11 E	369	Lake Mendota (4th Lake)	270

EDGERTON TO BLACK EARTH.

Chicago, Milwaukee & St. Paul Railway.

Place.	Altitude.	Place.	Altitude.
Edgerton depot	242	W. line, N. E. qr. Sec. 33, T. 7, R. 10 E	265
W. line, S. E. qr. Sec. 4, T. 12, R. 4 E	255	W. line, Sec. 28, T. 7, R. 10 E	265
W. line, N. W. qr. Sec. 4, T. 12, R. 4 E	262	W. line, Sec. 29, T. 7, R. 10 E	265
N. line, Sec. 5, T. 12, R. 4 E	268	W. line, Sec. 30, T. 7, R. 10 E	270
Mid. W. line, Sec. 32, T. 5, R. 12 E	275	N. line, Sec. 36, T. 7, R. 9 E	267
Mid. N. line, Sec. 31, T. 5, R. 12 E	284	West Madison depot	275
E. line, S. E. qr. Sec. 25, T. 5, R. 11 E	297	W. line, N. E. qr. Sec. 22, T. 7, R. 9 E	291
W. line, S. E. qr. Sec. 25, T. 5, R. 11 E	285	W. line, Sec. 22, T. 7, R. 9 E	291
W. line, Sec. 25, T. 5, R. 11 E	285	W. line, N. E. qr. Sec. 21, T. 7, R. 9 E	291
N. line, Sec. 26, T. 5, R. 11 E	272	W. line, Sec. 16, T. 7, R. 9 E	299
N. line, N. E. qr. Sec. 23, T. 5, R. 11 E	269	W. line, Sec. 20, T. 8, R. 9 E	326
W. line, N. E. qr. Sec. 15, T. 5, R. 11 E	280	W. line, N. E. qr. Sec. 19, T. 7, R. 9 E	332
S. line, S. E. qr. Sec. 9, T. 5, R. 11 E	273	W. line, Sec. 18, T. 7, R. 9 E	340
Mid. W. line, Sec. 9, T. 5, R. 11 E	279	N. line, Sec. 13, T. 7, R. 9 E	345
Stoughton depot	279	Middleton depot	347
S. line, Sec. 32, T. 6, R. 11 E	290	W. line, Sec. 11, T. 7, R. 8 E	353
N. line, Sec. 32, T. 6, R. 11 E	294	W. line, S. E. qr. Sec. 10, T. 7, R. 8 E	365
N. line, Sec. 29, T. 6, R. 11 E	267	W. line, Sec. 10, T. 7, R. 8 E	360
N. line, Sec. 20, T. 6, R. 11 E	267	W. line, Sec. 9, T. 7, R. 8 E	352
Mid. W. line, Sec. 17, T. 6, R. 11 E	278	W. line, Sec. 8, T. 7, R. 8 E	353
N. line, Sec. 18, T. 6, R. 11 E	275	W. line, Sec. 7, T. 7, R. 8 E	339
W. line, Sec. 7, T. 6, R. 11 E	269	W. line, Sec. 12, T. 7, R. 7 E	326
S. line, Sec. 1, T. 6, R. 10 E	273	W. line, Sec. 2, T. 7, R. 7 E	300
W. line, Sec. 1, T. 6, R. 10 E	282	Cross Plains depot	278
W. line, S. E. qr. Sec. 2, T. 6, R. 10 E	296	W. line, Sec. 4, T. 7, R. 7 E	268
McFarland depot	289	Center Sec. 31, T. 8, R. 7 E	250
S. line, Sec. 34, T. 7, R. 10 E	292	Black Earth depot	232
W. line, Sec. 34, T. 7, R. 10 E	276		

CAMP DOUGLAS TO RANDOLPH.

Chicago, Milwaukee & St. Paul Railway.

Place.	*Altitude.*
Camp Douglas depot	368
New Lisbon depot	311
Mauston depot	306
Kilbourn City depot	316
Lewiston depot	231
W. line, Sec. 35, T. 13, R. 8 E	229
W. line, Sec. 6, T. 12, R. 9 E	243
Portage depot	232
E. line, Sec. 6, T. 12, R. 9 E	233
Near center Sec. 5, T. 12, R. 9 E	236
Canal crossing N. W. qr. Sec. 4, T. 12, R. 9 E	211
Fox river crossing N. W. qr. Sec. 4, T. 12, R. 9 E	211
E. line, Sec. 3, T. 12, R. 9 E	224
E. line, Sec. 2, T. 12, R. 9 E	227
E. line, Sec. 1, T. 12, R. 9 E	225
E. line, Sec. 6, T. 12, R. 8 E	205
E. line, Sec. 5, T. 12, R. 8 E	213
E. line, Sec. 4, T. 12, R. 8 E	232
Pardeeville depot	237
Cambria depot	284
Randolph depot	378

TOMAH TO WAUSAU.

Wisconsin Valley Railroad.

Place.	*Altitude.*
Tomah depot	383
Valley Junction depot	350
N. line, Sec. 6, T. 19, R. 2 E.	379
N. line, Sec. 32, T. 20. R. 2 E	379
Beaver Station	379
N. line, Sec. 22, T. 20, R. 2 E.	384
N. line, Sec. 12, T. 20, R. 2 E.	386
N. line, Sec. 6, T. 20, R. 3 E.	339
N. line, Sec. 31, T. 21, R. 3 E.	391
N. line, Sec. 28, T. 21, R. 3 E	395
Yellow river crossing, Sec. 14, T. 21, R. 3 E.	401
W. line, Sec. 13, T. 21, R. 3 E.	400
W. line, Sec. 18, T. 21, R. 4 E.	403
W. line, Sec. 8, T. 21, R. 4 E.	405
W. line, Sec. 9, T. 21, R. 4 E.	408
W. line, Sec. 10, T. 21, R. 4 E.	409
W. line, Sec. 2, T. 21, R. 4 E.	410
W. line, Sec. 1, T. 21, R. 4 E.	414
W. line, Sec. 6, T. 21, R. 5 E.	419
W. line, Sec. 5, T. 21, R. 5 E.	421
W. line, Sec. 4, T. 21, R. 5 E.	425
W. line, Sec. 34, T. 22, R. 5 E.	413
Port Edward station	388
N. W. corner, Sec. 36, T. 22, R. 5, E.	397
N. W. corner, Sec. 25, T. 25, R. 5 E.	426
N. line, Sec. 24, T. 22, R. 5 E.	433
Centralia depot	431
Crossing Green Bay R. R	442
N. line, Sec. 5, T. 22, R. 6 E	454
N. line, Sec. 32, T. 23, R. 6 E.	458
N. line, Sec. 29, T. 23, R. 6 E.	478
N. line, Sec. 21, T. 23, R. 6 E.	507
N. line, Sec. 16, T. 23, R. 6 E.	529
Rudolph depot, Sec. 9, T. 23, R. 6 E.	562
N. line, Sec. 4, T. 23, R. 6 E.	560
N. line, Sec. 33, T. 24, R. 6 E.	570
N. line, Sec. 27, T. 24, R. 6 E.	556
N. line, Sec. 22, T. 24, R. 6 E.	558
Crossing Mill cr., S. 22, T. 24, R. 6 E	543
N. line, Sec. 15, T. 24, R. 6 E.	554
N. line, Sec. 10, T. 24, R. 6 E.	563
Junction City depot	572
N. line, Sec. 35, T. 25. R. 6 E.	601
N. line, Sec. 25, T. 25, R. 6 E.	590
N. line, Sec. 24, T. 25, R. 6 E.	576
N. line, Sec. 13, T. 25, R. 6 E.	566
N. line, Sec. 12, T. 25, R. 6 E.	554
Crossing Little Eau Pleine	544
N. line, Sec. 6, T. 25, R. 7 E	554
N. line, Sec. 32, T. 26, R. 7 E.	553
Crossing Wisc. River { grade	550
Crossing Wisc. River { high water	538
Crossing Wisc. River { low water	523
Knowlton depot	547
N. line, Sec. 20, T. 26, R. 7 E.	561
N. line, Sec. 17, T. 26, R. 7 E.	571
N. line, Sec. 8, T. 26, R. 7 E.	579
N. line, Sec. 5, T. 26, R. 7 E.	578
N. line, Sec. 32. T. 26, R. 7 E.	558
N. line, Sec. 28, T. 26, R. 7 E.	575
N. line, Sec. 21, T. 26, R. 7 E.	586
N. line, Sec. 15, T. 26, R. 7 E.	593
N. line, Sec. 2, T. 26, R. 7 E.	606
N. line, Sec. 35, T. 28, R. 7 E.	579
N. line, Sec. 25, T. 28, R. 7 E.	593
N. line, Sec. 19, T. 28, R. 8 E.	612
N. line, Sec. 18, T. 28, R. 8 E.	633
N. line, Sec. 7, T. 28, R. 8 E.	641
N. line, Sec. 1, T. 28, R. 7 E.	643
Wausau { depot	643
Wausau { river above dam	623

Amherst to Merrillon.

Green Bay and Minnesota Railway.

Place.	Altitude.
Amherst depot	553
W. line, Sec. 18, T. 23, R. 10 E.	539
S. W. qr. S. W. qr. Sec. 13, T. 23, R. 9 E.	543
S. W. qr. S. W. qr. Sec. 14, T. 23, R. 9 E.	560
N. W. qr. Sec. 22, T. 23, R. 9 E.	614
S. E. qr. S. W. qr. Sec. 21, T. 23, R. 9 E.	595
N. E. qr. S. E. qr. Sec. 20, T. 23, R. 9 E.,	575
N. W. qr S. W. qr Sec. 19, T. 23, R. 9 E.	559
W. line, Sec. 19, T. 23, R. 9 E.	528
N. E. qr. S. W. qr. Sec. 24, T. 23, R. 8 E.	522
N. E. qr. S. W. qr. Sec. 23, T. 23, R. 8 E.	514
Plover depot	504
N. E. qr. S. W. qr. Sec. 21, T. 23, R. 8 E.	501
N. E. qr. N. W. qr. Sec. 29, T. 23, R. 8 E.	499
W. line, N. E. qr. Sec. 30, T. 23, R. 8 E.	501
N. W. qr. S. E. qr. Sec. 25, T. 23, R. 8 E.	497
S. W. qr. S. E. qr. Sec. 26, T. 23, R. 8 E.	497
N. E. qr. N. E. qr. Sec. 34, T. 23, R. 8 E.	495
N. E. qr. S. E. qr. sec. 33, T. 23, R. 8 E.,	493
S. E. qr. S. E. qr. Sec. 32, T. 23, R. 8 E.,	488
N. W. qr. N. E. qr. Sec. 5, T. 22, R. 7 E.	485
S. E. qr. N. W. qr. Sec. 6, T. 22, R. 7 E	484
S. W. qr. S. W. qr. Sec. 1, T. 22, R. 6 E.	478
S. line, S. W. qr. Sec. 2, T. 22, R. 6 E.,	470
S. E. qr. N. W. qr. Sec. 10, T. 22 R. 6 E.	470
N. E. qr. S. W. qr. Sec. 9, T. 22, R. 6 E.,	465
Grand Rapids depot	448
N. E. qr. S. W. qr. Sec. 7, T. 22, R. 6 E.	435
N. E. qr. S. W. qr. Sec. 12, T. 22, R. 5 E.	435
S. E. qr. S. W. qr. Sec. 11, T. 22, R. 5 E.	436
W. line, S. E. qr. Sec. 15, T. 22, R. 5 E.,	438
S. W. qr. N. E. qr. Sec. 16, T. 22, R. 5 E.	433
S. E. qr. N. W. qr. Sec. 17, T. 22, R. 5 E.	430
S. E. qr. N. W. qr. Sec. 18, T. 22, R. 5 E.	430
Elm Lake	433
S. E. qr. Sec. 15, T. 22, R. 4 E.	433
S. W. qr. S. W. qr. Sec. 16, T. 22, R. 3 E	450
Hemlock creek crossing	423
N. E. qr. N. E. Sec. 24, T. 22, R. 3, E.,	417
Crossing Yellow river, Dexterville	417
N. W. qr. N. E. qr. Sec. 21, T. 22. R. 3 E.	419
S. E. qr. N. E. qr. Sec. 20, T. 22, R. 3 E,	439
Haycreek crossing, Sec 19.	410
S. E. qr. N. E. qr. Sec. 24, T. 22, R. 2 E.,	410
N. E. qr. S. E. qr. Sec. 23, T. 22, R. 2 E.,	417
Hay creek crossing, Sec. 22, T. 22, R. 2 E.	390
Kirk creek crossing, Sec. 28, T. 22, R. 2 E.	392
S. W. qr. N. W. qr., Sec. 28, T. 22, R. 2 E.	395
N. W. qr. S. W. qr. Sec. 29, T. 22, R. 2 E.	390
Scranton depot.	386
Smoky creek crossing, Sec. 25, T. 22, R. 1 E.	382
S. E. qr. N. W. qr. Sec. 35, T. 22, R. 1 E.	385
W. line, Sec. 28, T. 22, R. 1 E.	395
Creek crossing, S. E. qr. Sec. 29, T. 22, R. 1 E.	404
N. W. qr. S. E. qr. Sec. 30, T. 22, R. 1 E.	382
Creek crossing, N. W. qr. Sec. 25, T. 22, R. 1 W.	393
1-5 mile west	416
S. W. qr. S. W. qr. Sec. 23, T. 22, R. 1 W.	426
Near center, Sec. 22, T. 22, R. 1 W.	402
S. W. qr. N. E. qr. Sec. 21, T. 22, R. 1 W.	400
S. W. qr. N. E. qr. Sec. 20, T. 22, R. 1 W.	393
N. W. qr. N. E. qr. Sec. 19, T. 22, R. 1 W.	384
N. line, S. E. qr. Sec. 24, T. 22, R. 2 W.,	384
S. E. qr. S. E. qr. Sec. 14, T. 22, R. 2 W.	364
N. E. qr. S. E. qr. Sec. 15, T. 22, R. 2 W.	362
S. E. qr. N. E. qr. Sec. 16, T. 22, R. 2 W.	347
W. line, N. W. qr. Sec. 16, T. 22, R. 2 W.	335
W. line, N. W. qr. Sec. 17, T. 22, R. 2 W.	333
S. W. qr. N. W. qr. Sec. 18, T. 22, R. 2 W.	334
S. E. qr. S. E. qr. Sec. 12, T. 22, R. 3 W.	323
S. line, N. E. qr. Sec. 11, T. 22, R. 3, W.,	338
Crossing Black river, grade	302
Crossing Black river, surface	255
N. E. qr. N. E. qr. Sec. 4, T. 22, R. 3 W.,	338
S. E. qr. S. E. qr. Sec. 22, T. 23, R. 3 W.,	350
S. E. qr. S. W. qr. Sec. 20, T. 23, R. 3 W.	388
Hall s creek crossing, grade	344
Hall s creek crossing, surface	328
Merrilon depot	356

PORTAGE TO STEVENS POINT.

Wisconsin Central Railroad Surveys.

Place.	Altitude.
Portage depot	232
N. line, S. E. qr. Sec. 23, T. 13, R. 9 E.	227
N. line, Sec. 21, T. 13, R. 9 E	223
N. line, Sec. 16, T. 13, R. 9 E	220
N. line, Sec. 9, T. 13, R. 9 E	276
N. line, Sec. 4, T. 13, R. 9 E	225
N. line, Sec. 32, T. 14, R. 9 E	228
N. line, Sec. 29, T. 14, R. 9 E	227
N. line, Sec. 17, { grade	265
N. line, Sec. 17, { surface	285
W. line, Sec. 8, T. 14, R. 9 E	230
S. line, Sec. 30, T. 15, R. 9 E	218
N. line, Sec. 30, T. 15, R. 9 E	218
N. line, S. E. qr. Sec. 19, T. 15, R. 9 E.	225
N. line, Sec. 4, T. 15, R. 8 E	344
N. line, Sec. 33, T. 16, R. 8 E	344
N. line, S. E. qr. Sec. 21, T. 16, R. 8 E.	338
N. line, S. E. qr. Sec. 16, T. 16, R. 8 E.	344
N. line, S. E. qr. Sec. 32, T. 17. R. 8 E.	401
N. line, Sec. 32, T. 17, R. 8 E	434
N. line, Sec. 19, T. 17, R. 8 E	499
N. W. corner Sec. 18, T. 17, R. 8 E.	550
N. line, Sec. 17, T. 17, R. 7 E	544
N. line, Sec. 36, T. 18, R. 7 E	534
N. line, Sec. 25, T. 18, R. 7 E	516
Middle E. line, Sec. 24, T. 18, R. 7 E.	514
N. line, Sec. 18, T. 18, R. 8 E	524
S. line, Sec. 4, T. 18, R. 8 E	524
N. line, Sec 28, T. 19, R. 8 E	519
Hancock depot	513
N. line, Sec. 10, T. 19, R. 8 E	520
N. line, Sec. 11, T. 19, R. 8 E	529
N. line, Sec. 2, T. 19, R. 8 E	538
N. line, Sec. 35, T. 20, R. 8 E	542
N. line, Sec. 26, T. 20, R. 8 E	561
N. line, Sec. 24, T. 20, R 8 E	561
N. line, Sec. 13, T. 20, R. 8 E	532
Plainfield depot	532
N. line, Sec. 1, T. 20, R. 8 E	518
N. line, Sec. 36, T. 21, R. 8 E	527
N. line, Sec. 25, T. 21, R. 8 E	524
N. line, Sec. 12, T. 21, R. 8 E	495
N. line, Sec. 1, T. 21, R. 8 E	494
N. line, Sec. 36, T. 22, R. 8 E	493
N. line, Sec. 25, T. 22, R. 8 E	492
N. line, Sec. 24, T. 22, R. 8 E	494
N. E. qr. N. W. qr. Sec. 13, { grade	492
N. E. qr. N. W. qr. Sec. 13, { surface	485
W. line, N.W. qr. Sec. 12, T. 22, R. 8 E.	485
N. line, Sec. 2, T. 22, R. 8 E	496
Plover depot	496
Stevens Point depot	508

STEVENS POINT TO THE NORTH LINE OF TOWNSHIP 29.

Wisconsin Central Railway.

Place.	Altitude.
Stevens Point depot	508
Cutting N. E. qr. Sec. 31, T. 24, R. 8 E. { grade	517
Cutting N. E. qr. Sec. 31, T. 24, R. 8 E. { surface	548
N. W. corner Sec. 31, T. 24, R. 8 E.	511
N. line, S. W. qr. Sec. 25, T. 24, R. 7 E.	511
S. line, S. E. qr. Sec. 23, T. 24, R. 7 E.	513
W. line, Sec. 15, T. 24, R. 7 E	550
W. line, Sec. 16, T. 24, R. 7 E	526
W. line, Sec. 8, T. 24, R. 7 E	519
W. line, Sec. 7, T. 24, R. 7 E	522
W. line, Sec. 1. T. 24, R. 6 E	543
W. line, Sec. 2, T. 24, R. 6 E	563
W. line, Sec. 3, T. 24, R. 6 E	587
W. line, Sec. 4, T. 24, R. 6 E	606
W. line, Sec. 32, T. 25, R. 6 E	615
W. line, Sec. 31, T. 25, R. 6 E	615
W. line, Sec. 36, T. 25, R. 5 E	612
W. line, Sec. 35, T. 35, R. 5 E	623
W. line, Sec. 34, T. 25, R. 5 E	608
W. line, Sec. 28, T. 25, R. 5 E	588
W. line, Sec. 29, T. 25, R. 5 E	588
W. line, Sec. 30, T. 25, R. 5 E	583
W. line, Sec. 25, T. 25, R. 4 E	631
W. line, Sec. 26, T. 25, R. 4 E	639
W. line, Sec. 22, T. 25, R. 4 E	650
W. line, Sec. 21, T. 21, R. 4 E { grade	658
W. line, Sec. 21, T. 21, R. 4 E { surface	665
W. line, Sec. 20, T. 25, R. 4 E	626
W. line, Sec. 19, T. 25, R. 4 E	658
W. line, Sec. 13, T. 25, R. 3 E	678
W. line, Sec. 14, T. 25, R. 3 E	670
W. line, Sec. 15, T. 25, R. 3 E	680
W. line, Sec. 9, T. 25, R. 3 E	693
W. line, Sec. 8, T. 25, R. 3 E	716
N. W. corner Sec. 6, T. 25, R. 3 E	699
N. line, Sec. 26, T. 26, R. 2 E	721
N. line, Sec. 22, T. 26, R. 2 E	735
N. line, Sec. 16, T. 26, R. 2 E	721
N. line, Sec. 8, T. 26, R. 2 E	731
W. line, S. W. qr. Sec. 18, T. 28, R. 2 E	768
W. line, S. W. qr. Sec. 7, T. 28, R. 2 E.	789
E. line, S. E. qr. Sec. 1, T. 28, R. 1 E.	821
N. line, Sec. 35, T. 29, R. 1 E	830
N. line, Sec. 25, T. 29, R. 1 E	847
N. line, Sec. 24, T. 29, R. 1 E	842
N. line, Sec. 13, T. 29, R. 1 E	838
N. line, Sec. 12, T. 29, R. 1 E	866
N. line, Sec. 1, T. 29, R. 1 E	855

BAROMETRICAL ALTITUDES.[1]

Primrose. T. 5, R. 7 E.

Stream crossing, N. E. qr Sec. 3	375
Mid. E. hf. Sec. 3	420
Mid. S. line S. E. qr. Sec. 3	520
N. E. cor. Sec. 7	375
Mid. E. line N. E. qr. Sec. 7	510
Mid. E. line S. E. qr. Sec. 7	545
Road at Grist Mill, N. W. qr. Sec. 8,	395
Mid. E. line Sec. 8	500
Stream crossing, S. E. qr. Sec. 10	360
N. W. cor. Sec. 11	480
Center Sec. 11	410
Stream crossing, E. hf. Sec. 11	330
W. line N. E. qr. N. E. qr. Sec. 15	410
Mid. E. hf. Sec. 15	390
S. W. cor. Sec. 15	480
S. W. cor. Sec. 16	430
Center W. line Sec. 16	490
Center W. line Sec. 17	445
Road forks, N. W. qr. S. E. qr. Sec. 19	610
Center W. line S. W. qr. Sec. 20	595
Top of isolated bluff near mid. E. line N. E. qr. Sec. 22	490
Top of Mount Julia, N. W. qr. Sec. 24	450
Base of Mount Julia, N. W. qr. Sec. 24	380
Stream crossing, N. W. qr. Sec. 25	340
Road forks, W. line N. W. qr. Sec. 25	385
Center S. W. qr. Sec. 26	570
Center W. line S. W. qr. Sec. 26	560
Center S. E. qr. Sec. 27	580
Center N. E. qr. Sec. 28	570
Center Sec. 29	540
Stream at center S. W. qr. Sec. 29	420
Mid. N. line Sec. 35	550
Center Sec. 36	550
N. W. cor. Sec. 36	530

Montrose. T. 5, R. 8 E.

Center Sec. 1	430
Mid, S. line Sec. 1	470
N. E. cor. Sec. 1	465
N. W. cor. Sec. 1	430
Stream crossing, N. W. qr. Sec. 2	360
Paoli Hotel, Sec. 2	315
Center S. W. qr. Sec 11	310
Mid. E. hf. S. E. qr. Sec. 14	405
Crossroads, E. hf. S. W. qr. Sec. 14,	305
Stream crossing, S. W. qr. Sec. 19	320
⅛ mile S	360
Mid. E. line Sec. 22	310
Road, S. line S. W. qr. Sec. 23	300
Road, E. line, N. E. qr. Sec. 23	330
Mid. E. line Sec. 25	300
Center S. E. qr. Sec. 25	320
S. W. cor. Sec. 25	320
S. W. cor. Sec. 26	280
Mid. W. line, Sec. 26	295
Road, N. line N. W. qr. Sec. 26	300
Center Sec. 30	450

Oregon. T. 5, R. 9 E.

Railroad crossing, W. hf. Sec. 1	380
Center Sec. 2	393
Mid. W. line Sec. 2	412
Mid. W. line Sec. 3	390
Center Sec. 4	380
Center Sec. 5	405
Mid. N. line Sec. 7	470
Mid. W. line Sec. 7	400
Mid. N. line Sec. 8	383
Center Sec. 8	410
Center Sec. 9	390
N. E. cor. Sec. 9	280
20 rods E of mid. of N. line Sec. 10	430
Road under railroad, Oregon	352
Mid. S. line S. E. qr. Sec. 12	357
Road forks, near S. W. cor. Sec. 12	380
Mid. E hf. Sec. 13	407
Mid. N. line Sec. 14	455
N. W. cor. Sec. 14	490
Mid. N. line Sec. 15	425
Center Sec. 15	460
N. W. cor. Sec. 15	385
Mid. E. hf. Sec. 16	460
Center Sec. 16	440
N. W. cor. Sec. 16	360
Mid. W. line Sec. 16	380
Center Sec. 17	355
Mid. E. line Sec. 17	380
Mid. N. line Sec. 17	360
N. W. cor. Sec. 17	370
Center Sec. 18	380
Mid. N. line Sec. 18	365
Mid. N. line Sec. 19	325
N. W. cor. Sec. 20	320
Mid. W. line N. W. qr. Sec. 21	340
Mid. E. hf. Sec. 21	410
Mid. E. hf. Sec. 22	450
Mid. N. line N. E. qr. Sec. 22	420
Mid. N. line Sec. 23	420
Mann's quarry, N. E. qr. Sec. 24	407

Rutland. T. 5, R. 10 E.

Mid. W. hf. Sec. 2	295
Mid. S. line S. W. qr. Sec. 2	310
Creek crossing, S. E. qr. Sec. 15	255
S. W. cor. Sec. 15	290
Mid. S. line Sec. 16	295
Road at mill, N. E. qr. Sec. 19	315
Forks of road, S. W. qr. Sec. 20	330
Road at head of stream, S. hf. Sec. 20	312
Mid. E. line S. E. qr. Sec. 20	350
Mid. E. line Sec. 21	290
S. E. cor. Sec. 21	290
Mid. S. line S. W. qr. Sec 22	330

Dunkirk. T. 5, R. 11 E.

Mid. E. line Sec. 1	365
Mid. W. line Sec. 1	410
Mid. W. line Sec. 2	335
Mid. W. line Sec. 3	280
Railroad, N. line Sec. 5	290
Mid. N. line N. W. qr. Sec. 7	325
N. E. cor. Sec. 7	305

[1] I have been compelled, at the last minute, to throw out several hundred of these altitudes, in order not to exceed the limits assigned to this report.

BAROMETRICAL ALTITUDES — *continued.*

Dunkirk. T. 5, R. 11 E. — (con.)	
Stoughton depot, Sec. 8	279
N. E. cor. Sec. 8	310
N. E. cor. Sec. 9	320
Railroad, E. line, Sec. 9	278
N. E. cor. Sec. 10	310
Mid. W. line Sec. 11	335
Mid. N. line Sec. 11	335
Mid. W. line Sec. 12	370
Mid. N. line Sec. 12	360
N. E. cor. Sec. 12	325
Mid. E. line Sec. 12	295
N. W. cor. Sec. 13	340
Mid. E. line Sec. 13	255
Mid. W. line Sec. 13	330
Railroad, S. line Sec. 15	269
Railroad, N. line Sec. 16	273
Mid. W. line Sec. 17	340
Mid. N. line Sec. 18	280
Mid. S. hf. Sec. 19	310
Forks of road, near mid. E. line Sec. 21	280
Mid. E. line Sec. 21	325
Mid. W. hf. Sec. 22	310
Center Sec. 23	310
Mid. E. line N. E. qr. Sec. 24	240
N. W. cor. Sec. 25	320
Mid. W. hf. Sec. 28	290
Mid. N. E. qr. Sec. 29	290
Mid. N. line Sec. 29	325
Mid. N. line Sec. 30	305
Porter's quarry, S. hf. Sec. 30	330
Mid. N. line Sec. 31	345
Center Sec. 31	320
Mid. N. line Sec. 32	290
Mid. N. line Sec. 33	300
Crossing Catfish creek, N. line Sec. 34	215
Mid. N. line Sec. 35	265
Mid. N. line Sec. 36	295
N. E. cor. Sec. 36	325
Albion. T. 5, R. 12 E.	
Mid. W. line S. W. qr. Sec. 6	365
N. W. cor. Sec. 7	325
Mid. N. line N. W. qr. Sec. 7	330
Humphrey's quarry, S. E. qr. Sec. 10	320
Center Sec. 11	300
N. W. cor. Sec. 13	290
Surface of Rice lake	230
Mid. N. line Sec. 14	250
N. W. cor. Sec. 14	310
Center Sec. 14	300
Mid. S. hf. Sec. 14	290
Mid. S. hf. Sec. 18	260
Mid. N. line Sec. 20	280
Mid. N. line N. W. qr. Sec. 20	320
N. E. cor. Sec. 20	270
Road forks, N. line Sec. 21	295
Mid. E. line Sec. 21	245
Mid. E. hf. Sec. 22	255
Mid. E. hf. Sec. 23	270
Surface Koshkonong lake, Sec. 25	200
Mid. W. line S. W. qr. Sec. 26	270
Center S. E. qr. Sec. 27	265
Mid. E. hf. Sec. 27	260
Mid. N. line Sec. 27	250
Albion. T. 5, R. 12 E. — (con.)	
N. W. cor. Sec. 28	280
Mid. N. line Sec. 29	285
Mid. N. hf. Sec. 29	295
Center N. E. qr. Sec. 30	260
Mid. W. line Sec. 31	320
Center Sec. 32	315
Mid. N. line Sec. 32	305
Mid. E. line Sec. 34	270
Crossroads, near center Sec. 35	245
S. E. cor. Sec. 35	255
Road forks, E. hf. Sec. 36	285
Stream crossing, N. W. qr. Sec. 36	235
Verona. T. 6, R. 8 E.	
Mid. N. line N. E. qr. Sec. 2	500
Center S. line Sec. 3	430
Head of stream, W. hf. Sec. 6	400
N. E. cor. Sec. 6	520
Stream crossing, N. hf. Sec. 7	380
Mid. E. hf. Sec. 7	420
Center Sec. 8	450
Mid. S. line Sec. 10	450
S. E. cor. Sec. 12	480
S. E. cor. Sec. 13	480
Verona P. O., Sec. 15	380
Mid. S. line Sec. 17	365
Center Sec. 18	480
S. W. cor. Sec. 23	445
Mid. S. line Sec. 23	460
S. E. cor. Sec. 23	500
Mid. W. line Sec. 24	463
Center Sec. 24	490
Mid. E. line Sec. 24	490
N. E. cor. Sec. 24	460
Mid. S. line Sec. 24	500
Mid. N. ½ Sec. 25	520
Center Sec. 26	520
S. W. cor. Sec. 26	460
Mid. S. line Sec. 26	435
Center Sec. 35	395
Mid. S. line Sec. 35	380
Fitchburg, T. 6, R. 9 E.	
Cross roads, E. hf. Sec. 1	300
Mid. S. hf. Sec. 1	380
Mid. S. line Sec. 1	407
Stream crossing, center Sec. 2	260
Mid. S. line Sec. 2	325
Mid. S. line S. E. qr. Sec. 2	320
Center N. E. qr. Sec. 3	430
Mid. S. line S. E. qr. Sec. 6	395
Top of bluff, N. W. qr. Sec. 7	500
Cross roads, S. line S. W. qr. Sec. 8	395
S. E. cor. Sec. 9	370
Waldron's quarry, S. line Sec. 10	450
S. E. cor. Sec. 10	365
Center Sec. 22	333
Mid. S. line Sec. 12	295
Mid. E. hf. Sec. 13	355
Mid. N. hf. Sec 13	325
S. W. corner Sec. 14	393
Mid. S. line Sec. 15	400
S. W. cor. Sec. 15	425
Mid. N. E. qr. S. E. qr. Sec. 16	480
S. W. cor. Sec. 18	470
Mid. W. line Sec. 19	490

BAROMETRICAL ALTITUDES — *continued.*

Fitchburg. T. 6, R. 9 E. — (con.)

Cross roads, E. hf. Sec. 19	470
Mid. E. line Sec. 19	440
S. W. cor. Sec. 19	490
Mid. S. line Sec. 19	460
Center Sec. 20	430
Center Sec. 21	550
School House, E. hf. Sec. 21	470
Road, S. E. qr. S. E. qr. Sec. 21	455
Mid. E. hf. Sec. 22	425
Creek crossing, S. E. qr. Sec. 24	316
Mid. S. line S. E. qr. Sec. 24	340
S. E. qr. S. E. qr. Sec. 25	409
Mid. W. line N. W. qr. Sec. 26	460
Center Sec. 27	421
Center Sec. 28	367
Mid. E. hf. Sec. 29	480
Mid. W. hf. Sec. 29	450
Center Sec. 30	420
Mid. W. line Sec. 30	480
Mid. W. line Sec. 31	465
Oak Hall, center Sec. 33	354
Mid. E. line Sec. 33	353
Center Sec. 34	345
Mid. W. hf. Sec. 36	407
Center Sec. 36	385

Dunn. T. 6, R. 10 E.

Road forks, E. line N. E. qr. Sec. 1	280
Road forks, W. line N. W. qr. Sec. 1	290
Mid. N. hf. Sec. 2	320
Creek crossing, center N. W. qr. Sec. 7	255
Mid. E. hf. Sec. 16	315
Mid. W. hf. Sec. 16	315
Mid. W. line Sec. 16	300
Creek crossing, S. line S. W. qr. Sec. 16	270
Center Sec. 17	265
Center S. line Sec. 17	290
Creek crossing, N. W. qr. Sec. 18	255
S. W. cor. Sec. 18	270
Mid. E. line Sec. 19	330
Stream crossing, near center Sec. 20	316
S. W. cor. Sec. 20	340
Center Sec. 21	325
Center S. line Sec. 21	325
Center S. line S. W. qr. Sec. 21	360
S. E. cor. Sec. 21	293
Mid. E. line S. E. qr. Sec. 21	354
Mid. S. line Sec. 22	285
S. W. cor. Sec. 23	298
Mid. S. line Sec. 25	275
Mid. E. line Sec. 31	360
Mid. S. line Sec. 33	315
Mid. S. line S. E. qr. Sec. 33	275
Mid. S. line S. W. qr. Sec. 34	275
Mid. S. line S. W. qr. Sec. 35	295

Pleasant Springs. T. 6. R. 11 E.

Bend in road, S. line S. W. qr. Sec. 2	350
Mid. S. line Sec. 3	350
S. W. cor. Sec. 3	335
Mid. W. line Sec. 3	400
N. W. cor. Sec. 3	400
Mid. S. line Sec. 4	380
Mid. W. hf. Sec. 4	325

Pleasant Springs. T. 6. R. 11 E.— (con.)

Mid. S. line S. E. qr. Sec. 6	340
Center S. line Sec. 8	270
S. E. cor. Sec. 8	285
S. E. cor. Sec. 9	329
Mid. E. line Sec. 9	340
Quarry, N. E. qr. N. E. qr. Sec. 10	410
Mid. N. hf. Sec. 11	280
Center S. E. qr. Sec. 11	320
Mid. N. hf. Sec. 13	320
Mid. E. line, S. E. qr. Sec. 13	325
S. E. cor. Sec. 13	370
Mid. W. line N. W. qr. Sec. 13	300
S. W. cor. Sec. 14	320
Mid. S. line Sec. 15	290
Mid. W. line S. W. qr. Sec. 15	260
Mid. S. line Sec. 17	265
Center Sec. 22	268
Mid. S. line Sec. 22	340
S. E. cor. Sec. 24	400
Mid. E. line Sec. 25	380
Mid. W. line Sec. 31	305
Center Sec. 31	300
Center Sec. 32	280
Mid. W. hf. Sec. 34	308
Mid. N. hf. Sec. 34	260
Mid. W. hf. Sec. 35	340
Mid. E. line Sec. 36	310
S. E. cor. Sec. 36	350

Christiana. T. 6. R. 12 E.

Mid. W. line Sec. 2	290
Mid. E. hf. Sec. 3	280
N. W. cor. Sec. 6	315
Mid. S. line S. E. qr. Sec. 6	285
Stream crossing, N. hf. Sec. 7	275
Mid. S. hf. Sec. 7	330
Mid. E. hf. Sec. 10	320
Mid. W. hf. Sec. 11	280
Mid. E. line Sec. 11	260
Mid. N. hf. Sec. 12	230
Mid. E. hf. Sec. 12	230
Stream crossing, mid. W. line Sec. 14	290
S. E. cor. Sec. 15	325
Mid. S. line Sec. 15	350
Mid. E. line N. E. qr. Sec. 15	315
Mid. S. line Sec. 16	385
S. W. cor. Sec. 16	400
Mid. S. line S. E. qr. Sec. 17	410
S. W. cor. Sec. 17	355
Center Sec. 18	315
Mid. S. line Sec. 18	340
Stream, E. line S. E. qr. Sec. 21	315
Mid. E. line S. E. qr. Sec. 22	360
S. E. cor. Sec. 22	320
Cross-roads, S. line S. E. qr. Sec. 23	310
N. W. cor. Sec. 27	375

Cross Plains. T. 7, R. 7 E.

Mid. E. line Sec. 1	400
Cross Plains depot, Sec. 3	274
Top of bluff, N. line N. W. qr. Sec. 3	420
Mid. S. line Sec. 3	400
Mid. E. line N. E. qr. Sec. 7	345
Center Sec. 10	325
Center S. E. qr. Sec. 10	330
Mid. E. line Sec. 11	326

BAROMETRICAL ALTITUDES — *continued.*

Cross Plains. T. 7, R. 7 E. — (con.)	
Mid. E. line S. E. qr. Sec. 12	339
Mid. W. line N. W. cor. Sec. 15	480
Center S. W. qr. Sec. 15	490
Mid. S. line S. W. qr. Sec. 15	400
Mid. N. hf. Sec. 17	325
Mid. W. line N. W. qr. Sec. 17	340
Mid. E. line Sec. 19	550
Mid. E. line N. E. qr. Sec. 19	480
Mid. E. line S. E. qr. Sec. 19	595
S. E. cor. Sec. 19	570
Mid. S. line Sec. 20	495
S. E. cor. Sec. 21	490
Mid. W. hf. Sec. 22	390
Mid. W. line S. W. qr. Sec. 27	405
Stream, center S. E. qr. Sec. 33	405
Middleton. T. 7, R. 8 E.	
Road forks, E. hf. Sec. 2	367
Mid. W. line Sec. 2	367
Center Sec. 3	367
Center Sec. 4	447
Mid. W. line Sec. 4	407
Mid. E. hf. Sec. 5	421
Mid. W. hf. Sec. 5	507
Mid. E. hf. Sec. 6	547
Mid. W. hf. Sec. 6	527
Mid. W. line S. W. qr. Sec. 7	339
Center Sec. 9	352
Center Sec. 10	365
Stream crossing, N. hf. Sec. 11	357
Road forks. E. hf. Sec. 12	320
Mid. E. line Sec. 13	345
Mid. S. line Sec. 13	415
Mid. S. line Sec. 14	410
S. W. cor Sec. 14	390
Mid. S. line S. E. qr. Sec. 15	380
Mid. W. line Sec. 16	553
Mid. W. hf. Sec. 17	453
Mid. S. line Sec. 17	518
Center S. W. qr. Sec. 17	555
Mid. S. line S. W. qr. Sec. 17	518
Mid. E. line N. E. qr. Sec. 18	353
Center N. E. qr. Sec. 18	428
20 rods south of last	541
Mid. N. hf. Sec. 20	540
Mid. S. hf. Sec. 20	503
S. E. cor. Sec. 20	508
Mid. S. line Sec. 21	538
Mid. S. line S. W. qr. Sec. 22	508
Mid. S. line S. E. qr. Sec. 22	478
S. E. cor. sec. 23	450
Mid. S. line Sec. 24	425
Mid. S. line Sec. 27	498
S. W. cor. Sec. 27	550
S. W. cor. Sec. 28	495
Mid. S. line Sec. 29	480
S. W. cor. Sec. 29	535
Mid. E. line Sec. 31	540
Mid. E. line N. E. qr. Sec. 31	600
S. W. cor. Sec. 32	560
Center Sec. 34	508
Mid. S. line Sec. 34	478
S. E. cor. Sec. 34	558
Mid. S. line S. W. qr. Sec. 35	513
Mid. S. line S. E. qr. Sec. 35	433
Middleton. T. 7, R. 8 E. — (con.)	
Center Sec. 35	448
Mid. E. line S. E. qr. Sec. 35	530
Mid. E. line Sec. 35	428
Center Sec. 36	488
Mid. E. hf. Sec. 36	458
Madison. T. 7, R. 9 E.	
Lake Mendota	270
Capitol Hill, S. W. cor. Sec. 13	348
University Hill, S. W. cor. Sec. 14	372
Railroad, S. line Sec. 16	260
Mid. S. line Sec. 18	332
Mid. S. line S. W. qr. Sec. 19	450
Mid. S. line Sec. 19	415
S. E. cor. Sec. 19	400
Mid. S. line S. W. qr. Sec. 20	360
Mid. S. line S. E. qr. Sec. 20	435
Mid. S. line S. W. qr. Sec. 21	415
Center N. W. qr. S. E. qr. Sec. 21	390
Lake Monona	262
Road, mid. S. line Sec. 26	315
Center S. W. qr. Sec. 28	295
S. line S. W. qr. S. W. qr. Sec. 28	360
Mid. W. line Sec. 31	478
Center Sec. 31	458
Mid. E. line Sec. 31	448
Mid. W. hf. of E. hf. of Sec. 32	438
Mid. S. hf. Sec. 33	320
Mid. E. line Sec. 34	290
Center Sec. 35	300
Blooming Grove. T. 7, R. 10 E.	
Mid. N. line N. W. qr. Sec. 3	338
Mid. E. hf. Sec. 4	315
Mid. W. hf. Sec. 9	325
Center Sec. 9	310
Mid. W. hf. E. hf. Sec. 10	390
Mid. W. hf. W. hf. Sec. 11	410
Mid. W. hf. Sec. 11	455
Mid. W. hf. Sec. 12	400
⅛ mile W. of center of Sec. 12	330
Center N. E. qr. Sec. 15	340
Center S. line S. E. qr. Sec. 15	290
S. W. corner Sec. 15	310
Mid. W. hf. Sec. 16	310
Mid. W. hf. E. hf. Sec. 20	320
Mid. W. line Sec. 21	330
Center S. W. qr. Sec. 21	290
Center S. E. qr. S. E. qr. Sec. 21	270
N. W. cor. Sec. 22	310
Center S. E. qr. Sec. 22	290
Mid. W. line Sec. 26	290
⅛ mile E. of W. line Sec. 27	280
Mid. N. line Sec. 30	300
Mid. W. line N. E. qr. Sec. 30	310
One-sixth mile E. N. W. cor. Sec. 35.	350
Center Sec. 35	340
Cottage Grove. T. 7, R. 11 E.	
Mid. N. line Sec 1	320
Mid. E. line Sec. 1	350
Center N. W. qr. Sec. 1	295
Mid. W. line S. W. qr. Sec. 2	365
Center S. W. qr. N. W. qr. Sec. 2	275
Mid. W. line S. E. qr. Sec. 3	360
Mid. W. line N. E. qr. Sec. 4	320
Mid. W. line S. W. qr. S. W. qr. Sec. 55	35

BAROMETRICAL ALTITUDES — *continued.*

Cottage Grove. T. 7, R. 11 E. — (con.)

Center Sec. 6	330
Mid. N. hf. Sec. 7	325
Mid. E. line N. E. qr. Sec. 7	345
Mid. N. hf. Sec. 8	345
Mid. E. line Sec. 8	315
Mid. N. hf. Sec. 9	320
Mid. S. hf. Sec. 9	300
Center N. W. qr. Sec. 10	300
Mid. N. hf. Sec. 10	340
Mid. E. line N. E. qr. Sec. 10	270
Mid. S. hf. Sec. 11	300
Mid. N. hf of N. E. qr. Sec. 11	345
Center of S. W. qr. Sec. 12	360
¼ mile S. mid. E. line N. E. qr. Sec. 13	275
Mid. N. hf Sec. 13	275
$\frac{1}{16}$ mile S. W. of N. E. cor. of Sec. 14	320
$\frac{1}{16}$ mile E. of center of Sec. 14	330
1 mile N. E. of S. W. cor. Sec. 19	280
Mid. W. line S. W. qr. Sec. 21	280
Mid. N. line Sec. 21	260
N. E. cor. Sec. 21	300
Mid. S. line S. E. qr. Sec. 29	240
Mid. S. line Sec. 29	300
Mid. S. hf. S. W. qr, Sec. 29	310
Mid. W. line Sec. 29	280
⅛ mile S. E. N. E. cor. Sec. 30	280
Mid. E. hf Sec. 32	255
Mid. N. hf Sec. 33	350
S. E. cor. Sec. 33	420
Mid. E. line S. E qr. Sec. 33	340

Deerfield. T. 7, R. 12 E.

Mid. N. line Sec. 4	320
Mid. S. hf Sec. 4.	290
Center S. E. qr. S. E. qr. Sec. 5	335
Mid. E. line Sec. 7	325
S. W. cor. S. E. qr. S. E. qr. Sec. 8.	285
Mid. N. hf Sec. 9	325
Mid. W. line S. E. qr. S. E. qr. Sec. 9	280
Mid. S. hf Sec. 10	265
Mid. S. hf Sec. 11	275
Mid. W. hf Sec. 12	290
Center S. W. qr. S. W. qr. Sec. 12.	310
Mid. S. hf Sec. 12	300
S. E. corner Sec. 12	270
Mid. E. line Sec. 13	265
Mid. S. line Sec. 13	250
Crossroads, N. W. qr Sec. 14	285
Road corners E. line N. E. qr. Sec. 18	295
Center S. E. qr. Sec. 23	325
Mid. W. hf Sec. 25	280
Mid. W. line N. W. qr. Sec. 25	270
Road corners, S. E. qr. Sec. 26	260
Mid. E. hf Sec. 28	280
Mid. S. line S. E. qr. Sec. 29	360
S. E. cor. Sec. 31	320
Center S. E. qr. Sec. 32	300
Center N. W. qr. Sec. 33	365
S. E. cor. Sec. 33	305
S. E. cor. Sec. 34.	305
Mid. S. line S. E. qr. Sec. 35	290

Deerfield. T. 7, R. 12 E. — (con.)

Mid. S. line Sec. 36	300

Berry. T. 8, R. 7 E.

Mid. S. line S. E. qr. Sec. 3	340
S. W. cor. Sec. 3	330
Mid. W. line Sec. 3	340
Mid. S. line Sec. 5	330
Center Sec. 7	280
Roadforks, N. W. qr. Sec. 8	280
Roadforks, N. W. qr. Sec. 9	310
Mid. S. line Sec. 9	450
Mid. S. line S. E. qr. Sec. 10	450
Center S. E. qr. Sec. 10	365
Mid. S. line S. W. qr. Sec. 13	440
Mid. E. line S. W. qr. Sec. 13	515
S. W. cor. Sec. 14	540
Road forks, N. E. qr. Sec. 15	385
S. W. cor. Sec. 15	370
Center N. W. qr. Sec. 15	380
Center S. E. qr. Sec. 16	350
Center Sec. 16	435
Mid. N. hf. Sec. 16	475
Mid. S. line S. W. qr. Sec. 16	300
Center N. E. qr. Sec. 17	500
Mid. N. hf. Sec. 17	465
Mid. N. hf. Sec. 18	445
Mid. W. line Sec. 18	440
N. W. cor. Sec. 21	275
Mid. W. line Sec. 21	310
Mid. E. line N. E. qr. Sec. 21	450
Mid. E. line Sec. 21	540
Mid. S. line S. W. qr. Sec. 22	350
Mid. E. line Sec. 22	400
Mid. N. hf. Sec. 23	450
Road corners, N. E. qr. Sec. 23	510
Mid. E. line S. E. qr. Sec. 24	415
S. E. corner Sec. 24	360
Mid. E. hf. Sec. 25	340
Mid. W. line Sec. 25	400
Center Sec. 27	335
Mid. S. hf. Sec. 27	345
Road-forks S. E. qr. Sec. 27	440
Road corners S. W. qr. Sec. 27	330
Center S. E. qr. Sec. 29	480
Center N. E. qr. Sec. 29	490
Mid. E. hf. Sec. 29	460
Center N. E. qr. Sec. 32	430
Mid. S. line S. E. qr. Sec. 33	310
Mid. E. line Sec. 33	290
Mid. E. line N. E. qr. Sec. 34	520
Mid. S. line Sec. 35	320
Center N. E. qr. Sec. 35	400
Mid. E. hf. Sec. 35	325
Center N. E. qr. Sec. 36	460

Springfield. T. 8, R. 8 E.

Mid. S. line S. W. qr. Sec. 1	420
Mid. S. line S. W. qr. Sec. 2	335
Mid. S. line Sec. 3	350
Mid. S. hf. of N. hf. Sec. 4	410
Center Sec. 4.	480
Road-forks W. line Sec. 5	410
Road-forks S. W. qr. Sec. 8	520
Mid. E. hf. N. W. qr. Sec. 8	480
Road corners N. E. qr. Sec. 9	350
Mid. W. line S. W. qr. Sec. 10	340

BAROMETRICAL ALTITUDES — *continued.*

Springfield. T. 8, R. 8 E. — (con.)

Center N. W. qr. Sec. 12	330
Mid. W. hf. Sec. 15	395
Mid. S. line Sec. 15	400
S. W. cor. Sec. 15	450
Mid. S. line S. W. qr. Sec. 16	520
Mid. E. hf. Sec. 17	520
Mid. W. line Sec. 17	450
Mid. W. line N. W. qr. Sec. 17	450
S. part N. E. qr. Sec. 18	402
S. part S. E. qr. Sec 18	380
Road corners S. W. qr. Sec. 19	375
Center Sec. 19	380
Mid. N. line S. W. qr. S. W. qr. Sec. 19	450
Center Sec. 21	480
Mid. W. hf. Sec. 21	450
Center N. W. qr. Sec. 21	480
Mid. W. hf. E. hf. Sec 22	370
Center Sec. 22	429
S. E. corner Sec. 22	390
Mid W. hf. Sec. 23	450
Mid S. line, Sec. 24	350
Mid. W. line, Sec. 25	390
Mid. E. hf. E. hf. Sec. 26	430
Mid W. line Sec. 26	390
Center Sec. 27	380
Mid W. line, Sec. 27	420
S. W. cor. Sec. 27	380
S. line S. W. qr. S. W. qr. Sec. 28	450
Center N. W. qr. Sec. 31	525
Mid. W. hf. E. hf. Sec. 31	500
Center S. W. qr. N. E. qr. Sec. 31	560
Center S. W. qr. Sec. 31	450
Mid. E. line, Sec. 33	350
Mid. S. E. qr. Sec. 34	360

Westport. T. 8, R. 9, E.

Mid. E. hf. S. E. qr. Sec. 1	300
Center S. E. qr. Sec. 2	350
Waunakee depot	341
Mid S. line S. E. qr. Sec. 6	335
S. E. cor. Sec. 7	390
Mid. S. line Sec. 11	403
S. E. cor. Sec. 11	403
Mid. N. hf. Sec. 12	320
S. W. Sec. 17	325
Stream crossing, E. hf. Sec. 19	290
Bluff-top N. hf. Sec. 19	400
Mid. S. line S. E. qr. Sec. 19	295
Mid. E. line Sec. 19	325
Roadforks, N. E. qr. Sec. 22	277
Mid. N. hf. Sec. 23	371
Quarry, N. line S. W. qr. Sec. 25	394
Mid. S. line Sec. 25	290
Center Sec. 26	340
Mid. E. line S. E. qr. Sec. 36	310

Burke. T. 8, R. 10 E.

Mid. E. line Sec. 1	400
Mid. N. line, Sec. 3	296
Quarry, S. W. qr. S. W. qr. Sec. 2	460
Creek, N. line N. W. qr. Sec. 3	285
N. W. cor. Sec. 4	307
N. W. cor. Sec. 5	295
N. W. cor. Sec. 6	282
Mid. S. line Sec. 8	302

Burke. T. 8, R. 10 E. — (con.)

1-8 mile E	392
S. E. corner Sec. 8	332
Mid. S. line Sec. 9	334
S. E. cor. Sec. 9	354
Mid. S. line Sec. 10	380
S. E. cor. Sec. 10	380
School, N. W. cor. Sec. 13	332
Center Sec. 12	327
Mid. S. hf. Sec. 14	372
S. W. cor. Sec. 17	277
Mid. N. hf. Sec. 19	292
Mid. S. line Sec. 19	327
Mid. E. line Sec. 21	314
Mid. E. line S. E. qr. Sec. 21	354
Center Sec. 22	390
Mid. S. line Sec. 22	340
Railroad, E. line N. E. qr. Sec. 23	355
Quarry. N. W. qr. Sec. 27	325
Mid. W. line Sec. 28	308
Center Sec. 29	280
Center Sec. 30	302
Mid. S. line Sec. 30	302
Center Sec. 31	392
Crossroads N. W qr. Sec. 33	315
Mid. E. line N. E. qr. Sec. 33	274
Mid. W. hf. Sec. 35	420
Quarry, N. E. qr. N. W. qr. Sec. 35	462

Sun Prairie. T. 8, R. 11 E.

Mid. W. line S. W. qr. Sec. 1	315
S. E. cor. Sec. 13	330
Mid. S. line S. E. qr. Sec. 13	350
Center Sec. 24	350

Medina. T. 8, R. 12 E.

Mid. W. line Sec. 1	290
S. W. cor. Sec. 1	250
Mid. S. line S. W. qr. Sec. 2	260
Mid. S. line Sec. 3	315
S. W. cor Sec. 3	315
Mid. N. line Sec. 4	300
Stream, W. line Sec. 4	280
Mid. E. line Sec. 7	320
S. E. cor. Sec. 7	320
Mid. E. line Sec. 11	255
N. W. cor. Sec. 13	295
Mid. W. line Sec. 13	255
S. W. cor. Sec. 13	270
Mid. S. line Sec. 14	305
Mid. E. hf. Sec. 15	260
Marshall, Sec. 15	290
Center S. W. qr. Sec. 16	280
Mid. W. line N. W. qr. Sec. 16	295
Center Sec. 17	300
S. W. cor. Sec. 18	330
S. E. cor. Sec. 20	305
Mid. E. line Sec. 22	315
S. E. cor. Sec. 22	360
Mid. S. hf. Sec. 23	370
Mid. S. line Sec. 23	360
Mid. N. hf. Sec. 24	320
Mid. S. line S. E. qr. Sec. 24	300
Mid. S. line Sec. 25	365
S. W. cor. Sec. 25	315
Mid. N. hf. Sec. 26	420
Mid. S. line Sec. 26	390

BAROMETRICAL ALTITUDES — *continued.*

Medina. T. 8, R. 12 E. — (con.)	
Mid. E. line N. E. qr. Sec. 27	320
Stream, N. W. qr. Sec. 27	290
Mid. E. hf, Sec. 29	310
Mid. S. line Sec. 29	315
Center Sec. 32	290
Mid. S. line Sec. 32	320
Center Sec. 33	338
Mid. W. hf. Sec. 33	300
Mid. N. hf. Sec. 33	340
Mid. S. hf. Sec. 33	340
Center N. W. qr. Sec. 36	305
Roxbury. T. 9, R. 7 E.	
S. W. cor. Sec. 3	275
S. W. cor. Sec. 4	265
Bluff near center Sec. 5	430
Center S. E. qr. Sec. 5	250
Road crossing, mid. S. hf. W. line Sec. 5	285
Center N. E. qr. S. E. qr. Sec. 6	310
Mid. E. line Sec. 7	275
Mid. S. line Sec. 7	200
Mid. S. line S. E. qr. Sec. 7	200
Mid. S. line S. E. qr. N. E qr. Sec. 7	300
Center S. E. qr. N. W. qr. Sec. 8	450
S. E. cor. Sec. 8	320
N. E. qr. S. E. qr. Sec. 9	350
S. W. cor. Sec. 10	340
Forks of road, S. E. qr. Sec. 10	330
Mid. E. line S. E. qr. Sec. 10	305
S. line S. E. qr. S. W. qr. Sec. 10	340
S. line S. W. qr. S. E. qr. Sec. 10	285
Mid. E. line N. E. qr. Sec. 11	400
Mid. N. hf. Sec. 11	340
N. W. cor. Sec. 12	430
Mid. N. hf. Sec. 12	340
Center N. E. qr. S. W. qr. Sec. 12	500
Center N. W. qr. S. E. qr. Sec. 12	410
Mid. E. line Sec. 12	430
S. W. cor. Sec. 12	365
S. E. cor. Sec. 12	370
Mid. N. line N. W. qr. Sec. 13	430
Mid. S. hf. Sec. 13	370
Mid. W. hf. Sec. 13	330
Mid. S. line Sec. 13	400
Center N. E. qr. Sec. 14	271
Mid. S. line Sec. 16	270
Mid. S. line S. W. qr. Sec. 16	270
Mid. S. line S. E. qr. Sec. 17	255
S. W. cor. Sec. 17	255
Mid. E. line N. E. qr. Sec. 19	215
Mid. N. hf. S. hf. Sec. 20	205
Mid. S. line S. W. qr. Sec. 21	375
Mid. E. line Sec. 22	305
Mid. N. W. qr. Sec. 23	305
Mid. E. line N. E. qr. Sec. 23	410
Mid. N. line N. W. qr. See. 24	425
Mid. E. line Sec. 24	530
Mid. E. line Sec. 25	500
S. E. cor. Sec. 25	550
S. W. cor. Sec. 25	390
Aldens Corner, Sec. 26	365
Mid. W. line S. W. qr. Sec. 27	305
Mid. W. line, Sec. 28	290
Mid. W. line N. W. qr. Sec. 28	280
Roxbury. T. 9, R. 7 E. — (con.)	
Mid. W. line N. W. qr. Sec. 29	315
Center S. E. qr. Sec. 30	490
Center N. E. qr. N. E. qr. Sec. 31	390
Center S. E. qr. Sec. 31	255
Center E. line S. E. qr. Sec. 31	265
Center S. hf. Sec. 32	285
⅛ mile N.	340
Mid. E. line S. E. qr. Sec. 32	375
Mid. W. hf. Sec. 33	385
Mid. E. hf. Sec. 33	505
Mid. E. line Sec. 33	400
Center S. E. qr. Sec. 34	380
Mid. E. line Sec. 36	600
Dane. T. 9, R. 8 E.	
Mid. S. line S. W. qr. Sec. 2	320
Mid. W. line, Sec. 2	375
N. W. cor. Sec. 2	300
Center N. hf Sec. 4	280
⅛ mile W	500
Mid. W. line N. W. qr Sec. 4	520
Mid. E. line Sec. 7	355
S. E. cor. Sec. 7	410
Cross roads, N. W. qr. S. E. qr. Sec. 7,	330
Center S. W. qr. Sec. 7	425
⅛ mile N.	500?
Mid. S. line Sec. 7	540
Center Sec. 9	380
Center Sec. 11	420
S. E. cor. Sec. 11	510
Center N. E. qr. Sec. 12	400
Mid. E. line Sec. 12	500
Dane Station, Sec. 13	477
Mid. W. line Sec. 15	440
S. W. cor. Sec. 15	550
Center S. W. qr. Sec. 17	510
Mid. S. line S. W. qr. Sec. 17	445
Center Sec. 19	490
Center Sec. 20	450
Mid. S. line Sec. 20	500
S. E. cor. Sec. 20	560
Mid. S. line S. W. qr. Sec. 23	445
Mid. S. line S. E. qr. Sec. 23	560
Mid. W. line Sec. 27	560
Center N. W. qr. Sec. 30	590
Mid. W. line S. W. qr. Sec. 31	560
Center S. E. qr. Sec. 33	480
Vienna. T. 9, R. 9 E. —	
Mid. W. hf. Sec. 7	540
Mid. W. line Sec. 7	500
Mid. E. hf. Sec. 7	530
Mid. W. hf. Sec. 8	470
Center Sec. 8	500
Mid. S. hf. Sec. 8	440
S. W. cor. Sec. 15	480
Knob, S. hf. Sec. 20	520
Mid. E. line Sec. 21	490
Mid. W. line Sec. 27	540
Windsor. T. 9, R. 10 E.	
Mid. S. line S. W. qr. Sec. 1	416
Mid. S. line S. E. qr. Sec. 2	426
Mid. S. line Sec. 2	426
S. W. cor. Sec. 2	416
Mid. S. line, S. W. qr. Sec. 3	396
Mid. S. line S. E. qr. Sec. 4	436

BAROMETRICAL ALTITUDES — *continued.*

Windsor. T. 9, R. 10 E. — (con.)

Mid. S. line Sec. 4	416
Center N. W. qr. Sec. 10	406
Center N. W. qr. S. E. qr. Sec. 10	396
S. W. corner Sec. 10	376
Mid. E. hf. Sec. 11	411
Mid. S. line Sec. 11	416
S. E. cor. Sec. 11	416
Center N. W. qr. Sec. 13	396
Mid. W. line S. W. qr. Sec. 13	416
Quarry, S. E. qr. Sec. 14	466
Forks of road, S. E. cor. Sec. 14	426
N. W. qr. Sec. 16	376
Mid. W. line N. W. qr. Sec. 16	386
S. W. cor. Sec. 16	386
Mid. W. line N. W. qr. Sec. 21	401
Mid. W. line S. W. qr. Sec. 21	405
Mid. E. line Sec. 23	416
S. E. cor. Sec. 23	376
Mid. W. line Sec. 25	396
S. W. cor. Sec. 25	386
Mid. S. line S. E. qr. Sec. 25	346
Mid. N. line Sec. 25	356
S. E. cor. Sec. 25	356
Mid. S. line Sec. 26	306
Mid. S. line S. E. qr. Sec. 27	336
Mid. W. hf. Sec. 27	386
Center N. W. qr. Sec. 28	396
Mid. E. hf. Sec. 28	411
Mid. W. line Sec. 28	366
Center Sec. 29	326
Forks of road, N. W. qr. Sec. 34	311
Center N. W. qr. Sec. 35	336

Bristol. T. 9, R. 11 E.

Mid. S. line S. W. qr. Sec. 1	366
S. W. cor. Sec. 1	346
Mid. S. line S. E. qr. Sec. 2	376
Mid. S. line Sec. 3	376
Mid. W. line Sec. 3	356
Mid. S. line Sec. 4	376
Mid. E. hf. Sec. 5	371
Mid. S. line Sec. 5	366
Mid. S. line S. W. qr. Sec. 5	366
Mid. S. line S. E. qr. Sec. 6	386
Mid. E. hf. Sec. 7	366
Mid. S. line S. E. qr. Sec. 7	356
N. W. cor. Sec. 9	366
Center S. E. qr. Sec. 9	376
Center N. E. qr. Sec. 9	366
Mid. S. line S. W. qr. S. W. qr. Sec. 10	376
Mid. E. line Sec. 10	376
Mid. E. line N. E. qr. Sec. 11	376
S. E. cor. Sec. 12	366
Center Sec. 13	371
Mid. E. hf. Sec. 16	371
Mid. E. hf. Sec. 17	416
Mid. S. line Sec. 17	406
Mid. S. line S. E. qr. Sec. 18	386
N. W. cor. Sec. 20	396
Center N. E. qr. Sec. 20	381
S. W. cor. Sec. 20	406
¼ mile south	406
Mid. E. line S. E. qr. Sec. 21	366
S. E. cor. Sec. 21	356

Bristol. T. 9, R. 11 E. — (con.)

Mid. S. hf. Sec. 22	386
Mid. E. line N. E. qr. Sec. 23	371
Mid. E. line Sec. 23	356
Center Sec. 25	336
S. W. cor. Sec. 25	366
Center Sec. 26	376
Mid. W. hf. Sec. 26	386
Mid. W. line Sec. 26	376
N. W. cor. Sec. 27	356
S. W. cor. Sec. 27	416
Mid. E. hf. Sec. 29	416
Mid. S. line S. W. qr. Sec. 29	406
S. W. cor. Sec. 29	376
S. W. cor. Sec. 30	356
Mid. E. line N. E. qr. Sec. 31	386
S. E. cor. Sec. 31	421
Mid. E. hf. Sec. 32	396
S. E. cor. Sec. 34	371
Mid. E. line Sec. 34	376
N. W. cor. Sec. 35	396
Mid. E. line Sec. 35	376

York. T. 9, R. 12 E.

Mid. W. line S. W. qr. Sec. 1	310
Mid. S. line S. W. qr. Sec. 1	340
S. W. cor. Sec. 1	325
Mid. N. line Sec. 2	335
S. W. cor. Sec. 2	360
Mid. S. line Sec. 3	345
S. W. cor. Sec. 3	365
Mid. S. line Sec. 4	355
S. W. cor. Sec. 4	358
Mid. W. line S. W. qr. Sec. 4	365
Center Sec. 5	355
Mid. S. line Sec. 6	385
Center Sec. 7	365
S. W. cor. Sec. 7	345
Mid. N. line N. E. qr. Sec. 8	360
Mid. E. line Sec. 8	350
Mid. S. line S. E. qr. Sec. 8	340
S. E. cor. Sec. 9	390
Mid. S. line Sec. 9	360
Mid. N. hf Sec. 10	345
Mid. S. line Sec. 10	380
Mid. N. line Sec. 11	335
Mid. E. line Sec. 11	340
Mid. S. line S. E. qr. Sec. 12	265
S. E. cor. Sec. 12	290
S. E. cor. Sec. 13	340
S. W. cor. Sec. 15	360
Mid. W. line Sec. 16	350
Center Sec. 17	350
N. E. cor. Sec. 19	320
Center Sec. 19	320
S. E. cor. Sec. 20	330
Mid. E. line N. E. qr. Sec. 21	340
S. E. cor. Sec. 21	360
Mid. S. line Sec. 21	370
Center Sec. 22	375
Mid. S. line Sec. 22	350
Mid. S. line S. E. qr. Sec. 23	375
S. E. cor. Sec. 24	320
S. E. cor. Sec. 25	325
Mid. S. line Sec. 25	335
Mid. N. line Sec. 26	340

BAROMETRICAL ALTITUDES — *continued.*

York. T. 9, R. 12 E. — (con.)
S. W. cor. Sec. 26 355
Mid. S. line Sec. 26.............. 375
Mid. W. line Sec. 27......... 390
Mid. E. line Sec. 34 355
S. E. cor. Sec. 34................ 325
Mid. E. line Sec. 36 330

West Point. T. 10, R. 7 E.
Gibraltar Bluff, Mid. E. line Sec. 13 635
Marsh at foot of same, E. hf. Sec. 13 230
Cemetery, S. E. qr. S. E. qr. Sec. 14 370
Mid. S. line S. E. qr. Sec. 15 270
S. W. cor. Sec. 14 290
Mid. S. line Sec. 15............... 280
S. line S. E. qr. Sec. 16 290
Mid. S. line Sec. 16............... 280
Bend in road, N. line N. E. qr. Sec. 20 250
Top of limestone bluff, N. E. qr. Sec. 20 485
S. E. cor. Sec. 21................. 320
Mid. S. line S. E. qr. sec. 22....... 280
Mid. E. line Sec. 22 325
Mid. S. line Sec. 24............... 420
Center S. E. qr. Sec. 25............ 400
Mid. E. hf. Sec. 27........... 270
Center S. E. qr. Sec. 27 310
S. E. cor. Sec. 27................. 275
Center S. W. qr. Sec. 27........... 310
Mid. S. line S. W. qr. S. W. qr. Sec. 27 340
Mid. E. line Sec. 28....... 330
S. W. cor. Sec. 28 290
Mid. S. line S. W. qr. Sec. 29 280
Road, S. E. qr. Sec. 31........... 290
Mid. W. hf. N. E. qr. Sec. 33 370
Crossroads, N. hf. Sec. 36 345

Lodi (and West Point in part). T. 10, R. 8 E.
Bluff-top, S. W. qr. Sec. 7 520
Road-corners, N. W. qr. Sec. 14 ... 330
Mid. S. line S. W. qr. Sec. 14 420
Mid. N. hf. Sec. 14 475
Center N. W. qr. Sec. 15.......... 340
Center N. W. qr. Sec. 16.. 315
Mid. E. line Sec. 19............... 310
Mid. W. hf. Sec. 20 250
⅛ mile S. of Cent. of Sec. 20........ 240
S. W. cor. Sec. 20 440
Center N. W. qr. Sec. 23.......... 360
Mid. E. line N. E. qr. Sec. 23...... 460
Mid. S. line S. W. qr. Sec. 23...... 340
Bluff-top, S. E. qr. Sec. 23 560
Bluff-top, N. W. qr. Sec. 24....... 560
Center Sec. 26 250
Center S. E. qr. Sec. 27 330
Center S. W. qr. Sec. 28 470
Mid. W. line S. W. qr. Sec. 28 420
Mid. W. line Sec. 29.............. 360
Bluff-top, mid. N. hf. Sec. 31...... 475
Mid. E. line Sec. 31............... 350
Mid. E. line Sec. 32... 380

Arlington. T. 10, R. 8 E.
Creek crossing, N. E. qr. Sec. 1.... 300
Bluff-top, S. E. cor. Sec. 2......... 445

Arlington. T. 10, T. 8 E. — (con.)
S. W. cor. Sec. 2 380
Center Sec. 3..................... 305
Creek crossing, S. E. qr. Sec. 3..... 270
Mid. S. line S. W. qr. Sec. 4....... 375
S. W. cor. Sec. 4 355
S. W. cor. Sec. 5 370
Mid. W. line Sec. 5............... 340
S. line S. W. qr. Sec. 7 525
S. E. cor. Sec. 7.................. 425
S. E. cor. Sec. 8.................. 465
Mid. E. line Sec. 8 440
Mid. E. line Sec. 10............... 520
S. E. cor. Sec. 10................. 480
Mid. N. line N. W. qr. Sec. 13 440
Mid. S. line S. E. qr. Sec. 13 460
Arlington station, Sec. 13 460
S. W. cor. Sec. 14 470
S. W. cor. Sec. 15 500
Mid. S. line Sec. 16............... 460
S. W. cor. Sec. 16 440
S. W. cor. Sec. 17 490
Mid. W. line Sec. 17...... 460
Center Sec. 19.................... 540
S. E. cor. Sec. 19. 460
Knob, S. line S. E. qr. Sec. 21 525
Mid. E. line S. E. qr. Sec. 21 500
Bluff-top, S. W. qr. Sec. 27........ 520
Bluff-top, N. W. qr. Sec. 28....... 525
Bluff-top, W. line S. W. qr. Sec. 28. 520
Mid. W. line Sec. 28.............. 420
S. W. cor. Sec. 29 480
Bluff-top, N. E. qr. Sec. 34... 520

Columbus. T. 10, R. 12 E.
Mid. S. line Sec. 7................ 300
Stream, S. line S. E. qr. Sec. 8..... 275
Mid. N. line Sec. 9................ 310
N. E. cor. Sec. 9.................. 385
N. E. cor. Sec. 16................. 285
N. W. cor. Sec. 17................ 295
Mid. N. line Sec. 17............... 285
W. line N. W. qr. Sec. 19......... 365
Mid. E. line Sec. 20............... 325
N. E. cor. Sec. 20................. 305
Mid. E. hf. Sec. 21................ 285
Stream crossing, N. W. qr. Sec. 28. 300
Mid. N. hf. Sec. 32 395
Mid. E. hf. Sec. 33................ 395

Dekorra. T. 11 N., R. 8 E.
Mid. E. hf. Sec. 23 240
Mid. E. line Sec. 23............... 240

Dekorra. T. 11, R. 9 E.
Mid. W. line S. W. qr. Sec. 11 280
Cross-roads, W. hf. Sec. 14........ 335
Mid. W. line Sec. 17......... 340
S. W. cor. Sec. 17 370
S. W. cor. Sec. 20 220
Mid. S. line S. E. qr. Sec. 16....... 380
Cemetery, W. hf. Sec. 23.......... 310
Mid. W. hf. Sec. 28............... 320
Stream crossing, N. E. qr. Sec. 30.. 220
Mid. E. line N. E. qr. Sec. 30...... 240
Mid. S. hf. Sec. 33................ 270
Poynette depot.................... 264

BAROMETRICAL ALTITUDES — *continued.*

Lowville. T. 11 N., R. 10 E.
S. E. cor. Sec. 1 360
Mid. S. line S. W. qr. Sec. 2....... 330
Mid. S. line S. W. qr. Sec. 3....... 320
Bluff ¼th mile north.............. 425
Ravine, S. W. cor. Sec. 4.......... 260
S. W. cor. Sec. 5 320
Mid. S. line S. W. qr. Sec. 6....... 300
Mid. E. hf. Sec. 8 280
Bluff-top, S. E. qr. Sec. 9.......... 400
Mid. S. line S. W. qr. Sec. 9....... 330
Mid. S. line Sec. 10............... 350
S. W. cor. Sec. 11 350
S. E. cor. Sec. 11 370
S. E. cor. Sec. 12 370
Mid. W. line Sec. 13.............. 350
Mid. S. W. qr. Sec. 17 310
Mid. W. hf. Sec. 18............... 290
Mid. E. line Sec. 19 340
Mid. E. hf. Sec. 20............... 360
Mid. S. line S. E. qr. Sec. 20....... 420
Knob, S. line S. E. qr. Sec. 23 460
S. E. cor. Sec. 23 400
Mid. S. line Sec. 24............... 400
Mid. W. line N. W. qr. Sec. 28.... 400
Cent. N. E. qr. Sec. 29............ 420
Bluff top, S. E. qr. Sec. 31 410
Mid. E. line Sec. 31............... 350
Mid. E. hf. Sec. 32 400

Otsego. T. 11, R. 11 E.
Mid. W. hf. Sec. 1 345
Mid. W. line Sec. 1............... 375
Cent. Sec. 2...................... 345
Mid. E. hf. Sec. 3 330
Mid. W. line Sec. 3................ 350
Cent. Sec. 4....................... 375
Cent. Sec. 5....................... 340
Mid. W. line Sec. 5 360
Mid. W. line Sec. 7 420
Mid. E. line Sec. 11 365
Doylestown, Sec. 12 360
S. W. cor. Sec. 15 380
S. W. cor. Sec. 16 390
Mid. S. line Sec. 17............... 365
S. W. cor. Sec. 17................ 380
Mid. S. line Sec. 19............... 340
S. E. cor. Sec. 19................. 350
Mid. S. line Sec. 20............... 355
Cent. S. W. qr. Sec. 22 360
Mid. N. hf. Sec. 22............. 365
Otsego, Sec. 22.................. 355
Stream, E. line N. E. qr. Sec. 23... 345
Mid. E. line Sec. 23 365
Mid. E. line S. E. qr. Sec. 23...... 345
Mid. E. hf. Sec. 32 365
Mid. E. line Sec. 32............... 365
Cent. Sec. 33..................... 365
Cent. Sec. 34. 365
Mid. W. hf. Sec. 35 355
Mid. E. line Sec. 35 350

Fountain Prairie. T. 11, R. 12 E.
Marsh, W. hf. Sec. 2 312
Cent. N. W. qr. Sec. 2............ 370
Mid. S. line S. W. qr. Sec. 6........ 400
Mid. S. line Sec. 6 340

Fountain Prairie. T. 11, R. 12 E.—(con.)
Mid. S. hf. of N. hf. Sec. 7 370
Mid. W. line S. W. qr. Sec. 8..... 370
Mid. S. line S. W. qr. Sec. 8 360
Mid. S. line S. W. qr. Sec. 9 350
Mid S. line, Sec. 9................ 330
Stream, S. line S. W. qr. Sec. 10... 300
Mid. S. line Sec. 10.. 330
Mid. W. hf. Sec. 11............... 360
Stream crossing, N. hf. Sec. 14 320
Center N. E. qr. Sec. 13 314
Mid. W. line Sec. 28.............. 350
Mid. E. hf. Sec. 29 360
Stream, S. E. cor. Sec. 30 295
¼ mile south 340
S. E. cor. Sec. 31................. 310
Mid. S. line S. E. qr. Sec. 32 335
Mid. S. line Sec. 33 295
Mid. S. line Sec. 34........... ... 280
S. E. corner Sec. 36 252

Caledonia. T. 11, R. 8 E.
Mid. N. W. qr. Sec. 3 360
Mid. S. line Sec. 7................ 480
Mid. S. hf. Sec. 8................. 510
Center S. E. qr. Sec. 8 395
Center S. E. qr. Sec. 9 520
Mid. S. line Sec 16 485
Mid. W. line, Sec. 16............. 385
Mid. W. line N. W. qr. Sec. 21.... 330
Mid. W. line Sec. 21.............. 375

Caledonia. T. 12, R. 8 E.
Church, N.W.qr.N.W.qr.Sec.21. 280
⅓ mile south 420
Mid. S. line S. W. qr. Sec. 22...... 500
Mid. N. hf. Sec. 25 205
Cent. N. W. qr. Sec. 25........... 340
Road, W. line N. W. qr. Sec. 25... 505
Mid. E. hf. Sec. 26................ 560
Center Sec. 26.................... 560
S. E. qr. N. E. qr. Sec. 26.. 620
Center Sec. 27 510
Stream crossing, S. W. qr. Sec. 27. 480
Mid. S. line S. E. qr. Sec. 27 610
Center S. E. qr. Sec. 28 470
S. W. cor. Sec. 28................ 440
Mid. S. line Sec. 29 360
S. W. cor. Sec. 29 420
Mid. N. hf. Sec. 29 580
Mid. W. line N. W. qr. Sec. 29. .. 505
Center N. W. qr. Sec. 30.......... 505
Mid. W. line N. W. qr. Sec. 30.... 540
Bluff top, S. E. qr. Sec. 34......... 760
Mid. S. line S. W. qr. Sec. 35...... 310

Caledonia. T. 12, R. 9 E.
Bridge, Sec. 7.................... 220

Wyocena. T. 12, R. 10 E.
Railroad, W. line Sec. 1........... 235
Mid. W. line Sec. 10 225
S. W. cor. Sec. 10 240
Center Sec. 12 230
Stream, S. line Sec. 12 215
Center Sec. 13.................... 260
Mid. W. line Sec. 13.............. 275
Stream, center Sec. 14 210
Center Sec. 15................. ... 250

BAROMETRICAL ALTITUDES — *continued.*

Wyocena. T. 12, R. 10 E. — (con.)

Mid. W. line Sec. 15	230
Wyocena depot	240
Center Sec. 28	280
Mid. W. line Sec. 28	310
Mid. E. hf. Sec. 29	275
S. W. cor. Sec. 29	320
Mid. E. hf. Sec. 31	280
Mid. W. hf. Sec. 31	235
Mid. W. line N. W. qr. Sec. 36	290

Springvale. T. 12, R. 11 E.

One-fourth mile N. of cent. of Sec. 1	235
Mid. E. line Sec. 1	240
Mid. W. line N. W. qr. Sec. 2	280
Mid. N. hf. Sec. 3	290
Mid. W. line Sec. 4	235
Railroad, W. line Sec. 5	240
S. W. cor. Sec. 5	230
Mid. E. hf. Sec. 7	235
Center Sec. 7	230
Center Sec. 15	360
Mid. W. line Sec. 15	360
Bluff top, N. E. qr. Sec. 16	370
Mid. E. hf. Sec. 17	300
Stream crossing, N. hf. Sec. 18	222
Stream crossing, N. hf. Sec. 22	266
Mid. S. hf. Sec. 22	320
Mid. N. hf. Sec. 27	270
Road, W. line N. W. qr. Sec. 27	260
Mid. S. line S. E. qr. Sec. 28	280
Mid. S. line Sec. 28	300
S. W. cor. Sec. 28	290
Mid. S. hf. Sec. 29	250
S. W. cor. Sec. 29	300
Mid. S. line S. W. qr. Sec. 29	280

Courtland. T. 12, R. 12 E.

Randolph depot, Sec. 1	378
S. E. cor. Sec. 1	360
Mid. N. hf. Sec. 2	365
Center Sec. 2	355
Mid. W. line Sec. 2	375
Mid. W. hf. Sec. 3	355
Mid. N. line N. W. qr. Sec. 3	355
Mid. N. line N. E. qr. Sec. 4	355
Mid. N. line N. W. qr. Sec. 4	325
Mid. S. line S. W. qr. Sec. 5	375
Cambria depot, Sec. 6	284
Mid. W. hf. Sec. 8	380
S. W qr. Sec. 8	390
Center N. W. qr. Sec. 11	402
Mid. W. hf. Sec. 11	390
S. W. cor. Sec. 11	383
S. W. cor. Sec. 13	377
Mid. S. line Sec. 14	364
Mid. W. line S. W. qr. Sec. 14	380
Mid. E. line N. E. qr. Sec. 13	367
Mid. W. hf. Sec. 17	410
Center Sec. 19	430
Mid. S. hf. Sec. 19	350
Mid. W. hf. Sec. 20	390
Mid. N. hf. Sec. 23	360
Stream crossing, N. hf. Sec. 26	335
Mid. S. hf. Sec. 26	357
Mid. N. hf. Sec. 30	400
Mid. S. line Sec. 30	360

Courtland. T. 12, R. 12 E. — (con.)

Mid. S. hf. Sec. 31	360
Mid. N. hf. Sec. 35	369
Mid. S. line Sec. 35	370

Lewiston. T. 13, R. 7 E.

Lewiston depot, Sec. 26	231

Lewiston. T. 13, R. 8 E.

Mid. N. hf of S. W. qr. Sec. 14	250
Center S. W. qr. Sec. 23	220
Mid. W. line Sec. 25	240
Mid. N. hf. Sec. 36	230
Center S. E. qr. Sec. 36	245

Fort Winnebago. T. 13, R. 9 E.

Mid. W. hf. Sec. 16	230
Mid. W. line S. W. qr. Sec. 16	260
S. W. cor. Sec. 16	280
Center S. E. qr. Sec. 19	300
Mid. S. line S. E. qr. Sec. 19	250
Mid. S. line Sec. 20	260
Mid. W. line Sec. 21	240
Coughlin's quarry, E. hf. Sec. 20	350
Center N. E. qr. Sec. 30	240
Mid. E. hf Sec. 31	390
Mid. N. hf. Sec. 36	265
Bluff-top, N. W. qr. Sec. 36	390

Marcellon. T. 13, R. 10 E.

N. E. cor. Sec. 1	260
Mid. N. line N. E. qr. Sec. 1	320
N. W. cor. Sec. 1	260
Mid. W. line Sec. 1	300
Mid. W. line N. W. qr. Sec. 12	320
Mid. S. line N. W. qr. Sec. 12	290
Mid. W. line N. W. qr. Sec. 13	270
Center S. E. qr. N. E. qr. Sec. 14	285
Center N. W. qr. S. E. qr. Sec. 14	295
Mid. S. hf. S. W. qr. Sec. 14	290
⅛ mile E. S. W. cor. Sec. 14	270
Center Sec. 16	370
Mid. S. hf. Sec. 16	340
Mid. S. line S. E. qr. Sec. 16	350
Mid. S. line Sec. 16	350
Mid. E. line N. E. qr. Sec. 21	355
Mid. E. line Sec. 21	305
Center S. E. qr. S. E. qr. Sec. 21	335
Center S. E. qr. N. E. qr. Sec. 22	320
S. W. cor. Sec. 23	350
Mid. S. line S. W. qr. Sec 23	360
Mid. S. line Sec. 23	350
Mid. S. line Sec. 24	300
Mid. S. line S. E qr. Sec. 24	290
Mid. E. line N. W. qr. Sec. 25	350
Center N. W qr. N. E. qr. Sec. 28	260

Scott. T. 13, R. 11 E.

⅛ mile E. N. W. cor. Sec. 2	390
Mid. N. line Sec. 2	360
Mid. N. hf. Sec. 2	360
Mid. N. line N. E. qr. Sec. 3	300
N. W. cor. Sec. 3	280
Mid. N. line N. W. qr. of N. E. qr. Sec. 4	280
Mid. N. line N. W. qr. Sec. 4	260
Mid. N. line N. E. qr. Sec. 5	320
⅛ mile E. N. W. cor. Sec. 5	260
Mid. N. line N. E. qr. Sec. 6	280
Mid. N. hf. of N. hf. Sec. 11	350

BAROMETRICAL ALTITUDES — *continued.*

Scott. T. 13, R. 11 E. — (con.)
Mid. S. line, Sec. 11 340
Mid. N. hf. Sec. 14.......... 385
Mid. N. hf. S. hf. Sec. 14.......... 340
Mid. S. line Sec. 14.......... 320
Mid. N. line S. E. qr. S. W. qr. Sec. 14 370
1/16 mi. north S. E. cor. Sec. 19.......... 230
Mid. S. line Sec. 19.......... 270
Mid. N. hf. N. hf. Sec. 23.......... 290
Mid. S. line Sec. 23.......... 370
1/8 mi. north center Sec. 26 380
1/16 mi. south N. W. cor. Sec. 29.......... 230
Mid. W. line Sec. 29.......... 240
S. W. cor. Sec. 29 325
Mid. E. line Sec. 31 400
1/8 mi. north S. E. cor. Sec. 31.......... 375
1/8 mi. east S. W. cor. Sec. 32.......... 350
S. E. cor. Sec. 32.......... 440
Mid. S. line S. E. qr. Sec. 33.......... 380
Mid. S. line S. W. qr. Sec. 34 275
S. E. cor. Sec. 34.......... 400
Mid. S. line Sec. 35.......... 420
S. E. cor. Sec. 35.......... 425
Mid. S. line Sec. 36.......... 420
S. E. cor. Sec. 36.......... 400

Randolph. T. 13, R. 12 E.
N. W. cor. Sec. 1 415
Center S. E. qr. Sec. 1.......... 320
Mid. N. line Sec. 2.......... 420
N. W. cor. Sec. 2.......... 250
Mid. W. line Sec. 2 370
Mid. N. hf. S. hf. Sec. 5.......... 350
Mid. S. line Sec. 5 340
Mid. W. line Sec. 6.......... 320
S. W. cor. Sec. 6.......... 350
Mid. S. line, Sec. 7.......... 420
Mid. W. line S. W. qr. Sec. 7 320
Mid. N. hf. Sec. 8.......... 350
Mid. S. line Sec. 8.......... 360
Mid. E. line Sec. 9 365
Mid. E. line Sec. 11.......... 395
Center Sec. 12 395
S. W. cor. Sec. 15 390
Mid. W. line Sec. 15.......... 356
Mid. N. hf. N. hf. Sec. 16.......... 356
Mid. N. hf. S. hf. Sec. 16 432
Mid. S. line Sec. 16.......... 409
Center S. E. qr. Sec. 17.......... 400
Center N. W. qr. Sec. 17.......... 365
Mid. W. line S. W. qr. Sec. 18.......... 380
Mid. W. line N. W. qr. Sec. 19.......... 400
Mid. N. hf N. hf. Sec. 20 400
Center S. W. qr. Sec. 20 400
Mid. E. line S. E. qr. Sec. 21.......... 386
Mid. N. hf. N. hf. Sec. 24 350
Center S. W. qr. S. E. qr. Sec. 24.......... 330
Center N. E. qr. Sec. 25.......... 350
Mid. W. line Sec. 25.......... 365
Mid. W. line Sec. 27.......... 420
Center Sec. 28.......... 353
S. E. cor. Sec. 28.......... 420
Center S. E. qr. N. W. qr. Sec. 29.......... 360
N. W. cor. Sec. 30.......... 440
1/8 mile N. S. W. cor. Sec. 30.......... 400

Randolph. T. 13, R. 12 E. — (con.)
Mid. W. line N. W. qr. Sec. 31.......... 350
S. W. cor. Sec. 31.......... 240
S. E. cor. Sec. 31 260
Center S. W. qr. N. W. qr. Sec. 32, 390
Mid. S. hf. N. W. qr. Sec. 32.......... 382
S. E. cor. Sec. 36 360

Spring Green. T. 8, R. 4 E.
Bluff, N. W. qr. Sec. 3, base 144
Bluff, N. W. qr. Sec. 3, top 374
Bluff, N. W. qr. Sec. 5, base 200
Bluff, N. W. qr. Sec. 5, summit 465
Spring Green depot, Sec. 7 144

Spring Green. T. 9, R. 4 E.
Bluff top, N. E. qr. Sec. 28.......... 430
S. E. qr. N. W. qr. Sec. 30 460
Road, N. W. qr. Sec. 31 360
Bluff, S. E. qr. Sec. 32 320
Stream, S. W. qr. N. W. qr. Sec. 34 140

Troy. T. 8, R. 4 E.
Bluff base, Sec. 1.......... 170
Bluff top, Sec. 1.......... 420
N. W. cor. Sec. 2.......... 130

Troy. T. 9, R. 4 E.
Road, N. W. qr. Sec. 24 185
Bluff top, N. W. qr. Sec. 24 375
Mid. N. hf. Sec. 25 270
Mid. W. hf. Sec. 25.......... 440
Mid. W. line Sec. 25 270
Stream crossing, S. W. qr. Sec. 35 . 134
Bluff top, S. W. qr. N. E. qr. Sec. 35, 370

Troy. T. 9, R. 5 E.
Mid. N. line Sec. 8 180
N. E. cor. Sec. 8 160
Road, S. W. qr. S. W. qr. Sec. 11.......... 330
Bluff base, N. W. qr. N. W. qr. Sec. 14 210
Bluff top, N.W. qr. N.W. qr. Sec. 14, 500
Road, S. E. qr. S. W. qr. Sec. 17.......... 170
Bluff top, S. E. qr. S. W. qr. Sec. 17, 250
Center Sec. 17.......... 170
N. line N. W. qr. Sec. 19 170
N. W. cor. Sec. 24.......... 370
Mid. S. hf. S. hf. Sec. 35.......... 190
Bluff base, N. hf. Sec. 35.......... 190
Bluff top, N. hf. Sec. 35.......... 410

Prairie du Sac. T. 9, R. 6 E.
Sauk City, Sec. 12 210
Bluff base, N. W. qr. Sec. 17 180
Bluff top, N. W. qr. Sec. 17.......... 490
Bluff base, S. W. qr. Sec. 21.......... 166
Bluff top, S. W. qr. Sec. 21.......... 486

Prairie du Sac. T. 10, R. 6 E.
Mid. E. hf. Sec. 25.......... 250
Center Sec. 26 250
Mid. W. line Sec. 27.......... 220

Franklin. T. 9, R. 9 E.
Mid. S. line Sec. 2.......... 195
Road, S. E. qr. Sec. 9 220
Road, N. E. qr. Sec. 18 250
Road, S. W. qr. Sec. 18.......... 320
Road, N. W. qr. Sec. 19 465
Mid. W. hf. Sec. 19 490

Franklin. T. 10, R. 4 E.
Summit, E. line Sec. 21.......... 380

BAROMETRICAL ALTITUDES — *continued.*

Frankliin. T. 10, R. 4 E. — (con.)	
Mid. S. line Sec. 29	250
Honey Creek. T. 10, R. 4 E.	
Center Sec. 1	530
Mid. N. line Sec. 1	570
Bluff-base, Sec. 12	205
Bluff-top, Sec. 12	480
Bluff-top, N. W. qr. Sec. 13	300
Bluff-top, N. E. qr. Sec. 14	290
Bluff-top, Sec. 35	462
Center Sec. 36	250
Honey Creek. T. 10, R. 5 E.	
S. E. qr. Sec. 2	610
Ochsner's, N. W. qr. Sec. 31	200
Sumpter. T. 10, R. 6 E.	
Mid. S. line Sec. 10	240
Center Sec. 15	250
Stream crossing, W. hf. Sec. 15	230
Bluff-top, W. hf. Sec. 15	415
Sumpter. T. 11, R. 6 E.	
Mid. N. line Sec. 26	550
Road, N. E. qr. S. E. qr. Sec. 26	575
Road, S. E. qr. S. E. qr. Sec. 26	625
Center N. W. qr. Sec. 27	600
Center Sec. 34	280
Road, N. E. qr. N. E. qr. Sec. 35	480
Mid. S. line S. E. qr. Sec. 35	320
Merrimack. T. 11, R. 7 E.	
Ridge, S. W. qr. S. E. qr. Sec. 19	471
Center N. W. qr. Sec. 23	580
Mid. N. line N. W. qr. Sec. 26	295
S. hf. N. W. qr. Sec. 28	280
Mid. S. E. qr. N. E. qr. Sec. 28	260
Road, N. hf. S. E. qr. Sec. 31	285
Mid. N. hf. Sec. 32	290
Under bridge, N. E. qr. Sec. 32	270
Westfield. T. 11, R. 4, E.	
Mid. E. line Sec. 1	497
Center Sec. 1	500
Mid. N. line Sec. 1	500
S. W. cor. Sec. 2	530
Bluff-top, center Sec. 3	471
Center Sec. 11	610
Mid. S. line Sec. 11	660
Center N. W. qr. Sec. 11	560
N. W. cor. Sec. 11	510
Mid. S. hf. Sec. 12	627
Creek-crossing, E. hf. Sec. 13	477
W. hf. S. W. qr. Sec. 13	650
Center Sec. 13	530
Center Sec. 14	650
Logansville, Sec. 17	330
Center N. W. qr. Sec. 17	351
Center S. W. qr. Sec. 17	361
Bluff, N. line Sec. 17	471
S. W. cor. Sec. 25	540
Mid. S. line Sec. 26	520
Mid. E. line N. W. qr. Sec. 29	401
S. E. qr. S. E. qr. Sec. 35	400
Center S. W. qr. Sec. 36	580
Freedom. T. 11, R. 5 E.	
Bridge, E. hf. Sec. 2	268
Bloom's Station, Sec. 2	280
Mid. N. line N. W. qr. Sec. 5	437
Mid. W. line Sec. 14	340
Freedom. T. 11, R. 5 E. — (con.)	
S. hf. Sec. 23	700
Near S. E. cor. Sec. 23	830
Mid. E. line Sec. 26	830
Baraboo. T. 11, R. 6 E.	
Baraboo depot, Sec. 2	280
Mid. S. line S. E. qr. Sec. 11	325
Mid. E. hf. Sec. 23	635
Railroad at Cliff House, Sec. 24	386
Bluff-top, S. E. qr. Sec. 24	805
Bluff-base, S. E. qr. Sec. 24	390
Cliff-top, mid. W. line Sec. 24	850
Baraboo. T. 12, R. 6 E.	
Mid. W. hf Sec. 25	430
Mid. E. line Sec. 25	380
S. W. qr. S. E. qr. Sec. 27	420
S. W. qr. S. E. qr. Sec. 28	310
N. E. cor. Sec. 35	400
Mid. N. line N. W. qr. Sec. 36	370
Greenfield. T. 11, R. 7 E.	
Summit, S. W. qr. Sec. 1	715
Mid. W. line Sec. 1	535
Mid. W. line N. W. qr. Sec. 1	543
Near Mid. S. hf Sec. 5	275
Center S. E. hf Sec. 5	275
Road forks, N. line N. W. qr. Sec. 7	270
Near center N. hf Sec. 14	740
Near center Sec. 15	850
Near Mid. W. line Sec. 15	900
Road, S. hf N. E. qr. Sec. 16	845
W. line Sec. 16	750
⅛ mile S. center Sec. 16	600
Mid. W. hf Sec. 17	610
Greenfield. T. 12, R. 7 E.	
Quarry, center Sec. 25	410
20 rods N	425
Road, N. line N. E. qr. Sec. 26	215
Bluff, top N. line N. E. qr. Sec. 26	515
Mid. W. line Sec. 27	325
Mid. W. line Sec. 29	405
Mid. E. hf Sec. 30	475
Center Sec. 30	405
Mid. E. hf Sec. 32	345
Mid. W. hf Sec. 32	275
Center Sec. 33	270
N. W. cor. Sec. 36	350
N. E. cor. Sec. 36	365
Stream-crossing, N. W. qr. Sec. 36	345
S. W. cor. Sec. 36	465
Reedsburg. T. 12, R. 4 E.	
Creek-crossing, S. line Sec. 1	285
Mid. S. line Sec. 2	320
S. W. cor. Sec. 9	330
Reedsburg depot, Sec. 10	296
Mid. E. line Sec. 17	320
E. hf S. E. qr. Sec. 20	340
Mid. S. line Sec. 20	500
Mid. W. line Sec. 22	451
Mid. N. line S. E. qr. Sec. 25	332
Center Sec. 25	302
Mid. S. line Sec. 25	307
Mid. S. line S. W. qr. Sec. 26	290
Mid. W. hf Sec. 29	550
Quarry, S. W. qr. Sec. 29	530
S. E. cor. Sec. 29	380

BAROMETRICAL ALTITUDES — *continued.*

Reedsburg. T. 12, R. 4 E. — (con.)	
Center Sec. 30	580
S W. cor. Sec. 30	560
Cross roads, N. hf Sec. 30	335
Mid. W. line Sec. 30	580
Mid. N. line N. W. qr. Sec. 31	500
Creek crossing, Sec. 35	280
Mid. S. hf Sec. 36	467
Mid. S. line Sec. 36	517
Center Sec. 36	460
Excelsior. T. 12, R. 5 E.	
Mid. N. hf Sec. 2	290
Mid. S. line S. W. qr. Sec. 3	325
Mid. S. line S. W. qr. Sec. 4	365
S. W. cor. Sec. 5	320
Bluff top, Mid. E. hf E. hf Sec. 5	575
Center Sec. 28	500
Bluff top N. E. qr. N. W. qr. Sec. 31	507
Ableman's depot, Sec. 33	297
Fairfield. T. 12, R. 7 E.	
Mid. S. line Sec. 17	315
Center S. E. qr. Sec. 17	230
Mid. W. line S. W. qr. Sec. 19	335
Center S. W. qr. Sec. 20	340
Center N. W. qr. Sec. 20	350
Road, mid. E. hf Sec. 22	226
Bluff top, ⅛ mile S	450
Bluff top. E. line S. E. qr. Sec. 22.	590
Bridge, center Sec. 23	225
Winfield. T. 13, R. 4 E.	
S. W. qr. Sec. 24	372
S. E. cor. Sec. 24	468
W. hf. Sec. 27	413
S. E. cor. Sec. 27	286
Mid. W. line S. W. qr. Sec. 33	307
Center Sec. 35	408
Dellona. T 13, R. 5 E.	
Mid. N. hf. Sec. 5	300
Center N. W. qr. Sec. 19	390
Juneau County.	
T. 14, R. 2 E.	
Mid. S. line Sec. 6	430
Mid. E. hf. Sec. 7	310
Mid. W. hf. W. hf. Sec. 24	550
T. 14, R. 5 E.	
High crest, Sec. 28	700
T. 15, R. 3 E.	
Mid. S. line S. E. qr. Sec. 7	360
Bluff Sec. 13, base	300
Bluff Sec. 13, top	500
Juneau County — (con.)	
T. 17, R. 2 E.	
Target bluff, Sec. 28, top	476
Target bluff, Sec. 28, base	356
T. 18, R. 3 E.	
Foot of bluff, Necedah	340
Top of bluff, Necedah	510
T. 18, R. 4 E.	
Petenwell peak, Sec. 9, top	530?
Adams County.	
T. 14, R. 6 E.	
S. E. qr. Sec. 21, Eleph. back, top.	550
Wis. river hf. mile west, Sec. 21	240
T. 17, R. 6 E.	
Friendship mound, Sec. 6, top	750
Bridge at foot, Sec. 6	440
T. 7. R. 7 E.	
N. E. qr. Sec. 3. Pilot knob, base	540
N. E. qr. Sec. 3, Pilot knop, top	705
Marquette County	
T. 14, R. 8 E.	
E. line Sec. 12	235
T. 14, R. 9 E.	
Merrils' S. E. qr. N. E. qr. Sec. 7	196
T. 14, R. 10 E.	
Observ. hill, S. E. qr., Sec. 7 base	240
Observ. hill, S. E. qr., Sec. 7 top	490
T. 17, R. 8 E.	
N. W. qr. Sec. 7, lime bluffs. top	730
N. W. qr. Sec. 7, lime bluffs, base	570
Portage County.	
T. 21, R. 8 E.	
Mosquito bluff, Sec. 23, top	630
Mosquito bluff, Sec. 23, base	520
Marathon County.	
T. 28, R. 7 E.	
Top Rib hill, W. end, W. hf. Sec. 8	1263
Top Rib hill, E. end, W. hf. Sec. 9	1143
Lower Mosinee hill, center Sec. 27, top	880
Lower Mosinee hill, river at foot	600
Upper Mosinee hill, N. E. qr. Sec. 27, top	1030
Upper Mosinee hill, river at foot	600
T. 29, R. 7 E.	
Mid. N. line Sec. 1	890
Wausau depot, Sec. 36	643
Jackson County.	
T. 21, R. 4 W.	
Isolated bluff, Sec. 23, base	230
Isolated bluff, Sec. 23, top	489

RELATIONS OF THE TOPOGRAPHY TO THE GEOLOGY OF THE REGION.

The topography of all countries is chiefly dependent upon the nature of the geological formations immediately underlying the surface. This is markedly so in Central Wisconsin. The rock systems of this portion of the state are altogether Archæan and Lower Silurian; the former consisting of gneisses, granites and schists, with other crystalline rocks, the latter of a series of alternating sandstones and limestones, in nearly horizontal beds. These include, in ascending order, the Potsdam, or Lower sandstone, the Mendota limestone, the Madison sandstone, the Lower Magnesian limestone, the St. Peters sandstone, the Trenton limestone, and the Galena limestone. The last named covers but a very small portion of our district. The Archæan rocks lie in a great central mass in the northern part of the state, the Silurian formations encircling this mass in imbricating order, and, coming to the surface in a series of receding concentric bands, together forming the southern, eastern and western parts of the state. The surface features of the Archæan and Silurian regions differ much. In the Archæan area we have unquestionable proof, in the crumpled condition of the rocks, of its former mountainous character. Denudation has gradually, in the great lapse of time during which these beds have been exposed, stripped it entirely of these characteristics, leaving it now merely a high, and, in general, a gently undulating area, broken only very occasionally by small isolated ridges or peaks of quartzose rocks, which have remained standing by virtue of their superior hardness and power of resisting chemical action. In minor detail, however, the Archæan area is much roughened by low ridges whose sides frequently show outcropping ledges of tilted rock. In the Silurian area, on the other hand, the original condition must have been a nearly level one, and denudation has worked here in an opposite direction, removing great portions of the horizontal beds, gouging them everywhere into valleys, and producing thus narrow ridges and bold isolated bluffs. The horizontality of the Silurian strata, which is more nearly exact in central Wisconsin than elsewhere in the state, together with their alternately hard and soft characters, has resulted in producing a peculiar, abruptly roughened surface — narrow valleys with abrupt, bluffy sides, and irregular table-like outliers.

These peculiarities of topography, resulting from the different effects of the eroding agencies on the different kinds of rocks, have, however, in a large portion of the region, been much modified and obscured by other causes. I refer to those causes which gave rise to the glacial drift. The southwestern quarter of the state of Wisconsin is without trace of the glacial depositions, whilst all of the rest of the state is characterized by the presence of unusually large quantities of these materials. The line of demarkation, moreover, between the drift-bearing and driftless areas, is a sharp and easily traced one. Entering the state from the south on the southern line of Green county, the drift limit traverses this county centrally from south to north, and continues northward through western Dane and central Sauk; then, curving eastward across the southern end of Adams, it follows along the eastern line of that county, passes into Portage, curves westward, and crossing the Wisconsin river again, continues in a nearly westward direction across Wood, Clark, Jackson, Trempealeau and Buffalo counties, to about the foot of Lake Pepin, on the Mississippi. The driftless region is thus nearly altogether within the Silurian area. North and east of the drift limit the general contours are usually flowing, the valleys frequently wide and ill defined, the rock exposures not frequent, and the outliers not many in number, being usually of large size and without jagged edges or peaks. On the other side of this line the topography is strikingly different; the changes of level are abrupt, the valleys narrow, with steep and high sides, the rock exposures frequent, and the outliers often of very small dimensions horizontally, though of very considerable height, and often showing precipitous sides with jagged, peak-like summits, even when of soft sandstone. The drift forces have contributed to this result in two ways; (1) by planing down the irregularities resulting from subaerial erosions, and (2) by the deposition of great quantities of clay, sand and gravel. The peculiar mode of deposition of this material has, however, itself, in much of the region, produced a peculiar irregularity of surface, leaving it covered with ridges of low rounded knobs, and intervening rounded depressions, which are frequently filled by small ponds or lakes. It is also true that the change of topography noted in passing from the driftless to the drift-bearing area is not exclusively due to the former presence or absence of the glacial forces, but is in some measure owing to the fact that for a long distance the drift limit is nearly on the line of a change from a horizontal position of the strata to a gradually increasing eastward slope.

A much closer connection can be traced between the variations in surface features and the changes in the formations, which will receive attention hereafter.

VEGETATION AND SOILS.

These are noticed here only in their most general relations; the soils only in reference to their connection with the underlying geological formations.

The three different kinds of surface in the district, as to vegetation, are the **prairies, marshes and timber land.** The *prairies*, or treeless areas, are restricted to the Silurian region, and are chiefly characteristic, in central Wisconsin at least, of limestone districts, though occurring also on the sandstone formations. In many places regions once prairie have been invaded by a timber growth, which has come in since the settlement of the country, having been in former times checked by the annual prairie fires. Very large areas in Adams county, for instance, which are now covered with a thick growth of small oaks, are said to have been open prairies at the time of the first settlements. The prairie areas are by no means always flat; indeed, the flat prairies are the exception, and have chiefly been noticed along the bottom land of the Wisconsin river. The ordinary prairie, however, as in northern Dane and eastern Columbia county, is very rolling, commonly showing abrupt changes of level, even up to fifty or a hundred feet. These changes in level are, in places, due to heaped up drift, but more commonly to unequal denudation of the rocky strata. In many cases, as, for instance, in the town of West Point, Columbia county, the prairie area includes both lowland and bold outlying bluffs, as much as two hundred or even three hundred feet in height. The Central Wisconsin prairies are, with one notable exception, of small size, occupying at most not more than two or three sections. The exception is the limestone prairie belt which occupies large portions of the towns of Springfield, Westport, Dane, Vienna, Windsor and Bristol, in northern Dane county; and of West Point, Lodi, Arlington, Leeds, Hampden and Lowville, in Columbia county. The same belt, though somewhat broken in the towns of Otsego and Courtland, continues to the northeast and passes into Green Lake county. This large prairie area is for the most part on high land, occupying the summit of the watershed between the Wisconsin and Rock rivers. It is nearly always underlaid by the Lower Magnesian limestone, whose irregular upper surface contributes much to the rolling character of the prairie.

The *marshes* are widely scattered, occurring over both the Archæan and Silurian areas, though more numerously in the former. As a general rule they are small, but in some cases are of very considerable size, as, for instance, those extending along Duck creek and the upper Fox river east of Portage, which are many miles in length, and the great marsh south of Plover, in Portage county, which covers the greater part of four townships. Many of these marshes, as, for instance, the Plover marsh just alluded to, are underlaid by a valuable quality of peat.

With regard to *timber*, it may be said that all of the counties of Dane, Columbia, Sauk (except on the quartzite bluffs), Juneau, Adams, Marquette and Waushara (except on the east), are covered by a prevailing growth of small oaks; whilst Marathon, Portage, eastern Waushara, most of Wood, Clark, and much of Jackson, are heavily timbered with pine interspersed with hardwood on the more elevated lands. The Archæan region is generally heavily timbered, north Wisconsin being one of the great lumbering districts of the continent.

Geologically, we may distinguish the drift, the purely sandstone, the purely limestone, and the crystalline rock soils. The last three terms are meant to apply to such soils as result exclusively from the disintegration of the underlying rocky formations. Inasmuch as these formations are not always perfectly pure limestone or sandstone, their disintegration gives other ingredients to the soil than lime or sand. The drift soils are either bad or good as the material is more largely sandy, or shows a predominating admixture of clayey and calcareous substances; those resulting solely from the disintegration of the sandstone, of the poorest quality; whilst the limestone soils are usually the best in the region. The crystalline rock soils are often good, but as the region of crystalline rocks is nearly everywhere invaded by the drift, its soils are commonly dependent upon the nature of the drift, rather than upon that of the subjacent rock. In some portions of the Archæan region, where either the drift is not present in very large quantity, and the felspathic rocks have disintegrated into a good clayey soil, as in the high land in the western part of Marathon county, or where the drift is itself of a non-arenaceous character, as in much of Clark county, and in many places along the line of the Wisconsin Central Railroad, excellent lands for farming are made by clearing the heavy growths of hardwood timber. Where the drift is more sandy, as in a large region about the headwaters of the Wisconsin river, the land is worthless for agricultural purposes, though frequently covered with a valuable growth of pine. Through the sandy nature of the drift materials the sand region of central Wisconsin extends in places far beyond the district occupied by the Potsdam sandstone. In all of the region in which the last named rock is the surface formation, and where the drift is either absent, or present in small quantities only, or is altogether sandy in nature, as in most of Adams, Juneau, Sauk, Jackson, Marquette, and Waushara counties, in much of Columbia, and in places all along the valley of the Lower Wisconsin, the soil is generally a loose sand, and the land of the poorest quality. Where the drift overlies the sandstone and contributes clayey or calcareous matter, as in the southern part of Adams county, or the eastern part of Waushara, the land is often good. In other cases, a good soil within the Potsdam area and where the drift is absent seems to have resulted from the filling of valleys with fine stream detritus, as along the valley of the Wisconsin; or from the nearness to the surface of certain clayey layers included within the sandstone, as in the town of Reedsburg, Sauk county; or from the presence of considerable dolomitic material in the sandstone, as in the town of Honey Creek, Sauk county. All of these, are, however, but exceptions to the general rule, that, for the most part, the Potsdam area, on both sides of the drift limit, is a barren sandy region.

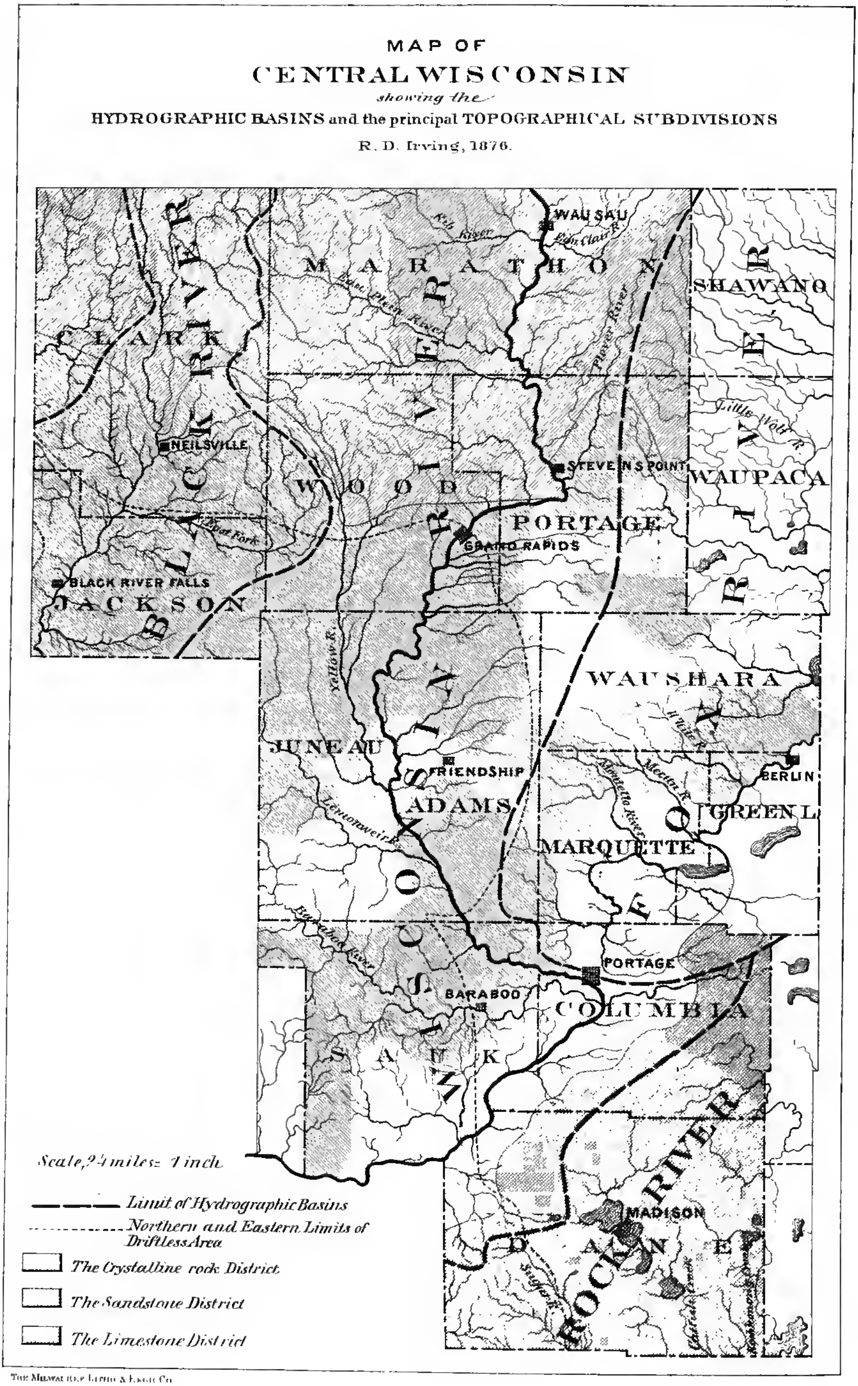
Above the lowest sandstone, we find, first, a layer thirty feet in thickness of clayey or sandy dolomitic limestone, to which I have given the name of Mendota limestone. Where it is the surface rock, as in portions of the towns of Scott and Marcellon, Columbia county, a good clay soil usually results. Next above the Mendota is again a layer of sandstone, which I will designate as the Madison sandstone, having a thickness of 30 to 40 feet. Where it is the surface rock, as in a large part of the town of Otsego, Columbia county, the soil is a loose sand, and of little value. These rapid alternations explain the change of soil noticed with a slight change of elevation in many places along the borders of the areas occupied by the Lower Magnesian limestone, which is the next formation in order.

The Lower Magnesian is a great mass of dolomitic limestone, 80 to 200 feet in thickness, often carrying much silicious and clayey matter in its composition. The country occupied by it is hence nearly always one of most excellent soils. Such is the soil of the high prairie belt of northern Dane and eastern Columbia. These prairies are often much covered with drift, which occasionally lends a sandy character to the soil, but not frequently, since the drift of this particular district itself is commonly calcareous and clayey.

The next rock above the Lower Magnesian, the St. Peters sandstone, but rarely forms the surface rock, being generally concealed, when present, by overlying beds, and showing only on hill-sides and steep slopes. Where, however, it comes to the surface, as in the valley of Sugar river in western Dane county, and the drift is absent, the same sandy soil is observed as that produced by the disintegration of the Lower sandstone.

The Trenton limestone soils are usually of excellent quality, and frequently somewhat more argillaceous and less dolomitic than those from the Lower Magnesian. The Galena is so unimportant a formation in Central Wisconsin that it need not be especially alluded to in this connection.

PLATE, XVI



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TOPOGRAPHICAL SUBDIVISIONS — RÉSUMÉ.

The foregoing details, with regard to the surface slopes, river systems, surface reliefs, prairies, marshes, timber, etc., of central Wisconsin, will serve to render intelligible to the reader a very brief summary of the topographical features of the whole district.

First, then, we find on the north, occupying all of Marathon and most of Portage, Wood, and Clark counties, a comparatively elevated **region of crystalline rocks,** which descends gradually from an altitude of 900 feet on the north, to one of 400 to 500 feet on the south. In general, this section has a gently undulating surface, which is, however, often broken in minor detail by low, abrupt ridges with outcropping tilted rock ledges, and is dotted occasionally with high points of quartzose rocks. The whole area is densely covered with a forest of pine interspersed with marshes, and hardwood ridges, which when cleared yield excellent land. It is traversed from north to south by two large rivers, the Wisconsin on the east, and the Black on the west, which, as also their numerous branches, are rapid streams, broken constantly by chutes and water falls over tilted rock ledges; and is covered everywhere with accummulations of drift material, which are, however, much greater in some places than in others.

Proceeding now further southward we come next upon the great **central sandstone region** of the state. This covers all of Jackson, Juneau, Adams, Marquette and Waushara counties, southern Wood, Portage and Clark, northern and western Columbia, and most of Sauk. It extends east and west about eighty miles, north and south about one hundred, and really includes several subordinate areas, which are, in some respects, topographically distinct, but all of which have in common the basement rock of sandstone, and, for the most part, the sandy soil. For the greater part of its area, the sandstone district is out of the heavy timber, which, however, invades it in eastern Waushara, in southern Portage and Wood, and in eastern Jackson. For the rest of the district, the prevailing growth, except on the high Archæan bluffs of Sauk, is of small oaks.

Of the subordinate areas, we note first on the east a district (1), including Waushara, southern Portage, those portions of Marquette and Green Lake which lie north of the Fox river, and southern Adams, which is everywhere heavily covered with glacial drift, to whose irregular morainic method of deposition is to be attributed a peculiar roughened surface, dotted in places with small lakes that occupy the drift depressions. The streams of this region are numerous, large, rapid, and extraordinarily clear, but without rock rapids. Rock bluffs are not frequent, and those that occur are without the castellated appearance so characteristic of the more western outliers. The whole of the area descends from its highest parts in northwestern Waushara, where the altitude is about 540 feet, in a southeasterly direction towards the Fox river, whose altitude at Portage is 200 feet, and at Berlin 175 feet. The soil of this district is for the most part sandy. In central Waushara, however, good land occurs on limestone and crystalline rock drift, whilst in eastern Waushara the stratified drift clays yield an excellent soil. West of the high ground along the line of Adams and Waushara counties, we come upon an altogether different region, (2) the next of our subordinate divisions. This is the central sand plain of Adams and Juneau counties, which is traversed from north to south by the Wisconsin river. Here we find no drift at all, a generally flat surface, rising gradually from the river in each direction, and dotted by numerous lofty and jagged peaks of sandstone, large and clear streams, and a prevailing growth of small oaks, interrupted by a few prairies and marshes, and mingling with small pine towards the north. Crossing now the divide on the northwest corner of Juneau county, we find ourselves in the sandstone portion of the Black river valley, (3) which resembles, for short distances from the river, in its general sandy, plain-like character, and gigantic, castellated outliers, the region last described. As we pass westward, however, from Black river, or southward along its course, we find ourselves in a region of narrow but deeply eroded valleys and of steep hills. Returning now to the central plain of Juneau county, and proceeding towards its southwest corner, we cross, in the towns of Summit, Wonewoc, Plymouth and Lindina, a high, narrow, and deeply indented watershed, and find ourselves in the upper part of the Baraboo river valley, (4) which we may regard as another of the subordinate districts of the central sandstone region. The upper part of this valley shows the usual characters of the valleys of the driftless part of the state, being narrow, with abrupt sides, which are often of precipitous sandstone. The tributary streams have similar, but narrower and steeper valleys. On either side the country rises rapidly, and shows frequently excellent land. As the river is followed into Sauk county, its valley widens, but the same deeply indented divides are observed; that on the south, in the towns of Westfield and Reedsburg, rising into the horizon of the Lower Magnesian limestone, so that large patches of good limestone country occur here. In central Sauk county the Baraboo traverses the length of the valley between the two quartzite ranges, whose topography has already been sufficiently indicated. About midway in the east and west length of this valley the western limit of the glacial drift is met with, which is here in a morainic condition. Crossing now to that portion of Sauk county which lies to the south of the limestone-capped divide in the towns of Westfield and Franklin, and of the southern quartzite range, we reach a part of the valley of the Wisconsin itself, which may be designated as the Honey Creek district (5). On the west side of this triangular area we find deeply eroded valleys with limestone-capped separating ridges; further south and east towards the river, numerous outliers and peculiar narrow ridges are seen; further east still these cease suddenly, and on the wide prairie in the towns of Prairie du Sac and Sumpter, morainic drift begins as suddenly again. Along the Wisconsin in the southwest corner of this area, the limestone-capped bluffs of an immense outlier bound the river bottom for a number of miles. We have yet to consider the last of these subordinate areas, (6) which includes that portion of Marquette county south of the Fox river, and the northern, central and western towns of Columbia county, being limited on the east and south by the western face of the limestone divide between the Wisconsin and Rock rivers. This is an area in general level, having an elevation of about 250 feet, with many bold limestone outliers. It is drift covered, showing numerous large bowlders, has everywhere a sandy soil, and a somewhat sparse growth of small oaks.

The third and last of the great topographical subdivisions of Central Wisconsin we may designate as the **limestone district,** since in it one or other of the Silurian limestones is almost always the surface rock. It includes eastern and southern Columbia, and all of Dane, is characterized nearly everywhere by an excellent soil, includes the largest prairie areas of central Wisconsin, shows a prevailing growth of oak, and has a rolling and diversified surface. The drift materials are everywhere present, except in the southwestern towns of Dane, which show the usual abrupt topography of the driftfess area. On the northern side of this district, in the towns of Scott, Randolph, Courtland, Otsego, Lowville, Hampden, Leeds and Arlington, in Columbia county, and of Vienna, Westport, Dane, Springfield and Middleton, in Dane county, there is a nearly continuous belt of high rolling prairie from about 400 to 600 feet in altitude. The underlying rock on this prairie is limestone, and the soil of the very best quality. From the east and south flanks of this high land the country descends rapidly, and is watered by the various head streams of Rock river.

In western Dane, the descent is almost entirely towards the south, but in the center of the county the dip of the strata begins to veer eastward, and the surface slope corresponds. On the west side of this county, again, in the valley of Sugar river, the topography is more abrupt than elsewhere, owing to the entire absence of the drift materials; in the center we find the broad southeast valley of the Catfish, with its chain of lakes lying in N. E. – S. W. valleys, and its morainic glacial drift; whilst further east still we find a more nearly level drift-covered region, sloping gradually eastward.

CHAPTER II.

GENERAL GEOLOGICAL STRUCTURE OF CENTRAL WISCONSIN.

The region of country included within the boundaries of the state of Wisconsin is quite simple as to the grand features of its rock structure, and may be briefly described as consisting of a great nucleus of ancient crystalline rocks, encircling which, but more especially on the east, south, and west, are succeeding bands of limestone and sandstone, belonging to the Silurian series.

Forming most of the northern half of the state is a great mass of crystalline rocks — granites, gneisses, chloritic micaceous and hornblendic schists being the predominating kinds — which are folded and eroded so as to offer the greatest obstacles to their detailed study, and which appear, for the most part, to be referable to the **Laurentian** division of the Archæan.

On the northern edge of this central nucleus, just south of Lake Superior, in Bayfield and Ashland counties, is a narrow belt of quartzites, magnetic and specular iron ores, diorites, talcose chloritic and black slates, etc., which overlie unconformably the gneisses of the Laurentian immediately to the south. This fact, taken together with their nature and relations to the newer adjoining formations, would seem to throw these beds, without any doubt, into the same catagory with the Iron Bearing series of Michigan, and the **Huronian** system of Canada. Similar rocks, with similar relations to the surrounding formations, exist in Oconto county, on the northeast border of the state, from where they stretch far into the Upper Peninsula of Michigan, and include the famous iron regions of Marquette and the Menomonee. On the south side of the Laurentian core, on Black river, in Jackson county, are again similar rocks, whose Huronian age is not so clearly made out. Still farther south, and within the area of the Silurian formations, are projecting portions of the here buried Archæan. These isolated masses are made up chiefly of quartzites and dark-colored quartz-porphyries, and are scattered widely over Marquette, Waushara, Green Lake, Columbia and Sauk counties, preserving in their positions a sort of rough parallelism to the southern and eastern borders of the main Archæan mass. There is no proof at hand that the rocks of these patches are unconformably superposed upon Laurentian strata, but the contrast between them and the Laurentian gneisses and schists, their resemblance to Huronian rocks elsewhere, and more especially the parallelism just referred to, strongly suggest the possibility of their forming part of a continuous band of Huronian, of which the Lake Superior and Oconto areas are other portions, encircling the Laurentian core, after the manner of the later and undisturbed Silurian accumulations. Regarding the Black river ferruginous schists, and the associated gneisses as Huronian, a continuation of the same belt, completing the circuit, may possibly exist in the northwestward trending gneissic and hornblendic beds of the lower Chippewa,[1] the arenaceous and conglomeratic quartzite of the hills in T. 32, R. 7 W., near the Chippewa river,[2] and the quartzite and associated pipestone of Rice Lake, in Barron county.[3] This idea of a continuous Huronian belt encircling a Laurentian core is thrown out as a suggestion only, a generalization towards which the facts in my possession at this writing would seem to point. At present all that we can affirm with any degree of certainty of the great crystalline rock area of northern Wisconsin is that most of its rocks are Laurentian, that on its northern and northeastern edges are some undoubted Huronian beds, and that on its southern and southwestern borders are again rocks between whose Laurentian and Huronian age there remains some question, although they quite probably are to be assigned to the latter period.

From its northeastern corner the Wisconsin Archæan nucleus, including now both Huronian and Laurentian rocks, sends a long projection across the Upper Peninsula of Michigan to the shores of Lake Superior, possibly connecting, beneath the lake, with the great Canadian Archæan area. Thus, from the earliest Paleozoic times, the rock depositions skirting the Archæan of Wisconsin on the east, south and west, must have gone on independently of those on its northern side.

The outcrops of the undisturbed and unaltered **Silurian** formations, which succeed one another in receding concentric bands on the eastern, southern and western sides of the Archæan of Wisconsin, are the direct continuations of the outcrop bands of a series of strata, which, after following the southern side of the Canadian Archæan westward through New York and Canada, make a great curve to the northward across the peninsula between Lakes Huron and Erie, and also across

[1] E. T. Sweet, manuscript report and also Transactions Wis. Acad. Sci., Vol. III.
[2] E. T. Sweet, Loc. cit.
[3] Owen's Geological Survey of Iowa, Wisconsin and Minnesota.

the Upper Peninsula of Michigan, and enter Wisconsin on its northeastern corner with a sharp southwestward trend, having thus accommodated themselves to the southern line of the ancient Archæan continent. On crossing into Wisconsin, these formations dip quite rapidly to the eastward, and their southward trending outcrops succeed one another in comparatively narrow bands. As they are traced southward, however, these outcrops curve gradually westward, the eastward dip at the same time lessening, and the exposed portion of each formation becoming wider. Along the central north and south axis of the state, the eastward dip has entirely disappeared, each formation is the surface rock over a wide extent of country, and the bounding line of each makes a wide bow to the southward before the return northwestward, parallel to the western side of the Archæan area. Thus it follows that in the Central Wisconsin district are to be observed a smaller number of the Silurian formations than occur further eastward and westward in the state.

The latest one of the Silurian formations of Central Wisconsin is of the age of the Trenton limestone of New York. Elsewhere in the state, the Upper Silurian is represented by immense thicknesses of limestone, and over a small area near Milwaukee, even Devonian beds are to be seen. The exact extent to which the original areas of these various formations exceeded their present ones, it is quite difficult to arrive at, so great has been the amount of denudation.

After the close of the Silurian — for much of Central Wisconsin probably after the close of the Lower Silurian — no farther depositions of any kind were made until the time of the **Glacial Drift,** when immense masses of gravel and boulders, as also stratified sands and clays, were largely deposited. During all of the intervening time the region must have been out of water and exposed only to the ordinary subærial eroding agencies. Thus we see how it is that we find here proofs of a denudation unusually great for non-mountainous regions.

The following table shows at a glance the several formations that enter into the structure of the Central Wisconsin district, with their geological relations:—

QUATERNARY.	*Recent* — Peat beds; bog iron ores.		
	Champlain — Lacustrine clays, over 200 feet thick.		
	Glacial — "Drift"; including bowlders, till, sand, gravel, etc.		
LOWER SILURIAN.	*Trenton.*	Galena limestone; dolomite, 300 to 350 feet.	
		Trenton limestone; alternating limestones and dolomites; in all 100 to 120 feet.	
	Canadian.	St. Peters sandstone; 15 to 120 feet.	
		Lower Magnesian limestone; dolomite, 50 to 125 feet.	
	Primordial.	Beds of passage.	Madison sandstone beds, 35 to 50 feet.
			Mendota limestone beds, 30 to 45 feet.
		Lower or Potsdam sandstone.	Including possibly two distinct formations, the one lying upon the eroded surface of the other; in all 800 to 1000 feet thick, but varying much on account of the irregular surface of the underlying rocks.
ARCHÆAN.	*Huronian.*	Quartzites, schists, quartz-porphyries, silicious iron ores, gneiss (?); many thousand feet thick.	
	Laurentian.	Gneiss, granite, schist, diorite, quartzite, etc.; no crystalline limestone; many thousand feet thick.	

CHAPTER III.

THE ARCHÆAN ROCKS.

THE MAIN ARCHÆAN AREA.

I. In General.

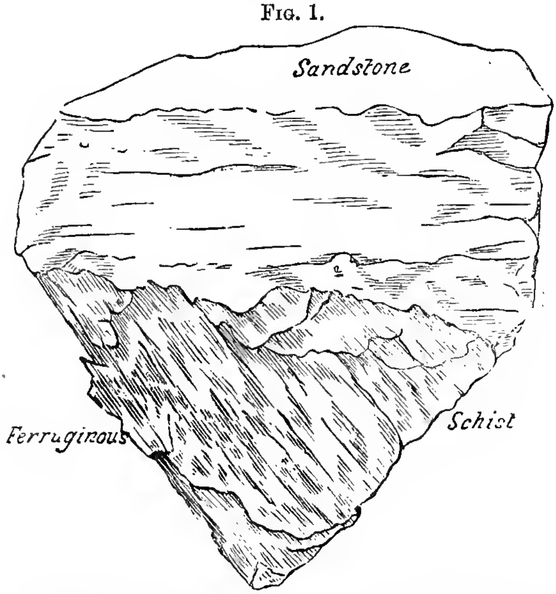
The crystalline rocks of the Central Wisconsin district may be conveniently separated into two groups, for the purposes of description; those of the main Archæan body constituting one of these, and those which occur in isolated protruding patches within the region of the Silurian sediments, the other. The two are of course but parts of the same grand mass, which everywhere underlies the undisturbed Silurian beds, a fact proven, not merely by geognostical theory, nor the evident passage of the crystalline rocks beneath the Silurian, but also by the numerous Artesian borings which have penetrated through the horizontal strata into the underlying Archæan, at points widely scattered over the state. At present, however, we have to do only with those of the crystalline rocks that appear at the surface.

The **area occupied** by the rocks of the main Archæan mass, so far as the district at present under consideration is concerned, covers all of Marathon, most of Wood, and much of Clark, Jackson and Portage counties.

The **line of junction** between the Archæan area and that of the next formation to the south, the Potsdam, or Lower, sandstone, is exceedingly irregular, and often quite difficult to trace. The sandstone is frequently found stretching far northward along the watersheds between the southward flowing streams, whilst the gneissic and other crystalline rocks are to be observed stretching as far south along the stream valleys, the areas of the two formations thus dovetailing into one another. Thus the Wisconsin and the Black rivers make rapids over tilted gneissic strata for many miles south of their first entrance upon the sandstone region, and as their courses are followed downwards the exposures of these rocks are to be found more and more closely restricted to the stream limits, until they finally occur in the river beds only, the sandstone overlying them in the banks. A more definite idea of the position of the boundary line between the sandstone and Archæan areas may be obtained from the general geological map of the state (Atlas Plate I), and also from Plate XV of the Atlas, which give the boundary, for the region examined by the writer, with as great accuracy as present knowledge will permit.

The **unconformability** between the tilted crystalline rocks and the horizontal sandstones is frequently to be observed along the boundary line between the areas of the two formations, and especially where the streams have cut through the sandstones into the underlying Archæan In a number of places, as to which details are given in subsequent pages, the exact junction of the two formations can be seen. In one place on Black river it is even possible to obtain hand specimens showing both formations, and their respective bedding and lamination lines. Fig. 1 is taken from one of these hand specimens.

Fig. 1.



Sketch of a specimen from near Black River Falls, showing the exact junction of the Potsdam sandstone and Archæan schists; half the original size.

The general **topographical features of the crystalline rock district** have already been indicated. It is an elevated area with an altitude of from 500 to 900 feet, and highest on the north. In general, it may be said to have a surface of gradual, though considerable, changes in elevation. Looked at more minutely, however, the surface is observed to be broken up frequently by low and narrow, but quite steep, ridges, often with rock exposures at top. The whole region is densely timbered, chiefly by pine. These pine trees, on account of the small depth of their roots, are easily and frequently prostrated by the wind, often over many square miles at once. Such windfalls, when burnt over and grown up with a small second growth, combine with the steep rocky ridges and the numerous small intervening marshes, to render traveling in this region to the last degree difficult. On the higher swells of the country, however, the pine is often replaced by hard wood, maple especially. In such parts, traveling is easier, and excellent farms are obtained by clearing. The soil in these cases sometimes evidently results for the most part from a direct disintegration of the felspathic rocks in place, but sometimes also from a disintegration of similar rocks in the drift. The descent of the region southward has caused the river valleys and smaller watercourses to be cut deeply into the rocks, which are hence best exposed along streams. As already said, however, exposures occur also somewhat widely scattered away from the streams. Some large areas, as, for instance, the country along the Fourth Principal Meridian, from town 30 to town 42, are without rock exposures, the drift covering being especially heavy.

By far the most common one of the crystalline **rocks** in this area is gneiss; next in order of abundance are granitoid gneiss, granite, syenite, hornblende rocks, chloritic schists, mica-schists, quartz-schists, quartzite and felsitic rocks. In one small district on Black river in Jackson county are large exposures of silico-ferruginous schists (iron ores), associated with silico-magnesian (talcose) schists. All of these general kinds include many varieties, which are noted in the following detailed descriptions. The granitoid and gneissoid kinds have most commonly a moderately coarse character.

The original **bedded condition** of the whole series is rendered sufficiently evident, not only by a prevailing gneissoid and schistose character, but also by the existence of distinct bedding planes and lamination lines, which, though often obscured by cross-jointing, especially in the granitoid kinds, can nevertheless, in general, be readily made out. That the processes of metamorphism and disturbance have been carried almost to their last extremes is shown by the highly crystalline character of the rocks, the grading of the gneiss into granite, the greatly contorted condition of the gneiss laminæ,[1] and the close folding of the whole series. In some places, portions of the arches are left; but in general erosion has removed or obscured all the crowns, and has made of what must once have been a lofty mountainous region, one in which the variations from a general level are only those of insignificant ridges, and comparatively shallow, eroded watercourses.

Whilst the bedding of the whole series is thus evident, distinctly **intrusive granite** occurs, its nature being indicated by the way in which it joins and penetrates the bedded rocks. This extravasated granite is usually of a pinkish to reddish color, often very bright red, and occurs in very large masses.

A **tendency to weather** characterizes most of the gneisses and other

[1] Most beautifully exhibited on Black river, just below the crossing of the Green Bay Railroad.

felspathic rocks, and also those that are largely hornblendic. The alteration usually extends but a small distance into the body of the rock, which can generally be observed in its true unaltered character by removing the surface crust. In some localities, however — and these are altogether without the drift area, or at least where the drift materials are scanty — the whole exposed portion of the rock is so disintegrated as to crumble to dust under a blow of the hammer, or is completely altered, by removal of alkaline ingredients and absorption of water, to a clayey mass, which, when the original rock was non-ferruginous, or when the iron oxides have been also completely removed, is a mixture of pure kaolinite and quartz grains, and is of considerable commercial value. The almost entire restriction, so far as known, of this kaolinized rock to those districts where there is nothing to indicate the former presence of the glacial agencies, is a fact of very considerable interest. Its absence everywhere where the drift occurs may indicate that it has been removed by the drift forces. It is true, however, that the kaolin district coincides with one in which there is generally more or less of a sandstone covering to the crystalline rocks, and that many of the kaolin occurrences are beneath a few layers at least of sandstone. It may then be that the surface waters, percolating through the porous sandstone — in ancient times much thicker than now — have formed natural watercourses along the junction between it and the less easily penetrable crystalline rocks, and have thus exerted an unusual disintegrating action; whilst the sandstone itself has subsequently acted as a preserver of the kaolinized rock from the ordinary eroding agencies.

No one system of **strikes** prevails over the whole region, but yet for long distances a marked parallelism can be observed in the courses of the outcrops of the various layers. Thus along the Wisconsin from its southernmost exposures of crystalline rocks, at Point Bass, in Wood county, as far north as Wausau, in Marathon county, the strikes are, for the most part, east of north, whilst the dips, though of course far less constant in amount and direction, are more commonly north than south. On Black river, again, for the whole distance examined, the strikes are just as markedly northwest, and on Yellow river more commonly west, than east of north. Whilst no general system of strikes can be laid down for the whole region, and no further generalizations can be drawn from the observations made in the Central Wisconsin district, it is nevertheless very probable that by comparing the results of different observers on the strike directions for the whole Archæan region of the state, some quite important conclusions may yet be reached. At the time of writing investigations on this region are still in progress, and such generalizations would now be premature. Attention may be drawn, however, to the fact that the general directions of the strikes preserve a sort of parallelism to the sides of the somewhat irregularly shaped Archæan area. Thus, on the Wisconsin, Wolf,[1] Peshtigo[2] and Oconto,[3] the strikes are northeastward, coinciding with the long boundary line on the southeast side; on the Black, Yellow, and lower Chippewa, the directions are northwestward, corresponding in general to the southwestern boundary line; on the upper Chippewa, and in the Penokee region, the strikes are generally north of east, corresponding with the Lake Superior side of the Archæan area. Whether this correspondence has any significance or not, remains to be seen. It is quite possible that the northwestward strikes of the Black, Yellow and lower Chippewa indicate the existence of a continuous band of Huronian (including then gneissic rocks and granites) which, curving around to the north and northeast, includes the quartzites of Rice lake, in Barron county, and joins finally with the Iron Range series of Ashland county. The remaining northeastward strikes, on this view, would be those of the original Laurentian nucleus.

It has already been said that most of the rocks of the main Archæan area are referred to the **Laurentian.** This is done partly because of their general lithological characters, but more especially because they are found near Lake Superior, and also near the Michigan boundary, in Oconto county, underlying unconformably other metamorphic beds, chiefly of a slaty character, which, from their relations both to the Copper-bearing series and Silurian sandstones of Lake Superior, and to the Potsdam sandstone of Central Wisconsin, quite evidently occupy the horizon of the Canadian Huronian. When these relations are taken into account with their great resemblance in lithological characters to the typical Canadian formations, from which they are but little removed, and with which they are indeed quite probably continuous underneath the waters of Lake Superior, the reference of the two Wisconsin series of crystalline rocks to the Laurentian and Huronian seems unavoidable.

The *undoubted* **Huronian** beds of Wisconsin lie entirely without the district which is the object of the present report. Those lying within the district, on Black and Yellow rivers, already alluded to as doubtfully Huronian, are as yet too doubtfully so to merit further attention in this place.

The only **materials of economic importance** yet known to occur in the Archæan of Central Wisconsin are kaolin or rotted rock, and

[1] Manuscript report, E. T. Sweet. [2] Oral communication, T. C. Chamberlin.

building stones, especially ornamental building granite. Beds largely charged with the specular and magnetic oxides of iron occur on Black river, but, so far as known, contain too little iron to be used as ores of that metal. Judging from the character of the rocks of this age in Canada, a great variety of materials of economic importance might reasonably be expected, including the precious metals, lead, copper and iron ores, all of which are found and profitably worked in the Canadian Archæan. Small traces of precious metals have been found in quartz from Clark county. Details as to the kaolins of the Black, Yellow and Wisconsin rivers, and as to the ornamental granites of Yellow river and other places, are given on subsequent pages. Both of these materials are obtainable in large quantity, and are destined to become important factors in the industries of the state. The red granites are quite extraordinary in their fine qualities, and are hardly to be equaled by any in the country.

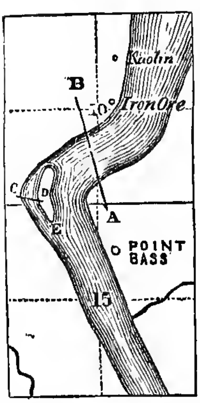
II. Local Details.

The various rock exposures belonging to the main Archæan area which have been examined by the writer, are chiefly in the vicinities of the three main streams, the Wisconsin, Yellow and Black, and their tributaries. A corresponding grouping of the detailed descriptions is here adopted, the valley of each stream being followed upwards from its southernmost crystalline-rock exposure.

Upper Wisconsin Valley.

At Whitney's Rapids, near Point Bass, on the S. W. qr. of Sec. 10, and the N. W. qr. of Sec. 15, T. 21, R. 5 E., occur the southernmost exposures of crystalline rocks on the Wisconsin river. They are here confined entirely to the river bed, the horizontal Potsdam sandstone overlying them in the banks. The following sketch map serves to show the occurrence of the various outcrops at this point.

Fig. 2.



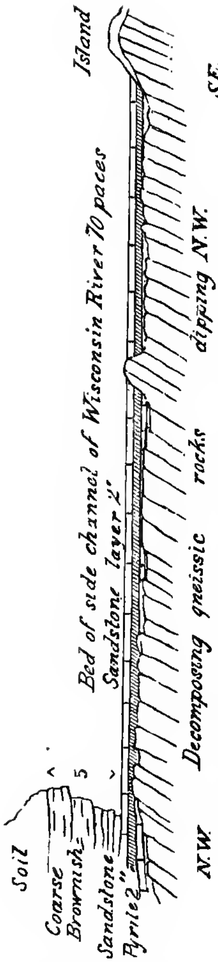
Vicinity of Point Bass, Wood County.

Scale, 1 mile to the inch.

The southernmost exposure seen, and this only at unusually low stages of the water, is a low rounded one of quartzose gneiss (869), a few square yards in area, in the river bed at the point E of the map. Ten paces up the stream from here is a similar exposure of a greenish-black, pyritiferous, hornblendic rock (870), traversed by pinkish felspathic veins, and striking N. 50° E.,[1] with a nearly vertical dip. Continuing northward along the bed of the stream, between the western shore and the island D, we find occasional exposures of decomposing gneiss, which is, for the most part, concealed by water and river gravel. At about eighty paces, a section across the stream was taken, on the line C D of the map, which is represented by Fig. 3. Here the white, kaolinized, but still firm, gneissic rocks (871) are overlaid by 2 to 6 inches of sandstone, the lowest layer of which, about 2 inches thick, is highly charged with pyrite, which, in places, excludes the sand

[1] All bearings are referred to the true meridian.

FIG. 3.



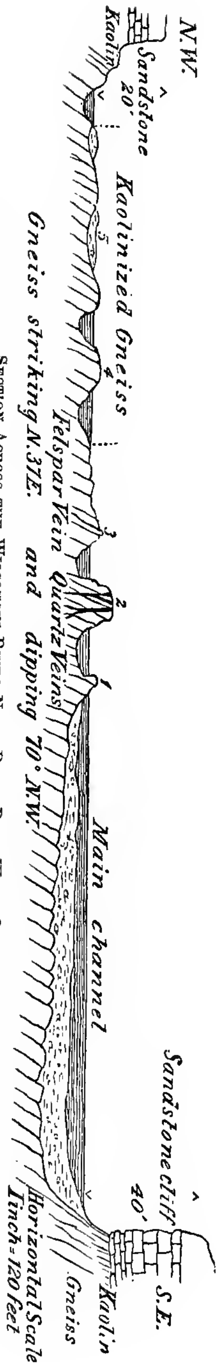
SECTION ACROSS SIDE CHANNEL OF WISCONSIN RIVER, NEAR POINT BASS, WOOD COUNTY.

entirely. The upper sandstone layers are coarse and brownish-colored, and lie in large, flat slabs, giving the river bed, for many rods, the appearance of a paved street.

On the line A B of the map, a section was measured across the stream, which is shown in Fig. 4. At the southeast end of this section a vertical cliff of heavily bedded sandstone, 35 feet high, forms most of the river bank. Beneath the sandstone, gneiss shows for about 5 feet down to the water's edge. Its upper portions are altered to a soft kaolin, about 2 feet in thickness. Immediately at the foot of the cliff runs the main channel of the river, here about 400 feet in width. Beyond it to the northwest, a series of low outcrops of gneiss alternate with narrow water channels across the remainder of the river bed. The first exposure beyond the main channel was not reached. The next showed a coarse-grained, pink-white-and-black-mottled, quartzose, gneissoid granite (864), striking N. 42° E., and dipping northwestward 70°, with marked bedding planes. A second set of joints, much less marked, strikes N. 50° W., and dips 80° N. E. The quartz of this rock is hyaline, and in fine grains aggregated into large blotches; the mica is blackish and fine-grained, and aggregated along certain lines; and the felspar is both white and pink, in large facets. The weathered surface is brownish and dull, with a white undercrust, and deeply pitted from kaolinization of the felspar. Quartz veins, a few inches in width, traverse the exposure in an east and west direction, standing vertically.

The next exposure to the northwest on the line of the section is 71 feet wide and of the same rock (865) as the last, with rather more felspar, and showing the same

FIG. 4.



SECTION ACROSS THE WISCONSIN RIVER NEAR POINT BASS, WOOD COUNTY.

bedding. A red felspathic vein was noted, 2 inches wide, dipping 70° N., and also the same east and west quartz veins as before. Towards the northwest end of this exposure the gneiss is quite thoroughly decomposed into a crumbling, earthy-textured, brown- and white-blotched material, showing still a few mica flakes and quartz granules in the interior, and containing 4.96 per cent. of water. The same partly kaolinized rock is found all along the section until the west bank of the river is reached, showing, however, still quite plainly the lamination and bedding planes of the unaltered rock, the dip and strike remaining the same. At the foot of the west bank, which is about 20 feet in height, unaltered quartzose granite shows, with north and south quartz veins ½ inch thick. Above this, and some few feet above the water level, fine, white, soft kaolin shows in a little swamp, and above this again are seen a few thin layers of the sandstone.

On the N. W. qr. Sec. 10 are openings in the river bank, here some 20 feet in height, showing a considerable quantity of white kaolin. The various exposures are at different levels, and may indicate a thickness of as much as 15 feet in some places, but as the clay is merely an alteration of the gneissic rock in place, it forms no continuous bed, the less altered portions of the rock occasionally rising entirely through it. At the principal opening 22 inches of soft, bluish-white clay were noticed. The following are analyses of samples from this place:

	861.		862.	
	A	*B*	*A*	*B*
Potash	1.25	2.81	1.51	1.54
Soda	.08	trace	.81	.22
Iron	2.88	....	1.17	....
Water	....	....	....	8.69

861 A is the raw kaolin from the lower part of the exposure; 861 B is the fine or kaolinite portion of 861 A, separated by levigation. Nos. 862 A and 862 B are, in like manner, raw and washed clay from the upper part of the same opening. The amounts of alkalies are considerable, and no lessening in their percentages appears to be effected by levigation. The state of oxidation of the iron was not determined, but it would appear to be chiefly in the protoxide state, judging from the color of the clay. These facts would indicate a less thorough kaolinization here than at other places in the vicinity. Immediately above the kaolin openings are two feet of coarse, brownish, friable sandstone, whilst below it, down to the water's edge, gneiss in decreasing stages of decomposition is seen. At the foot of the bank is a low exposure of unaltered, fine-grained, light-colored gneissoid granite (868). The three ingredients of the rock are all distinctly visible, the felspar being both pink and white, the latter without apparent striations; the quartz is abundant, in hyaline grains; the mica is aggregated into layers and produces a greasy feeling on some surfaces of lamination.

At the foot of the rapids, on the west side of the Wisconsin, just above **Port Edward,** on Sec. 25, T. 22, R. 5 E., a rather coarse grained, mottled, red-weathering gneissoid granite (879) is exposed. A distinct parallel grain is perceptible, with corresponding bedding joints, which strike N. 45° E. and dip 50° N. W. Other joints, which make large smooth faces, strike N. 75° E. About 50 feet further up stream is exposed a coarse-grained, pinkish, highly felspathic rock, which shows a very distinct, sometimes contorted, lamination, trending in the same N. 45° E. direction as before. In this rock the mica is nearly excluded by the felspar and quartz, which themselves are largely separated into distinct bands. In places much pyrite is present. Fifty feet further a low exposure shows an apparent N. 50° W. strike, but this seems to be due to numerous close veins running in this direction, for a few feet beyond, the same strike direction as before observed reappears, accompanied now by a southeast dip, in a fine grained, greenish, decomposing, pyritiferous, mica-schist (881). At the fall at the upper end of the channel the rock is hard, very fine-grained, light-colored, distinctly banded gneiss (882), containing much quartz and greenish, greasy mica along the lamination planes. The northeast strike and southeast dip (50°) show here very plainly.

It would appear that we have in these exposures the synclinal line at which the northwest dip of all the beds further down the river gives place to the southeast one which prevails for many miles above.

Continuing now along the west bank of the Wisconsin, we note next an occurrence of kaolin on the land of Mr. L. P. Powers, lot 5, sec. 24, T. 22, R. 5 E. The kaolin is exposed naturally in the river bank at several points, and has been at one place laid bare by digging,[1] several carloads having been sent away for trial. The exposures are some ten feet above the river at low water, and show an apparent thickness of about three feet. Much of this is pure white, plastic clay, easily removed with a spade, but in many places, and especially towards the base of the exposure, it grades into a partially altered rock of varying degrees of firmness. In much even of the perfectly soft clay the lamination planes of the unaltered rock are still distinctly to be seen, and thin plates of solid quartz remain in their original positions, dipping east of south, at about 65°. Where these lines are so distinct the clay is frequently of a bluish cast, and then appears to be less refractory than usual. All of it tends to be stained superficially by a brownish oxide of iron, which may be due to the infiltration of ferruginous waters, and is not in sufficient quantity to affect the value of the clay. In a few places, however, large dark-reddish patches are seen imbedded in the white clay, and are undoubtedly due to the presence of a large and pernicious quantity of iron oxide. Immediately above the kaolin is found a layer, 1½ feet thick, of quartz fragments, mostly angular, and evidently derived from the decomposing rock just below. Above this in a few places are to be seen one or two thin layers of crumbly, brownish sandstone, a remnant of the sandstone which overlies the crystalline rocks everywhere in the vicinity. Above, again, is found the soil, three feet in thickness. Below the kaolin, at the water's edge, low exposures of unaltered gneiss appear. A series of specimens for analysis obtained from this place yielded the following results:—

	822		823		824		825
	A	B	A	B	A	B	
Silica	70.82	.....	.....	.....	70.25	....	69.34
Alumina	18.98	.....	.....	.....	17.68	....	19.19
Iron peroxide	1.24	.....	2.34	.....	2.32	....	1.75
Lime	.24	.....	.....	.....	.33	....	.44
Magnesia	.02	.....	.....	.....	1.49	....	.39
Potash	2.49	1.21	2.30	1.96	1.69	2.33	3.30
Soda	.10	trace	trace	trace	.39	.10	2.43
Water	5.45	8.84	.....	6.30	5.61	8.84	2.67
Carbonic acid	.02	.....	.....	.....	.....	....	.....
	99.36	....	.....	.....	99.76	....	99.51
Specific gravity	2.55	.....	.....	.....	2.50	....	2.85

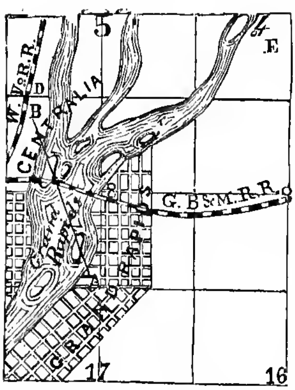
822 A is from the exposure furthest down stream, and was analyzed just as taken from the ground, after drying at 100°. It represents a thickness of about three feet. It will be noticed that the alkali is chiefly potash, a fact which seems to be attributable to the greater difficulty with which the potash felspar decomposes, both potash and soda felspars entering into the composition of the gneisses of the vicinity. The small trace

[1] This kaolin has been much further developed since the time of my examination in 1874.

of carbonic acid remains as an indicator of the mode of decomposition which has led to the formation of the kaolin. 822 B is the fine portion of the same clay separated by levigation in the laboratory from the admixture of coarse sand composed of quartz and undecomposed felspar fragments, the former predominating. The smaller percentage of alkalies is due to the removal of the felspar fragments and mica flakes. 823 A and 823 B are raw and washed clay from the next exposure above, along the stream. A lessening of the alkali percentage is again to be observed in the washed clay. 823 represents an apparent thickness of nearly three feet. 824 is from the exposure furthest up stream. It is quite soft and clayey, but in places retains the rock lamination to a marked degree. 824 A and 824 B are respectively the raw and levigated clay. It will be noticed, that, although retaining the rock structure, this clay is yet pretty completely decomposed, the only point indicating a lack of thorough decomposition being the larger amount than usual of soda. 825 is a still firm, partly decomposed rock from the same place as 824. It is of a dirty white color on the exterior, nearly pure white on the interior, quite porous, has an evident gneissoid texture, and is speckled with small flakes of silvery mica. With the exception of this mica no distinct constituent minerals can be seen with the naked eye; with a magnifying glass, however, a fresh fracture reveals in a few places minute grains of quartz and undecomposed orthoclase felspar. The large tenure of alkalies, especially of soda, and the small amount of water, indicate the only partial decomposition.

Appearances would indicate the existence of a considerable body of kaolin at this point. Since my examination the locality has been much further developed and a large number of fire brick made. In 1875, Mr. E. T. Sweet, of the Geological Survey, visited the place and found that no care was taken to select the clay, nor was it put through any washing process to separate the undecomposed portions. He was informed that woodash was used largely to counteract the shrinking of the clay on burning; an addition, which, of course, introduced the ingredient most to be dreaded. As a result of this method of manufacture and lack of selection, a very great variation was observable in the quality of the bricks, some even showing a tendency to agglomerate in the kiln. The clay from this locality has also been largely shipped raw to Milwaukee where it has been used by the Iron Companies and Gas Light Company. In 1874, about one thousand brick were burned for the Gas Light Company from a mixture of the Grand Rapids kaolin and pulverized fire-brick, and were found to be of the very best quality.[1] A brick made in this way, and procured for me by Mr. S. G. Lapham, yielded 2.06 of potash and 0.31 of soda. It presented a peculiar jagged, porous appearance on a fracture, with blotches of a white porcelain-like substance, and was said to be an excellent brick. At the Bayview Iron Works[2] the clay has been tried raw, and found very refractory. Bricks made from it and used here were found to vary very much in their refractoriness, some being extraordinarily refractory, others succumbing readily to the heat.

Fig. 5.



Vicinity of Grand Rapids, Wood County.
Scale, one mile to the inch.

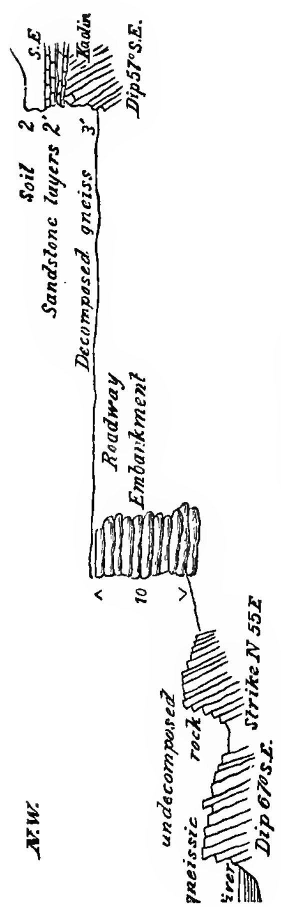
On **Mr. H. Canning's land** on the west half of the N. E. qr. of Sec. 26, T. 22, R. 5 E., several pits and a well have been sunk into decomposing rock and kaolin. Specimens from here yielded the following analytical results:

[1] Letter from Dr. I. A. Lapham, Milwaukee, Nov. 13, 1874. [2] Letter from Mr. J. J. Hagerman.

	826 A	826 B	827	828
Silica	....	....	.....	54.86
Alumina	....	....	.....	28.87
Oxide of iron	1.93	....	.....	2.48
Lime	....	...	.....	.16
Magnesia	....	....	.....	.98
Potash	1.84	2.65	2.95	2.57
Soda	.27	.21	.83	.07
Water	....	7.96	.....	9.98
				99.97
Fine clay	....	....	.....	56.61
Coarse residue	....	....	.....	43.39
				100.00

826 A and 826 B are the raw and washed kaolin from Mr. Canning's well; 827 is washed clay from the two pits on the same land, several hundred feet from the well; 828 is the fine clay levigated from an exceedingly white unbaked brick, said to have been made from clay from Mr. Canning's well.

Fig. 6.



KAOLIN AT GRAND RAPIDS.
Scale 20 feet to the inch.

The next rock and kaolin occurrences that we note in ascending the Wisconsin are those in the vicinity of the cities of Grand Rapids and Centralia. The localities are shown on the sketch map, Fig. 5.

Here the river makes a long series of wild rapids over gneissic rocks, which on the shores, at short distances from the water, appear at several points altered to kaolin and overlaid by a few thin layers of sandstone.

One of the most instructive occurrences in the vicinity is to be seen on the roadside in the city of **Grand Rapids**, near the Rablin House (Point A on Fig. 5). Here some cutting has been done into the bank for grading the street, and kaolin, decomposing rock, and overlying sandstone laid bare. The following is the section obtained here (Fig. 6.)

A specimen of decomposing gneiss (816), occurring beneath the sandstone, yielded:

Potash	7.16
Soda	5.02
Water	3.55

The very partial nature of the decomposition is thus rendered evident. In appearance however, nearly all resemblance to the original rock has been lost, the color being a dirty white, and the interior, though still firm and hard, of a somewhat earthy texture. In some fragments a few minute grains of unaltered felspar can be detected with the magnifier.

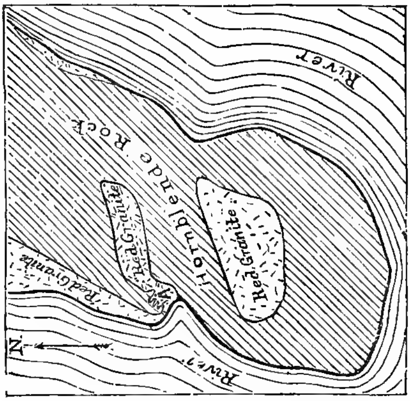
From the gneiss exposures shown at the water's edge in the sketch just given (Fig. 6), the following measured section was taken entirely across the great ledges of gneiss which form the Grand Rapids of the Wisconsin. This section runs N. 20° W., on the line A B, or at right angles to the general trend of the layers, which is usually quite plainly to be seen. The exposures are not entirely continuous along the line of section, but are nearly so, and gaps could be filled with ledges a little distance on one side or the other. At the time of our examination, the river was low, and an unusual amount of rock laid bare. The measurements given indicate horizontal widths. Since the general dip is southeastward the first beds of the section are the highest in the series.

	Feet
1. *Gneiss:* at the beginning of the measurement (833) coarse-grained, distinctly laminated, black-white-and-pink-mottled; striking N. 80° E., dipping 60° S. E. The mica of this rock is greenish and brownish, and aggregated into large blotches; the felspar is both pink and white, the latter not plainly striated, and occurring in large facets; the quartz is abundant and limpid. Pyrite is present in small quantity. Twenty-five feet from the beginning, the felspar is much increased in quantity (834). At fifty feet the grain of the rock becomes much finer, and the mica is largely restricted to the surfaces of the quite distinct laminæ (835). This variety gives place soon again to a coarser kind (836), similar to that at the beginning of the section (833), but with the quartz somewhat more prominent. At seventy feet the bedding directions are quite plain and show a strike of N. 75° E, and a dip of 60° S. E. Here the rock laminæ are contorted, and the mica very abundant, almost excluding the felspar. A few pinkish granite veins occur, from ¼ inch to 2 inches wide, conforming to the bedding of the rock. The vein matter (838) is predominatingly of pinkish, flaky quartz, felspar being subordinate, and the mica restricted to the sides of the vein, ...	100
2. *Covered*, by water, ...	20
3. *Gneiss*: at the beginning of the measurement coarse-grained, schistose, contorted in places, pinkish-white, very quartzose, carrying pyrite (839), striking N. 85° E. Twenty feet beyond, this changes to a finer-grained, dark-grayish, schistose kind (840), embracing some thin veins of white quartz and pinkish granite. At 30 feet, the strike is N. 80° E., the dip 65° S. E. At 80 feet occurs a reddish granite vein six feet wide. The vein-matter (843) shows a fine-grained texture and dark reddish color, and appears to be a mixture of very fine, pinkish felspar facets, and translucent quartz grains, no mica being apparent. At 100 feet the grain becomes coarser again until at 130 feet (844), the rock is again like that at the beginning of the section (833). Beyond, the grain again becomes finer (845), the pinkish felspar at the same time increasing in amount, and occurring to some extent in a porphyritic manner, ...	170
4. *Covered*, by water, ...	250
5. *Hornblende rock* (846): very fine-grained, highly crystalline, distinctly bedded; in places thin bedded; dark-colored or black; strike N. 60° E., dip 60° S. E., ...	20
6. *Covered*, on islands	70
7. *Hornblende rock:* similar to the last described, but much weathered and broken by joints; strike and dip obscure............	20
8. *Covered*	35

Feet.

9. *Red granite* (847): medium-grained, structureless, pinkish to red, highly felspathic. By following the strike directions south-westward for some hundreds of feet, the junction between this and the preceding dark-colored rock is found on a large water-worn surface near the dam at the Grand Rapids foundry. Here the two rocks are seen to interlock in a curious manner, the granite occurring in large masses, entirely surrounded by the other rock. The contrast between the bright red color of one, and the black of the other, makes their irregular junction-line very marked. Fig. 7 shows this junction line. Fig. 8 is the part of Fig. 7, at A, enlarged. Where the sketches were taken the granite (894) is somewhat deeper red in color and of coarser grain than on the line of section, its deep red color being due to the abundance of red felspar, which is sometimes in facets ½ inch in diameter, and is blotched with large patches of translucent quartz. The rock is a very handsome one, and would have value as an ornamental building stone 35

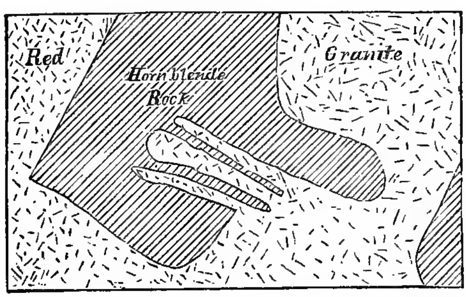
FIG. 7.



JUNCTION OF GRANITE AND HORNBLENDE ROCK.
Scale 100 feet to the inch.

10. *Hornblende rock* (848): rather fine-grained, highly crystalline, dark colored; strike and dip obscure. Hornblende and a whitish felspar appear to be the main ingredients. Magnetite is present, and with a magnifier, can be seen in bright, metallic particles. Quite coarse fragments are held up by the magnet. At 100 feet this rock becomes very fine-grained (849), and rises into large exposures, over which the dip needle stands vertical... 120

FIG. 8.



ENLARGEMENT OF PORTION OF FIG. 7.
Scale 4 feet to the inch.

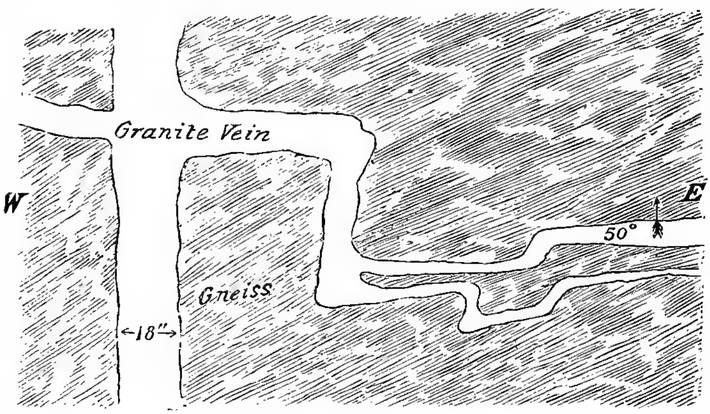
11. *Red granite* (850): moderately coarse, pink to red; weathered surface bright red; much jointed; no bedding; similar to No. 9. The mica in this rock is very subordinate, and in patches of small flakes; the quartz is hyaline, in considerable blotches of granular appearance; the felspar is pink to red, bright-lustred, large-surfaced, and very abundant........................ 57

12. *Hornblende rock:* fine grained, dark-colored, much jointed; strike and dip obscure 58

Feet.

13. *Gneiss:* first 4 feet is coarse-grained, pinkish, and quartzose (851), resembling that at beginning of section. This grades into a light-gray, coarser kind, which has a very jagged fracture, is less micaceous, shows whitish felspar predominating over pink, and only obscure lamination, and is much cross-jointed (853). At 100 feet the bedding becomes distinct, the strike being N. 85° E., the dip 52° S. E. At 230 feet the strike is N. 85° E., the dip 50° S. E., the rock (854) being coarsely mottled gneiss with much greenish mica and large-faced reddish felspar. At 280 feet the bedding is the same, and a small red felspar vein occurs. At 300 feet the strike is N. 70° E., the dip 55° S. E. A fine-grained, red granite vein occurs here having the form indicated in Fig. 9.

Fig. 9.



Granite Vein at Grand Rapids.

At 340 feet the bedding and lamination of the rock become obscure again and continue so for a hundred feet. At 360 feet numerous thin veins of quartz occur, and at 380 feet one of pure white quartz 4 feet wide. At 420 feet are some large veins of red granite. One of these is figured in Fig. 9. At 440 feet the bedding becomes plain again, the strike being N. 85° E. and dip as before. The rock here (856) is much less micaceous and more felspathic than for some distance back, and is much weathered............. 494

14. *Covered* 190

15. *Granite:* pinkish, jointed, without indications of bedding................ 40

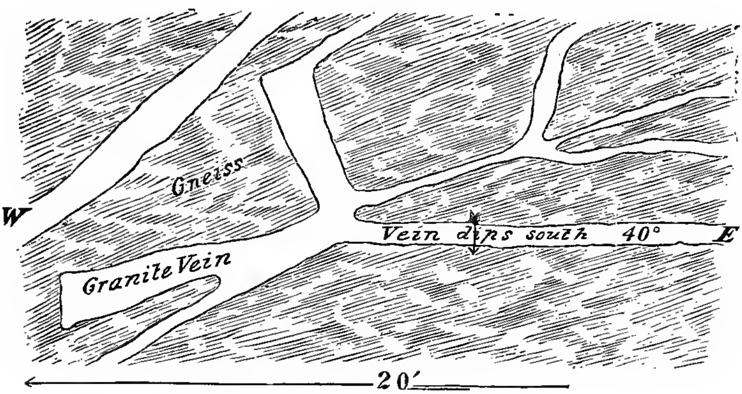
16. *Gneiss:* dark-colored; at 40 feet this changes to a rock (858) which closely resembles that at the close of 3 (856), and is moderately coarse, not very distinctly gneissoid, with much hyaline quartz and large-faceted felspar. At 60 feet a granite vein 50 feet long occurs in this rock, coinciding with the bedding, and striking N. 75° E., with a dip 50° S. E. The vein matter (859) is a rather fine-grained, pinkish-red granite, weathering dirty brick-red, and showing in places a partial kaolinization. Fine grained translucent quartz and pinkish felspar make up most of this granite. Mica is present, but in very small quantity 130

17. *Covered* 30

18. *Gneiss:* gray, with much black mica, similar to that of 16 (858). At 10 feet a granite vein 2 feet wide occurs, coinciding with the bedding, which here shows a strike of N. 73° E., and a dip 55° S. E. Other smaller granite veins occur. Junction with the next rock concealed 100

	Feet.
19. *Hornblende rock* (859½): very fine-grained, highly crystalline, dark greenish-black; contains much of a highly lustrous black mineral (hornblende); pyritiferous; adheres slightly to the magnet in a fine powder. See also Mr. Wright's microscopic examination, Appendix B	50
20. *Gneiss:* resembling that of 18; at first obscurely bedded, then at 60 feet more distinctly bedded, the strike being N. 75° E., and the dip 53° S. E. At 100 feet 3 granite veins, each 3 inches thick, occur	120
21. *Covered*	40

FIG. 10.



GRANITE VEIN IN GNEISS AT GRAND RAPIDS.

22. *Granite:* fine-grained, light pinkish, slightly gneissoid; jointed. The three ingredients are all perceptible with a magnifier. The mica shows some tendency to a stringy arrangement	80
23. *Covered*	45
24. *Granite:* same as last described	35
25. *Hornblende rock:* strike N. 85° E., dip 75° S	10
26. *Covered*	150
27. *Granite:* pinkish, gneissoid	50
Total horizontal length of section	2,519
Approximate thickness of rocks exposed	2,200

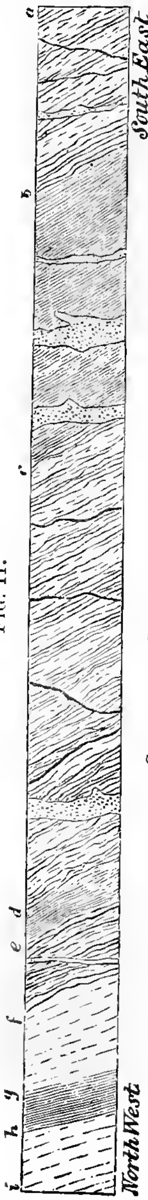
From the foregoing details we may construct the generalized section of Fig. 11, the red granite of portions of the section being regarded as an intrusive rock.

At the first dam below the wagon bridge at **Centralia**, on the west side of the river, a ledge of hornblende rock, 40 feet wide, occurs. This rock (884) is moderately coarse-grained, dark-colored to black, and appears to be composed of hornblende and a white felspar with much magnetite, the latter very distinctly visible, by the aid of the magnifier, in lustrous grains. Quite coarse pieces are lifted by the magnet. On the river bank a short distance up stream, micaceous gneiss is exposed, forming apparently the next layer. These beds are higher in the series than any of those in the section at the rapids.

At the pail mill, just below Centralia, is a large exposure of fine-grained, pinkish, gneissoid granite, containing much reddish felspar, and fine, glistening, greenish mica, with a stringy arrangement.

On the N. W. qr, of Sec. 5, T. 22, R. 6 E. (point D of map), on the west side of the Wisconsin, kaolin occurs on the **land of Mr. C. B. Garrison.** The clay here is reached about 18 inches to 2½ feet below the surface, and has been exposed in places for a distance of some rods, by "borrowing" for the railroad near by. Several grades are to be seen. In some places the spade turns up a brilliant white article; in others, for the most part nearer the surface, a kind that is largely stained with the brown oxide of iron; whilst at others again, the lamination of the unaltered rock is still distinctly perceptible in the soft clay, in which cases it is more apt to show a slight bluish cast, and many silvery mica scales. All of the clay is quite gritty from the presence of undecomposed felspar and quartz grains. Rounded, reddish quartz pebbles up to ½ inch in diameter, are occasionally to be seen. The depth of the clay at this place is said to be at times as much as 4 feet. Samples of the whitest kinds yielded the following results:

FIG. 11.



GENERALIZED SECTION, GRAND RAPIDS.

Scale 400 feet to the inch.

a b. Coarse micaceous gneiss, with occasional granite and quartz veins. *b c.* Hornblende rock or schist, with granite masses and veins. *c d.* Coarse micaceous gneiss, occasionally finer and less micaceous, with numerous veins of granite, quartz, and felspar, and pink granite masses. *d e.* Hornblende schist. *e f.* Dark colored gneiss with granite veins. *f g.* Pink gneissoid granite. *g h.* Hornblende schist. *h i.* Pink gneissoid granite.

	807 A	*807 B*	*807 C*
Silica	78.83	49.94	92.86
Alumina	13.43	36.80	2.08
Iron oxyd	.74	.72	.74
Lime	.64	trace	.96
Magnesia	.07	.....	.10
Potash	.37	.51	.28
Soda	.07	.08	.05
Water	5.45	11.62	2.53
	99.60	99.67	99.60
Carbonic acid	.01	.....	.....
Specific gravity	2.52	2.52	.....

807 A is the raw clay dried at 100° C.; 807 B is the fine clay obtained from A by repeated stirrings and washings; 807 C, the coarse residue from the washing. The composition of this residue is calculated from the two preceding analyses. Under the microscope it is seen to consist chiefly of angular fragments of quartz from $\frac{5}{100}$ to $\frac{1}{10}$ inch in diameter, mingled with very fine fragments of felspar. The approximation in composition of the roughly washed fine clay to typical kaolinite is noteworthy. The unwashed kaolin (A) is composed of 32.7 fine clay (B), and 67.3 coarse residue (C). The following are the compositions of B and C expressed in percentages of the unwashed clay (A). The manner of distribution by washing of the various ingredients of the raw clay is thus indicated, and the practical advantage to be obtained by washing shown:

	807 B		807 C		807 A
Silica	16.33	+	62.50	=	78.83
Alumina	12.03	+	1.40	=	13.43
Iron oxide	.24	+	.50	=	.74
Lime	.00	+	.64	=	.64
Magnesia	.00	+	.07	=	.07
Potash	.12	+	.25	=	.37
Soda	.03	+	.04	=	.07
Water	3.75	+	1.70	=	5.45
	32.50	+	67.10	=	99.60

The most ferruginous clays seen at Mr. Garrison's yielded 1.68 per cent. (808), and 2.31 per cent. (809) of iron sesquioxide. These are apparently much more plenty than the white clay. About 10 rods from the kaolin openings, on the river edge, is a low outcrop of a highly micaceous, weathering gneiss (803). having a moderately coarse, jagged texture. The felspar of this rock is largely still brilliant, but little white kaolin patches dot the surface. Another outcrop near by shows a more highly felspathic kind, with very coarse, pinkish orthoclase. These gneisses closely resemble the prevailing ones in the Grand Rapids section, but are evidently much lower in the series than any of those.

At the Green Bay and Minnesota depot, Grand Rapids, it is reported that in excavating for a turn-table, first a few layers of compact sandstone were penetrated, then 5 to 6 feet of soft white clay and decomposed rock. Near the center of Sec. 4, T. 22, R. 6 E. (point E of map), about two miles above Grand Rapids, on the east bank of the Wisconsin, on **Mr. Rablin's land**, very white kaolin shows, overlaid by two feet of sandstone. This kaolin has been used with success to line the furnaces at the Grand Rapids foundry. The following are analyses of samples from here:

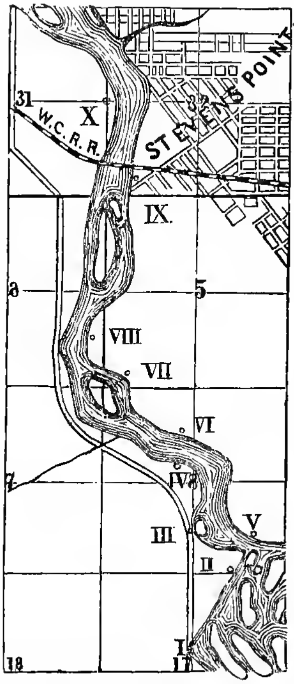
	829		828 1-2
	A	B	B
Oxide of iron	4.43	...	...
Potash	1.21	.87	.38
Soda	.46	...	.08

829 A and 829 B are raw and washed clay taken from the stock-pile at the foundry; 828½ is washed from a sample taken from the opening itself.

On the line of the **Wisconsin Valley Railroad, between Centralia and Junction City**, are several low cuttings, which expose usually crumbling, and partially decomposed, laminated gneissic rocks. The exposures are very poor and the rock is generally out of position. About 3½ miles north of Centralia is a cutting 400 feet long, through a rather fine-grained, granular textured, pinkish granite (965). This rock consists of brownish, translucent, granular, glassy quartz, largely predominating; pinkish bright-lustered felspar; and fine black mica sparsely but uniformly scattered. It would dress readily, but shows some tendency to weather and iron stain.

West of the railroad line, in the **western part of T. 23, R. 6 E.**, sandstone occurs in places, sometimes capping the hills, sometimes low in the valleys, and lying evidently upon a very irregular crystalline rock surface. On Sec. 8, near the northwest corner of the section, a well passes through sand 6 feet, sandstone 2½ feet, soft red and white kaolinized rock 20 feet. This is the greatest depth of softened rock that has come to my notice in Wisconsin.

Fig. 12.



Sketch-map showing Localities of Rock Exposures at Conant's Rapids and Stevens Point Rapids.

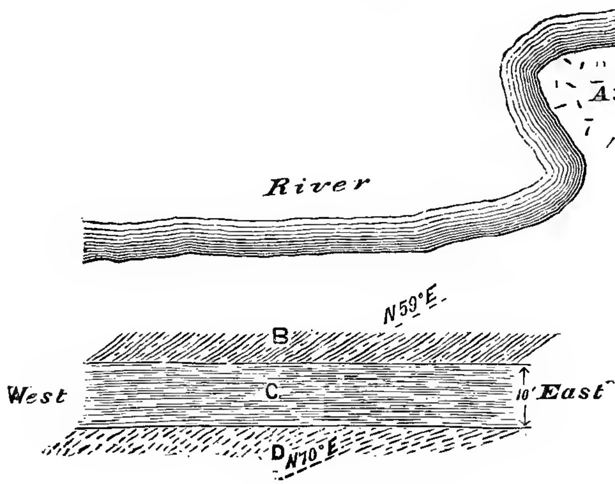
Scale, one mile to the inch.

At **Conant's Rapids**, sections 18 and 17, T. 23, R. 8 E., Portage county, are large rock exposures in the bed and on the sides of the Wisconsin river. The sketch-map, Fig. 12, shows the localities of the occurrences at this place, as also at the Stevens Point rapids, above.

On the west side of the river the rock exposures and rapids are found continuing further down stream than on the east, on account of the northeast strike of the rocks. Beginning at the foot of the rapids on the west side, we note first on the N. W. qr. of the N. E. qr. of Sec. 17, a low exposure some 500 feet in length, under the river bank, No. I of map. The rock here (775) is a fine-grained, pinkish-gray gneiss, showing fine-granular, translucent quartz, predominating; fine-faceted white felspar, abundant; black mica in very fine separate scales, arranged in lines. The lamination is quite close and distinct. The weathered surface of the exposure is brownish in color, smooth, and highly polished by the running action of the river. From this smoothed and brown-tinted surface numerous reddish granite veins stand out in bold relief, having resisted the eroding action more successfully than the surrounding rock. The bedding is not very distinct, being obscured by many cross-joints; the strike is N. 81° E., and the dip N. W. 60° to 67°. Other quite prominent joints occur, bearing N. 55° E., and standing vertical. Numerous veins are to be seen here, both of white quartz, and of reddish felspathic granite, varying in thickness up to several inches. One granite vein 5 inches wide trends N. 26° E., for a distance of 50 feet. The vein matter (775) is a very fine-grained felspathic granite, in which all the ingredients can, however, be distinguished. Numerous thin feeders extend from the vein into the rock around. The next exposure above, No. II of the map, is a large one, stretching across a side channel of the river, just about on the line beetween sections 8 and 17. The rock here (778) is a very coarse-grained, micaceous, granite, consisting of very large-flaked brilliant black mica; white, very distinctly striated felspar, in facets up to $\frac{1}{8}$ inch by $\frac{1}{4}$ inch in size; limpid quartz; some brownish-stained mica; and some little hornblende. In some places a very distinct tendency to crumble is perceptible, and then the mica is much iron-stained, and the rock is blotched with large patches of white, kaolinized felspar. Even where exposed to the running water this rock presents nowhere the peculiar smoothed and glistening appearance of the exposure below, but on the contrary shows everywhere a rough, coarsely pitted surface. This is rendered the more striking by the innumerable reddish granite and white quartz veins which intersect the rock in every direction, making up nearly half of the exposure, for these having resisted better the weathering influences, show the smoothed appearance alluded to, and stand out in relief from the lighter colored, jagged surface of the surrounding rock. The veins are from 1 inch to 18 inches in width. The reddish ones are of granite, having a large predominance of reddish felspar, which, in some of them, occurs along the sides of the vein free from admixture, and in large crystalline surfaces. One vein $2\frac{1}{2}$ inches wide showed alternating bands of white quartz, pink, coarsely crystalline felspar, and felspathic granite (777).

Exposure No. III of the map is on the road side in the S. W. qr. of the S. E. qr. of Sec. 8. The rock here is a fine-grained, light-pink, gneissoid granite (779), having the three ingredients distinctly visible, though fine, and showing a few whitish kaolinized patches. At No. IV of the map, are large exposures at the top of the bank and in the river below. Fig. 13 shows the occurrences.

FIG. 13.



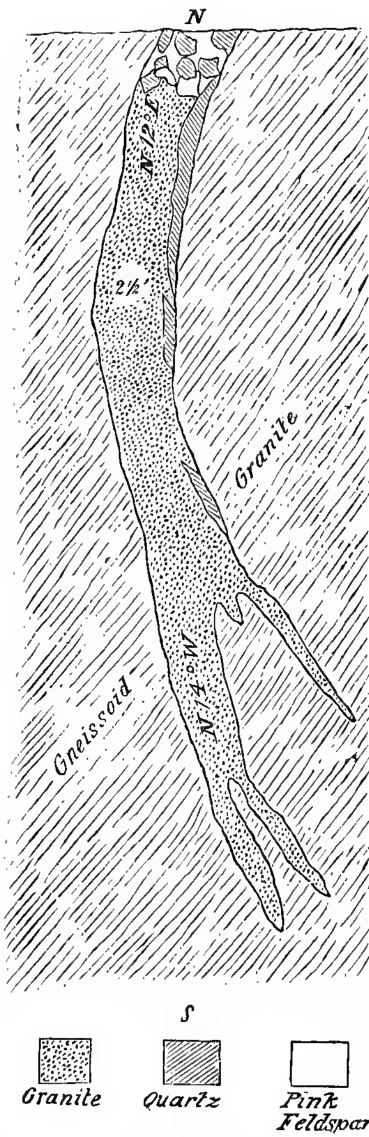
Scale, 30 feet to the inch.

At A is a bold exposure of smooth-jointed, fine-grained, light-reddish granite (780), in which red-stained granular quartz is the predominating ingredient, mica being very subordinate, occurring in fine brilliant brownish flakes, and showing a slight tendency towards a stringy arrangement. The numerous joints which traverse this rock strike N. 17° W., and stand nearly vertical. At B (782) is a coarse-grained, red-and-black-mottled, micaceous gneiss, striking plainly N. 59° E. This rock resembles that of No. III, but contains much more reddish non-striated felspar. Whitish kaolinized patches occur. Bounding this on the south. at C, and sharply defined from it, is a fine-grained, dark-greenish crumbling rock (781), having a marked E. W. lamination. This rock appears to contain, predominatingly, fine blackish mica, with which appears to be mingled some fine whitish felspar (mica-schist?). Little pinkish felspathic threads traverse the rock. To the south of this again, at D, comes in a fine-grained, very compact, greenish, gneissoid granite (783), striking N. 70° E. and showing as constituents, fine-flaked, blackish mica, pink and white felspar, and limpid quartz.

Passing now to the east side of the river, we note first on the N. E. qr. of the S. E. qr. of Sec. 8, near the foot of the rapids, and just above the mouth of Plover river, at No. V of the map, large, but low, outcrops of quartzose gneiss, bearing nearly east and west, dipping south 60°, and overlaid by 25 to 35 feet of horizontal sandstone. This point appears to be on the anticlinal line where the southeast dips of the Grand Rapids series give place to the northeast dips of the Conant's and Stevens Point rapids.

On the N. E. qr. of the N. W. qr. of the same section (No. VI of map), large exposures begin, which extend up stream for a long distance, and show all along a very marked trend of N. 25° E. The southernmost rock examined here is a fine-grained, dark-colored, highly micaceous gneiss, traversed by numerous large veins of reddish granite and smaller ones of white quartz. In some of the veins, quartz, felspar, and granite all occur separately, as, for instance, in the one shown in Fig. 14.

FIG. 14.



GRANITE VEIN AT CONANT'S RAPIDS.
Scale, 6 feet to the inch.

The vein rock here (799½) is a fine-grained admixture of quartz and pinkish felspar, mica being almost wholly absent. The vein, and its ramifications as well, are sharply defined from the wall rock. A short distance up stream from this vein the gneiss shows an exceedingly fine lamination, and becomes much contorted (799). The lamination is due in part to a general stratified structure of the rock, independently of its ingredients, but in part, also, to an aggregation of the fine black mica along the surfaces of laminæ. The ingredients of the rock are fine-grained, colorless quartz, predominating; coarser, pinkish, translucent quartz; black, shining, small-flaked mica, very abundant; and small-faceted, white felspar. The exposure of contorted gneiss is quite abruptly limited up stream, by a large, pinkish granite mass, which stands 6 to 10 feet above the surrounding rock at No. VII of the map. The rock of this large vein (798) is similar to that of the vein last described, but is somewhat more quartzose. Next above the granite vein is a fine-grained, felspathic gneiss (797), striking N. 35° E., dipping 80° N. W., and intersected by numerous cross-joints. Next above this are again high exposures of fine-grained, structureless, pinkish granite (796), resembling the masses and veins further down, but much larger in size.

At VIII of the map, fine-grained, greenish-brown gneiss (795) is exposed, striking N. 50° E., and dipping 45° N. W., and composed of silvery mica, pinkish felspar, and translucent quartz. A short distance above, this grades into a coarser kind (794), which is very plainly laminated, in places even schistose, and carries small greenish epidote (?) veins.

In the **Rapids at Stevens Point**, on Secs. 32 and 31, T. 24, R. 8 E., are some considerable exposures, which are, however, not so large as those at Conant's Rapids, a mile below. The localities of the main outcrops in the Stevens' Point Rapids are shown on the map, Fig. 12. At the point IX of the map, on the south line of Sec. 32, is a low exposure, at the water's edge, of a moderately course, laminated, brownish-stained micaceous gneiss (785), striking N. 45° E., and dipping 70° to 80° N. W. This rock is composed of abundant brilliant black mica, which weathers brownish; coarse faceted, plainly striated, white felspar; and limpid quartz. The weathered surface is dark-brownish, and rough, and has underneath a whitish kaolinized crust. Throughout small white kaolin patches occur. This rock closely resembles that on the west side of Conant's rapids (778). In the bank above, sandstone is exposed.

Under the central abutment of the railroad bridge, and about 100 feet northwest from the exposure last described, occurs another of the same rock, but somewhat coarser and less predominatingly micaceous. The bedding is the same as before.

About 300 feet further across the strike, and now on the west side of the river, point X of map, is a large exposure of the same mottled micaceous gneiss, extending several hundred feet along the river bank. At the lower end of the exposure, the felspar surfaces are very large and very finely striated (787), and the rock is more weathered than usual, the ordinarily brilliant black mica being largely changed to a brownish tint, which affects the appearance of the whole rock. Reddish veins, composed almost entirely of coarse, cleavable felspar, occur, and also others in which the felspar is coarsely mingled with white quartz. The character of the rock remains the same throughout the length of the exposure, as far north as the wagon bridge, the bedding throughout being very distinct, and showing a strike of N. 75° E., and a dip of 45° N. W. A short distance west from the river bank, at this place, horizontal sandstone is exposed in the railroad cutting and in a large quarry.

The crystalline rock series at Conant's rapids and Stevens Point may be briefly described as consisting of beds of highly micaceous gneiss, dipping northwest from 45° to 80°, trending N. 25° to N. 65° E., with which are interstratified some layers of a finer grained, less micaceous gneiss, and penetrating which are reddish granite veins and masses. Compared with the gneisses of Grand Rapids, those just described are found to be more highly micaceous and usually coarser grained. They differ from the Grand Rapids rocks also in having as a prominent constituent a triclinic (striated), whitish felspar, and in having no interstratified beds of dark-colored, fine-grained hornblendic rocks. The Grand Rapids rocks dip southeastward, those of Conant's rapids and Stevens Point, except at the southernmost point, northwestward, the strikes in both cases being northeast, but not always equally so. The anticlinal line cannot be far from the great bend and long southwestward stretch of the Wisconsin in southern Portage and Wood counties, and to this anticlinal line the peculiar change in the course of the river evidently bears a close relation. See, in this connection, Atlas plate XV of Area F, and its accompanying north and south section.

On **Plover river**, in the N. E. qr. of Sec. 12, T. 24, R. 8 E., three quarters of a mile north of Jordan, is a low ledge of moderately coarse, pinkish. porphyritic granite (806). The felspar is in facets up to ⅛ inch in diameter, both white and pink, the former finely striated; the quartz is both hyaline and abundant; the mica is in medium-sized, brilliant, black flakes. Numerous white kaolin patches indicate a tendency to decompose.

On the line of the **Wisconsin Central Railroad**, between Stevens Point and Junction City, are several small rock cuttings. One of these, on Sec. 22, T. 24, R. 7 E., is in a pinkish, fine-grained granite (800), showing pink and white felspar, quartz, and fine black mica. Another, one mile below Junction City, on Sec. 1, T. 24, R. 6 E., is in a decomposing, medium-grained to fine-grained, whitish-weathering gneiss (801, 802, 803, 804), composed chiefly of quartz and pinkish felspar in blotches, with a greenish, greasy mineral (chlorite or altered mica) on surfaces and in fine strings throughout. Pyrite is present, and white kaolinized blotches are characteristic. The more decomposed portions show a schistose tendency, and in all there is a marked parallel grain. The bedding structure shows a strike of N. 22° E, and a dip of 80° E. These are also the directions of the grain of the rock. On Sec. 2, half a mile from Junction City, is a small exposure of a decomposed brick-red, ferruginous, schistose gneiss (805), showing on the interior numerous shining mica flakes, but too far altered to show any other minerals.

On the line of the **Wisconsin Valley Railroad, between Junction City and Knowlton**, there are numerous small rock cuttings, chiefly in more or less decomposed gneissic and schistose rocks. The drift along the line is very light, and every little cutting exposes the rock. Half a mile north of Junction City, in the north part of Sec. 2, T. 24, R. 6 E., small exposures are seen for a distance of 300 feet, of much decomposed, fine-grained, dark-colored mica-schist or micaceous gneiss. A similar rock shows a quarter of a mile further north, on Sec. 35, T. 25, R. 6 E. Here the rock is a fine-grained, very closely laminated, blackish schist (963). The predominating black mineral is partly hornblende, partly mica. In the north part of Sec. 35, 1½ miles from Junction City, a cutting shows for 50 feet at its south end a blackish schist, similar to the last described, in all stages of decomposition, even to a light colored clay. The lamination lines are marked, and bear N. 50° E. At the north end of the cut a decomposing, fine grained, arenaceous, light-colored schist (962) is exposed, composed apparently chiefly of fine granular quartz. On some of the laminæ light-colored, altered mica is perceptible. One-fourth mile further north is a small, indefinite exposure of the same arenaceous schist. In the east part of Sec. 26, 2½ miles from Junction City, the railroad cutting makes an exposure 200 feet long and 8 feet high. The rock (959, 960, 961) is a fine-grained, dark-greenish to black, calcareous mica-schist, or gneiss, showing very fine and uncontorted lamination, and a peculiar knotty appearance in places from the occurrence of lumps of quartz and calcite between the laminæ, which are then bent around these nodules. The preponderating black mineral is in fine shining scales, and appears to be chiefly mica. Veins, ¼ to ½ inch in width, of a greenish, translucent mineral (epidote?) occur. The lamination of the rock causes it to break out in columnar forms, some of the columns reaching a size of 8 × 4 × 4 feet. The apparent dip is N. N. W. 85°. A somewhat similar calcareous gneiss occurs on Black river in Clark county. Three miles from Junction City, on Sec. 24, T. 25, R. 6 E., is a small exposure of a fine-grained, white-weathering, crumbling, arenaceous, talco-mica-schist (858), showing very fine lamination, and closely allied to the light-colored rock seen in the cutting 1½ miles north of Junction City. With a lens, fine-grained quartz is seen to be the predominating constituent. Half a mile further north is an indefinite exposure of a fine-grained, dark-colored gneiss, or mica-schist, similar to that seen in the large cutting on Sec. 26. About 4 miles from Junction City, on Sec. 13, T. 25, R. 6 E., light-colored, fine-grained, arenaceous mica-schist (999) is again exposed, for 300 feet, on the side of a cutting. The lamination planes strike N. 30° E., and dip 80° S. E. A few small masses of milky quartz, and reddish felspathic veins are included, and, in places, stand out in relief from the surrounding decomposed rock. On the north part of Sec. 13, 4½ miles south of Knowlton bridge, an indistinct exposure of pinkish, weathered granite occurs. Another indefinite exposure of the same rock occurs a quarter of a mile further north, on Sec. 12. In the north part of Sec. 12, 3.7 miles south from Knowlton bridge, the following section occurs in a low cutting, the rock exposures not rising more than one or two feet above the railroad track, and being considerably out of position. The section begins at the north end of the exposure:

	Ft.	In.
1. *Granite* (992): very fine-grained, red colored, felspathic; partly kaolinized on surface; penetrated by veins of white quartz	2	..
2. *Decomposed gneiss:* clayey; containing occasionally seams of partly kaolinized reddish granite (993)	50	..
3. *Quartz:* white	1	..
4. *Granite* (994): partly decomposed; very fine-grained; granular, pink colored, quartzose; crumbles in fingers to a sand	3	..
5. *Decomposed gneiss:* clayey, but showing still a distinct contorted lamination	6	.

	Ft	In.
6. *Granite* (995): similar to No. 4; holding veins and masses of quartz	10	..
7. *Decomposed gneiss:* similar to No. 5	20	..
8. *Granite:* light-pinkish, felspathic	..	4
9. *Decomposed gneiss:* similar to No. 7	30	..
10. *Red felspathic seam:* altered; standing vertical	2	..
11. *Dark-green rock* (997): composed almost entirely of a fine, flaky mineral, which appears like an altered amphibole	5	..
12. *Granite:* reddish; resembling No. 6	..	6
13. *Decomposed gneiss:* contorted; holding seams of quartz and partly altered, fine-grained granite	75	..
Total	204	10

At the south end of the railroad bridge at Knowlton, in the north part of Sec. 29, T. 26, R. 7 E., is a cutting 100 feet long, and 5 to 10 feet deep, through rock. The northern portion of the cut exposes a fine-grained, blackish, hornblende schist (890), having a distinct crystalline texture, and resembling much some of the hornblendic beds of the section at Grand Rapids. The apparent strike of this rock is N. 55° W., and the dip 60° N. E. Its horizontal width at right angles to this strike direction is about 40 feet. The remainder of the cut is in medium-grained, highly crystalline, grayish, granitoid rock (889), which weathers white. Quartz, white felspar, and dark-colored, small-flaked mica, the latter showing a slight stringy arrangement, can be seen with a lens. Some of the dark-colored mineral may be amphibole. The apparent bedding of this rock coincides with that of the preceding; and its horizontal width is also about 40 feet.

On the wagon road **between Knowlton and Mosinee,** on the east side of the Wisconsin, several small and indefinite exposures occur of decomposing fine-grained rocks, resembling those observed on the line of the Wisconsin Valley Railroad. Two miles north of Knowlton, where the road ascends a high ridge, exposures occur of a fine-grained to aphanitic, dark colored, slaty rock (892.) This rock is pyritiferous, and distinctly attracted by the magnet in coarse powder; it weathers with a dirty-white, earthy surface. At 3.7 miles north of Knowlton, another exposure, of a similar rock, occurs in the road. This rock (968), according to Mr. Wright's microscopic examination, is composed of chlorite, altered felspar and magnetite. These exposures were all too poor to show any definite bedding structure.

At **Little Bull falls,** on the Wisconsin river, at Mosinee, Sec. 29, T. 27, R. 7 E., Marathon county, are quite large rock exposures. The river here is divided into two widely separated channels by a high rocky island about a quarter of a mile in width. On its northeast end this island is itself cut by several smaller channels, dry at low water, which show high walls of bare rock. Most of the water of the river passes through the easternmost channel, which in one place, for a distance of 130 feet, is a gorge only 35 feet wide. The main fall of the river was formerly in this gorge, but has lately been moved down stream by a dam erected below. The rocks of the various exposures at this place are all closely allied and may be designated by the general term of syenite. They are all characterized by the presence of much greenish-black amphibole, and white striated felspar, the quartz, though present, being always subordinate. Two general kinds were noted. The prevailing rock (896, 898, 900) is a moderately coarse-grained, highly crystalline, syenite, with a greenish-gray, mottled appearance, and without any sign of parallel arrangement of the various ingredients, which are uniformly intermingled. On a weathered surface this rock appears greenish to white, the latter color being due to a kaolinization of the felspar. On a fresh fracture the two main ingredients are readily perceptible to the naked eye. The hornblende is usually of a bright-lustred, greenish-black color; the felspar facets are commonly white.

translucent, and beautifully striated, as can readily be seen with an ordinary lens. More rarely pinkish felspar occurs. That variety of this rock which has a medium degree of coarseness presents a very handsome appearance on a dressed surface; and, since it shows no tendency to iron-stain or decompose, might make a valuable building stone. The second variety found here (897, 905, 903) is very much finer in grain, and of a dark.greenish-gray color, showing the crystalline texture only under the lens, and then not plainly. It is evidently merely a phase of the coarser rock. It occurs both in small imbedded patches (879) and in large, distinct outcrops (905, 903). According to the microscopic examination, these finer kinds, whilst having the same ingredients as the coarser, show a larger proportion of hornblende, and may be designated as "hornblende rock." Chlorite appears to occur in all, more especially in the finer kinds, as an accessory.

For the most part the bedding of the Little Bull rocks is indistinct. In two places, however, it is plainly to be seen. One of these is on the west wall of a dry side channel near the head of the main island. Here very marked planes dipping 27° S. W. and striking N. 5° W., are to be seen along a perpendicular exposure, 20 feet in height and 50 in length, of the prevailing coarse syenite. Across the bedding lines run a number of joints bearing N. 42° W., and dipping 87° S. W. The other place, distant from here 800 feet in a nearly due south direction, is on the same island, and on the west side of the east or main channel, just below the dam. Here are a number of distinct layers of the finer grained rock (903), averaging 14 inches in thickness, and dipping 20° E., with a north and south strike. We have thus indications of a low anticlinal, whose nearly north and south axis runs diagonally across the island, and nearly in the direction of the river above.

On the large exposure mentioned as showing a westward dip, the bedding planes are cut by a vertical north and south vein of fine-grained, dark-colored, brown-weathering, hornblendic rock (899), which is itself traversed and partly faulted by joints that affect it and the wall rock alike. Several large, white quartz veins show under the bridge across the first dry channel west of the main gorge. One of these bears N. 40° E., dips 17° N. W., is five feet wide, and composed of parallel bands a quarter of an inch to three inches in width. A still larger one occurs at the bottom of the gorge, where it stands out very prominently, the surrounding rock having been worn away by the running water. The wall rock, seen in only one place, is fine-grained, schistose, dark-greenish, and apparently chloritic (902). It would seem to be an advanced stage of alteration of the normal amphibolic rock of the vicinity. A less advanced alteration is shown by the rock (905) of the large outcrops on the northwest corner of the island.

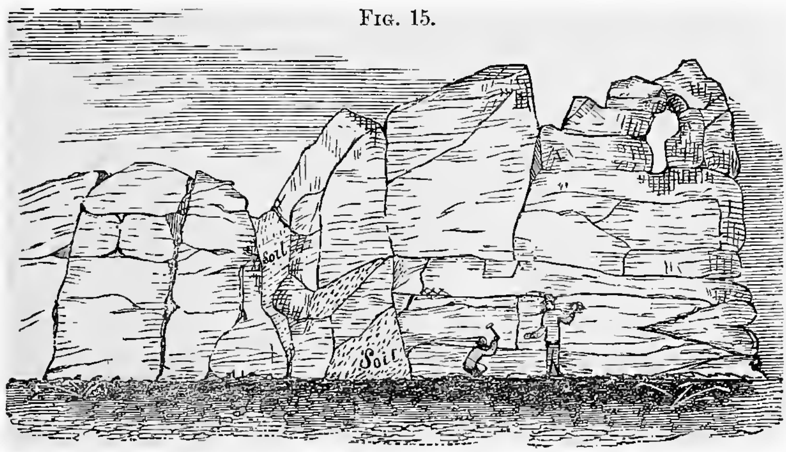
The **Mosinee hills** are two spurs of an isolated elevation on the west bank of the Wisconsin, in Secs. 27, 26, 25 and 22, T. 28, R. 7 E., Marathon county. They are both of quartzite, and are higher than the rest of the elevated ground around them.

The Lower Mosinee hill is near the center of Sec. 27, and about a mile from the river bank. It is conical in shape, with slopes of about 30° near the summit, and rises to an altitude of 880 feet above Lake Michigan, or about 280 feet above the river near by. Its slopes and summit are covered with loose masses of quartzite, one-foot cube to four-feet cube in size. This quartzite (923) or quartz, is greyish-white, occasionally stained yellow, vitreous, and translucent in thin pieces, and peculiarly brittle. Sometimes a slight tendency to a granular structure is to be noticed.

The Upper Mosinee hill is reached from the Lower hill by crossing a saddle between the two. On this saddle, on the N. E. qr. of Sec. 27, numerous more or less rounded fragments of a fine-grained, reddish felspathic rock occur. The Upper hill is on the S. E. qr. of Sec. 23, near the corner of the section. It reaches an elevation of 1,030 feet, or about 430 feet above the adjacent river. Its slopes, like those of the Lower hill, are covered with loose angular fragments of white, vitreous quartz of all sizes, up to five feet in diameter. On the summit are to be seen some large irregular exposures of the same rock (924), showing no sign of bedding structure. None of the quartzite of either hill has any trace of lamination.

About three-quarters of a mile immediately east of the Upper hill, at the water's edge on the west bank of the Wisconsin, is a low outcrop, several hundred feet in length, of a reddish syenite. At the upper end of the exposure the rock (919) is very coarse, composed of a deep-red, cleavable felspar, mottled with patches of brilliant black hornblende, up to a quarter of an inch in diameter, and showing a small quantity of translucent, brownish-stained quartz. The deep red color is evidently partly due to weathering. Two sets of widely separated joints occur, one set, the most marked, bearing N. 30° E., the other N. 10° W. A hundred feet below, this rock changes to a very light-colored, fine-grained variety (920), poor in hornblende; and immediately below again to a very coarse kind (921) bluish-grey in color, owing to the preponderance of large surfaces of bluish, cleavable, non-striated felspar, and mottled with black patches of hornblende. This is evidently the normal variety from which the reddish crumbling kinds result by weathering. The rock of this exposure is the same that is

Fig. 15.



Quartzite Exposure on Rib Hill, Marathon County.

largely displayed at Big Bull falls, five miles to the north, and is entirely unlike any rock noticed farther down the stream.

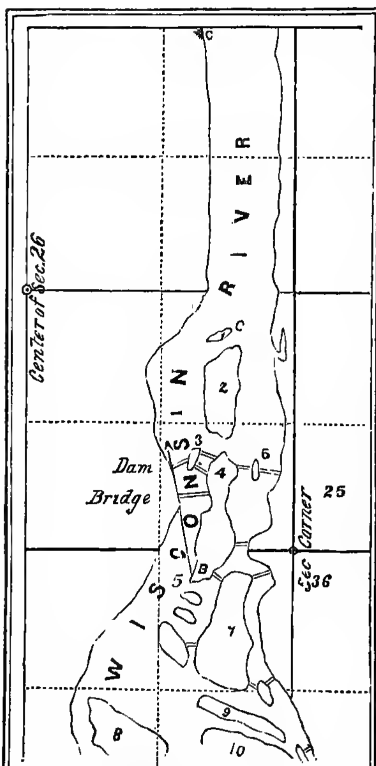
Rib hill, on Secs. 8 and 9, T. 28, R. 7 E., shows large exposures of the same sort of quartzite as that occurring on the Mosinee hills, three miles southeast. This hill is a bold isolated crest, about a mile in length, trending north of west, across the southern half of Sec. 8, and gradually increasing in height from an altitude of 1,143 feet at its eastern extremity, on the western side of Sec. 9, to one of 1,263 feet at its western extremity near the west line of Sec. 8. This western end is thus, so far as definitely known, the highest land in the state. It rises 660 feet above the Wisconsin river, three miles east, and 620 above the railroad track at Wausau. The summit of the hill is rather flat, and is traversed longitudinally by a line of precipitous exposures of quartzite, from five to forty feet in height. The slopes on all sides are very steep and are covered with a heavy talus of loose, angular masses of quartzite, of all sizes. The northern side is the most abrupt. For several hundred feet it slopes away from the summit at angles of from 25° to 30°.

The exposures and talus show everywhere but the one kind of rock (927), a hard, brittle, non-laminated, glassy translucent quartz, usually of a dirty white color, but often almost colorless. No bedding structure was observed, the rock being apparently even without any one persistent set of cross-joints, though all of the exposures show fractures, some quite irregular, and others approaching to plane surfaces. At one point several parallel N. E. joints occur. Fig. 15 is a sketch of one of the large exposures near the western extremity of the hill.

On the **Eau Claire river**, at the crossing of the Stevens Point and Wausau road, Sec. 7. T. 28, R. 8 E., there is a fall over coarse, pinkish syenite (926) resembling that on the Wisconsin, near the Mosinee hills, and also the prevailing syenite at Big Bull falls, a short distance northward.

On the upper Eau Claire, in Sec. 4, T. 29, R. 10 E., are exposures of a very coarse, rough-textured, felspathic granite, consisting of pink, cleavable felspar; very large-flaked, black mica; and gray quartz.

FIG. 16.



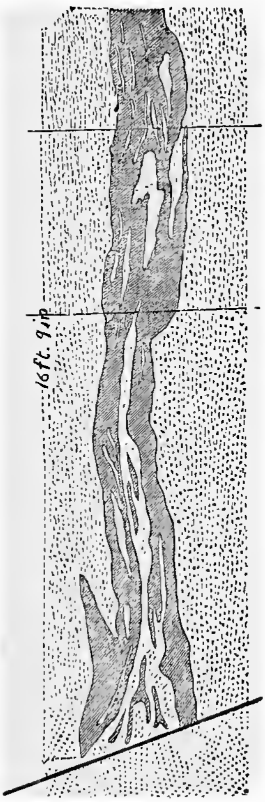
BIG BULL FALLS

At **Wausau**, on sections 25, 26, 35 and 36, T. 29, R. 7 E., Marathon county, the Wisconsin makes bold rapids known as **Big Bull falls.** Here the river is divided into a series of channels by a number of small rocky islands, and the exposures are large, the rock on all being of one general kind, *i. e.*, syenite or syenitic granite. This syenite varies in degree of coarseness, but is commonly very coarse, the separate minerals being very plainly perceptible to the naked eye. There is no resemblance between it and any other rock observed on the Wisconsin river, except that of the Eau Claire river, and a small outcrop previously alluded to as near the upper Mosinee hill, both of these being evidently merely continuations of the Wausau rock. From the rock of Little Bull falls it differs, (1) in being commonly much coarser in grain, (2) in having usually a more jagged fracture, (3) in showing greater tendency to iron-stain, and weather, (4) in having the hornblende black instead of greenish-black, (5) in having the felspar orthoclase, and (6) in containing usually some blackish mica.

The bedding of the rocks at Big Bull is for the most part sufficiently distinct, the general strike being N. 80° E. and the dip from 30° to 40° N. W., most commonly about 38°. In a few places a marked gneissoid structure, coinciding with this bedding, and owing to a parallel arrangement of the hornblende, was observed. For the most part, however, the several constituent minerals are quite uniformly intermingled, without arrangement of any kind. In the exposures in the bed of the stream, and on the walls of the various channels, large bedding-plane surfaces frequently show, so that the bedding can usually be made out with very considerable accuracy. The separate layers are often not more than 2, 3, or 4 inches in thickness.

The sketch map, Fig. 16, serves to show the localities of the various exposures examined at this place. Islands No. 1, 2, 5, 8, 9, 10, 11 and 12 are without bare rock. The main or west channel of the river, between island No. 4 and the main-land, shows large exposures both in the bed and on the walls of the gorge, which are 15 to 20 feet in height. A section in this channel on the line A B, bearing N. 10° W., and beginning a short distance (100 feet) above the bridge, showed the following succession, the measurements being horizontal distances:

FIG. 17.



BLACK VEIN IN SYENITE, WAUSAU.

Feet.

1. *Moderately coarse syenite* (912, 941): brownish-pink to gray, mottled with black, weathering with a dark-brown, uniform-tinted surface. Of the three ingredients, all of which are very plainly perceived by the naked eye, the felspar is much the coarsest, its facets reaching ⅛ inch in diameter; in color the felspar is brownish-pink to gray, and it is without striations. The several ingredients are quite uniformly intermingled. In most of this measurement the bedding is quite distinct, except in one or two places where it is obscured by cross-joints. On island No. 3 prominent joints trend N. 78° E. and dip S. E. 75°. On the west side of the stream, just below the wagon bridge, the bedding planes show finely in a rock somewhat more pink than usual, the dip being 38° N. W. and the strike N. 80° E. The same rock as that of this measurement shows also at the north end of island No. 4, and on the small rocky islet, No. 6 490
2. *Finer-grained syenite* (907): similar to the rock of No. 1, but of grayer color from the gray color of the felspar; less weathered and of a finer grain. In the middle of the stream, the surface of the layers of this rock dip very plainly 30° N. W. Vertical joints occur here nearly along the strike... 116
3. *Still finer-grained syenite* (908): dark gray to black in color; much more hornblendic and less quartzose than the preceding kinds. The junction of this rock with No. 2 is quite sharp, and shows well on the east side of the gorge, where the bedding is also quite plainly to be seen, with a strike of N. 75° E., and a dip of 38° N. W. Prominent cross-joints occur at this place, trending with the strike direction, and standing vertically 202
4. *No exposures* 62
5. *Coarse syenite* (911): allied to the rock of No. 1 (912, 907), but containing much more pink orthoclase; penetrated by many patches and veins of a fine-grained, but distinctly crystalline, dark-gray to black, hornblendic rock. A large one of these veins is represented by Fig. 17.................... 165
6. *No exposure*.. 70
7. *Very coarse syenite* (910): bluish-gray, showing large unstriated grayish felspar surfaces, and coarse brilliant black hornblende, in pieces up to ⅛ inch

	Feet.
by ¼ inch; containing but little quartz. The weathered crust of this rock is $\frac{1}{16}$ inch thick, dark-brown outside, and pure white beneath, the latter due evidently to kaolinization	125
8. *Coarse iron-stained syenite* (909): close to the preceding, but not quite so coarse, and having the felspar brownish from iron-staining, and more abundant	80
Total horizontal length of section	1,230
Thickness of rock layers about	600

On Island No. 7 of Fig. 19, are exposures which lie south of the end of this section. At the north end of the island, the rock (941) resembles No. 1 of the section, and contains a vein of reddish felspathic granite 30 feet long, 1 foot wide, and having a central band of white quartz, 1 inch to 2 inches wide. At the south end of the island a long, low exposure shows a fine-grained, light-pinkish, distinctly gneissoid syenite, or syenitic granite (943), which is very much more quartzose than any of the other Wausau rocks. The quartz is granular, glassy and wine-colored. The parallel grain is due to an arrangement of the black hornblende, which stands out quite prominently against the surrounding light-colored quartz.

At the point C of Fig. 19, on the west side of the river, and near the north line of Sec. 26, a large exposure shows rocks quite different from those at the falls below. The main rock (915) at this place is fine-grained, dark-gray and hornblendic, having a distinctly parallel structure, and weathering to a light-pinkish color. A number of heavy beds of this rock are to be seen dipping 20° to 26° N. W., and striking N. 60° E., thus corresponding in bedding with the rocks at the falls. Intersecting the dark-colored rock are numerous small pinkish veins. In one place, on the river edge, a large, smooth joint-surface shows a nearly horizontal vein 16 inches wide, the vein matter (916) being composed of pink cleavable felspar and limpid white quartz. Cutting vertically through this vein and the inclosing rock is a mass of a very fine-grained, decomposing, schistose chloritic rock (917), 4 feet wide, having its lamination vertical. The lines of demarkation between the three kinds of rock on this exposure are all very sharply defined.

On the **Jenny road**, on the east side of the Wisconsin, N. hf. Sec. 24, T. 29, R. 7 E., 1¾ miles from Wausau, are several low outcrops of a white-weathering, in places iron-stained, slaty quartzite (931). On a fresh fracture this rock presents a non-crystalline, whitish aspect, and is quite hard. With a lens, a few minute felspar facets are seen. Pyrite is present in minute cubes. Some specimens show a slight tendency to effervesce in hot acid. The schistose structure is evident, the planes striking N. 85° E., and dipping 50° N. W.

One and a half miles further north, the same road ascends Marshall hill. All along this hillside in sections 12 and 1 are large, angular fragments of a fine-grained, grayish, aphanitic, silicious-schist (930). This rock is quite soft, very distinctly laminated, splitting very readily across the lamination planes. Some specimens effervesce very slightly on heating.

Eastward from Wausau, on the north line of T. 29, R. 8 E., the country rises rapidly, and is traversed by numerous low but abrupt ridges, such as are characteristic of large portions of the Archæan area. No rock outcrops were noted on any of these, but angular fragments of a white-weathering, porphyritic rock (929) were seen in great abundance. This rock has an aphanitic, light grey, not very hard matrix, through which are scattered a few felspar facets, and numerous amygdules of translucent, brownish quartz, the latter reaching ⅛ inch in diameter. It was noticed most abundantly on Sec. 33, T. 29, R. 7 E.

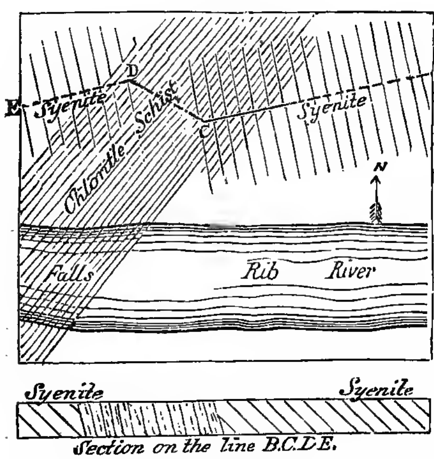
Westward from Wausau, in T. 29, R. 7 E., a number of outcrops occur. Near its south line, this town is traversed by Rib river. In Secs. 21, 22, 27 and 28, there is high ground trending north and south, which rises 200 to 300 feet above the Wisconsin at Wausau. In the S. E. qr. of Sec. 21, on the south slope of part of this ridge, a peculiar, fine-grained felspathic rock (937, 945) is exposed, and is quarried to some extent on Mr. Kolter's land. This rock has a brownish-pink color, the least weathered portions showing a grayish tinge, is rather fine-grained, and has a marked granular texture, looking almost like a mechanical rock. The most abundant ingredient is a pinkish felspar in cleavable fragments up to $\frac{1}{20}$th inch across. With this is much granular brownish quartz, and a little blackish mica in fine flakes, making the rock a granite. No arrangement of the minerals in parallel lines is perceptible. In the quarry the rock is seen to be nearly horizontal, dipping not more than 10° in a due south direction. A total thickness of about three feet was seen. Large thin slabs, 2 inches to 4 inches thick, splitting off parallel to the bedding, can be obtained.

Near **Single's Mill,** in the north part of S. E. qr. of Sec. 29, in the same township, and on the edge of a part of the same high ground, are exposures of a whitish, slaty, granular quartzite (936), in places iron-stained. Under the magnifying glass this rock is seen to be made up of rounded grains of glassy quartz. Some few places were noted where the variety with granular texture grades into a non-granular glassy quartz. Scales of silvery mica occur on the surfaces of laminæ. The bedding structure is distinct, and shows a strike of N. 75° E. and dip of 56° S. E.

About half a mile from this place, and on the south side of the valley of Little Rib river, S. E. qr. Sec. 29, the northeast face of a ridge shows quartzite in large exposures. The rock here (935) is glassy, translucent, and occasionally iron-stained, resembling that of Rib Hill. The bedding is obscure. On the slope of the hill below, the roots of the trees of a heavy wind-fall have upturned numerous fragments of a brownish-pink, granular-textured felspathic rock, similar to that at Kolter's quarry in Sec. 21. Half a mile northeast on the north face of the same elevation, N. E. qr. S. E. qr. Sec. 30, a high ledge shows the same felspathic rock, striking N. 80° E., and dipping 50° N. W.

At the **falls of Rib river,** S. E. qr. Sec. 28, T. 29, R. 5 E., are large exposures of greenish chloritic schist and syenite. On the south side of the river, at a point near the lower left hand corner of Fig. 18, is a rocky point about 15 feet high, showing heavily but distinctly bedded, greenish syenite, dipping 20° E., and striking N. 8° W. The uppermost layer (950), 3 feet thick, is moderately coarse-grained, mottled green and grey, weathering white. To the lens it shows much grayish quartz, green amphibole, and white altered felspar, the last least abundant, though coarsest of the three. In some specimens greenish chlorite accompanies the hornblende. The next layer below (948), 4 feet thick, is a very much finer-grained, almost aphanitic, greenish-grey rock, containing apparently a good deal of chlorite. The weathered surface is white, with numerous green, epidote-colored blotches. Microscopic examination shows that the ingredients of this fine-grained rock are the same as those of the coarser one above, but that the amphibole and felspar are both more altered. This rock breaks

FIG. 18.



ROCK OCCURRENCES AT THE FALLS OF RIB RIVER.
Scale, fifty feet to the inch.

out very readily into rectangular blocks, the planes of easiest cleavage lying at right angles to the bedding. The lowest layer, 3 feet thick, is again of a coarse (949) variety like that of the uppermost bed.

On the north side of the river, beginning from the point B, we find a continuous low exposure, extending several rods up the stream, and showing the same bedding structure as seen on the south side of the river. Passing over these exposures on the line B C, at right angles to the strike, we find first, for 40 feet, mottled, grayish syenite (951), resembling that on the south side of the river, but somewhat finer in grain. The weathered surface is of a uniform green hue, and a cross-fracture shows a greenish chloritic crust extending inward as much as ¼ inch, with a sharply defined inner edge. Beyond on the line B. C. is first seen a similar rock, which is however, more highly quartzose and felspathic, the amphibole being almost excluded (952). Beyond again green chlorite begins to appear, gradually increasing in quantity, the former dip and strike joints at the same time becoming confused by the introduction of schistose planes, until, at 80 feet from the beginning, the rock has become a well-marked green chloritic schist, the schistose planes bearing N. 45° E., and dipping 60° to 80° S. E. The gradation of the one rock into the other is unmistakable. Beyond again the chlorite-schist is largely exposed, and extends entirely across the river, forming the barrier rock of the falls. Its most common variety (953) is dark green in color, with large, interlocking, greasy-surfaced laminæ. The schistose surfaces are readily scratched with a knife, but much silicious matter is present. Pyrite is also to be seen throughout. In places the impurity is less than usual, and the rock nearly all chloritic (954). After crossing about 25 feet of this schist, its lamination lines are seen to become again obscure, signs of the former low dip reappearing, and the rock becoming again like that below (955).

We seem to have in these rocks an instance of the change of an amphibolic to a chloritic rock, with a simultaneous production of schistose planes crossing the ordinary bedding lines.

At **Marathon City**, Sec. 6, T. 28, R. 6 E., a low exposure occurs on the edge of the water in Rib river, which shows syenite (957) closely allied to the coarser syenite at Rib river falls. It is medium-grained, dark-greenish and grayish, showing surfaces of brilliant black lamellar hornblende up to ¼ inch in diameter, embedded in a matrix of very fine-granular quartz, and coarser, white, glassy felspar. The hornblende facets frequently show a tendency to alteration, and are then ill-defined on the edges, from the surrounding matrix.

The rocks of Rib river falls and Marathon City bear a resemblance to those found crossing the Wisconsin at Mosinee, but are rather more chloritic, or altered. The strike directions at the two places, N. 5° to 10° W. at Mosinee, and N. 8° W. at Rib river falls, also correspond. It seems probable that the two are portions of a continuous belt trending west of north. If so, the belt must have a considerable width, for the strike direction at Mosinee, if carried out northward, would not reach so far west as the falls of Rib river.

Yellow River Valley.

The upper part of Yellow river, in Wood county, north of the Green Bay and Minnesota Railroad, flows over gneissic and granitic rocks, which are exposed nearly continuously in the beds and on the sides of the stream, for many miles. The same is true of the branches of the river in this part of its course.

On the divide between Yellow and Black rivers, sandstone extends far to the northward, covering, and for the most part concealing, the crystalline rocks, which, however, occasionally rise through the sandstone. The boundary between the formations it is almost impossible to trace accurately, since the irregular surface of the crystalline rocks beneath may bring them up through to the surface at any point. The same is true to some extent of the region between Yellow river and the Wisconsin, but here the sandstone does not extend nearly so far north.

In **Hemlock Creek,** at the crossing of the wagon road from Grand Rapids to Dexterville, N. E. qr. of the S. E. qr. of Sec. 5, T. 22, R. 4 E., are ledges of rather fine-grained, flesh-colored, gneissoid granite (967). Translucent, wine-colored quartz, and pinkish orthoclase in small, brilliant facets, make up most of the rock; the mica is sparse, in fine, green-black flakes, which have a distinct linear arrangement. This rock is a handsome one, and would probably dress well, though showing some tendency to weather and iron-stain. The bedding directions appear to show a strike of N. 60° E., and a dip of 70° S. E.

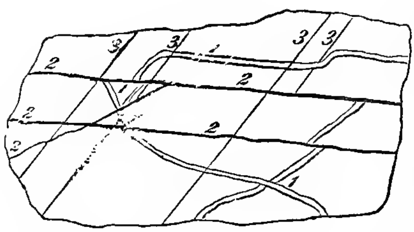
On **Yellow river** itself, the southernmost Archæan exposure is to be seen about **two miles north of Dexterville,** in the N. hf. of Sec. 14, T. 22, R. 3 E. The rock here is medium-grained, pinkish, quartzose, gneissoid granite (973), composed chiefly of limpid quartz and orthoclase felspar, the former the most abundant. Mica is present in fine black scales arranged in parallel lines. The strike appears to N. 55° W., and the dip 60° S. W. Near the top of the river bank, which rises directly from the granite, thin-bedded, friable, horizontal sandstone is exposed.

On Sec. 3, T. 22, R. 3 E., **three miles north of Dexterville,** there are large flat ledges in the bed of the river, of gneiss, bounded on the north by quartz-porphyry. The gneiss (969 and 971) is very fine-grained, laminated, dark gray to black in color, and consists of a black mineral (mica, hornblende, or both), in small brilliant flakes; and whitish quartz and felspar. Its weathered surface is earthy and of a dirty white color, but shows the fine lamination even more distinctly than the interior. The quartz-porphyry (970) consists of a light greenish-grey, aphanitic matrix, having the peculiar flaky appearance that is characteristic of the quartz-porphyries of the various isolated Archæan patches of Wisconsin, in which are imbedded somewhat sparsely scattered facets of pinkish orthoclase felspar up to one sixteenth of an inch in diameter. It is a very tough, compact, rock; and is worn by the running water into smoothed and polished surfaces. This porphyry appears to penetrate the adjacent laminated rock in a very irregular manner. In one place a mass of the gneissoid rock, some 50 feet in diameter, is nearly surrounded by the porphyry, the lines of junction between the two being very sharp, and rendered especially noticeable by the different appearances of their weathered surfaces. The lines of junction are not curved, but straight, bearing, respectively, N. 70° W., N. 30° E., and N. 70° W.; the first and last on opposite sides of the enclosed mass. The strike of the gneiss is N. 25° W., its dip 60° N. E. The porphyry is 20 to 30 paces wide, and appears to be bounded on the north by the same gneiss as before, with the same bedding. Beyond, porphyry again comes in.

At **Pitts' Mill,** five miles north of Dexterville, on Sec. 34, T. 23, R. 3 E., are very large exposures on Yellow river, which passes here through a narrow rocky gorge, of a very beautifully and coarsely banded gneiss (993), the bands being alternately dark-gray to black, and bright pink, and having a northwest direction. The dark-colored bands predominate, and run from ⅛ inch to one or two feet in breadth, but when so broad, are rarely free from fine lines resembling the material of the pink bands, which run in width from these fine lines up to 6 or 10 inches. The dark-colored portions are fine-grained, with an intimate parallel structure, and consist predominatingly of fine greenish-black mica, with which are seen fine white and red felspar facets, and some fine quartz. In places, greenish black, cleavable hornblende appears to partly replace the mica. The red bands consist chiefly of coarse-grained orthoclase felspar, with some limpid granular quartz and occasional blotches of mica, and show numerous whitish kaolinized patches, the whole rock having a tendency to decompose. Several folds in the strata occur, and are rendered especially striking by the very marked red and black banding. A complete arch is to be seen on the east bank of the river in front of Mr. Pitts' house. The plane of the bank, which at this point is about 15 feet in height, cuts directly across the strike, and slopes towards the northwest at an angle of 45°. Its base joins another surface sloping about 10° in the same direction. Along both surfaces the individual layers can be traced until they meet near the top of the bank. The central part of the fold as seen on both surfaces is a confused aud largely kaolinized felspathic mass (994).

On the N. E. qr. Sec. 21, T. 23, R. 3 E., **Rocky Run** enters Yellow river, which here traverses for many rods a rocky gorge, below which exposures continue along the river for a long distance. About half a mile below the mouth of Rocky Run, gneiss is exposed, striking N. W. and dipping E., and traversed by a vein 3 feet wide of a fine-grained, black, hornblendic rock. The vein cuts diagonally the lamination lines of the gneiss. Beginning about twenty rods below the mouth of Rocky Run, and extending up to it, are ledges of a fine-grained, greenish-grey, micaceous granite (974), which consists of very fine greenish-black mica, predominating, translucent quartz and pink orthoclase. In places occurs a more highly felspathic, reddish kind (975), which appears sometimes to enclose portions of the darker colored variety. No definite bedding structure was observed. Traversing this granite are numerous thin veins ⅛ to ¾ inch in width, of white quartz, pink, cleavable orthoclase, and greenish epidote. The felspar veins are in places so numerous as to make up a large portion of the rock. The epidote veins fault the others, being apparently the most recent. Fig. 19 represents a face 3 feet by 1½ feet. Nearly all of this rock shows a decided tendency to weather, being in places altered to an impure kaolin. Kaolin is reported to occur in quantity at points in the vicinity. From the crumbling condition of the rocks, this would seem very probable.

Fig. 19.

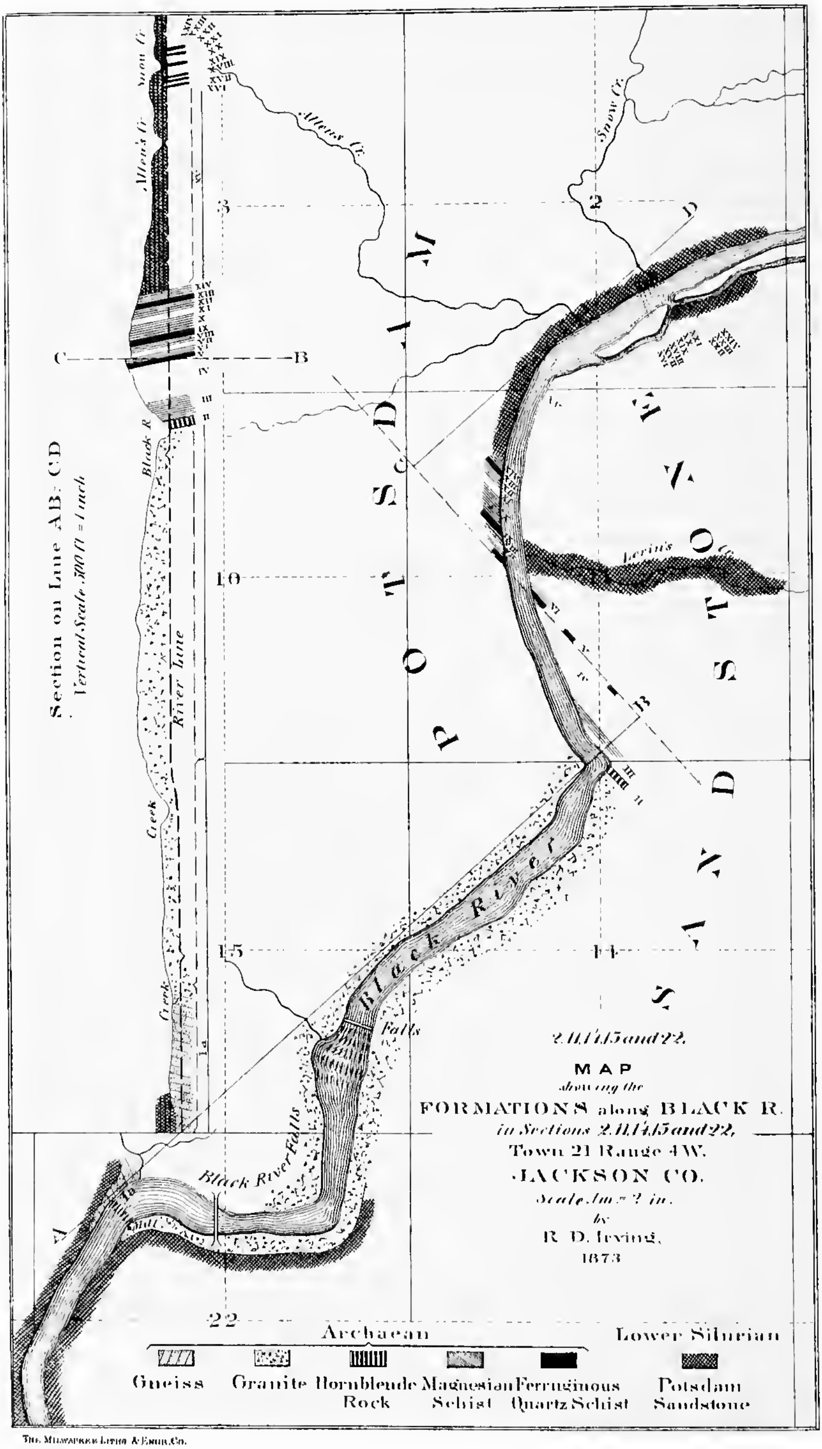


Faulted Veins in Granite, Yellow River.

Five miles north of Pitt's Mill, in the northern part of Sec. 3, T. 23, R. 3 E., the bed of Yellow river is made for 15 rods of a coarse-grained, flesh-colored granite, consisting of a very uniform admixture of flesh-colored orthoclase, glassy quartz, and black mica. No distinct bedding is to be seen.

At **Big Bull Falls**, nine miles north of Pitt's Mill, on Sec. 15 and 16, T. 24, R. 3 E., large exposures of medium-grained, highly felspathic, red granite extend along the bed and in the banks of Yellow river for a quarter of a mile. This granite has a base of cleavable reddish orthoclase, throughout which is quite uniformly distributed hyaline, occasionally smoky, quartz, in irregularly shaped patches $\frac{1}{32}$d to ¼th inch in diameter. Mica is present, but is very fine and sparse. For the whole length of the exposure, this rock is nearly uniform, and without any tendency to kaolinize. Its peculiar texture, composition and color combine to make it a very valuable and unusually handsome building granite. Polished specimens of the rock attracted great attention at the Philadelphia Exposition, where it was regarded by experts as among the finest of the many polished granites exhibited.

On Sec. 7, T. 24, R. 3 E., another exposure of a similar red granite was noted. Above this point, Yellow river is reported without exposures.



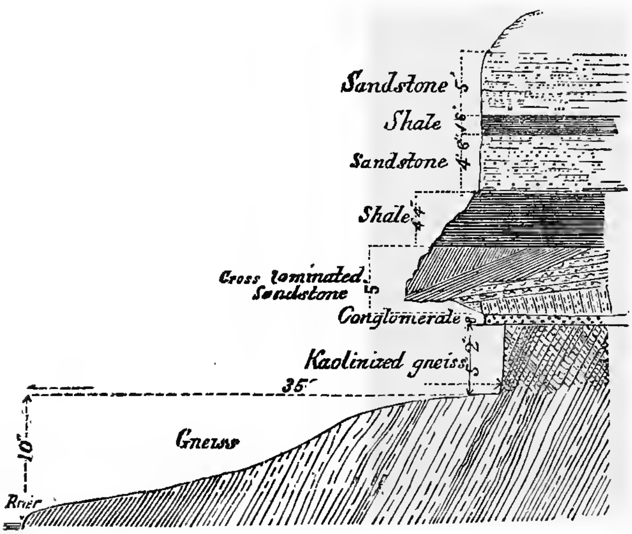
The Milwaukee Litho & Engr. Co.

Black River Valley.

The first exposures of crystalline rocks met with in ascending Black river are found a short distance below the town of Black River Falls, T. 21, R. 4 W., in Jackson county. From here they occur in the bed and on the sides of the stream, with only occasional interruptions, as far north as town 28, in Clark county. For the greater part of this distance, they are concealed, away from the river, by overlying horizontal sandstone, through which, however, they occasionally rise in knobby projections. In some of the branch streams, also, the sandstone is cut through and the crystalline rocks exposed. Along the river the rock ledges, in few places only, rise to any considerable height above the water.

In the vicinity of **Black River Falls** the exposures are large and interesting. The map of Plate XVII shows the relative positions of the various outcropping beds, their bedding and dip directions being shown by the accompanying section. From these it will be seen that at this place a central, nearly structureless, granitic mass is bounded on the southwest by layers of gneiss, dipping southwestward, into which it appears to grade; and on the northeast, by a succession of schistose beds, dipping northeastward, but not having exactly the same strike directions as the gneiss on the other side. In the following detailed descriptions, the various rock masses are numbered as on the map and section, beginning with the gneiss on the southwest:

Fig. 20.



Unconformability, Black River Falls.

I. *Gniess* (1,015): rather fine-grained, very plainly laminated, pink and gray banded; dipping S. W. 60°, striking N. 32° W. The constituent minerals are: pinkish orthoclase, predominating; pinkish and colorless translucent quartz; mica in very fine black scales, but quite abundant, and much more plenty in certain layers than in others; and also a whitish, partly altered, felspar, in fine facets. In some places, especially micaceous portions have a much darker color than usual; in others large nests of coarse, cleavable pink orthoclase occur. The laminæ are for the most part not over 1-32d inch in width, remarkably regular and parallel, and without contortion. Two sets of veins traverse the rock, both of reddish felspar, those of one set being but mere strings and faulting the others, which are one-fourth to one-half inch in width. This gneiss is exposed for several hundred feet along the river opposite Ledyard's old mill; and, as shown on the map and section, is, at the lower end of the exposure, overlaid by 25 to 30 feet or more of horizontal sandstone, which fills in the depression in the very irregular upper surface of the gneiss. The exact junction of the two formations is distinctly to be seen for a long distance. In some places the gneiss shows no alteration at its contact with the sandstone; in others again, as it is traced upward from the water's edge to the line of contact, a rapidly increasing decomposition is observed, until immediately below the sandstone the change to a soft bluish-white clay or kaolin (1,018) is complete. The kaolin retains still very plainly the fine lamination of the unaltered gneiss, it being even possible in some cases to trace individual laminæ from the unchanged into the kaolinized rock. Immediately below the sandstone the laminæ of the softened rock are seen to be bent over as though by the weight of the superincumbent sandstone. This is a fact of some interest, since it would confirm the view already presented, that the kaolinization was subsequent to the deposition of the sandstone; having been caused possibly by the currents of carbonated water which found passage along the junction line of the two formations. A section through the sandstone, kaolin, and gneiss, is presented in Fig. 20. Up the river gneiss continues to show, losing, gradually, its distinct lamination, to within a short distance of the wagon bridge, above which, after an interval without exposures, granite appears.

I a. *Granite* (1,008): medium-grained, pinkish, consisting of a nearly uniform admixture of pinkish orthoclase, in facets up to 1-16th inch, and fine-grained translucent quartz. Some mica is present, in fine scales, showing sometimes a slightly stringy arrangement. This granite is exposed from a short distance above the wagon bridge, as far north as the north line of Sec. 14, the river in this distance passing through a gorge whose walls sometimes reach a height of 80 feet. In the large exposures at the falls, the parallel grain of the gneiss below is almost entirely lost, being only occasionally indicated in an obscure arrangement of the mica. The rock here is traversed by several sets of joints mostly somewhat irregular, those showing the greatest irregularity trending N. 80° E. and dipping 72° S. E. but having no corresponding structure in the rock. Above, the granite shows the same general characters as at the falls, occasionally — as in the railroad cut on the west side of the river, just above the falls — showing a darker kind than usual from a greater quantity of fine dark mica. In this cut there are to be seen two sets of planes equally marked, one set trending N. W. and dipping N. E., the other trending N. E. and dipping N. W. A distinct stringy arrangement of the mica was noted parallel to the former set. Near the north line of Sec. 15, the granite exposures cease suddenly on the east side of the river, whilst they continue some distance farther on the west side — a fact to be explained by the northwest strike of the succeeding slaty rocks.

II. *Hornblende rock* or *schist* (501): fine-grained, crystalline-textured; dark-colored to black; breaking with conchoidal fracture; weathering out into rough prismatic fragments, with dirty brown color; striking, as a whole,

		Feet.
	N. W. This rock is exposed in a low ledge on the east side of the river, almost immediately succeeding the granite. It shows also, on a small rock in the middle of the stream, where a distinct contorted lamination is observable. Horizontal width	60
III.	*Magnesian slate* (516, 522): pale-gray, light-greenish-grey, dark-green, occasionally pink, or even bright brick-red, from presence of iron sesquioxide; sometimes quite soft, at others quite hard and gritty, from the presence of fine granular quartz, which appears never to be entirely absent; highly schistose, the laminæ striking N. 60° W. and dipping N. E. 70°. The magnesian mineral appears to be talc in the light-green kinds, and chlorite in the dark green, the former kind much predominating, and never sharply defined from the other. The light-gray to nearly whitish kinds are the most silicious, and most firm, the others showing much tendency to crumble and decompose. This is especially so with those that are stained bright-red, their contained oxide of iron arising from the oxidation of pyrite, which sometimes is to be seen still unchanged, in minute cubes. These schists are exposed on the east side of the river, on a nearly perpendicular bank, 100 feet in height, which forms the western end of "Tilden's Iron Mound." About 75 feet along the river bank from the lower end of the exposure, a bright-red layer, 30 feet thick, occurs, in which hematite forms a prominent constituent, the surfaces of some of the laminæ having even a bright specular lustre (522) and in which nests and seams of porous, iron-stained quartz are quite abundant. At one time this ferruginous schist was mined as an iron ore. Averaged specimens from it yielded respectively 9.81. 28.13 and 31.27 per cent. of metallic iron; the first representing a thickness of 24 feet, near the water's edge, the second the same thickness at an elevation of 30 feet above the river, the third, 6 feet, more ferruginous than the rest, immediately next below (stratigraphically) the preceding layer. The six feet layer does not continue the whole height of the bank. The length of the exposure of this rock along the river bank is about 700 feet, its horizontal width about..	200
IV	*Covered:* on Tilden's Iron Mound..	550
V.	*Ferruginous quartz-schist:* finely laminated, varying from a light gray, somewhat ferruginous quartz-schist, to a dark-colored highly magnetic rock; in many places weathered brownish, iron-stained, partly crumbling. This rock is exposed in a low outcrop on the water's edge on the east bank of the river; in a similar low outcrop on the west bank; and again (apparently the same layer) some distance east from the river on the north flank of the Iron Mound, at points indicated on the map. The first exposure shows a very much decomposed, crumbly, brown-stained, non-magnetic rock, containing 42.32 per cent. of metallic iron. The outcrop on the west bank of the river is somewhat larger, showing a material similar to that on the east side, with a very plain N. 50° W. strike, and N. E. dip. A sample across the whole width of 30 feet yielded 35.96 per cent. of iron. The exposures on the Iron Mound are partly artificial, a considerable quantity of the rock having been removed for smelting purposes. In one of the two main openings the rock or ore is brown-stained and magnetic, containing 34.22 per cent. of metallic iron; in the other, somewhat deeper in the hill, a much less oxidized material is seen. Of this, the innermost portions present a dark-gray to nearly black appearance, and exceedingly fine-grained texture, being composed of alternating darker and lighter colored (more quartzose) bands, but having this banding much less prominent than	

Feet.

on the weathered kinds. This dark-colored rock is distinctly magnetic, affecting the needle, and adhering to a magnet in quite coarse particles. An averaged sample yielded 32.1 per cent. of iron. A partial analysis of the same material yielded the writer, in 1872, the following results:

	Per cents.
Metallic iron	31.87
Silica	45.72
Lime	1.62
Alumina	8.56
Magnesia	trace.

Still another sample, averaged from the whole opening, and from the stock pile outside, yielded 37.18 per cent. of metallic iron. The horizontal width of this schist seen on the river is 60

VI. *Magnesian schist:* similar to No. III; bedding very plain; strike N. 50° W., dip 60° N. E.; width 20

VII. *Covered.* In this interval the west side of the river begins to rise, the east side being now depressed into the valley of Levins' creek. On each side of the mouth of this creek, and extending up it for a long distance, are ledges of thin-bedded, horizontal sandstone, which thus overlies and conceals the Archæan rocks, filling the depressions in their ancient eroded surface. The Archæan exposures are now transferred to the west side of the river. The horizontal width of this gap at right angles to the general strike, is.. 100

VIII. *Magnesian schist:* light-colored; silicious; similar to No. VI; showing plainly the same bedding structure; width 40

IX. *Ferruginous quartz-schist* (513): fine-grained, dark-gray, very quartzose; showing under the lens numerous grains of glassy quartz, which occur more abundantly on some seams than others. Seams and surfaces stained red; non-magnetic; contains 26.98 per cent. metallic iron; strike N. 45° W.; width 24

X. *Magnesian schist* (511,512): in the lower or more southern portions quite soft (512); light greenish-gray, and without indication of any quartzose ingredient; towards the upper portions becoming much more quartzose (511), losing the softness and greenish tinge. In these last, the lens reveals much granular, glassy, translucent and smoky quartz between the laminæ; width 200

XI. *Covered* 120

XII. *Magnesian schist* (504): greenish gray; having thin intercalated bands of ferruginous quartz-schist; width 120

XIII. *Ferruginous quartz-schist:* very much weathered. An old pit has been sunk on this near the water's edge. The loose material in the pit yielded 30.23 per cent. metallic iron. The width seen is 80

Nos. XII and XIII are well exposed in the railroad cutting at the top of the bank, about 80 feet high, at whose foot the pit alluded to is sunk. The cutting is not quite in the line of strike, being nearly north and south. In it are exposed, beginning at the north end (a) magnesian schist (508), 6 feet horizontal width; (b) banded ferruginous quartz schist, containing 29.17 per cent. of metallic iron, 2 feet; (c) magnesian schist with thin seams of ferruginous quartz-schist, 13 feet; (d) ferruginous quartz-schist, with small seams of magnesian schist — the more ferruginous portions containing 26.04 per cent. of iron — 16 feet; (e) the same as the last, but containing more magnesian bands, grading into the next layer, 16 feet; (f) ferruginous schist, with many magnesian bands, cut into small prismatic

blocks by close jointing and containing 28.63 per cent. of iron, 48 feet. *Feet.*
Returning now to the river bank below, we note next;

XIV. *Magnesian schist:* (502, 503) 60

XV. *Covered:* by sandstone. Immediately north of the magnesian schist No. XIV, and resting directly against it, horizontal sandstone is seen and continues to show in mural exposures 10 to 40 feet in height, all along the west bank of the river to a point beyond the limits of the section. The width of the gap is about 3,500

XVI. *Ferruginous quartz-schist:* much oxidized, containing 32.91 per cent. of iron 8

XVII. *Mica slate:* finely laminated; very light-colored; the mica in bright-lustered plates up to ⅛ inch in diameter 5

XVIII. *Ferruginous quartz-schist* (1017): fine-grained, very thinly and distinctly laminated, without contortion; brownish to grayish black in color; non-magnetic; streak red; under the lens seen to consist of mingled grains of white quartz, and a metallic-lustered black mineral (hematite?); contains iron, 32.49 per cent. 32

XIX. *Covered* 22

XX. *Ferruginous quartz-schist:* resembling No. XVIII 7

Nos. XVI, XVII, XVIII, and XX, all show plainly a strike of N. 65° W., and dip of 70° N. E. With the exception of XVIII, which rises 10 feet from the river, they are all seen on very low exposures barely rising from the water, and overlaid by heavy beds of sandstone, which shows in a perpendicular face in the bank above. The exact junction of No. XVIII with the overlying sandstone is well exposed, it being possible to obtain hand specimens showing both formations (1009). One of these has already been figured on page 462. Another remarkable feature in these exposures is the bending of the sandstone layers above, to conform with the irregular surface of the schistose rocks, suggesting the idea that a motion upward of the schist had caused the bending, which is seen, not only in the lower layers, but also in the heavy ones 6 to 10 feet above. This feature is represented in Fig. 21.

At the junction of the two rocks, the sand is seen to have frequently been wedged between the partly separated schist laminæ, and in one place includes a detached mass of the schist.

XXI. *Covered* by sandstone 150

XXII. *Ferruginous quartz-schist* 3

XXIII. *Covered* 40

XXIV. *Ferruginous quartz-schist* (519) 5

Total horizontal width of the slaty series measured 5,406

Approximate thickness 5,000

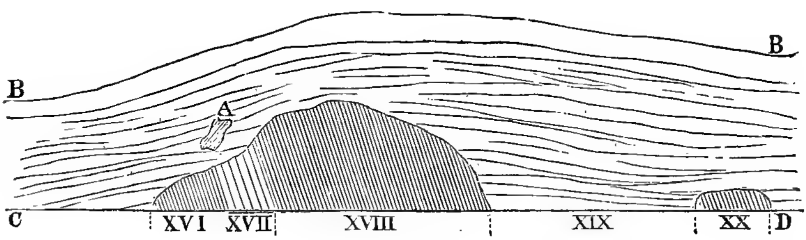
Nos. XXII and XXIV occur on the east bank of the river, and are barely seen above the water's edge, being overlaid by heavy beds of sandstone.

The existence, in the region about Black River Falls, of isolated hills of ferruginous schist, which rise through the surrounding horizontal sandstone, has already been alluded to. These hills are known locally as "iron ore mounds." They are from 100 to 250 feet in height, and rise somewhat abruptly from the level sandy plain, which is also dotted by loftier castellated outliers composed of higher layers of the same sandstone as that which forms its basement. The rocks of the "iron ore mounds" strictly come under another head, being isolated areas of Archæan; but are conveniently alluded to here on account of their close relations to, and short distance from, the slaty rocks just described as occurring on Black river. For the positions of the various mounds, see Atlas Plate XV, Area F. The exposures observed on them are mostly poor, and nearly always of ferruginous quartz-schist, like that occurring on Black river, and quartz. On those mounds, however, which lie on sections 15 and 14, T. 21, R. 3 W., and Sec. 31, T. 22, R. 3 W., the iron oxide, instead of being magnetic, or red, or brown and hydrated, is brilliant specular hematite. The specimens from the mound on Sec. 12, T. 21, R. 4 W., show chiefly a dark-colored magnetic rock, like that of Tilden's iron mound. On the mound on Sec. 17, T. 21, R. 3 W., white quartz only was observed.

The considerable amount of iron in the schists of Black river, and of the mounds in the neighboring country, has for many years attracted attention to these rocks, it being supposed that they were of value as ores of iron. Several attempts at smelting have been made. One small furnace was built on the banks of Levin's creek, as long ago as 1855, and another begun, but never completed, on the south side of Tilden's mound, near the river. In the first-named, the ferruginous quartz-schist of the north side of Tilden's mound was mixed with the hematitic magnesian schists from the west side of the same mound on the river bank. As a flux for this mixture, a dolomitic limestone from the Lower Magnesian formation was used. It may be readily seen that no successful work was ever done.

In view of the considerable interest that had been excited with regard to these ores, and the reputation they had already attained, the writer was sent, during the first year

Fig. 21.



POTSDAM SANDSTONE ON ARCHÆAN SCHISTS.

XVI Ferruginous quartz-schist, 8 feet. XVII Mica Schist, 5 feet. XVIII Ferruginous schist, 23 feet. XX Ferruginous schist, 7 feet. A, mass of Schist included in the sandstone. BB, Potsdam sandstone, top layer 3 feet thick. Scale, 20 feet to 1 inch. C. D., River level.

of the present survey, by the then Chief Geologist, Dr. I. A. Lapham, to make an examination as to their value. Samples for analysis were averaged from all the exposures and in all the openings seen; and analyses made of most of the samples, especially with regard to their richness in iron. The ores or iron-bearing rocks are of two general kinds: the ferruginous quartz-schists, in which the iron-bearing ingredient is at different times magnetite, specular hematite, red hematite, and the brown or hydrated oxide — the last two probably from weathering only — and the ferruginous magnesian schists, in which the iron oxide is red hematite. Of the former kind, the various samples yielded respectively, 26.04, 26.98, 28.63, 29.17, 30.23, 30.90, 31.87, 32.10, 32.49, 32.91, 34.22, 35.96, 37.18 and 42.52 per cents. of metallic iron. Of the latter, observed only in one place, the samples yielded 9.81, 28.13 and 31.27 per cents.[1] In the first kind, the only other important ingredient besides iron oxide is quartz; in the second, a silicate of mag-

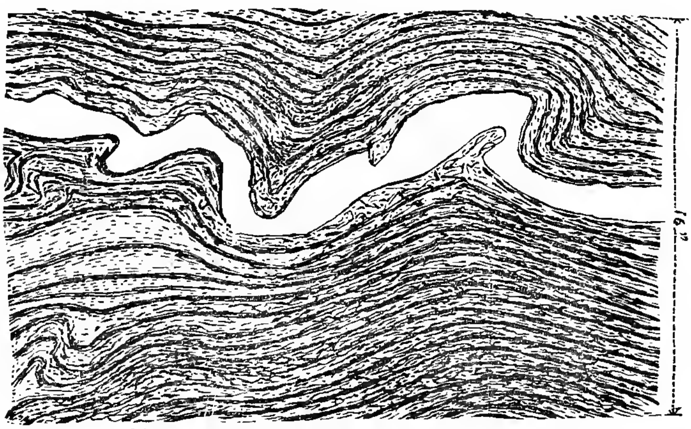
[1] For the "hard" or silicious ores of Michigan, 50 per cent. of iron is the minimum amount at which the ores can find purchasers.

nesia. Though obtained on carefully selected samples, the above figures are probably somewhat high. Whilst iron ores are worked with even lower percentages than these, such admixtures as quartz and magnesian silicates would necessitate quantities of iron at least half as large again. The Black river "ores" then, really cannot be regarded as ores, but are properly iron-bearing rocks. Whether valuable working ores may yet be discovered in these slaty rocks is another question. Similar rocks occur with the workable ores of Michigan. Taking, however, all the circumstances into account, it is deemed rather improbable that such ores can exist. Even if they do, they are not likely to be discovered, but rather to remain hidden underneath the sandstone that forms the surface rock throughout the region.

It has been said on a previous page that the peculiar lithological characters of the slaty rocks of Black river, and of the mounds of the vicinity, strongly suggest their Huronian age — a suggestion which is partly corroborated by their position on the border of the great Archæan area of the north part of the state. It has been supposed that the granite and gneiss of the foregoing section were Laurentian, the slaty rocks Huronian. From the details given it will be seen that all must be assigned to the same series.

At **Black River Station**, on Sec. 3, T. 22, R. 3 W., where the Green Bay and Minnesota Railway crosses Black river, crystalline rocks are exposed in the side and bottom of the gorge through which the river passes, and are overlaid at the top of the banks by a few thin layers of sandstone. The river here trends about S. 25° W., or in a direction roughly at right angles to the general strike. The southernmost exposure examined was about a quarter of a mile below the railroad bridge. Beginning with it, and passing northward on the west bank of the river, the following different rocks were noticed:

FIG. 22.



CONTORTED GNEISS ON BLACK RIVER.

I. *Gneiss:* showing in a rounded knob some 25 feet above the water, and about 100 feet long, and in the river bed below for about 200 feet northward. At the southern end of the exposure the gneiss (1,000) is very fine-grained, thinly laminated, pinkish-weathered, and quartzose; consisting of fine-granular, glassy quartz, predominating; fine pinkish felspar, and fine black mica, arranged in lines, the lamination of the rock being also independent of the arrangement of the mica; having a strike of N. 35° W., and a dip of 62° N. E. A hundred feet northward this merges into a kind (1,001) in which the granular quartz still more largely predominates, and the mica is almost wholly absent. A short distance beyond, this changes again to a dark colored, beautifully contorted kind (1,002), consisting of fine-grained white quartz, partly arranged in separate white bands, up to one inch in width, and partly also mingled with fine, brilliant black mica, and fine, white felspar, in dark gray bands. The weathered surface of this is dark brown with a white kaolinized undercrust. North of the gneiss no rock occurs for 400 feet, then come outcrops some 500 feet long of,

II. *Diorite* (1,003): rather coarse-grained, highly crystalline, grayish, felspathic; composed of large surfaced, bluish-gray felspar, with coarse hornblende; without definite bedding structure. Underneath the railroad bridge this rock is terminated by a mass or vein of,

III. *White quartz:* 5 feet wide. Immediately next to which begin outcrops about 200 feet long of

IV. *Gneiss* (1,005 and 1,006): rather fine-grained, pink-and-gray-banded, very quartzose; consisting principally of pink and colorless translucent quartz, with some fine greenish-black mica and pinkish orthoclase; in places a quartzite (1,004), the other minerals being almost wholly absent. Above this the rocks are concealed for a short distance, after which are seen, some 20 feet in width, of

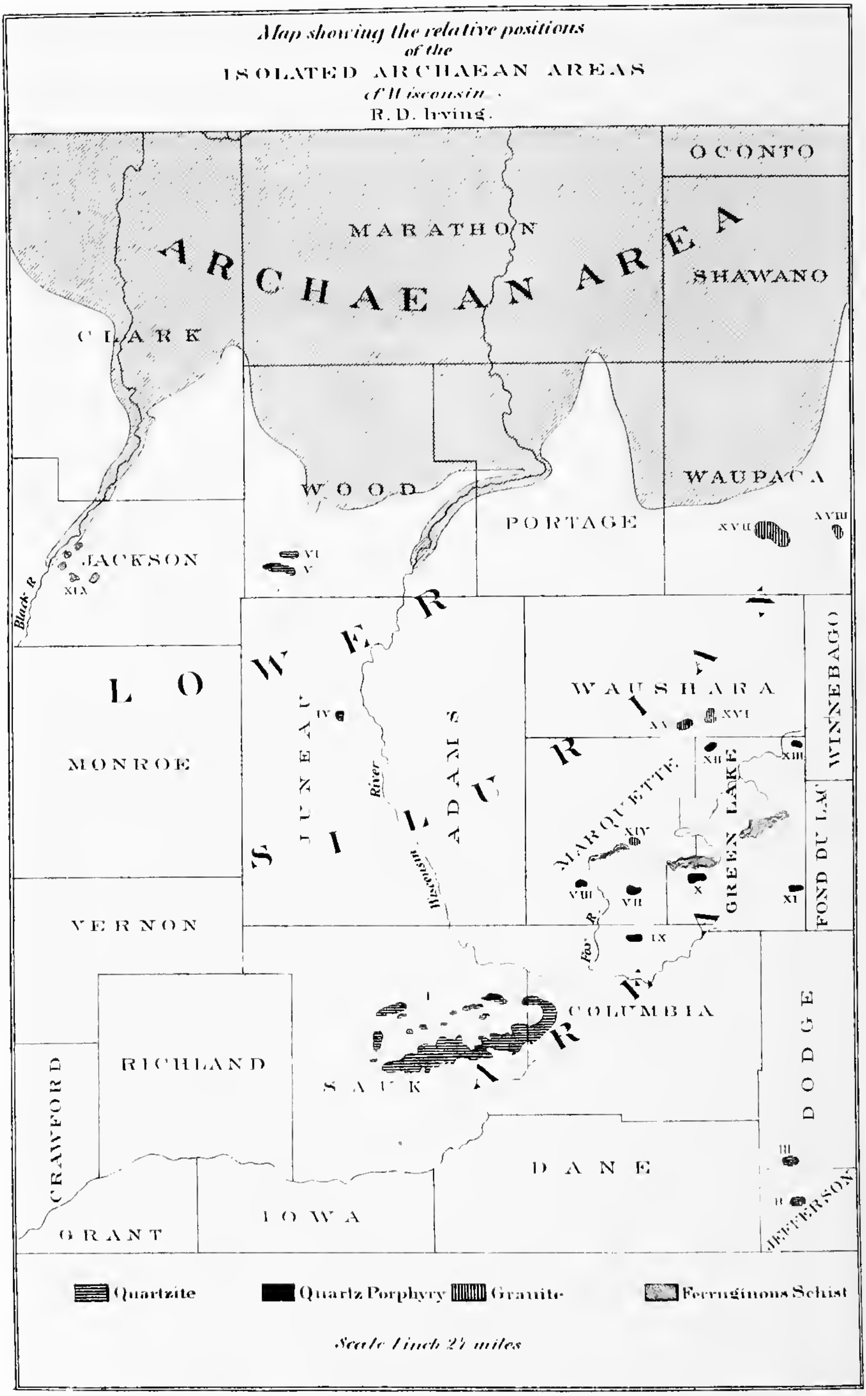
V. *Micaceous schist* (1,007): a very peculiar, fine-grained, dark-brown, earthy-textured, jointed rock. Under the lens it is seen to consist largely of angular grains of quartz. The smooth jointed planes of this rock strike N. W., and stand vertical.

In the river one mile above Black River Station, a ledge 150 feet long and 25 feet high, is seen, of fine-grained, dark-reddish granite (990), consisting of a rather uniform and close admixture of reddish orthoclase, in fine glittering facets, reddish-brown, translucent quartz, some colorless quartz, and a little, sparsely scattered, fine black mica. Half a mile further up stream, fine-grained, red and gray banded, quartzose gneiss (991) is exposed. The gray bands consist of fine-grained, glassy quartz, fine black mica and white felspar; the red of brown and red translucent quartz, mingled with a little orthoclase. From here to the mouth of the East Fork, the bed of Black river shows numerous small ledges, 3 to 4 feet high, of contorted gneiss and reddish granite.

Above the mouth of the East Fork, which is on Sec. 36, T. 23, R. 3 W., exposures of red granite are seen as far as **French's mill**, on Sec. 25. The wagon road which, for half a mile below the mill, follows the west bank of the river has, on the east side, ledges of red granite, and on the west, a ridge thirty to forty feet high, composed of horizontal, coarse-grained, quartzose, cross-laminated sandstone. In one place, the exact junction of the two formations is to be seen. At the mill, the granite exposures are especially large, both on the west bank and on a large island in the stream. Two kinds of the granite occur, both presenting a prevailing pinkish weathering: (1) a rather fine-grained, very uniform-textured, dark reddish kind (988, close to 990); and (2), a medium-grained, uniform-textured, pinkish-grey, quartzose kind (987), containing both colorless glassy, and pink translucent quartz; pink orthoclase; and fine black brilliant mica. Both kinds appear like handsome building or ornamental granites. No definite bedding structure is to be seen.

On the wagon road, three quarters of a mile south of **Neillsville**, Sec. 22, T. 24, R. 2 W., is a large outcrop 200 yards long, and 10 to 40 feet high, of porphyritic, calcareous gneiss, striking E. W., and dipping 80° S. At the northern end of the exposure, the rock (984), is medium-grained, fine-laminated, knotty, and highly micaceous. Fresh surfaces show a large quantity of fine-flaked brilliant black mica, white quartz in little nests, around which the micaceous laminæ curve, and white felspar, which sometimes occurs in smaller nests up to a quarter to half inch in diameter. In large quantity, the pulverized rock effervesces briskly in muriatic acid. In the middle portion of the ledge, the rock (985), closely resembles that just described; but shows much pink cleavable felspar and less mica, the pink felspar forming the knots. At the

PLATE, XVIII



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south end, the gneiss resembles that at the northern end, and contains large masses of white quartz, up to ten by four feet in size.

These knotty gneisses resemble closely others which occur on the line of the Wisconsin Valley Railroad, in Portage county.

Three-quarters of a mile west of Neillsville, at the crossing of Black river, on the S. W. qr. Sec. 15, T. 24, R. 2 W., fine-grained, light-pinkish, slightly gneissoid, and very quartzose granite (983) is exposed, with a vertical dip and E. W. strike. This rock is very hard and compact, and appears to be a fine ornamental granite.

The gneissoid and red granites of Black and Yellow rivers resemble one another closely, and appear to be directly continuous with one another underneath the sandstone, which nearly everywhere between the two rivers is the surface rock. Occasionally the crystalline rocks come to the surface in the interval, and are then of the same character as on the rivers; as for instance, on O'Neil's creek, in Secs. 1 and 2, T. 24 R. 1 W., Clark county, where red granite is exposed; and on a high bluff in the N. E. part of T. 23, R. 2 E., whose upper portions are reported to be of red granite with sandstone layers at lower levels.

The amount of these reddish ornamental granites of extraordinarily fine quality occurring on Yellow and Black rivers, and in the intervening country, appears to be very great.

THE ISOLATED ARCHÆAN AREAS.

I. In General.

We have next to consider those isolated areas of Archæan rocks which are found protruding through the surrounding horizontal Silurian strata, at points widely scattered over the central part of the state. Plate XVIII is a sketch map showing the relative positions of these various areas, as also the nature of the rocks of each area, and its distance from the southern boundary of the main Archæan mass. Near to this boundary line it is not always possible to be sure that we have to deal with an isolated area, when we find a mound-like exposure of crystalline rocks, with sandstone showing in the vicinity at lower levels, on account of the intricate and somewhat indefinite nature of the boundary itself. Besides these doubtful areas, which may be somewhere connected with the main Archæan region without intervening horizontal strata, there are, however, many others which occur as much as 50 or 100 miles within the region of the Lower Silurian rocks. Underneath these, the connection with the rocks of the main Archæan area is, of course, preserved, the separation being superficial only. All of the scattered patches are but points of the universal Archæan basement, upon which all the later strata are built, having earned their especial immunity from complete burial by virtue of the resistant nature of their materials. They are properly buried mountains, and were high islands and reef-ledges in the early Paleozoic seas.

All the areas, except the one, or rather the group, including the Baraboo ranges in Sauk county, are of small size, generally occupying much less than a square mile of area. With the same exception, they are all mound-like in form, rising, usually, somewhat abruptly from the surrounding country, which is frequently level, and showing always considerable rock exposures on the flanks and summits, being often almost all of bare rock. They reach heights of from 50 to 250 feet, but are usually lower than surrounding outlying bluffs of the horizontal strata. The Baraboo group, unlike the others, constitutes a series of bold ridges, one of which reaches elevations of 800 and 900 feet above Lake Michigan, and a length of over 20 miles. These ranges are so important an element in the topographical features of Central Wisconsin, that they have already received attention in the chapter on general topography. They are still more fully described in subsequent pages.

The nature of the rocks composing the several areas is not always the same. The large areas in Sauk county, and a few others, are chiefly of quartzite; a number are of quartz-porphyry; still others of granite, which is different in different cases; and yet others, occurring in Jackson county, and close to the main Archæan area, are of ferruginous quartz-schist.

Except in the cases of the granitic areas, these rocks are generally quite distinctly bedded, and are usually tilted at high angles.

In many of the areas, especially in those whose elevation is considerable, horizontal sandstone is found lying immediately against the tilted crystalline rocks, pebbles and boulders from which frequently occur in the sandstone, giving it often a rough, conglomeratic character, and proving at once the great antiquity and non-intrusive nature of the rocks from which they are derived. Some of the areas have, without doubt, been once entirely buried beneath the sandstone layers, to whose subsequent denudation they owe their resurrection.

The following tabulation gives, in a condensed manner, and in a form convenient for comparison, the location, size, nature, etc., of each of the known areas. The facts with regard to Nos. II, III, XI, XIII and XVIII, are furnished by Prof. Chamberlin, in whose report descriptions of them will be found.

LOCATION, SIZE, NATURE, ETC., OF THE VARIOUS ARCHÆAN OUTCROPS THAT OCCUR WITHIN THE SILURIAN AREA OF THE STATE.

No. on Plate XVIII.	Name of outcrop.	Location. Sec.	T.	R.	County.	Aproxim'te Area.	Height of Bluff.	Nature of Rock.	Dist. from main Arch'n
							Feet.		
I.	Baraboo Bluffs	....	.....	.....	Sauk and Columbia	75 sq. m.	100 to 700	Quartzite, quartz-porphyry, clay-schists and quartz-schists	60
II.	Lake Mills	24 & 25	8	13 E	Jefferson	20 acres.	Low.	Quartzite	90
III.	Portland	33 & 36	9	13 E	Dodge	$\frac{1}{16}$ sq. m.	50 to 75	Quartzite	84
IV.	Necedah	{ 19	18	4 E	} Juneau	⅛ sq. m.	175	Quartzite	28
		{ 24	18	3 E					
V.	South Bluff	21,22,23,25	21	2 E	Wood	3 sq. m.	200 +	Quartzite?	10
VI.	North Bluff	1	21	2 E	Wood	½ sq. m.	200 +	Quartzite?	6
VII.	Observatory Hill	7	14	10 E	Marquette	$\frac{1}{5}$ sq. m.	250	Quartz-Porphyry	48
VIII.	Moundville	5 & 8	14	9 E	Marquette	$\frac{1}{16}$ sq. m.	40	Quartz-Porphyry	48
IX.	Marcellon	7	13	10 E	Columbia	$\frac{1}{16}$ sq. m.	75	Quartz-Porphyry	52
X.	Marquette	{ 34, 35	15	11 E	} Green Lake	1½ sq. m.	75	Quartz-Porphyry	50
		{ 2	14	11 E					
XI.	Pine Bluff	36	15	13 E	Green Lake	⅛ sq. m.	100	Quartz-Porphyry	54
XII.	Pine Bluff	2	17	11 E	Green Lake	$\frac{1}{20}$ sq. m.	100	Quartz-Porphyry	30
XIII.	Berlin	2 & 3	17	13 E	Green Lake	¼ sq. m.	50 to 75	Quartz-Porphyry	30
XIV.	Montello	9	15	10 E	Marquette	$\frac{1}{16}$ sq. m.	40	Granite	42
XV.	Spring Lake	27	18	11 E	Waushara	⅛ sq. m.	50	Granite	27
XVI.	Marion	{ 12, 13	18	11 E	} Waushara	⅛ sq. m.	50	Granite	26
		{ 7, 18	18	12 E					
XVII.	Waupaca	31	22	12 E	Waupaca	⅛ sq. m.	100	Granite, etc.	....
XVIII.	Mukwa	26, 25	22	14 E	Waupaca	⅛ sq. m.	70	Granite	....
XIX.	Iron Mound. No. 1.	31	22	3 W	} Jackson	{ $\frac{1}{16}$ to ⅛ sq. m.	75 to 200	Ferruginous quartz-schist	....
	No. 2.	1	21	4 W					
	No. 3.	12	21	4 W					
	No. 4.	17 & 20	21	3 W					
	No. 5.	15 & 14	21	3 W					

II. Special Descriptions of the Several Areas.

The Baraboo Quartzite Ranges.

The Baraboo quartzite ranges occupy much the largest extent of territory, and are at the same time much the most striking and most important as influencing the topography of the state, of any of the isolated Archæan areas that occur within the region of the Silurian rocks. Their bold character, and the dissimilarity between their rocks and those of the country around, have drawn to them the attention of previous State Geologists, as well as of other scientific men. Percival[1] regarded the quartzites composing the ranges as resulting from a metamorphism of the Potsdam sandstone of the surrounding region. Hall[2] refers them correctly to the Archæan, making them Huronian, but his detailed examinations were not published. Alexander Winchell[3] calls them "Lower Potsdam," on the evidence of some fossils belonging to the middle Potsdam, and found in the sandstone lying against the quartzite. This he regards as proving the "Lower Potsdam" age of the quartzite, losing sight of the fact that the latter is unconformable with the sandstone, and projects upwards into the horizon, not only of the middle Potsdam, but even far above into that of the St. Peters. The Archæan age of the quartzite was first definitely proved by the writer in 1872,[4] and this conclusion has since been abundantly confirmed by the work of other geologists,[5] and also by his own further researches in the region.

The Baraboo Bluffs constitute two east and west ranges extending some 25 miles in length through the towns of Caledonia, in Columbia county, and Greenfield, Merrimack, Sumpter, Baraboo, Honey Creek, Freedom, Excelsior and Westfield, in Sauk county. The southern one of the ranges is much the bolder and more continuous, and the two are not exactly parallel, but diverge as they are traced westward. At their eastern ends, in Columbia county, they unite in a bold point, rising abruptly from the low ground of the Wisconsin river, here at the easternmost point of the great bend which the quartzite ranges compel it to take. Tracing them westward, we find the two ridges, about midway in their lengths, some four miles apart, and at their western ends a mile or so more than this. Here a bold, nearly north and south, cross-ridge, also with a quartzite core, unites the two, thus finishing an entire *cordon* of bluffs around a depressed interior. All around the outside of this circuit of hills, except beyond the western cross-ridge, the country is comparatively low, and often quite level, so that the ridges rise very boldly, forming, for a non-mountainous country, quite a striking feature of the landscape.

The southern quartzite range is broken down in only one place, the gorge in which lies the Devil's Lake, and, as seen from the low ground of the Wisconsin river on the south, presents a continuous, wavy crest, often with large areas of bare rock, and with elevations of from 500 to 700 feet above the river, and of 700 to 900 feet above Lake Michigan. Its higher portions have a width of from one to four miles, the outline being quite irregular on account of the deep and very anciently eroded valleys that indent its sides. The great antiquity of these valleys is evinced by their showing on their sides and bottoms layers of horizontal sandstone clinging to the underlying quartzite. The sandstone has evidently been deposited in valleys which were originally formed long before its deposition, and have been carved out anew in the same places, on account of

1 "Annual Report of the Geological Survey of Wisconsin," 1856, p. 101.

2 Geology of Wisconsin, 1862.

3 American Journal of Science II, vol. xxxvii, p. 226.

4 Am. Journal of Science, Feb., 1872.

5 See J. H. Eaton "On the Relations of the Sandstones, Conglomerate and Limestone, of Sauk county to each other and to the Azoic," Am. J. Sci. III, vol. V, p. 144, and T. C. Chamberlin on the "Methods of Upheaval of the Baraboo Ranges," Wis. Acad. Sci., vol. II.

its friable and non-resistant nature. The country on top of the range is heavily timbered presenting in this regard, as also in its almost universal heavy clay soil, a marked contrast with the lower country around. This clay soil has caused the making of many excellent farms on top of the range. It occurs alike on the quartzite and the high-level sandstone. In the eastern extension of the bluffs it might be regarded as of glacial origin, but to the westward the glacial drift limit is reached about midway in the length of the range, and some other origin must be sought.

The northern range is much less pronounced than the southern. For about seven miles west from the junction of the two, in Columbia county, it forms a continuous ridge some 300 to 400 feet in height, but generally much less than a mile in width. Further west its height lessens for long distances, the Archæan rocks forming its core at the same time becoming covered by the overlying horizontal sandstones, through which they appear here and there in small outcrops. Farther west still this range rises again, and where it joins the cross ridge at its western extremity has become again bold, with a height of 200 to 300 feet. Although thus indefinite in its middle portions, the higher ground never entirely disappears along the line of the range, except at the three points where the Baraboo river and one of its tributaries cut through in deep gorges.

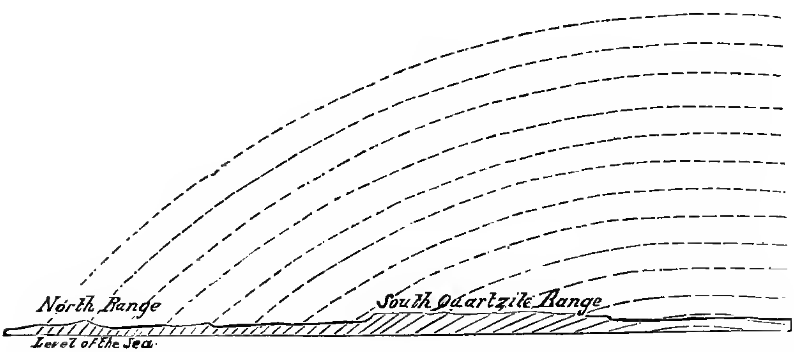
The depressed area within the circuit of the quartzite bluffs is, for the most part, somewhat higher than the surrounding outside country, and towards its eastern and western extremities rises rather rapidly up to the enclosing ridges. In Columbia county much of the area between the ranges is as high as the northern range itself, and is underlaid by a great thickness of sandstone, which fills in the canoe-shaped trough of the uniting quartzite belts. At one time the rest of the valley between the ranges was filled in a similar manner, and has since been partially recarved in the friable sandstone which still forms its bottom. This valley is now traversed longitudinally by the Baraboo river, which enters and leaves it by deep gorges through the northern ridge, having a fall between the gorges of about 70 feet.

The rock constituting the great body of the Baraboo ranges is a quartzite of a non-granular, usually flaky, texture, and of a color from nearly white, through gray, pink, and amethyst, to purplish-red and even brick-red, the gray and deep-red being the most common, the white the least so. Very rarely a distinct granular texture is seen, somewhat more commonly a slight tendency in that direction. The quartzite is frequently very distinctly laminated, the lines of lamination being contorted in a remarkable manner, and marked by alternating light-colored and dark-colored lines. There is never any cleavage parallel to the lamination lines. Next in abundance to the regular quartzite, and merging into it, are heavy beds of a fine metamorphic conglomerate, usually of a grayish to amethystine color, in which the matrix and pebbles are alike of quartzite, and not always very well defined from one another. Forming thin layers between the thick layers of quartzite, is in many places to be seen a peculiar greasy-surfaced quartz-schist, the laminæ of which are composed of quartzite like that of the regular quartzite layers, seamed and covered on the surface with a soft, lilac to white, talc-like, mineral. This slate or schist usually exhibits the true slaty or transverse cleavage. The soft mineral pervading it is suspected to be always, as it certainly is sometimes, aluminous rather than magnesian. It occurs occasionally forming slaty layers with but little quartz admixture, and, in small seams, even entirely pure. It then has rather the physical characters of a compacted clay, and this appearance is borne out by the analyses given beyond, which show that the pure clay-like kinds are probably not distinct minerals, but rather a mixture of a clayey substance with fine silica. In both physical properties and chemical composition this material is closely allied to the pipestone of southwest Minnesota, from which it differs only in color.

Other quartz-schists of quite a different character have been observed forming the lowest layers of the north quartzite range, both at the Lower Narrows of the Baraboo and at the Upper Narrows of the same stream. These are white to straw-colored, distinctly granular in texture, the quartz grains being of translucent glassy quartz. The whole rock is more or less pervaded by a soft clayey material, and splits out in large thin sheets. On the northernmost portions of the north range, at the Lower Narrows, and also for a short distance to the westward, a great thickness of quartz-porphyry is to be observed. This porphyry resembles that of the several small porphyry areas of the adjoining portions of Columbia, Marquette and Green Lake counties and proves at once that we must regard these areas as part of the same formation that appears in the Baraboo ranges.

In the quartzite, milk-white veins and nests are frequently to be seen. In some places, as at the Upper Narrows, the white quartz veins show frequently geodic cavities, lined with quartz-crystals of great clearness and beauty, and not unfrequently of very large size, though usually small. In the veins at the Upper Narrows, such crystal-lined cavities are exceedingly numerous. Along with the crystals, sometimes compacted over them, sometimes loose in the cavities, and again in thin seams by itself, is to be seen a soft, white mineral. This is often pulverulent, at times gritty, at others a nearly impalpable powder, and is shown by analysis to be essentially a silicate of alumina. With the white quartz, in nests of some size, is often to be observed brilliant specular iron in large crystalline surfaces. It occurs also in some of the layers of quartzite, in fine scales. Titanic iron is also reported. These, with the peculiar aluminous silicate alluded to in connection with the quartz-schists, are the only minerals known to occur in the Baraboo rocks.

FIG. 23.



IDEAL SKETCH, SHOWING ORIGINAL STRUCTURE AND AMOUNT OF EROSION OF THE BARABOO RANGES.

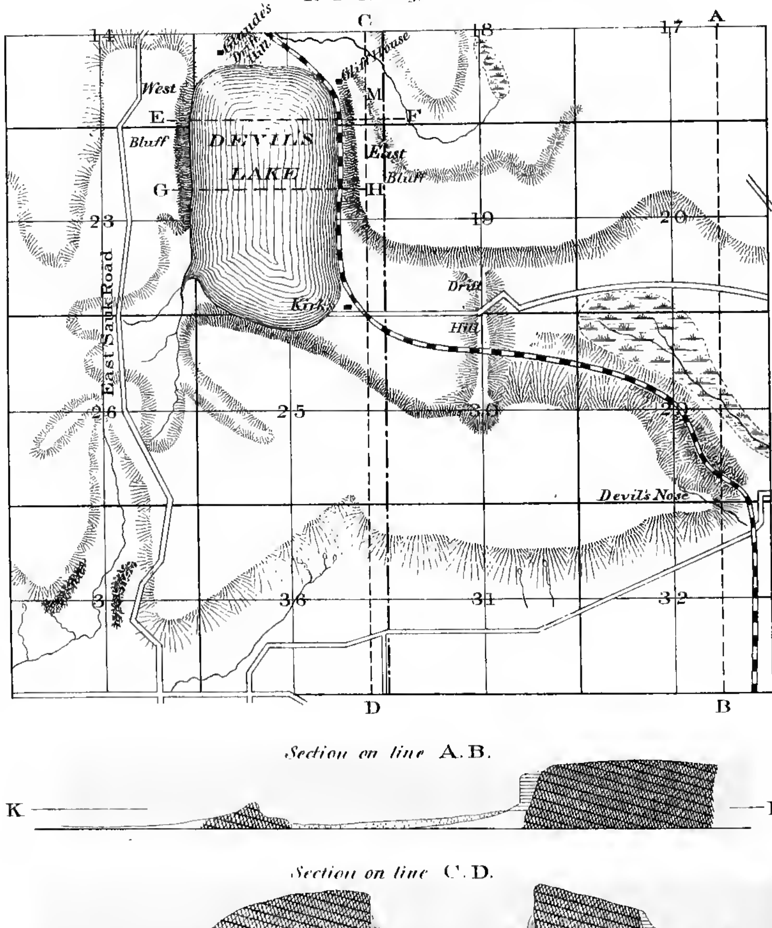
Scale natural, 12,000 feet to the inch.[1]

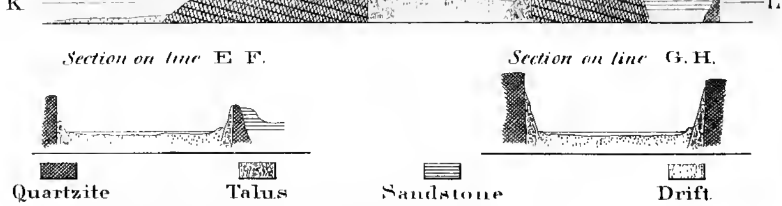
The quartzites and associated rocks are quite distinctly bedded, though the bedding is not unfrequently obscured by cross-jointing, which is often to be observed on a grand scale. The dip, wherever observed, is towards the north, through the whole extent of both ranges, but varies much in amount. In the southern range it is usually quite low, as low sometimes as 15° in the middle and broadest portions. In the northern range the dips are always much higher, running from 55° to 90°. The rocks of the two ranges appear, however, to be parts of a continuous series, the quartz-porphyry beds of the northern range constituting the uppermost layers.

For the relative positions of the different ranges and their relations to the surround-

[1] A sketch, similar to this, accompanies a paper by Prof. Chamberlin, "On the Method of Upheaval of the Baraboo Ranges," Trans. Wis. Acad. Sci., Vol. II, but it is not drawn on a natural scale.

MAP
and Cross Sections illustrating the Structure of the
DEVIL'S LAKE GORGE
T. II N. Ranges VI and VII E. Sauk County.
R. D. Irving, 1876.





Topography adapted from maps by W. H. Canfield.
Base line of Sections 200 feet above Lake Michigan.
Horizontal scale of Sections and Map 1 inch = 1 mile.
Vertical scale 1 inch = 1500 feet
K.L. Level of Devils Lake.

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ing horizontal strata, see Atlas Plate XIV, and the sections of Plate XXI of this volume. If the view, just indicated, that there are no folds concealed beneath the sandstone in the intervening valley, is the correct one, the thickness of the entire series must be very great, and the amount of erosion that has taken place correspondingly great. Fig. 23 indicates the present structure and relative positions of the ridges, and, by the dotted lines above, the possible original structure, and the extent of the erosion that has taken place. The figure is drawn to a natural scale, the line of section being the same as that of Fig. II of Plate XX. The heavy black line represents the overlying Potsdam sandstone. It is not impossible that the valley between the ranges owed its existence, to some extent, in the first place, to soft rocks intercalated between the harder quartzites. The hypothesis of Fig. 23 is not altogether satisfactory. The entire disappearance of the other side of the great arch, as well as the peculiar ways in which the ranges come together at their extremities are difficult to explain by it. It may be said in this connection that the dip observations toward the west are not so satisfactory or numerous as they might be.

The irregular areas over which the Archæan rocks are at surface, are indicated, as accurately as present knowledge will permit, on Atlas Plate XIV. The greatest difficulty in the tracing of the exact boundaries of the quartzite areas lies in the fact that remnants of the horizontal sandstones which flank and cover them may be found at almost any elevation upon the bluffs, so that no barometrical observations are of avail. The areas, as indicated, are, however, very nearly accurate. There are places within them where, without doubt, patches of the covering sandstone occur, but the quartzite is in every such case but a short distance beneath. The peculiar features of these sandstones and their relations to the other Silurian strata of the region are treated of on a subsequent page.

Beginning the detailed descriptions at the best known, and at the same time one of the most remarkable, points about the quartzite ranges, we note first the occurrences in the vicinity of **Devil's Lake**, in T. 11, ranges 6 and 7 E., Sauk county. Here the southern range is cut entirely through by a deep quartzite-walled valley or gorge, 500 feet in depth, and three-fourths of a mile in width. In its northern portion this valley trends due north and south for about a mile; turning then abruptly at right angles it extends eastward two miles and a half. In the north and south part lies Devil's Lake, with a length of something more than a mile, and a width one-fourth less than this, its surface being about 100 feet above the valley surface at the eastern end of the gorge, more than 100 feet above the Baraboo river at Baraboo, and more than 200 above the Wisconsin at Merrimack. It is held in this elevated position by two immense morainic heaps of glacial drift lying at either end of the lake and rising more than 100 feet above its level. The lake has a nearly level sandy bottom except near the shores, and is over most of its area some 30 feet in depth. It has no outlet, and but one small stream running into it. It is thus probably fed chiefly by springs, and maintains its level by evaporation and by filtering through the heaps of gravel and sand which hold it in place. Near the northwest corner a small stream running into the Baraboo passes within a few rods of the lake, and possibly carries with it some of the lake water.

As shown on the map of Plate XIX, on its west and south sides the lake washes the bases of the bounding cliffs of the gorge. Both east and west cliffs are highest near their southern ends, towards which they rise gradually from the north, following roughly the dip planes, which also rise southward, and the edges of which can be seen quite well marked on either wall of the gorge. By aneroid measurement the highest point of the west bluff is 475 feet above the lake level or 860 feet above Lake Michigan, and the southern portion of the east bluff but little lower. In their upper portions the cliffs are vertical, sometimes for as much as 200 feet or more, but their lower parts are clothed with a heavy talus or "ancle," composed of great blocks of the quartzite that have fallen from the cliffs above. These masses are often as much as 20 feet on a side, with a somewhat regular shape imparted by the powerful joints that everywhere traverse the quartzite, and cut it into blocks only needing to be slightly dislodged in order to fall down the cliff. For the greater portion of their lengths both east and west bluffs are quite narrow, being backed by deep ravines opening northward. The northern end of the east bluff, especially, is a mere crest, having behind it one of the ancient sandstone-lined ravines that have before been mentioned.

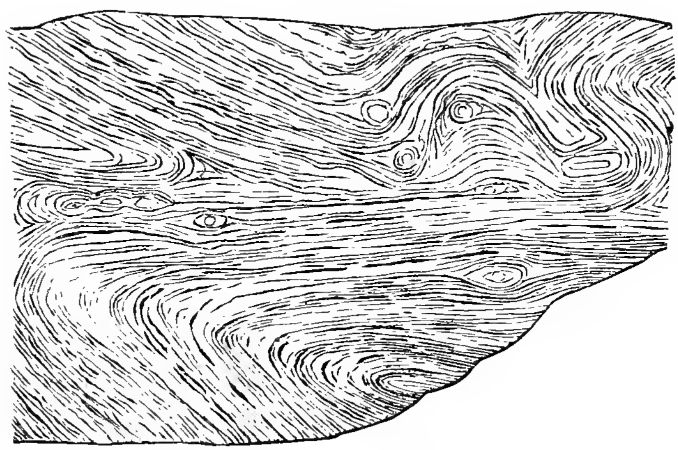
In its east and west extension, the valley preserves the same characters as above described, the cliff on the north side being the highest and boldest, and retaining for a long distance the height it attains at the corner where the valley bends. Along the face of this cliff the heavy quartzite beds are seen on the strike, and present, therefore, an appearance of horizontality when viewed from the valley below. At the mouth of the valley, S. E. qr., Sec. 20, T. 11, R. 7 E, the northern cliff is of horizontal sandstone, behind which the quartzite passes, whilst the south cliff terminates in a sharp rocky point known as the Devil's Nose. From the summit of this cliff, a short distance westward from the nose, is taken the view on Plate XV., the Frontispiece of this report. The outlook is northwestward through the east and west part of the valley to the lake, beyond which the western cliff of the lake is seen. Doubling the nose, we are on the south side of the range, with Sauk Prairie in front, and the high bluff with its *roches-montonées* surfaces of quartzite behind; these surfaces rise in rude steps, which are due to the gradual northern dip.

Near the top of the sides of the ravine shown by the map on the southwest corner of the lake, horizontal sandstone and coarse conglomerate occur, the pebbles of the conglomerate coming from the quartzite against which it lies. Nowhere else along the sides of the valley until we reach its eastern end are any indications of its ever having been filled with sandstone, and, consequently, of its equally great antiquity with other ravines about the quartzite ranges. This occurrence itself is not necessarily any such indication, for the sandstone is found only at a high level, and may therefore have been introduced from the northward, quite independently of the valley of Devil's Lake, which we are thus led to believe is of more recent origin than the Potsdam period.

This valley has evidently been at some time the passage of a large stream. We cannot suppose that it has been produced by any other process than that of erosion, and such an erosion as could only be effected by the agency of running water. Confirming this view, we find, high up on the cliff sides, within 150 feet of the summit, remnants of large potholes, several feet in diameter, presenting smoothed surfaces, and having about them many small pebbles and smoothed boulders which may have been engaged in the work of their formation. The large size of the valley suggests that it may have been the passage of the Wisconsin river, which at the close of the Glacial period found its ancient channel obstructed by the great drift heaps that are now to be seen in it, and was forced to find its way eastward to the valley of the great river that for long ages before the Glacial period drained the whole basin of the Wolf and Upper Fox through the valley of the Lower Wisconsin to the Mississippi. This valley, which the deflected river reached at Portage, and which it subsequently appropriated as its own, passes altogether to the eastward of the eastern extremity of the quartzite ranges. If this is a correct view, the river must have had a passage through the northern range also, and this passage would be found in the Lower Narrows of the Baraboo, a much wider channel than is needed by that small stream. This explanation of the origin of the Devil's Lake valley is offered as a suggestion only. The Baraboo may be the stream to which the work should be allotted, but, if so, we must imagine it to have been a much larger and more powerful stream than now. Only ten miles above on its course the gorge through which it passes the northern range presents no such proportions as seen about the Devil's Lake valley. For a further idea of the structure of this valley reference is made to the sections of Plates XIX and XX.

The rock in the vicinity of Devil's Lake, omitting reference now to the Silurian conglomerate and sandstones, is nearly altogether the typical quartzite of the region, as above described. It generally shows some shade of red. On the weathered surfaces of some of the large fallen masses in the edge of the lake, a distinct tendency to a granular texture is perceptible, whilst a fresh surface shows generally no traces of it. Fine lines of lamination are nearly everywhere to be seen, and are generally quite strikingly marked, but there is never any structure parallel to them. They are nearly always bent into sharp angles, or curved and contorted, presenting often the irregularities seen in the bedding of sandstone. Whilst many of the bendings in these lines may be due to original irregularities of deposition, or to contortion at the time of disturbance and alteration, there are surfaces where they present such a peculiar knotty and concentric appearance as strongly to suggest a concretionary origin. A portion about 3 feet square of such a surface is figured in Fig. 24. The lines are alternatingly light and dark red.

FIG. 24.

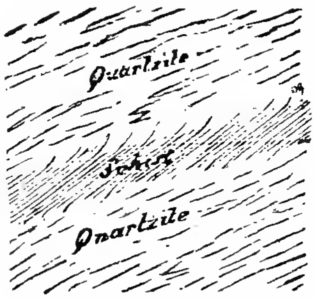


SURFACE OF QUARTZITE SHOWING CURVED LAMINATION.

In a few places white quartz veins with geodic quartz crystals are seen, but these do not characterize any considerable portion of the rock. All about the Devil's Lake valley the bedding of the quartzite is quite distinct, and is made apparent by the existence of large dip surfaces, often beautifully ripple-marked. At the northern ends of both east and west bluffs of the lake many such surfaces occur. Others are seen on the sides of the railroad track about midway the length of the lake. These all give an inclination to the north of 15° to 25°, the higher figure being seldom reached, and a strike of N. 80° E. The quartzite layers are many feet in thickness, showing no internal structure whatever parallel to the general dip direction, but being affected everywhere by the curved and bent lamination alluded to. Between the quartzite beds occur layers of greasy quartz-slate, usually but a few inches in width. Such a layer is well exposed on the side of the railroad track on the east side of the lake, the laminæ dipping N. 37°, or transverse to the bedding planes. The slate is quartzite, like that of the surrounding beds, but is penetrated by a soft, greasy mineral, and affected by slaty cleavage. As the cleavage planes of the slate approach the surface of the adjoining quartzite, they curve towards and penetrate it to a short distance, as indicated in Fig. 25. Large surfaces of quartzite, which have had one of these slaty layers removed from above them, show a peculiar ridgy appearance, evidently due to the passage into them of the slaty cleavage planes.

At the summit of the east bluff, near its southern end, indications of a somewhat lower dip than elsewhere are seen, whilst at the Devil's Nose, surfaces occur slanting as much as 29° northward. At the latter place, many cross-joints obscure the bedding, nearly all of the planes, however, sloping northward. Some very large ones were noted, with as high an angle as 82°, covered with a shining, soft, greasy film. In seams and nests in the quartzite, in this vicinity, occurs a compact, but soft, clay-like substance (1254) of a lilac color, which is penetrated by fine white strings, and contains: silica, 62.16; alumina, 29.67; iron oxide, 4.17; lime, 0.16; water, 2.50=99.36. This substance appear to be the same as that which pervades and gives character to the quartz-schists of the region, and is closely allied to the red "pipestone," that occurs with the quartzites of Barron county, and again in southwest Minnesota.

FIG. 25.

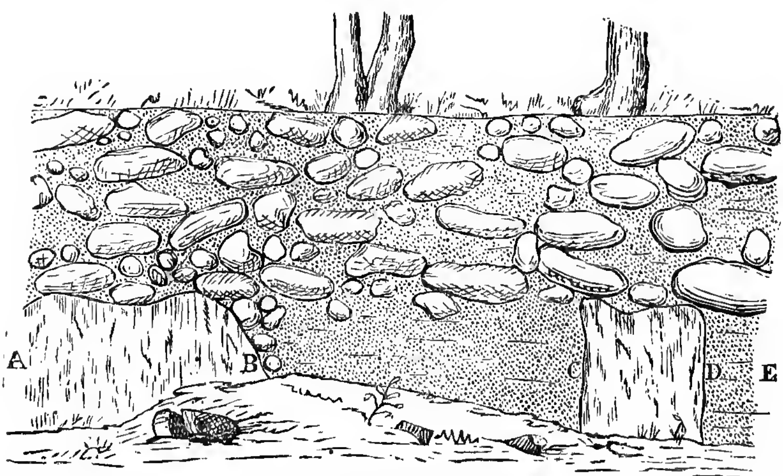


SLATY CLEAVAGE IN QUARTZ SLATE AT DEVIL'S LAKE.

On the summits and sides of all the cliffs about the lake and valley, two sets of very marked vertical cross-joints are to be seen, the more prominent and persistent set trending N. 45° W. These joints have produced, on the upper portions of the cliffs, a striking columnar appearance, the separate columns of quartzite, 20 to 40 feet in height, often standing entirely detached by the joint cracks from the main cliff. In some cases, intervening masses of quartzite have fallen, and left entirely isolated needles at a distance from the cliff face.

As in the ravine at the southwest corner of the lake, so also in many other places on the north flank of the ridge, horizontal ledges of sandstone and very coarse conglomerate occur, abutting against, and unconformably overlying the quartzite. At the northern point of the east bluff, the contact of the two formations is beautifully exposed, and the very instructive section represented in Fig. 26 occurs. Here the ends of columnar,

FIG. 26.

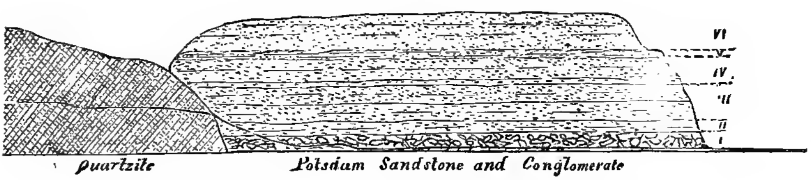


POTSDAM BOWLDER-CONGLOMERATE AND SANDSTONE ON ARCHÆAN QUARTZITE, DEVIL'S LAKE
Scale, ten feet to the inch.
A. B., Quartzite. B. C., Sandstone. C. D., Quartzite. D. E., Sandstone.

joint-detached, masses of the quartzite are surrounded and filled between by the horizontal sandstone, the whole capped with a heavy layer of a conglomerate composed of angular, subangular, and rounded masses of quartzite, embedded in a coarse, friable, sandy matrix, which is occasionally cemented by the brown oxide of iron, and is not unfrequently almost altogether excluded by the included boulders. The quartzite of the boulders and pebbles is the same as that of the ledges further up the bluff. Places also occur, as shown in the figure, where the sand and quartzite pebbles are wedged down into the joint-cracks of the quartzite.

Eastward from the mouth of the Devil's Lake valley, in Sec. 29, T. 11, R. 7 E, the southern face of the quartzite range continues high and bold on the right hand, as far as Sec. 25, T. 12, R. 8 E., in Columbia county. On Mr. Fitsimmons' place, on Sec. 22, T. 11, R. 7 E., Sauk county, near Parphrey's glen, and only a short distance from the south slope of the ridge, one of the highest points on the whole range of bluffs occurs, the elevation being nearly 100 feet greater than that of the Devil's Lake bluffs. The point is in use by the United States Coast Survey, as a signal station. North from the signal station, the quartzite range has a width on top of nearly three miles. As far as Sec. 3, T. 11, R. 8 E., Columbia county, the south face of the range, except at the higher levels, where large surfaces of bare quartzite occur, is composed of sandstone, with some coarse conglomerate, which flanks the quartzite in horizontal layers. These flanking sandstones are well exposed at the mouth of the Devil's Lake gorge; in Parphrey's glen, on the line between sections 23 and 22, T. 11, R. 7 E., Sauk county; and again in Dorward's or St. Mary's glen, on the line of sections 18 and 7, T. 11, R. 8 E., Columbia county. In all these places, the sandstone layers appear to possess a small dip, about 5°, away from the quartzite core. At **Dorward's Glen**, the quartzite is to be seen at the north end of the gorge, and lying upon and against it sixty feet of horizontal sandstone and bowlder-conglomerate, as shown in Fig. 27. These are exposed on the wall of the gorge, the conglomerate forming the base of the cliff and the stream bed, with a thickness seen of four feet. The bowlders of the conglomerate are largely irregular, angular masses reaching up to eight inches in size, and are almost entirely without surrounding matrix. The quartzite at the head of the glen is non-granular, pinkish-gray to red, and without plain bedding.

FIG. 27.



SANDSTONE AND CONGLOMERATE ON QUARTZITE AT DORWARD'S GLEN.

Scale 90 feet to the inch.

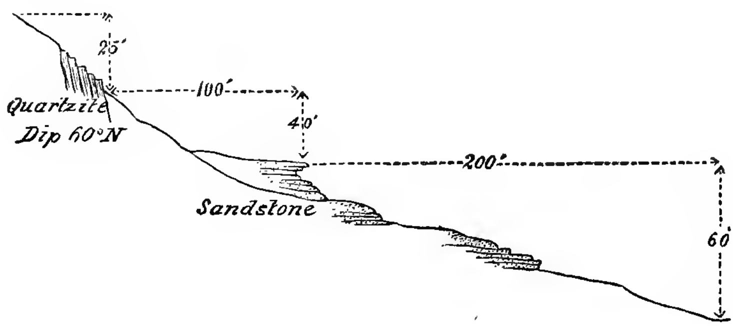
East of Sec. 3, T. 11, R. 8 E., as far as the end of the range, the flanking sandstone appears to be wanting, outcrops of quartzite in places extending from summit to base of the southern face of the range. Such a place occurs on the northern side of Sec. 3, and southern side of Sec. 34, T. 12, R. 8 E., near Mr. Fleming's house. Here the quartzite bluff rises immediately from the north side of the Portage road, showing for the first steep ascent of 250 feet, large loose masses and rough exposures of a metamorphic conglomerate, in which matrix and pebbles are both of quartzite, the pebbles being very small and in no way different from the matrix. From the top of this slope a gradually rising wooded step is crossed for about a third of a mile to a second nearly precipitous rise of over a hundred feet. The summit is of bare rock, and is a mere crest, others similar to it occurring east and west along the range. The bedding of the quartzite is distinct, the strike being N. 63° E., and dip 60° N.

On Secs. 34, 35, 26 and 27, T. 12, R. 8 E., numerous other large quartzite exposures occur. On the S. E. qr. of Sec. 27, large outcrops on the roadside show pinkish-gray, opaque quartzite (755) with very fine greenish-black streaks (Mica?).

The **eastern end of the quartzite ranges** is on Sec. 25, T. 12, R. 8 E., where the two ranges unite in the bold point that has been heretofore alluded to. On the north side of the point the horizontal sandstone begins again to flank the quartzite. On the N. W. qr. of Sec. 25, the road ascending the bluff shows sandstone, with a slight slant eastward, nearly to the top. Near by, on the S. E. qr. of N. E. qr. of Sec. 26, are large rounded exposures (*roches montonées*) of quartzite showing on the top glacial furrows and scratches, and also several large smoothed potholes, the largest two feet wide and one foot deep, with connecting furrows. Occurring where no stream could now possibly run, these potholes are of interest as showing the great erosion the quartzite must have undergone since their formation.

Along the northern side of the north range and westward from the eastern extremity, the flanking sandstone continues nearly to the county line. On the south side of section 23, well up on the bluff, a steep ravine has laid bare the sandstone and quartzite nearly in contact, as shown in Fig. 28. The quartzite here (753) is a fine metamor-

Fig. 28.



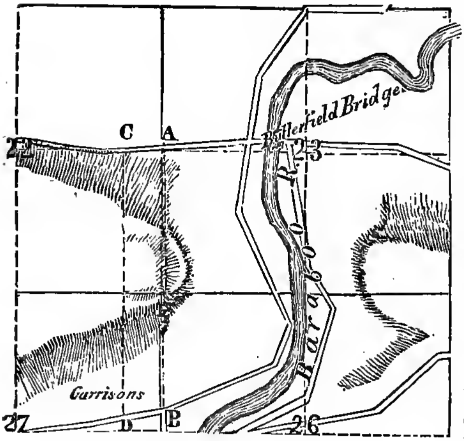
Unconformability, Sec. 23. Caledonia.

phic conglomerate, in which the matrix of pinkish-white quartz embraces darker-hued pebbles $\frac{1}{16}$ inch to $\frac{1}{4}$ inch in diameter. The pebbles are very firmly attached to the matrix, and are not always well defined from it. Nests and veins of white quartz (754) occur in this rock.

On the N. E. qr. of sec. 22, T. 12, R. 8 E., a deep ravine shows a great thickness of sandstone, with a bed of bowlder conglomerate, dipping northward, or away from the quartzite. Further westward along the road from Portage to Baraboo, which follows the foot of the bluff, sandstone is seen in numerous places. On the N. W. qr. of Sec. 21, high up on the bluff, a well goes through 10 feet of sandstone and then into quartzite. It is quite probable that the quartzite core is in places along here entirely covered by sandstone. The core does not extend, however, beyond the southern line of sections 19, 20, and 21, for here wells pass through over 170 feet of sandstone. After passing the county line, the north slope of the quartzite is again free from its sandstone mask, and is to be seen in small outcrops dipping N. 60°.

On Sections 23 and 26, T. 12, R. 7 E., Sauk county, the Baraboo river passes the north quartzite range in a gorge known as the **Lower Narrows of the Baraboo.** Fig 29 indicates the topography and points of interest in the vicinity of the Narrows. The passage is nearly half a mile in width, the level bottom extending to the foot of the cliffs on either side. The cliffs rise 400 feet above the river, and show finely the great beds of quartzite, and associated strata. The gorge is much wider than needed by the small stream that now occupies it, and may, as already suggested, have been at one time used by the Wisconsin, as the valley of Devil's Lake seems to have been. It is unlike the latter valley in having been, in part at least, formed first before the Potsdam period, as indicated by the way in which horizontal sandstone and conglomerate ledges occur around the heads of steep ravines that extend down the cliff towards the main gorge. Fig. 30 is a section north and south through the west bluff at the Narrows. It is a combination of a paced section made along the west line of sections 23 and 26, and of another, not so carefully measured, made about 40 rods further west. The first follows closely the edge of the cliff, where the quartzite beds are exposed to the southern edge of the ridge, the other runs a little west of north from Mrs. Garrison's house, in the N. E. qr. of Sec. 27, and passes for a long distance over horizontal sandstone and conglomerate layers filling an old ravine in the quartzite. The scale of the figured section is a natural one, and the contour indicated is quite closely that of the range on the westernmost of the two lines.

FIG. 29.

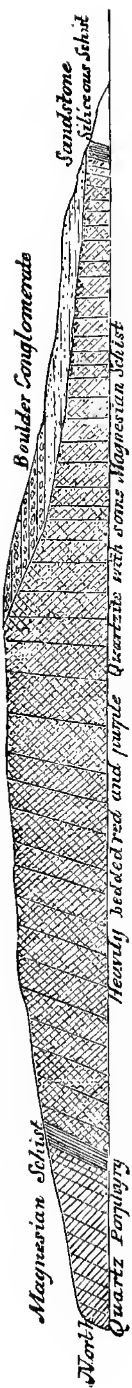


MAP OF THE LOWER NARROWS OF THE BARABOO.
Scale 1½ inches to the mile.

Beginning with the north end of the section, we find, forming the north face of the range, in bold northward sloping ledges, quartz-porphyry about 600 feet in width. This porphyry (1244, 1252) is for the most part dull-red to pinkish on the weathered surface, which is a good deal altered, often iron-stained, and has generally a whitish undercrust. The least altered specimens show a brownish-pink matrix, through which are scattered, very thickly, large facets, up to ⅛ inch in diameter, of bright-red cleavable felspar, and, more sparsely, minute facets of a white kind. In nearly all specimens a few small greenish-black blotches, apparently composed of fine mica scales, occur, as also small iron-stained cavities, which often show linings of minute quartz-crystals. The porphyry is very distinctly bedded, showing an E. W. strike, and a dip of 58° to 60° N. Towards its lowest portions, and higher up on the bluff, it becomes gradually more slaty in character (1245 and 1245a), the felspar facets, though very numerous, becoming at the same time less well defined, and the surfaces of the laminæ becoming covered with a soft greasy mineral. This finally changes to a distinct schist,[1] about 80 feet wide, containing a large proportion of the soft mineral, and allied to the greasy quartz-schists occurring at Devil's Lake, but without transverse cleavage. Continuing the ascent of the bluff southward, quartzite is seen lying immediately underneath the schist, and forming the body of the ridge to the foot of its southern slope. At first this quartzite is much veined and seamed with reticulating veins of white quartz, in which fine specular iron is occasionally to be seen. At the summit of the

[1] This schist is probably non-magnesian, like the schists of Devil's Lake, ordinarily called talcose.

FIG. 30.



NORTH AND SOUTH SECTION THROUGH THE WEST BLUFF OF THE LOWER NARROWS OF THE BARABOO.
Scale natural, 800 feet to the inch. Section about one mile long.

hill this character is less marked, and the rock (1253) is a dark reddish-purple quartzite with a distinct tendency to a granular texture, the individual grains being vitreous and translucent, but the rock as a whole having a dull, opaque appearance. The bedding of the quartzite is not everywhere very plain. Towards the north the layers appear to conform to the directions noticed in the overlying porphyry, but further southward the inclination is much steeper, and on the south slope, near the end of the ridge, beautifully ripple-marked vertical surfaces are seen. Interstratified with the quartzite in places are some greasy-surfaced schistose layers. At the foot of the hill, near Mrs. Garrison's house, the lowest member of the series is seen in a peculiar white to straw-colored quartz-schist or slate (1234). This slate occurs in regular smooth-faced, brown-tinted, layers, $\frac{1}{16}$th inch to 3 or 4 inches in thickness, and has a fine granular texture, the grains being of more or less angular quartz. Surrounding the grains and pervading the mass is a fine white pulverulent matrix, which renders the rock soft, and has a highly argillaceous odor when breathed upon. Only about 15 to 20 feet are exposed. The northward dip is very plain, the edges of the layers in places being much bent out of the true inclination, which, as seen in the old shaft near by, is as much as 60° to 70°. The whole thickness of the metamorphic rocks represented in this section is not far short of 5,000 feet.

A short distance westward, and a few feet above the quartz-schist just described, horizontal sandstone is quarried. Further up the bluff, this is succeeded by a great thickness, probably a hundred feet, of a horizontally bedded, coarse bowlder-conglomerate, the bowlders chiefly of red quartzite from the rocks near by, and the matrix usually a loose friable sand. The conglomerate rises nearly, or quite, to the summit of the ridge.

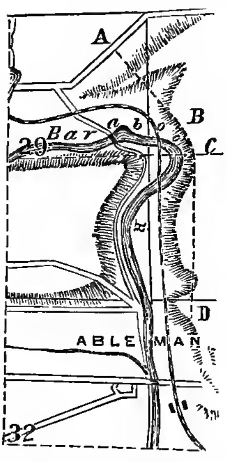
The east bluff of the Narrows does not present so fine a section as the one just described; the exposures are, however, very large. At the south point of the cliff, the elevation is 310 feet above the Baraboo, and the rock a very compact, red-tinged, slightly vitreous quartzite. Near the middle of the cliff, a very steep ravine indents its face. On the south side, and around the head of the ravine, are horizontal ledges of a conglomerate of quartzite pebbles up to 6 inches in diameter, for the most part without matrix. What matrix is present appears in many places to be almost as much of a quartzite as the pebbles themselves, though in others it is sandy and friable. On the north side of the ravine, semi-translucent, amethystine quartzite is seen, unconcealed by conglomerate. Further northward, the steep N. 70° dip of the quartzite is very plain, the dip surfaces being often laid bare for a great distance, and giving a very steep slope to the north side of the ridge. The east cliff of the Narrows does not extend so far north as that on the west.

West from the Narrows, for about two miles, the north face of the range trends north of west, continuing to show all along beds of quartz-porphyry. Since the strike throughout is E. W., the existence of a very much broader belt of porphyry than shown in the Narrows section is indicated. On the south side of the S. E. qr. of Sec. 16, the porphyry reaches its northernmost point, showing in a bold rocky projection. The rock here (1,242) presents a dull-brownish appearance on a weathered surface, and is much fissured by weathering, the surfaces of the fissures showing generally a brownish iron stain. A schistose structure is apparent in places, and the bedding is plain, with an E. W. strike, and dip of 55° N. A fresh fracture shows a compact, flaky matrix, of dark-brown to nearly black, sometimes grayish color, the last being characteristic of altered portions. The color is not quite uniform, but is mottled with fine strings and specks of whitish or pinkish color, and of indefinite outline. This matrix fuses easily to a black glass. In altered specimens it is easily scratched by the knife, in unaltered ones the knife makes almost no impression. Sparsely scattered through it are minute white and pink felspar facets, and still fewer large brick-red ones. In this regard the rock is quite different from that of the Narrows section.

About one-eighth to one-fourth of a mile eastward from this rocky point, in the N. E. qr. of the N. E. qr. of Sec. 21, the porphyry is seen again in a large exposure, showing the same weathered appearance, and bedding structure. Specimens from this place (1,243) resemble the rock last described, having somewhat more numerous felspar facets, and containing: silica, 71.24; alumina, 12.20; iron peroxide, 1.71; iron protoxide, 5.44; lime, 0.98; magnesia, 0.13; magnanese oxide, 0.97; potash, 1.86; soda, 4.29; water, 0.81 =99.63. The large content of soda, as compared with potash, is noteworthy.

The quartz-porphyries have thus been traced along the north flank of the range from the Baraboo Narrows, in Sec. 23, to the south side of Sec. 16. Judging from the bedding directions, their whole width cannot be less than three-fourths of a mile, nor their actual thickness short of 3,200 feet. They are found nowhere else in the Baraboo region. From the descriptions and analysis given it will be seen that these rocks have a matrix too silicious to be purely felspathic, through which are scattered crystals of orthoclase, possibly also of a soda felspar, the porphyritic quartz crystals generally characteristic of quartz-porphyry being absent. They are evidently nearer to true quartz-porphyry, however, than to the non-silicious porphyrites.[1]

FIG. 31.



UPPER NARROWS OF THE BARABOO.

Scale, 1½ inches to the mile.

Further west again, and until we reach the Upper Narrows of the Baraboo, in the town of Excelsior, the quartzite exposures along the north range are only occasional, as on the low ridge north of Baraboo, and on the N. E. qr. of Sec. 33, T. 12, R. 6 E.

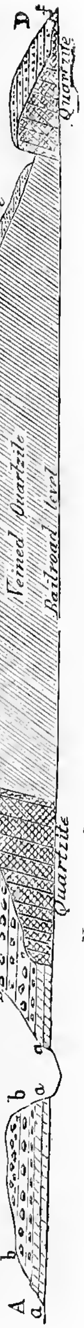
On Secs. 28 and 29, T. 12, R. 5 E., in the town of Excelsior, the Baraboo river breaks southward through the north quartzite range in a narrow gorge, 200 feet in depth, and something more than half a mile in length, known as the **Upper Narrows of the Baraboo.** For most of its length the ravine is just wide enough to admit of the passage of the river, railroad and a wagon road. Here the quartzite core of the north range is finely shown, flanked on either side, and even overtopped, by the horizontal sandstone and conglomerate. Fig. 31 is a map[2] showing the shape and character of the gorge. Fig. 32 is a section on the line A B C of Fig. 31, drawn to a horizontal scale of 750, and a vertical of 300 feet to the inch.[3]

[1] Von Cottas Lithology, pp. 168 and 214.

[2] Copied from Mr. W. H. Canfield's map of Excelsior.

[3] In Fig. 32, the inclined lines in the "veined quartzite" are meant for shading only, and do not indicate any structure to the rock, which, as described, is without distinct bedding,

Fig. 32.

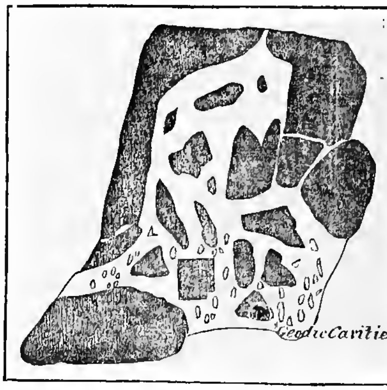


North and South Section, Upper Narrows of the Baraboo.

A, B, C, D, correspond to similarly lettered points on Fig. 31. a, a, a, cross-laminated sandstone; b, conglomerate; c, quartzitic and friable sandstone; dd, upper conglomerate, with quartzitic matrix; e, quartzitic sandstone; f, alternating quartzitic and friable sandstone.

At the southern end of the section — the "Jaws of the Narrows" — horizontal sandstone layers, alternatingly hard and quartzitic, and soft and friable, are seen abutting against and overlying heavy beds of northward-sloping, pinkish-gray, dark-gray, and purple, vitreous quartzite (1273, 1274). The exact contact of the two formations is finely exposed, the sandstone filling the cracks between the layers of quartzite and including large detached masses of the latter rock. A short distance northward, along the wall of the gorge, this quartzite is terminated by a steep ravine, on the north side of which comes in the veined quartzite that forms the body of the ridge. This curiously veined rock (1267, 1275) may be described as a light to dark-reddish, sometimes purple, usually somewhat vitreous, quartzite, which has been shattered throughout into small, sharply angular fragments, and these cemented together again by milky-white vein quartz, the numerous cavities in which are lined with small, brilliant, and very perfect quartz crystals. The extensive fissuring to which this rock has been subjected is indicated not only in the interlacing veins of white quartz, which often make up half the mass, but also in the frequent juxtaposition of different looking fragments of the quartzite. Certain portions of the rock are more fissured than other neighboring portions, and then appear like wide veins into which numerous fragments of the wall rock have fallen. Fig. 33 represents a small area, two feet by one and a half feet, of the veined quartzite, the white representing the vein-quartz, the black the fragments of red quartzite. In some of the crystal-lined cavities a soft white coating is noticed on the crystals. The same material is seen sometimes lying loose in the cavities and again filling minute cracks in a more compacted condition. According to Prof. Daniells' analysis it contains silica, 53.15 per cent, and alumina, 45.09 per cent., the balance being water. The bedding of the veined quartzite is indistinct. It appears to stand at a high angle to the northward.

Fig. 33.



Veined Quartzite.

North of and overlying the veined rock is another belt of quartzite (1277) without veins, of a pinkish color, and containing much of the greasy, talc-like mineral, which, in places, imparts a highly schistose character to the rock, sometimes predominating over the quartz. In these cases the slaty laminæ incline westward 15°, whilst the whole rock is intersected by E. W. planes standing at nearly 90°. The schistose layers are only in the upper portion of the belt which further south is purer quartzite with an evident northward dip.

As indicated in the figure, the quartzite is over-topped, for nearly the whole length of the section, by horizontal sandstone and conglomerate layers. The conglomerate capping the bluff in its higher portions, and overlying the veined quartzite, shows a mass of pebbles and small bowlders of the veined rock, compacted together without matrix, or with one that is very hard and quartzite-like, and of a brownish color. A fine exposure of this conglomerate is to be seen at the top of the cliff, at a point just east of the southernmost of the two railroad bridges within the Narrows, and on the south side of the bend which both gorge and river here make to the eastward. At the top of the cliff, on the north side of the bow, 140 feet above the railroad track, sandstone, partly hard and brownish, with a vitrified appearance, and partly friable, is underlaid by horizontal ledges of a conglomerate, having a hard quartzite matrix, and including red quartzite pebbles and bowlders of all sizes. Twenty-five feet below the top of the cliff, the junction of the conglomerate with the underlying vertically-bedded quartzite is seen. As viewed from the track below, the unconformability is very striking. The conglomerate extends northward from this point, and down the side of the ravine next north of the bend of the river, to within 30 feet of the railroad track. Its lower portions (1278) show a loose, friable, brownish matrix of coarse sand, the quartzite pebbles running up to a foot in diameter, but being usually smaller than this. Below the conglomerate, and abutting directly upon the railroad track, is a cliff 20 to 30 feet high, of coarse, brownish, friable sandstone, without pebbles, showing cross-lamination on a grand scale. North of the ravine, a low sandstone ridge is capped by the lower layers of bowlder-conglomerate.

On Sec. 31 of the town of Excelsior, is another gorge, known as the **Narrows of Narrows Creek.** In its structure and rock occurrences, this gorge is similar to the Narrows of the Baraboo, the veined quartzite, however, being less developed than at the latter place. Between the two gorges the summit of the range is quite level.

Westward from the passage of Narrow's Creek, the north quartzite range curves southward to meet the north and south ridge that connects it with the southern or main range. In the road near the center of Sec. 36, T. 12, R. 4 E., **Reedsburg**, well up on the ridge, quartzite is exposed with an E. W. strike and dip of N. 70°. This is its northern limit, and the western end of the range, for just west of the road a rocky ravine, over 100 feet in depth, shows the quartzite flanked on the north by heavy beds of coarse conglomerate and friable sandstone, the quartzite occurring only on the eastern wall of the ravine, the western side being altogether of sandstone.

South from the center of Sec. 36, along the connecting ridge, the ground rises steadily for several miles. For the first mile, horizontal sandstone ledges are seen rising to an elevation of 520 feet. In the north part of Sec. 13, T. 11, R. 4 E., **Westfield**, elevations of over 600 feet are reached. In this vicinity, and over a considerable area in sections 11, 12, 13, 14, 23 and 24, low outcrops of quartzite occur, the area including them being all very high, and constituting a rounded swell above the general level. A long, low outcrop near the Lutheran church in S. W. qr. Sec. 13, shows dark, purplish-red, flaky-textured quartzite (1322), which is plainly bedded, and laminated, and dips 57° N. W., the strike being N. 47° E.

Southward from the quartzite outcrops the elevation continues to be between 500 and 600 feet, in sections 23 and 26, but the only rock to be seen is horizontal sandstone. Westward from these sections, the elevation remains about the same, and one passes insensibly on to the Lower Magnesian limestone. Eastward, in sections 24 and 25, the descent of 200 feet to the headquarters of Seeley creek is very rapidly made, and sandstone is exposed through nearly the whole vertical distance.

On Sec. 35, a large exposure of reddish glassy quartzite occurs in a ravine, at an elevation much below that of the country occupied by sandstone to the northward. A few rods up the ravine, sandstone ledges occur at a higher level. Taken together with the construction of the high country all through the east side of the town of Westfield, this outcrop is believed to indicate the existence throughout of a quartzite core only slightly covered with sandstone layers.

The outcrop just referred to is on the slope downward towards the valley of the Wisconsin, and is really the western end of the southern quartzite range. From here eastward to Devil's Lake, we find this range as bold and wide as it is east of the lake, and characterized by the same heavy timber and clay soil. In T. 10, R. 5 E., **Honey Creek,** the southern slope of the range is in the northern row of sections. In the south side of T. 11, R. 5 E., **Freedom,** are very high rounded swells, some of which are amongst the highest points on the range. On the northern slope, in this town, the streams flowing north into the Baraboo set back into the ridge in deep ravines, about which sandstone sometimes occurs at high levels. On the N. W. qr. of Sec. 22, the quartzite shows in two bluffs, 150 feet high, on either side of the creek, with a distance between of about one-eighth of a mile. The rock here is for the most part closely like that at Devil's Lake, but portions are unusually light-colored (1,271), showing a light-brown weathered surface, and a nearly white, slightly granular, fresh fracture. Regularly interbedded is a soft, light-gray, greasy, finely laminated, clay-slate (1,272), containing according to analysis by Mr. A. C. Prescott: silica, 59.84; alumina and iron oxide, 35.39; magnesia, 0.10; water, 4.67 = 100; the iron oxide being in very small amount only. Both quartzite and slate are plainly bedded, the strike being N. 23° W., the dip 16° N.

On the road extending southward from Bloom's Station across the range, into Honey creek, horizontal sandstone ledges are seen, as far as the N. W. qr. of Sec. 23, at an elevation of 530 feet. In the southern part of the same section, quartzite is exposed at an elevation of 700 feet, and along the east side of Sec. 26, an elevation of 830 feet is reached.

In the southern row of sections of T. 11, R. 6 E., **Sumpter,** the south slope of the range is very bold and prominent, owing to the low ground of Sauk Prairie, which stretches from the foot of the bluffs for eight or nine miles to the southward. All along the slope towards the prairie are large rough exposures, — as, for instance, on the west Sauk road on Sec. 34; in the ravine on Sec. 27; on the east Sauk road, in Sec. 35, and all along the range eastward from here to the Devil's Nose. On the north slope of the range in the N. E. qr. of Sec. 15, T. 11, R. 6 E., dark-grayish, somewhat granular quartzite shows in a large exposure, with a dip of 26° N.

Within the circuit of the quartzite ranges, are a few isolated points of quartzite and schistose rocks, which rise through the sandstone that forms the basement of the valley. One of these, on the south line of Sec. 29, T. 12, R. 7 E., on Peck's Prairie, is a low rounded ridge 75 feet high. The rock here (1,247) is a light pinkish-grey metamorphic conglomerate, composed of small rounded pebbles of quartzite 1-16th to 1-8th inch in diameter, embedded in a finer-grained matrix of similar character. An obscure N. 70° dip is to be seen at a few points, and veins of milky quartz occur, carrying nests of large-surfaced brilliant specular iron (1,248). One of these veins is 75 feet long and 2 feet wide, with nests and seams of specular iron, 1 to 3 inches wide. A few rods west of the quartzite, at the center of the north line of the N. W. qr. of Sec. 32, horizontal sandstone ledges are seen.

Other areas showing quartzite and slate occur on Sec. 5, T. 11, R. 6 E.; Sec. 4, T. 11

R. 5 E.; and Sec. 2, T. 11, R. 5 E. The two former are high, rocky points, the latter a low outcrop on the river side. Still another occurs on the S. E. qr. of Sec. 33, T. 12, R. 5 E., near Ableman's. Here a railway cutting passes through the point of a ridge, near the north bank of the Baraboo river. At the west end of the cutting coarse white sandstone, in horizontal ledges, lies against a craggy cliff of light-colored quartz-schist (1284), resembling that at the south side of the section at the Lower Narrows of the Baraboo (see Fig. 30), but less regularly slaty. At the junction of the two rocks large bowlders of quartzite are included in the sandstone, which itself fills in the cracks between the layers of schist. One hundred and thirty feet from the west end of the cutting, the light-colored schist gives place to a gray or greenish clayey rock (1283). Some of the layers are bright green in color, and marked with very fine lines of lamination. These layers are apparently quite silicious. Seventy feet further, pinkish granular quartzite (1282) is indefinitely exposed. The exposures throughout the cutting, though in places 40 feet high, are very much jointed and confused. The position near the end of the ridge has caused much weathering and alteration. There is evidently a high dip, apparently to the north.

The Marcellon Quartz-Porphyry.

On Sec. 7, in the town of Marcellon, Columbia county, on each side of the road in the south half of the section, are two low rounded hills, 40 to 60 feet in height, of quartz-porphyry (759). The rock exposures are large, and are much rounded and weather-worn, being separated into numerous bowlder-like masses by wide-open, earth-filled joints. The weathered surfaces have a prevailing pinkish tinge, giving the idea that the rock is largely composed of pink felspar. On obtaining a fresh fracture, however, only a very few, sparsely scattered, minute felspar faces are to be seen, the mass of the rock being composed of a brownish to blackish compact matrix. Two general varieties occur, one presenting a light brownish color, showing a tendency to flake off in fragments that are translucent on the edges, and containing no distinguishable felspar crystals, the other having a dark-gray to black matrix, in which are to be seen a few distinct crystals of felspar and numerous copper-colored points of iron-sesquioxide. The rock has nearly the hardness of quartz, and fuses only with the greatest difficulty. A more silicious character as compared with other quartz-porphyries of the state is thus indicated, and the indication is borne out by the content of silica — 76.98 per cent. — as shown by analysis. We have evidently, in this case, a porphyry which, in its large content of silica, and in the sparseness of its felspar crystals, approaches the true felsites (petrosilex, hälleflinta). Quite a distinct and uniform set of bedding joints occurs, the strike being N. 32° E., the dip 65° to 75° N. W. Numerous cross-joints traverse the rock, and, on weathered portions, cause it to fly into smooth-faced, angular fragments, at the least blow of the hammer. The surrounding country is occupied by the Potsdam sandstone, which is exposed at many points.

The Observatory Hill Quartz-Porphyry.

Six miles north of the Marcellon outcrop, in the S. E. qr. of Sec. 7, in the town of Buffalo, Marquette county, a knob of quartz-porphyry rises 250 feet above the general level, and 490 feet above Lake Michigan. On the flanks of the hill and up to a vertical distance above the base of 125 feet, are horizontal sandstone ledges. Above, to the top, are nearly continuous outcrops of porphyry, with a not very plain N. 32° E. strike, and 60° N. W. dip. These bedding directions are the same as on the Marcellon outcrop.

The porphyry (762) has a dark-grayish to black compact matrix, in which are thickly scattered quite large (one-eighth to one-fourth inch in diameter) brownish to pink facets of felspar, the whole presenting a very dark-colored appearance. The silica content is 73.56 per cent., and the specific gravity, 2.60. Numerous close joints occur throughout the exposure, causing the rock to split like that of the Marcellon outcrop into small, irregularly shaped, smooth-faced, angular fragments.

The surrounding country shows everywhere the Potsdam sandstone as the surface rock. A high bluff of this sandstone, some 100 feet lower than the top of the Observatory, lies on the S. W. qr. of the same section.

The Moundville Quartz-Porphyry.

On the edge of the Fox river marsh at the head of Lake Buffalo, on the line between sections 8 and 5, T. 14, R. 9 E., Moundville, Marquette county, are three low rounded outcrops of quartz-porphyry. These are five miles, in a direction 10° N. of W., from Observatory Hill, which is the nearest Archaean outcrop. No other rock shows in the neighborhood, the country being heavily drift-covered. The largest outcrop is on the east end of a low bluff 35 feet high, and several hundred feet in length. There are quite marked appearances here of the same N. E. strike, and N. 60° dip, as seen at Observatory Hill and in Marcellon. The rock (1430) has a dark brown matrix, resembling in this regard the Marcellon porphyry, from which it differs, however, in showing throughout traces of crystalline structure, and quite thickly scattered, large, brownish felspar surfaces. A few crystals are white and translucent. The weathered surface is often of a bright pink color. Mr. Wright's microscopic examination (Appendix) shows that fine magnetite particles are abundant. Their existence is not rendered evident even by the use of the ordinary lens. The silica content is 72.76 per cent.

The Seneca (Pine Bluff) Quartz-Porphyry.

A rounded elliptical knob of quartz-porphyry, 100 feet high, ⅛th mile long, and ¼th mile wide, lies on the north side of the White river marsh, in Sec. 2, T. 17, R. 11 E., Seneca, Green Lake county. The greatest extension of the hill is in an east and west direction. It is largely rocky, but there are no abrupt rock ledges, the exposures being almost entirely surfaces conforming to the general contour of the hill, and on a level with the surrounding sod. In places, the slopes of the hill are covered with angular fragments, apparently split off by frost. This is a peculiarity not noticed on any of the other porphyry outcrops, and appears to be due to the large content of comparatively coarse, cleavable felspar. The hill is only about two miles south from the granite hills of Spring Lake, in T. 18, R. 11 E., Waushara county. The surrounding country is marshy and drift-covered, and shows no outcrop of horizontal rocks. The loose fragments are many of them smoothed on one side, and some surfaces are most beautifully striated. Owing to the broken condition of the outcrop, no definite bedding planes were made out, though weathered specimens brought away show distinct traces of lamination.

This porphyry in its least weathered portions (1410) shows a light-gray to whitish fine-grained matrix, made up largely of fine glassy felspar crystals, and containing numerous large surfaces of the same kind. The more weathered specimens (1412) have a pink to white, quite distinctly granular matrix, in which with the lens can be seen what appear to be angular grains of quartz. The glassy felspar crystals are also abundant. The weathered surface is brownish, with a kaolinized undercrust. Nearly all of the rock shows signs of weathering. The silica content is 76.39 per cent.

The Marquette and Berlin Quartz-Porphyries.

The large outcrops of quartz-porphyry on sections 34 and 35, T. 15, R. 11 E., and sections 2 and 3, T. 14, R. 11 E., near the village of Marquette, Green Lake county, were originally regarded as within the Central Wisconsin district, of which, however, by subsequent agreement, the Fox river was made the southern boundary. They will, therefore, be described by Prof. Chamberlin, in whose district is also the outcrop at the city of Berlin, Green Lake county. As the writer has examined both localities carefully, he may be permitted to allude to the nature of the rock of each, for the sake of comparison In the Marquette outcrops, the prevailing rock (761, 1,426), noticed, has a black, compact, flinty matrix, which is streaked with white non-continuous lines. These lines are, for the most part, very prominent, and are frequently much contorted, the whole rock having a very evident parallel grain. The felspar crystals are minute and sparse. The silica content (1,426), is 70.29 per cent. less than obtained from any other of the Wisconsin porphyries. The general course of the contorted laminæ points to the same N. E. strike direction, as observed on the Marcellon, Observatory Hill, and Moundville outcrops.

The Berlin rock has a dark bluish-gray matrix, much streaked with white, and having a peculiar fine-granular, quartz-like texture, as seen under the lens. The felspar crystals are small, greyish to brownish, and rather numerous. The lamination is very fine and distinct, and often contorted, and the silica content 74.37 per cent.

A comparison of the rocks of the several porphyry areas shows that though all present the same general kind of rock, no two of the areas are exactly alike in this regard. The porphyry associated with the Baraboo quartzite has a dark brown to black matrix, numerous large, pink, felspar crystals, and 71.24 per cent. of silica. The Marcellon porphyry has a brown to black matrix, is almost without felspar facets, and contains 77 per cent. of silica. The Observatory Hill porphyry has a black, flinty matrix with numerous large, brownish felspar facets, and contains 73.56 per cent. of silica. The Moundville porphyry resembles the Marcellon rock in the color and appearance of the matrix, but contains much brownish felspar, some magnetite, and only 72.76 per cent. of silica. The Seneca porphyry is altogether different from the others, in having a light colored, nearly white, somewhat granular, and distinctly quartzose matrix, and in containing much white, glassy felspar, the percentage of silica being 76.39. The Marquette porphyry has a black, flinty matrix, in this regard resembling closely the Observatory Hill rock, from which, however, it differs in being almost without felspar facets and in having its matrix streaked with white, and thus presenting a very marked lamination, the silica content being 70.29, or less than that obtained from any other of these rocks. The Berlin porphyry resembles that from the Marquette outcrop in having a marked lamination, but differs in the color of its matrix, in containing plentiful felspar facets, and in having a larger percentage (74.37) of silica. Its peculiar fine granular matrix is also a very distinguishing characteristic.

The Montello Granite.

In the village of Montello, on the west side of Sec. 9, T. 15, R. 10 E., Marquette county, is an elliptical-shaped rounded mound of pink granite, about a third of a mile in length, and 40 feet high. Over most of the hill the rock (756, 758, 764, 765) is quite uniform on a fresh fracture, though presenting a weathered surface from bright pink to dull grayish-pink in color. The weathering is very slight, however, and the rock shows almost no tendency to decompose. It has a medium grain, close texture, is of a bright pinkish color, and without sign of arrangement of the ingredients in lines. These are: rather large-flaked, pinkish, cleavable felspar, predominating; somewhat granular, fine, pinkish, translucent quartz, abundant; and greenish-black mica, sparsely scattered, in blotches made up of very fine flakes. In places, thin light-green epidote-colored seams occur (757). Somewhat irregular N. W. joints traverse the rock which is, however, for the most part structureless, and is quarried by firing, the pieces that crack off presenting a conchoidal fracture. On the north side of the west end of the mound occurs a vertical layer (or vein?) three feet wide, trending N. 55° E., of a soft greenish, highly schistose, decomposing chloritic rock (758). The least weathered specimens show a blackish color and some tendency to a crystalline texture. The vein is weathered down for two or three feet below the enclosing granite walls, both of which are seen. The schistose laminæ are parallel to the walls. Greenish epidote seams in the rock near by have the same trend as the vein. Though this granite might be somewhat difficult to obtain in dressable masses, it would undoubtedly make a very handsome and durable stone.

The Marion Granite Areas.

In the the town of Marion, T. 18, R. 11 E. Waushara county, are three low granite knobs. Two of these, Stone and Pine Bluffs, are on the N. E. qr. Sec. 27, about two miles in a N. N. W. direction from the quartz-porphyry hill of the town of Seneca, Green Lake county; and the third, a larger and bolder hill, lies on the eastern border of the marsh, on Secs. 12 and 13, and stretches to some extent over the line into the town of Warren, On all of these areas the rock (766, Sec. 27; 767, 768, Sec. 12) observed is nearly the same, a pinkish felspathic granite, mottled with gray and green, closely resembling the Montello granite, from which it differs, however, in having a coarser grain, less close texture, and a marked tendency to decompose. Reddish cleavable felspar is the principal ingredient, occurring in facets up to 1/8th and 1/4th inch in diameter; quartz is abundant, fine-granular and translucent; mica is sparse, and scattered in small, greenish-black blotches. Large whitish porphyritic felspar occurs. There is no sign of any arrangement of the ingredients, or of any parallel grain to the rock. No definite bedding planes were observed on any of the outcrops, though numerous crossing joint planes occur, and quite regular flat slabs are sometimes obtainable. Veins of white quartz occur. The most marked characteristic of the rock is its tendency to weather and shell off in crumbling masses. Some of the large flat surfaces are so far crumbled as to be penetrated readily by a horse's hoof. The rock from these outcrops would polish easily, but its tendency to crumble renders it less valuable than the Montello granite.

Conclusions. As indicated by their common character and strike direction, as well as their relative positions, the quartz-porphyry and granite patches of Columbia, Marquette, Green Lake and Waushara counties, which have been described in the foregoing pages, are doubtless to be regarded as but projecting points of one northeastward trending belt, the rest of which is buried beneath the Silurian sandstone and later superficial deposits. All, both granites and porphyries, belong evidently to the same formation. Moreover, the occurrence of similar porphyry with the quartzites of the Baraboo ranges, throws all the areas, without question, into the same category as those quartzites. We have thus a great quartzite series, including, also, quartz-porphyries, and associated with these pinkish, close-textured, (intrusive?) granite. Such an association is not a new one.

Percival[1] in alluding very briefly to some of the porphyry and granite areas, the rocks of which, however, he calls by other and incorrect names, intimates that the granite patches (his *syenite*) form a belt altogether to the westward of the others. This conclusion is not borne out by the facts. The Moundville porphyry lies on a line, as indicated by the N. 32° E. strike, altogether west of the Montello and Marion granites, which are thus, evidently, but portions of the same series.

The entire width of the granite and porphyry belt, at right angles to the trend, is not less than twenty-five miles, the Mackford area lying on the extreme east, that of Montello on the extreme west. The length from the Marcellon area on the south, in a N. 32° E. direction, is 30 miles. Regarding the belt as continuous, as it undoubtedly is, with the Baraboo ranges, it is evident that it must make a great bend northeastward, in the region about Portage. A glance at Plate XVIII of this volume, will suffice to show that, towards their eastern ends, the quartzite ranges are already on the turn.

The parallelism of the belt thus made out with the edge of the main Archæan area to the northward, is striking, and strongly suggests that we have here part of a once continuous band of Huronian surrounding the old northern core, after the manner of the later Silurian formations.

The Necedah Quartzite.

Dotting the great sand plain of the Wisconsin in Juneau and Adams counties, are numerous bold castellated outliers of the Potsdam sandstone, rising abruptly from the plain, and constituting very marked features of the scenery. From the same plain, and only about three miles west from one of the greatest of the sandstone bluffs — Petenwell Peak — rises the quartzite hill at the foot of which the village of Necedah is built. The rounded contour of this hill serves to mark it at once as different in nature from the sandstone bluffs of the adjoining region.

The main Necedah bluff lies on the N. W. qr. of Sec. 25, T. 18, R. 3 E., the town line crossing over its eastern end; it is about half a mile in length, with its greatest extension east and west, and is highest, and at the same time most bold and rocky, on its eastern end, which rises 170 feet above the street below, and about 510 feet above Lake Michigan. A short distance southeast of the main bluff, on the N. W. qr. of the S. W. qr. of Sec. 19, T. 18, R. 4 E., is a small, craggy hill, 75 feet high, of the same rock as that composing the main hill, the intervening low ground being underlaid by horizontal sandstone.

[1] Annual Report of Geological Survey of Wisconsin for 1855, p. 105.

The exposures on the main hill are mostly on the eastern and southeastern portions where in places they rise nearly precipitously from the low ground at foot. The rock seen here is for the most part (1354) a glassy, translucent, subgranular, grayish quartzite, much more nearly allied to the quartzite of Rib and Mosinee hills in Marathon county, than to that of the Baraboo ranges. Much of the rock is quite dark-gray in color, the quartz then being still glassy but smoky-tinted. Numerous small cavities and seams occur, lined with half crystalline quartz, and carrying a soft, pinkish, clayey substance; bluish-white quartz veins (1355½) one-half to two inches in width, and nests, are also common, and these carry frequently fine-flaked, brilliant, specular iron, which occurs also occasionally in quite large masses, similar to those found in the Baraboo quartzite. No parallel grain is to be seen in this rock, nor any definite bedding planes. Numerous quite close joints occur, however, and these cause the rock to weather into smooth-faced, sharp-angled fragments. On the smaller bluff a very distinct parallel grain is to be seen trending N. 75° W., and showing a corresponding dip of 45° N. Here much of the quartzite is of a light pink color, looking, on a fresh fracture, almost like a fine-grained, pinkish granite (1358), but the only prominent mineral is subgranular, translucent, pinkish quartz. Some specimens show mica plainly in very sparsely scattered, small scales. In many places little centers of iron-staining seem to be decomposing mica scales. Other portions of this rock (1358, 1357) are opaque, white, and distinctly granular, and are seamed with fine black lines, arranged so as to show discordant stratification. These seams when split open, appear to be composed of blackish mica. Bluish-white veins and nests occur here also.

PLATE, XIV.

The Milwaukee Litho & Engr Co.

POTSDAM SANDSTONE,

Southern end of Roché a Cris Bluff, Adams Co. 225 ft. high.

CHAPTER IV.

THE LOWER SILURIAN ROCKS.

I. In General.

THE LOWER, OR POTSDAM, SANDSTONE SERIES.

Forming the base of the pile of Silurian strata everywhere in the states bordering the Upper Mississippi, but having a much greater surface development in Wisconsin than elsewhere, and resting directly upon the irregular surface and upturned edges of the older crystalline rocks, is a great thickness of sandstone, which, through the larger part of its mass, is made up of rolled grains of quartz, of varying size, cemented together by a minute quantity of hydrous iron oxide. Towards the upper part of the formation, in Central Wisconsin, this sand becomes mingled with more or less dolomitic and calcareous material, which further up tends to aggregate into thin bands of limestone, finally forming, at 35 to 50 feet below the base of the next great formation, the Lower Magnesian limestone, a well marked and very persistent yellow limestone layer, which has a thickness of 30 feet, and is so well marked and important a horizon in Central Wisconsin, that I have given it the specific name of *Mendota limestone*, from a large exposure at MacBride's point on the north shore of lake Mendota. Above the Mendota horizon, sandstone, 35 to 50 feet in thickness, again comes in, the larger part of which is either nearly pure white quartz sand, or sand turned brown by oxide of iron, thus approaching more nearly in character to the Upper or St. Peters sandstone than to that immediately beneath the Mendota beds. Towards its upper portions, however, just beneath the overlying limestone, it generally becomes again somewhat dolomitic, the upper limit being frequently marked by layers of greensand and oölitic chert. To this layer I have given the name of *Madison sandstone*, it yielding large quantities of a very excellent building sandstone at Madison. These names are not meant to be of anything more than local importance.

For some distance above the Madison horizon the Lower Magnesian itself often shows alternations of nearly purely dolomitic, and distinctly sandy layers, even including thin seams of white sand, whilst some sandy material occurs at horizons well towards the summit of this formation. The two series thus evidently graduate into one another, and in many parts of the northwest it is undoubtedly difficult to fix upon the dividing line. In Central Wisconsin, however, the alternating beds are well defined, and two horizons are well marked by beds of greensand. These are the base of the Lower Magnesian proper, and the base of the Mendota beds, 65 to 100 feet below. During the writer's earlier work in this field, the lower of these limits was adopted, in mapping, as the line of division between the two formations, whilst subsequently both horizons were mapped, the upper one being taken as the base of the Lower Magnesian, in order that that name might cover the same beds as included under it by other members of the geological corps.

The facts which led at first to the use of the lower limit may be briefly given here. In Dane and Columbia counties, where the Mendota and Madison horizons are very prominent, and were first made out, the entire thickness of the Lower Magnesian, between the upper surface of the Madison beds and the base of the St. Peters or Upper sandstone, was found to be only 50 to 80 feet. It was well known that not far to the westward, along the Wisconsin, this formation attains a thickness of 250 feet. It was not thought so great a thickening as this could exist, and to explain the difference, it was supposed that the Mendota and Madison beds were a local modification of the lower portion of the Lower Magnesian formation. This supposition was encouraged by the great similarity between the Mendota, as seen in the typical localities in Dane county, and the limestone beds immediately overlying the Madison sandstone, the former here being almost a pure dolomite, with only two or three per cent. of insoluble residue. Subsequently, however, it was ascertained beyond a doubt that the Mendota beds are to be recognized occupying the same position below the Lower Magnesian, even where that formation attains its greatest thickness, its irregularity in this regard being proved to be due to its having suffered a surface erosion prior to the deposition upon it of the St. Peters sandstone. The Madison and Mendota beds were therefore thrown back into the Potsdam series as its uppermost layers, and are so mapped on all of the Atlas maps.

For all those portions of the maps, however, which represent the Central Wisconsin district, except southwestern Juneau county, on Area II, the base of the Mendota beds is indicated by a brown line within the color for the Potsdam series, the space between this line and the brown-colored Lower Magnesian area being occupied by the Madison and Mendota beds. In the sections also, both of the Atlas plates and of the plates in this volume, the Mendota and Madison beds are given separately from the Potsdam. Having been mapped out with some care, it was thought best not to lose the work done on them by not so distinguishing them. Moreover, the close likeness often borne by the Mendota to the Lower Magnesian, and the graduation of one series into the other, render it a matter of doubt whether to affiliate these beds of passage with the upper or lower of the two series. Constituting so important a feature as they do in the Central Wisconsin stratigraphy, they deserve separate mention; they are really beds of passage, and as such are separately considered below. The term *Potsdam*, then, as used in the detailed descriptions and sections of this chapter, applies only to those beds terminating upwards at the Mendota base.

Of the **two names given to the series** the term "Lower Sandstone" was used by Dr. D. D. Owen, as distinguishing it from another much thinner, but very prominent, sandstone, which overlies the Lower Magnesian — the Upper or St. Peters sandstone. Hall and Whitney first used the term "Potsdam," transferring it from the sandstone series which forms the Silurian base in the state of New York, and contains a few fossils close to those in the Wisconsin beds, which, however, contain many that are not found in New York. That the two formations are somewhere nearly the equivalents of one another appears evident, as Hall has shown.[1] The extension of the New York name, originally given to a comparatively small thickness of rock which occupies a restricted area, to the lowest of the fossiliferous Silurian beds all over the country, seems, however, unfortunate, and especially so in the case of the Wisconsin formation, which has a thickness of 800 to 1,000 feet, comes to the surface over an extended area, and is far more fossiliferous than the New York beds.

Of **former investigations** on the Potsdam series, Dr. Owen's seem to have been much the most exhaustive. He presents a scheme of the subordinate structure of the formation which may be considered quite remarkable for so early a day. His detailed investigations, however, did not extend far away from each side of the Mississippi, and the great central area of Wisconsin, where the formation spreads over a district 100 miles in diameter, and presents elements of stratification contrasting much with those exhibited along the Mississippi, he left hardly touched. Having no data from Artesian borings, he greatly underestimated the thickness of the formation, putting it at

[1] 16th Annual Report N. Y. State Cabinet Natural History.

500 feet as an extreme, instead of 800 to 1,000 feet. Into this error he appears to have been led by committing the graver one of supposing that he had to do with the base of the sandstone whenever he found it in contact with the crystalline rocks, losing sight altogether of the great irregularities of the upper surface of the latter rocks, by virtue of which they rise high into the upper parts of the sandstone series. In cases like that exhibited at the Dalles of the St. Croix, where the Copper-bearing rocks are seen to rise nearly perpendicularly through many feet of the sandstone, he regarded the traversing rock as "intrusive," or of later origin altogether.

Hall's investigations in the Central Wisconsin region do not appear to have been any more extensive than those of Dr. Owen, to whose descriptions of the stratigraphy of the series he adds little that is new. As regards the fossils of the formation, however, he makes a very important contribution,[1] giving a list to which little has been added by the present survey, as far as Central Wisconsin is concerned, and a grouping of the fossils into those characterizing the lower, middle and upper beds, which, in its general order, proves to be quite correct. He commits the same error as Dr. Owen, however, with regard to the thickness of the formation, placing it at only 500 feet.[2] As a result of this, his list of fossils from the lower beds must be assigned to about the middle of the series, below which are full 500 feet, about whose fossils, or lack of fossils, we know nothing at all. This may be regarded as a point of some importance in comparing the Wisconsin Primordial with that of other regions by the fossils contained. Whitney, who reports on the Lead Region in Hall's volume on Wisconsin Geology, follows the latter gentleman in his under-estimate of the thickness of the Potsdam series.

Of all of the earlier accounts of the geology of Central Wisconsin, I have found that of Dr. Percival, who worked after Owen and before Hall and Whitney, by far the most reliable. Dr. Percival published two small annual reports, in pamphlet form, whilst geologist of the state, in both of which he gives descriptions of the Wisconsin formations, whilst one of the two gives an account of a reconnoisance in the Potsdam sandstone region of the heart of the state. He recognizes distinctly the very great thickness of the formation, its lack of uniform character, and the fact that much confusion had been caused by the reference to the Lower Magnesian, by Dr. Owen and his assistants, of several distinct limestone bands separated by sandstone strata, and regarded by Percival as included in the Lower sandstone, this

[1] 16th An. Rep. N. Y. State Cabinet of Nat. Hist.

[2] Report on the Geology of Wisconsin, Albany, 1862, p. 16.

applying especially to the succession of strata exposed along the St. Croix river. He notices also, distinctly, the bed I have called the Mendota, and also numbers of other minor points mentioned by no other geologist.

The **surface distribution** of the Lower Sandstone exceeds that of any other of the formations of the Central Wisconsin district. The region occupied by it embraces all of Juneau, Adams, Waushara and Marquette counties, as also more or less of Portage, Wood, Clark, Jackson, Sauk, Green Lake, Columbia and Dane counties — in all, an area of over 6,000 square miles. The total area occupied by the formation outside the Central Wisconsin district, and within the state, is probably as large again, but nowhere else is there one continuous area of so great diameter as in the central counties. Over a large portion of this district, in Jackson, Wood, Clark, Portage, and portions of Juneau and Adams counties, there is no distinct evidence that the newer formations ever spread. Another large portion, including Waushara, Marquette, northern Green Lake, western Columbia, northern Sauk and southern Juneau, well away from the regions of the newer rocks, was originally, beyond doubt, overlaid by at least the Lower Magnesian, this formation occurring on two outlying bluffs in the northwest corner of Marquette county, 25 miles distant from the main area of that formation. There are again smaller areas, as the strip along the Wisconsin below the great bend, and the district about the head waters of the Catfish, in Dane county, which occur altogether within the country of the newer formations, and have, beyond doubt, been reached by erosion along the existing valleys.

On the north, the main area occupied by the lower sandstone is limited by the larger one in which the crystalline rocks are at the surface. The **boundary between the Potsdam and Archæan areas** is quite difficult to trace. As stated on a previous page, the streams flowing southward from the Archæan area cut through the sandstone beds down to the crystalline rocks, for many miles after entering the sandstone district, whilst on the divides between the streams the sandstone stretches as far north into the Archæan regions. The difficulties in tracing the boundary line in any greater detail than thus stated lie in the peculiar irregularity of the upper face of the older rocks, which may bring them to the surface at any point; in the once greater spread northward of the sandstone, as a result of which it is liable to be found in little patches, filling the depressions of the older rocks; and in the heavy coating of drift that conceals the rock beneath over considerable areas. To these difficulties may be added the fact that the country is largely unsettled, and covered by heavy forests and swamps. The former spread northward of the sandstone beyond its present limits is indicated by the occurrence on the highest part of the dividing ridges of outliers of that formation, 100 to 200 feet in height, and also by the occurrence in the northern drift of large quantities of loose sand.

Notwithstanding these difficulties, it is believed that the boundary line, as indicated on Atlas Plate XV, Area F., is not far from correct. The principal facts upon which it is based may be here briefly stated. On the east side of Area F., sandstone is seen in a small quarry on a ridge on the west side of Plover river, on whose bank, just east, and at points all along whose course to the mouth, the crystalline rocks are exposed. From the quarry mentioned to Stevens Point, sandstone appears to underlie the surface. At Stevens Point, it appears at the top of the bank on both sides of the Wisconsin river, whose bed is on crystalline rocks. A short distance north of Stevens Point, on the road to Wausau, and also on the road following the west bank of the river, crystalline rocks are to be seen, and no sandstone is met with further north. The Wisconsin Central Railroad cuts through sandstone at Stevens Point, but farther to the west and north it is altogether on crystalline rocks, as shown by several cuts between Stevens Point and Junction City. The Wisconsin Valley Railroad, from Knowlton, Marathon county, to Centralia, Wood county, is also altogether on the crystalline rocks, which, for the most part, lie near the surface, with very little drift covering. Along the east side of the Wisconsin, below Stevens Point, sandstone 5 to 40 feet in thickness is constantly to be seen in the east bank of the river, the crystalline rocks appearing in the river bottom as far as Point Bass, Sec. 15, T. 21, R. 5 E., Wood county. At this point the crystalline rocks disappear, and the sandstone in turn forms the river bed. Northward from Point Bass, along the west bank of the river, sandstone shows again, at intervals, as far as Centralia. The Wisconsin Valley Railroad, north from Centralia, as already said, is always on the older rocks, but a considerable thickness of sandstone occurs in a ridge on the south side of Mosquito creek, Secs. 29 and 30, T. 23, R. 6 E. Farther north, along the line between sections 7 and 8 of the same town, small thicknesses of sandstone fill depressions between the ridges. On the north side of the Wisconsin, between Mosquito and Mill creeks, sandstone occurs at several points, but does not stretch far north, for crystalline rocks are at surface over the northern parts of T. 23, R. 6 and 7 E. Mill creek is altogether on the crystalline rocks. Along the line of the Green Bay and Minnesota Railroad, westward from Grand Rapids as far as Merrillon, Sec. 15, T. 23, R. 4 W., Jackson county, thin, shaly sandstone is frequently exposed in low cuts, but having evidently a small thickness only, for, at the crossing of Black river, gneiss is exposed, as also on Yellow river, a short distance north of the railroad crossing. Between Grand Rapids and Dexterville, the sandstone does not stretch far north of the railroad line, for along the wagon road between the two places granite is seen at the surface.

On Yellow river the crystalline rocks are first exposed about two miles above the railroad crossing, beyond which point they are constantly exposed in the bed of the river, sandstone appearing at points on the west bank as far north as the northern side of town 24. Rocky Run, in towns 23 and 24, is on crystalline rocks. In the towns on the divide between Yellow and Black rivers, sandstone appears to be generally the surface rock, the Archæan only occasionally appearing through it. All along the road from the crossing of Yellow river, on the south line of T. 25, R. 2 E., Wood county, to Neillsville, in Sec. 14, T. 24, R. 2 W., Clark county, the country is generally high and heavily drift-covered, wells passing through 5 to 100 feet of drift into sandstone. Sandstone is also occasionally seen at the surface, as in the road on the S. E. qr. of Sec. 12, T. 24, R. 1 W., and in an outlying bluff at the center of the S. E. qr. of Sec. 12, T. 24, R. 1 E. Sandstone also occurs in angular fragments on the ridges along the west fork of Yellow river in T. 25, ranges 1 and 2 E. Further north, in towns 25 and 26, ranges 1 E. and 1 W., drift covers the rocks heavily, and the exact extent of the sandstone has not been ascertained, as indicated by the blank space left on the map. O'Neil's creek, in T. 24, ranges 1 and 2 W., cuts down to the older rocks. On Sec. 11, T. 24, R. 2 W., sandstone occurs by the side of the road, and again in a high outlier on Sec. 3, of the same town, on the west side of Black river. Westward from this outlier the country shows sandstone at the surface. Similar bluffs occur in T. 25, R. 2 W., the crystalline rocks showing along the river, and at least one such bluff occurs in T. 26, R. 2 W., its exact location not being known to the writer. In T. 26, ranges 3 and 4 W., sandstone is reported by Dr. Randall[1] as extending as far as the Eau Claire river, beyond which it is absent. At the crossing of Black river, one mile west from Neillsville, S. W. qr. of Sec. 15, T. 24, R. 2 W., granite is exposed in the river, and is overlaid by sandstone in the banks. Similar conditions hold all along the river, as far as the falls in T. 21, R. 4 W., the

[1] Owen's Geological Survey of Wisconsin, Iowa and Minnesota.

Archæan rocks becoming more and more restricted to the stream bed, until they finally disappear.

The **boundary between the Potsdam and Lower Magnesian areas** is much more easily traceable, it being possible in the driftless district to map it with almost any degree of accuracy, the only limit being the amount of time spent in following its windings. In drift-covered regions this degree of accuracy is not attainable, but a distinct break in the topography generally suffices to give the line very closely. It has already been said that in the Central Wisconsin district there occur well-marked beds of passage between the Lower Magnesian and the Potsdam, whose surface distribution has been separately mapped. These layers, however, only occasionally have a wide surface spread, appearing generally on the steep flanks of the higher ground occupied by the Lower Magnesian, and thus forming on the map a narrow strip along the outer edge of the Lower Magnesian area. The limits of the Lower Magnesian, and of the beds of passage, are so close together that, in a general description like the present, they may be regarded as one. On the east we find this boundary without the limits of the Central Wisconsin district until the northern line of Columbia county is reached. This county it crosses in an irregular line, curving from northeast to southwest, and marked by a prominent and deeply indented escarpment. North and west of this line the country shows everywhere the Potsdam as the surface formation, except on the summits of the numerous outliers which flank the escarpment. At the southwest corner of Columbia county, the Wisconsin enters upon the territory of the Lower Magnesian, through which it cuts, however, deeply into the underlying sandstone, so that along the valley bottom we have a broad strip of the latter formation at surface, and along the numerous tributary streams on each side, strips of greater or less width. In the Four Lake country, about the city of Madison, the upper layers of the Lower sandstone are again brought to the surface by a different system of erosion, that of one of the main branch streams of Rock river. The valley surface is never, however, more than 30 to 50 feet below the summit of the sandstone (the Mendota base), and south of Lake Monona the southerly dip carries even the uppermost beds below the valley bottom. In Sauk county, north of the Wisconsin, the boundary of the main Potsdam area follows the west side of the town of Honey Creek, then bending around the western end of the Baraboo quartzite ranges, in the towns of Westfield and Honey Creek, crosses Reedsburg, Ironton, La Valle and Woodland, in a northwesterly direction along the west side of the valley of the Baraboo river to the very southwestern corner of Juneau county. This line is, however, anything but a regular one, the Lower Magnesian occurring in more or less detached areas crowning the summits of the higher grounds. In Juneau county only a few small summits in the southwest corner reach the Lower Magnesian horizon, the rest of the county being well down in the Potsdam series. West of Juneau county the boundary is without the Central Wisconsin district.

The **topographical characters** of the regions in which the Potsdam is the surface rock have already been generally given in the chapter on Surface Features, and further details are given in the latter half of the present chapter. It may be said, in general, that where this formation is at surface there is usually a loose, sandy, sterile soil, a sparse growth of small oak timber, mingling with and becoming replaced by small pine towards the north, and a general plain-like character, the plain dotted with lofty and rocky outliers of the same formation, or of the next higher one. To these general statements there are exceptions, the principal of which may be here given. Excellent soil is found within the Potsdam area where the drift covering is heavy, as in parts of Waushara county, or where alluvial depositions exist in the valley bottoms, as in places along the Wisconsin valley, or yet again where a rough, ridgy character to the country prevails, as in southwestern Juneau county, where good land occurs on the top of the ridges, being due possibly to the tendency of the loosened sand to wash downwards towards the valleys. To the general plain-like character of the Lower sandstone area, southwestern Juneau county and northwestern Sauk make an exception, the Baraboo river and its tributaries having worn the ridge that bounds the central sand plain into an adruptly ridgy country. Another exception is found in parts of Waushara county, where morainic drift occurs in great abundance.

The **general lithological characters and stratigraphical arrangement** of the Lower sandstone series will be best understood from a brief summary of the main facts obtained in the different districts in which the formation is at surface.

At Madison, Dane county, the Artesian well in the Capitol park passes through 126 feet of loose materials, apparently all belonging to the Drift, 704 feet of sandstone, for the most part purely silicious, light-colored, and fine-grained, the constituent grains being all more or less rolled, and cemented by a varying, but always very small, amount of hydrous iron oxide — and 10 feet of a red shale, underneath which are the crystalline rocks. Similar results are obtained from the well at the Milwaukee and St. Paul depot at Madison, the summit of this well being at a lower level, and the drift 70 feet in thickness. In the former well, the top of the rock is 63 feet, in the latter, 100 feet below the base of the Mendota limestone, as exposed in the neighborhood. On the banks of Lake Mendota, near Madison, we find exposed, beneath this limestone and above the lake level, one foot of greensand and 31 feet of fine-grained, light greenish, very friable, sandstone, including very thin dolomitic seams, and carrying throughout some dolomitic and calcareous matter, the content of purely silicious sand being 84.45 per cent. Altogether, then, we find in the Madison region, the following succession of layers between the Mendota base and the Archæan:

	Feet.
1. Greensand layer	1
2. Calcareous and dolomitic, friable, fine-grained, greenish, sandstone	31
3. Not known	31
4. Light colored sandstone, for the most part purely silicious, being made of rolled quartz grains; but no specimens obtained from the uppermost layers	704
5. Red shale	10
Total	777

Along the Wisconsin river bluffs in Columbia, Sauk and Dane counties, the Mendota horizon is very prominent, the sandstone showing below it for a thickness of 150 to 200 feet. The very bold bluff that rises from the north bank of the Wisconsin river at the mouth of Honey Creek, in the town of Prairie du Sac, Sauk county, shows the following section, from the Mendota base downwards:

	Ft.	*In.*
1. Greensand with thin, brown, calcareous layers; the greensand layers made up of fine grains of glauconite and white sand, mingled with crystalline calcite	3	..
2. No exposure	7	..
3. Fine-grained green and brown sand, calcareous	2	2
4. Loose white and brown sand, some layers partly calcareous	10	..
5. Firm and heavy layers of yellowish, porous, calcareous, sandstone, interstratified with layers of white sand	6	3
6. Alternations of pure white, non-calcareous, fine-grained sand, with nodular-weathering, yellow, calcareous layers, and layers of dark greensand, the whole showing fine cross-lamination; the white sand layers predominating,	45	..
7. Fine-grained light-colored sandstone; often pure white, and loose; in parts cross-laminated, the lines of cross-lamination being marked by rows of glauconite grains	9	6
8. Porous, yellowish-brown, slightly calcareous layers	4	11
9. No exposure	11	6
10. Fine-grained, friable, greyish sandstone, only slightly calcareous, carrying a few yellow calcareous layers as above	11	5
11. Firm layers of ferruginous sandstone, more calcareous than the last	5	6

	Ft.	In.
12. Loose brown sand	11	..
13. Unexposed	7	..
14. Porous and crystalline-textured, yellow limestone, with much coarse and bright green glauconite	1	..
15. Unexposed	3	5
16. Like No. 14, interstratified with bright green seams	2	4
17. Heavy brown layer of slightly calcareous sandstone	3	..
18. Greensand layer; a mixture of very fine white sand and glauconite grains, with some crystalline calcite	..	10
19. Light yellow, friable sandstone; only slightly calcareous; cross-laminated,	5	4
20. Greensand layer, like 18, false bedding very marked, cross-laminæ very plain	..	13
21. Porous, yellow, slightly calcareous sandstone	..	6
22. Fine-grained, cross-laminated, slightly calcareous sandstone, with much greensand	1	11
23. Greensand, like No. 20	..	10
24. Fine-grained, friable, white sandstone, slightly calcareous	1	..
25. Unexposed	12	7
26. Fine-grained, white sandstone, entirely non-calcareous; made up altogether of fine rounded grains of limpid quartz	22	..
Total	189	3

The horizon of the base of this section is 146 feet below the top of the rock in the capitol well at Madison, thus covering the gap in the Madison section. Combining the two sections, we obtain for the whole series the following general succession:

	Feet.
1. Alternations of layers of purely silicious white sand, ferruginous brown sand, yellowish calcareo-arenaceous layers, and layers of greensand; the calcareous bands increasing in amount of lime and in number towards the top, as is also the case with the greensand layers	165
2. Entirely non-calcareous, white and yellow, sandstone; friable to indurated; fine to coarse-grained	602
3. Red shale	10
Total	777

The calcareous layers have never been observed extending more than 150 feet below the Mendota base. The "greensand" layers mentioned are mixtures of green grains of a mineral probably closely allied to the glauconite of the Cretaceous formation, rounded grains of quartz, and usually more or less of angular pieces of calcite. These layers are very characteristic of the lower sandstone, occurring, according to Dr. Owen, at many different horizons throughout the series as developed along the Mississippi. In Central Wisconsin, however, none have been recognized more than 160 feet below the Mendota base. No chemical investigation of Central Wisconsin greensand has ever been made, but Dr. T. S. Hunt has given an analysis of a greensand from the Lower Magnesian limestone of Minnesota, at Red Bird, on the Mississippi, which is beyond doubt the same material. This analysis (I), as also another, by the same gentleman, of the Cretaceous greensand of New Jersey (II), is given below:[1]

	I.	II.
Silica	46.58	50.70
Alumina	11.45	8.03
Iron protoxide	20.61	22.50
Magnesia	1.27	2.16
Lime	2.49	1.11
Soda	0.98	0.75
Potash	6.96	5.80
Water	9.66	8.95
	100.00	100.00

The green grains of both Cretaceous and Silurian greensands, as also of similar deposits in existing seas, are often found as casts of the shells of rhizopods. So far as the writer's knowledge goes no such observation has ever been made with regard to the Wisconsin greensand. The greensand layers are by no means restricted to the Potsdam series; they occur in both the Lower Magnesian and St. Peters. Greensand grains occur also apart from the regular green layers. The thin, yellow and brown, rough-textured, calcareous bands, that characterize the layers immediately beneath the Mendota, are often dotted with coarse grains of glauconite, which are not in sufficient quantity to impart their color to the rock.

The generalized section given above for the Potsdam series, below the Mendota base, holds true for a large part of the Central Wisconsin district, and would be satisfactory for all of it, but for the facts next to be stated. Proceeding northward from the valley of the Wisconsin, we encounter, traversing Sauk and eastern Columbia counties for 25 miles from east to west, the Archæan quartzite ranges described in the last chapter. The Mendota horizon continues well marked directly up to the ranges, whilst in the country west and east, it extends much further to the northward. Everywhere about the quartzite, however, we find, lying unconformably upon it, layers of sandstone and bowlder-conglomerate, which, as regards altitude, appear to occupy the entire distance between a horizon considerably below the Mendota, and one nearly as high as, if not higher than, the summit of the Lower Magnesian. These layers of sandstone and conglomerate cannot, in all, be less than 400 feet in thickness, being nearly always without calcareous admixture. Single cliffs occur showing 225 feet

[1] Geology of Canada, p. 488.

of friable, entirely non-calcareous, sandstone, the summits far above any apparently possible position of the Lower Magnesian, whilst below their bases numerous other sandstone exposures occur, carrying the sandrock down further. Nor are these occurrences of thick and high-level sandstone at any considerable distances from points where the regular succession of Lower Magnesian, Madison and Mendota is to be observed. In places in the town of Westfield, on the western end of the quartzite ranges, it is possible to pass within a quarter of a mile from Mendota limestone, occupying its normal position, to sandstone ledges which rise from the same level for over 250 feet.

As already described, the quartzite ranges almost completely encircle the intervening valley, whose altitude is somewhat greater than that of the surrounding outside country. Within the valley, non-calcareous, occasionally much-indurated, sandstone, with local conglomerate beds, is to be seen at almost all levels to the summits of the quartzite ranges, but at two points limestone is known to occur. These localities are described fully in a subsequent page. It is now merely necessary to say that at one of the places, on the south flank of the north quartzite range, near the Lower Narrows of the Baraboo, are to be seen 20 feet of limestone, containing a number of fossils, mostly of new species, which Mr. R. P. Whitfield regards as unquestionably not lower than the Lower Magnesian. Below on the side-hill are numerous but not continuous exposures of sandstone, those nearest the limestone evidently forming the next lower layer, and resembling closely the Madison beds. Across the valley, one-half mile southeastward, is a vertical cliff of red-and-white-banded, fine-grained, friable sandstone, rising from 75 to 165 feet above the summit of the limestone, whose altitude is what would be expected for the Lower Magnesian, from the occurrences of that formation a few miles to the southward. One mile further west sandstone and bowlder-conglomerate, flanking the quartzite, rise similarly above the limestone.

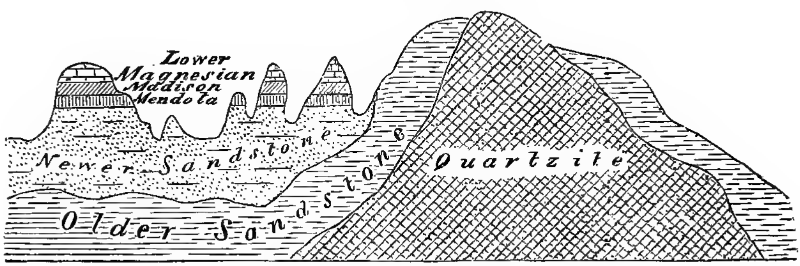
At the other point, not far from the village of Baraboo, and on the north slope of the south quartzite range, exactly similar limestone is found, without fossils, covering a small summit, and underlaid by ferruginous, fine-grained sandstone, carrying *Scolithus* and *Dicellocephalus Minnesotensis*. At a still lower level, near by, a fine-grained, yellowish, aluminous limestone occurs, the three different layers having just the characters and relative positions for the Lower Magnesian, Madison and Mendota beds. Below the lowest limestone layer, and within a few rods of it, are, however, ledges of much indurated, non-calcareous rock, entirely unlike the friable dolomitic sandstone normally occurring beneath the Mendota. Three miles south of east from here, about Devil's Lake, the high level sandstones, with bowlder-conglomerate beds, are again found, with a total thickness exposed of over 300 feet, the base being nearly on a level with the lowest of the limestones at the locality just described. In one place, a short distance northeast of Devil's Lake, large loose masses of this sandstone occur at an altitude between 100 and 150 feet above the last named limestone, carrying fossils, among which are *Dicellocephalus Minnesotensis* and others supposed to indicate the upper layers of the Potsdam series.

For these anomalous occurrences, which will be more fully understood from a study of the sections of Plates XIX and XX, and Figs. 48 and 49 of this volume, and of the detailed descriptions in the following pages, it is not easy to find a satisfactory explanation. It appears altogether inadmissible to attribute the great elevation of the high-level sandstone to a sudden affection of the nearly horizontal strata by a violent northern rise as they near the quartzite ranges. This supposition is forbidden by the utter lack of any indication of such a rise in the large exposures that occur; by the normal succession of beds that holds true in all the region east, west and north of the quartzite ranges; and by the great amount of rise that would be necessary. In Westfield it would have to be 300 to 400 feet to the mile. Moreover, within the space enclosed by the quartzite ranges, as described, occur the Lower Magnesian, Madison and Mendota, in their normal succession, and with their normal lower level, whilst in one case the limestone and perfectly horizontal high-level sandstone are so near by that no amount of dip could possibly account for the occurrence. It may be regarded as beyond question that entirely non-calcareous sandstone with bowlder-conglomerate and Potsdam fossils does, not only apparently, but actually, occupy the whole space between the horizon of the base of the Mendota, and that of the summit of the Lower Magnesian.

It might be supposed that the wear of the quartzite ranges continued to produce sandstone and conglomerate beds during the growth of the limestone in the deeper water near by, but the suddenness of the transitions, the occurrence of Potsdam fossils in the sandstone, and the existence of the limestone layers close to and within the quartzite ranges, appear great difficulties in the way of such an explanation. That the high-level sandstones represent really an older series, upon whose eroded upper surface rest the calcareous sandstone of the Potsdam, the Mendota, the Madison, and the Lower Magnesian, as indicated in the ideal sketch of Fig. 34, appears a more satisfactory explanation, but one which meets a considerable difficulty in the occurrence of upper Potsdam fossils in the high-level beds, and one which I am somewhat loath to advance, as too bold a generalization from the facts in hand. It is not impossible that the true explanation may lie in the supposition that during the deposition of the Potsdam series the quartzite ranges, being high islands and reefs in the ancient seas, received synchronous littoral depositions at high and abnormal altitudes, the sand and bowlders for these depositions coming from the wear of the quartzite itself.

Leaving now the Baraboo region, and proceeding northward along the eastern side of the district, we find, everywhere in the neighborhood of the escarpment that forms the western edge of the main area of the Lower Magnesian, the same succession of layers as seen along the Wisconsin in Columbia and Sauk counties, i. e., Madison and Mendota beds, underlaid by 100 to 150 feet of calcareo-arenaceous layers, and these again by brown and white non-calcareous sandstone. This succession holds true at least as far as Waupaca county, and probably further than this. West of the escarpment, in Waushara, Marquette and Columbia counties, the country surface is generally

FIG. 34.



IDEAL STRUCTURAL SKETCH, SHOWING POSSIBLE RELATIONS OF THE HORIZONTAL FORMATIONS IN THE VICINITY OF THE BARABOO QUARTZITE RANGES.

well down in the Potsdam, and much drift-covered. In central Waushara county, however, are some high hills reaching into the limy beds just beneath the Mendota, and showing the normal succession of layers; whilst in the very northeast corner of Marquette county, 25 miles from the boundary of the main Lower Magnesian area, are two isolated bluffs, capped by that formation, which show also the usual layers. It is thus evident that for all this region there are no departures from the Madison section. At several points in Marquette and Waushara counties quarries are opened in beds that lie about 200 feet below the Mendota, and yield a much indurated, white sandrock, which is occasionally quite coarse, and is made up of nearly glassy quartz pebbles.

Proceeding now westward into Adams and Juneau counties, we find again some apparently abnormal occurrences. One mile west from the lime-capped bluffs at the northwestern corner of Marquette county, are other bluffs, showing large exposures of the limy layers that come immediately beneath the Mendota. One and a half miles northwest from here, on Sec. 3, T. 17, R. 7 E., across an intervening level stretch of sand, is one of the towers of sandstone that characterize the central plain — known as Pilot Knob. This peak rises 25 feet above the top of the calcareous layers seen just across the valley, and 65 feet above their base, and yet from its summit down for 150 feet, we find only altogether non-calcareous sandstone, much of which is highly ferruginous, and all of which is quite unlike any of the layers that are usually found within 200 feet of the base of the Mendota. Moreover, two fossil horizons, yielding *Ptychaspis Miniscœnsis*, and other forms, supposed to be characteristic of the middle portion of the lower sandstone, occur in this exposure. We have, then, here, to some extent, a repetition of the anomalous occurrences of the Baraboo region—noncalcareous, red, ferruginous sandstone, with fossils indicating a horizon full 300 feet below the Mendota, rising through the horizon of the upper calcareous beds, into that of the Mendota. Some nine miles west of Pilot Knob, near Friendship, Adams county, occur other similar sandstone towers, all showing entirely non-calcareous, friable rock. On the summit of one of them, the Roche à Cris, is to be recognized the uppermost of the fossil horizons of Pilot Knob, the lower one of which, marked by a peculiar lithological character, is still more unmistakably to be recognized on another bluff, some five miles south of Friendship. Both of these horizons indicate a slight rise of the layers *eastward* towards Pilot Knob. Still another one of these outliers, the Friendship Mound, rises 85 feet higher than the Roche à Cris near by, carrying the light-colored, friable, non-calcareous sandstone all the way. The horizon of the summit of this bluff is, then, 85 feet above that of the summit of Pilot Knob, or, if the latter rises into the horizon of the Mendota, as high as the position that would be expected for the Lower Magnesian, from its occurrences in northeast Marquette county.

At the southern end of Adams county, the Wisconsin passes the gorge known as the Dalles. At the northern end of the gorge is another of the large sandstone outliers like those just mentioned — the Elephant's Back. This bluff, with the walls of the gorge below, gives a nearly continuous section of 310 feet. At Kilbourn City, two miles below, an Artesian boring penetrates into the underlying Archæan. Combining the results of the section and boring, we have the following general succession:

	Feet.
Fine-grained sand layers; of varying colors, in upper portions; with gaps of 10 to 70 feet; including at base some quite coarse-grained sand layers; all formed of rolled quartz, and all entirely non-calcareous	310
The same continued in the Artesian well	385
Red shale	15
Total	710

At the summit of the Elephant's Back, fragments of trilobites occur in the loose sand rock, and the horizon may be the same as that on the top of Roche à Cris. The occurrence here of the same red shale as observed in the Madison wells is worthy of notice. The same layer has been reached by Artesian borings in other parts of the state.

Returning now to the Baraboo ranges and passing northward from their western ends along the west side of the district, we find in the town of Reedsburg, Sauk county, the Lower Magnesian, Madison and Mendota, with their usual characters. In the same town, at points some miles apart, exposures of a bed of red shale are to be seen whose horizon is 140 feet below the Mendota base. Further north, in northwestern Juneau, a high, ridgy country is met with, carrying sandstone at high levels, in what would be expected to be the Lower Magnesian horizon. This, however, appears to be due to a thickening of the Madison beds, since the Lower Magnesian is found capping a few very high points, and the Mendota beds below continue recognizable. In southwestern Juneau county, on the inner side of the high ground bordering the central plain, are numbers of isolated sandstone outliers. Some of these show a bed of red shale and soft greensand, which appears to be the same as that seen in the town of Reedsburg. This greensand layer, about 130–140 feet below the Mendota, is the lowest seen anywhere in the Potsdam series of Central Wisconsin.

Still further north, the country is generally eroded well down into the middle of the Lower sandstone, so that the Archæan rocks are not very far beneath the surface, which they come nearer and nearer to, towards the north. Over much of Portage, Wood, Jackson and Clark counties, the thickness of the sandstone cannot be more than 25 to 60 feet. In places in this region, the sandstone lying within 20 to 40 feet of the crystalline rocks is a much indurated, coarse, white rock, which yields a valuable quarry stone, and appears to occupy the same horizon as a similar rock in Waushara and Marquette counties. It is probably to be referred nearly to the middle part of the Lower sandstone. The sandstone immediately in contact with the crystalline rocks is usually a quite friable, fine to coarse-grained, brownish rock, containing pebbles from the rock below.

It is not at all impossible, as already indicated, that the anomalous occurrences about the Baraboo quartzite ranges, and in Adams county, may mean that the Lower sandstone really consists of two series, the one, including the ordinary calcareous sandstone that comes beneath the Mendota, and an unknown thickness below, resting upon the eroded surface of the other. Dr. Owen gives sections from the St. Croix region, showing the Lower Magnesian occupying positions lower than the Potsdam in the immediate vicinity, which may indicate the same thing. These occurrences on the St. Croix are also described by Dr. Percival in some detail, he considering them best explained by the existence of several alternations of limestone and sandstone. Still more strongly confirming the idea, are the occurrences in the vicinity of the Archæan patches at Berlin, in Green Lake county, and Portland, in Dodge county, as described to me by Professor Chamberlin. In the former case, a mound of quartz-porphyry projects into the horizon of the Lower Magnesian, but is flanked by sandstone containing the fossils regarded by Hall as belonging to the middle Potsdam. In the latter case, several distinct mounds of Archæan quartzite lie in the horizon of the St. Peters sandstone, which shows on the margin of the low ground in which the mounds occur. Flanking the quartzite, however, are layers of a bowlder-conglomerate carrying *Scolithus*, which is usually regarded as restricted to the lower sandstone. It is quite evident that even if the lower sandstone really does include two formations so distinct in age as these facts seem to suggest, such a division of the series would be quite difficult to demonstrate, on account of the great lithological similarity between the two divisions, whilst, if proved, the separation of the two in mapping would be even more difficult.

The **beds of passage** between the Potsdam and Lower Magnesian series include, as already said, two well marked beds, 60 to 90 feet in combined thickness — the *Mendota limestone* and the *Madison sandstone* — which, from their prominence in Central Wisconsin, are worthy of separate mention. For the most part these layers come to the surface only on the flanks of the higher levels occupied by the Lower Magnesian, so that they present on the map only narrow bands bordering the areas of the last named formation. In that part of the Catfish valley, however, which lies between the southern shores of Lakes Monona and Kegonsa, they are at the surface over a wide area, whilst in some parts of Columbia county the belt occupied by them sometimes reaches two or three miles in width. Both beds are to be distinctly recognized throughout the Central Wisconsin district, wherever the base of the Lower Magnesian can be inspected. The northernmost point at which I have recognized them is at the northwest corner of Marquette county, the southernmost on the south shore of Lake Kegonsa in Dane county; the two points being about 70 miles apart. The most distant points east and west at which they have been seen in Central Wisconsin are about as far from one another. To the northeast, however, Prof. Chamberlin thinks he has recognized the Mendota as far as the Michigan line, whilst Mr. Strong carries the same layer westward to the Mississippi.

The Mendota and Madison beds often have a marked effect upon the topography, producing, by their different hardnesses, benches in the sides of bluffs. Where the Mendota is at surface over any considerable area, it produces generally an excellent clayey soil; whilst the Madison soils, as in a large part of the town of Otsego, Columbia county, are as loose and sandy as those of the Potsdam proper. About Madison, where the two layers were first distinctly recognized, the Mendota has a thickness of 30 to 35 feet, of which the lower 20 feet are of a heavily-bedded, dark-yellow and brown, jointed, conchoidal-fracturing rock, which is stained in seams and patches by the red oxide of iron, and leaves on solution 3 to 10 per cent. of an aluminous and non-arenaceous residue. This rock quite closely resembles the lower portions of the Lower Magnesian proper, having sometimes the concretionary structure characterizing that formation. The upper part of the Mendota about Madison resembles the lower, except in being in thin, rough-surfaced, layers, and in carrying a somewhat larger percentage of silicious matter. To show the close similarity in composition which this phase of the Mendota bears to the Lower Magnesian, the following analyses are given, I being the Mendota, from the quarry near Greenbush, Madison, and II, Lower Magnesian from Williams' quarry, on the south line of the town of Madison:

	I.	II.
Silica	4.18	1.09
Alumina	2.17	.44
Iron sesquioxide	1.45	.43
Iron protoxide	....	.63
Lime carbonate	55.68	66.82
Magnesia carbonate	36.52	30.40
Water	.58	.35
	100.58	100.26

It will be noticed that in both the proportion of lime to magnesia carbonate is greater than in true dolomite (1.19:1). Both yield, also, on solution, an argillaceous residue, differing in this regard from the limy layers of the Potsdam proper, which always yield a residue of white quartz-sand, with or without glauconite grains. The close earthy texture of the Mendota also contrasts greatly with the porous and highly crystalline character of the lower calcareous seams.

The Madison beds, in the country about Madison, are about 35 feet thick, and consist usually of pure white, frequently loose, sand, overlaid by brown and yellow, firmer rock. The upper layers show generally a slight calcareous admixture, which locally increases to 10 or 15 per cent., the rock then becoming a good building material, and not being very sharply defined from the limestone above. The calcareous layers show well in the quarry just west of the city of Madison, where they are as much as 15 feet in thickness, and also in the large quarry near the village of Middleton. The section at the latter place, given in detail on a subsequent page, is of interest as showing the gradation of the Potsdam series into the Lower Magnesian, there being a number of thin alternating sandstone and limestone layers, whilst the upper Madison beds contain as much as 50 per cent. of lime and magnesia carbonates. West of Lake Kegonsa, in the town of Dunn, the Madison sandstone is as much as 50 feet in thickness, closely resembling the St. Peters, and grading downwards into the Mendota.

About the village of Lodi, in Columbia county, both Madison and Mendota are frequently exposed, with characters like those just described. Further northeast, along the western edge of the Lower Magnesian, they undergo some change. At Rio the lower portions of the Madison are composed of a firm, white, purely silicious material, which is made up of sharply angular quartz, whilst above, the ordinary brown, fine-grained rock comes in. Near Cambria, still farther north, the same thing is to be seen, the Mendota layers becoming at the same time largely replaced by reddish clay-shale, but still retaining in parts the typical yellow appearance. Near Marquette, in Green Lake county, the Madison has its usual brownish, friable character, whilst the Mendota is largely composed of a light yellow, regularly bedded, aluminous limestone, and is not well defined from the sandstone below.

Along the valley of the Wisconsin, in Sauk and Dane counties, both of the layers are well marked, the Mendota having most commonly the character last described. Its regular bedding makes it valuable as a building stone, and it is hence frequently quarried. Near Spring Green it reaches a thickness of as much as 45 feet in all, its upper layers being shaly and fossiliferous. The Madison sandstone in this section has also an increased thickness, reaching 45 feet, but otherwise it shows the characters before noted. Northward, along the west side of Sauk county, both layers continue well marked as far as the Baraboo river. Still farther north the Madison beds thicken to 60 feet, are made up of fine-grained, red and white, saccharoidal sandstone, closely resembling the St. Peters, and have at top one or two feet of cherty quartzite-like material.

To the list of **fossils** of the lower sandstone series given by Hall, but little has been added by the present survey, as far as Central Wisconsin is concerned. It has already been said that his general grouping, of upper, middle, and lower species, appears to hold true as regards the order, but that his lower species must really be assigned to the middle of the series, since its thickness is about twice as great as Mr. Hall supposed. Fossils are not plenty in the Central Wisconsin Potsdam. In the ordinary non-calcareous rock they occur as mere ferruginous coatings on the loose sand, trilobite fragments being the most common. In the upper shaly layers of the Mendota beds, very large impressions of *Dicellocephalus Minnesotensis* are quite abundant. The pygidium is most frequently found, some specimens measuring as much as six inches across. The same fossil, however, is found in the loose friable sandstones that lie upon the quartzites of the Baraboo ranges, and not improbably has a considerable vertical range, since it is quoted by Hall from the Lower Magnesian of Minnesota. One new fossil of some interest has been added to Hall's list. This is a very large new species of the genus *Palæacmea*, which was originally established by Hall and Whitfield, in 1867, to cover a "conical, patelliform, univalve shell," which occurs in the Potsdam sandstone of New York. The Wisconsin species is twice as large as that from New York, and is found in a very hard quartzite, which occurs interstratified with loose, friable sandstone on the Trempealeau river, in Jackson county, in the middle portion of the Potsdam series.

The **economic contents** of the Lower sandstone come under the heads of building stones, glass sand, and iron ores. These are described here in general only, all details, exact locations, etc., being given in subsequent pages.

The Madison sandstone, in the vicinity of Madison, yields a buff-colored calcareous sandstone which is largely quarried and used for building in that vicinity. This rock contains about ten per cent. of the carbonates of lime and magnesia, is easily cut, and obtainable in large blocks. It has a very pleasing appearance in the fresh state, but has some tendency to darken and become blotched under the action of the weather. The same rock is opened upon at Middleton, and in one or two places in the town of Westport, Dane county, and probably exists in considerable quantity in the country about Lake Mendota. The peculiar phase which yields the Madison building stone is, however, local, and quite inconstant. More commonly the formation is made up of white and brown friable sandstone, nearly or altogether without calcareous admixture. The brown layers are occasionally quite ferruginous and firm, yielding a fair quarry stone. The white sandstone is frequently a loose, white, purely silicious sand, and would be of considerable value for glass making. In one place on the western side of the town of Honey Creek, the Madison sandstone has a very unusual character, containing layers of a much indurated, fine-grained, smooth-faced, pink-tinted rock of very pleasing appearance.

The Mendota limestone is more frequently quarried than the Madison sandstone. It is not anywhere burnt into lime, being usually too impure, and always too dark colored, but the heavy yellow layers that characterize some ten to 15 feet of its middle portions, are to be seen in scores of quarries, most numerously along the Wisconsin valley. These layers yield a very regular stone, of any thickness from a few inches to two or three feet, which is commonly used for flagging or foundations, but occasionally for constructing entire buildings. The mill at Cambria, Columbia county, is built of rock from the Mendota horizon.

The Potsdam sandstone itself is generally altogether too friable to be used as a building material. At numbers of points in the Baraboo valley, however, a firm, fine-grained, white rock is obtained in large blocks. A similar rock is quarried on several of the isolated bluffs in Juneau, Adams and Jackson counties, the horizon being about 200 to 300 feet below the summit of the series. A very much indurated, frequently quite coarse, rock is obtained at a still lower horizon at Packwaukee, Marquette county, near Wautoma, Waushara county, at Stevens Point, Portage county, near Grand Rapids, Wood county, and at Black River Falls, Jackson county. This rock is very regular in bedding, white to straw colored, and makes a very durable and sightly building stone.

Limonite iron ores, of good quality, and in sufficient quantity to run two small blast-furnaces, occur in connection with the Lower sandstone in Sauk and Richland counties, just west of the limit of the Central Wisconsin district. Within that district, the only ore observed in any promising quantity occurs in the upper layers of the high-level sandstone that flanks the quartzite range in the eastern part of the town of Westfield, Sauk county. Here, at a number of points several miles apart, this sandstone may be seen very highly charged with the brown iron oxide, which, at times, almost entirely excludes the sandstone, having then mingled with it much of the red or anhydrous oxide. It appears quite probable that the amount of merchantable ore to be obtained in this neighborhood is sufficient to warrant exploitation. Very ferruginous sandstone, at a similar horizon, occurs at other points along the Baraboo ranges, but nowhere else have promising indications been observed.

THE LOWER MAGNESIAN LIMESTONE.

Succeeding the uppermost layer of the Potsdam series, the Madison sandstone, is a very persistent and wide spread bed of magnesian limestone, to which Owen gave the **name** of *Lower Magnesian*, to distinguish it from another equally persistent, and in many respects quite similar, magnesian limestone, that occurs higher in the series. To the latter the name *Galena limestone* has since become attached, whilst no other designation has been given to the lower formation. In neither case can the term *magnesian* be regarded as at all distinctive, since almost all of the limestone beds of Wisconsin, including the whole of the great thickness belonging to the Niagara group, are highly magnesian, the only exception to the general rule being the Blue limestone of the Trenton group. There appears to be but little doubt that the Lower Magnesian is nearly the exact equivalent of the Calciferous Sandrock of New York and Canada, with which formation, indeed, it is nearly continuous through the northern peninsula of Michigan and Canada West.

The **surface extent** of the Lower Magnesian limestone in Central Wisconsin is not nearly so great as that of the Lower sandstone, being, in all, not more than about 75 square miles. The main belt occupied by the formation enters Columbia county on the northeast ,with a width of about 6 miles, and, spreading further and further west as it is followed southward, occupies much, or all, of the towns of Randolph, Scott, Springvale, Courtland, Lowville, Otsego, Fountain Prairie, Columbus, Hampden, Leeds, Arlington, Lodi, and West Point in Columbia county, and large portions of Roxbury, Berry, Dane, Springfield, Vienna, Westport, Windsor, Bristol and York, in Dane county. Still further south, again, the formation occurs only in narrow areas, crowning the summits of the ridges between the valleys in which run the several head streams of the Catfish river, or forming narrow strips between the low ground of the valley of that stream, and the higher country which on each side is occupied by the St.

Peters standstone, and Trenton limestone. On the southern side of Dane county the Lower Magnesian sinks to the level of the Catfish valley, spreading over a considerable area in the towns of Rutland, Dunn, Pleasant Springs and Dunkirk. The numerous narrow steep-sided valleys, tributary to the valley of Sugar river, in Primrose, Springdale and Cross Plains, and the valley of Sugar river itself in Verona and Montrose, cut down to the upper surface of the Lower Magnesian, which thus forms narrow strips along their bottoms.

Along the edge of the main area, in Columbia county, and northwestern Dane, and usually not more than two or three miles west or north from it, though occasionally more than this, are many small isolated bluffs crowned by the Lower Magnesian. These vary in area from a few acres to three or four square miles. North of the Wisconsin river and along the west side of Sauk county, as far as the southern side of the Baraboo valley, the Lower Magnesian, in areas of varying size, occupies all the higher ground, the country being characterized by numerous narrow ridges, with intervening narrow valleys. North of the Baraboo, in northwestern Sauk county and southwestern Juneau, the Lower Magnesian occurs only in rare and very small cappings on the highest ground.

The **topographical characters** of the regions occupied by the Lower Magnesian differ much, according as they occur within or without the drift-bearing area, and also according to whether the formation exists on the higher grounds only, or has sunk down to the lowest levels. All of these regions, however, are alike in possessing a most excellent soil, the Lower Magnesian area including the best agricultural land in the district. In Columbia county the formation occupies a region which is for the most part very fertile, high, rolling prairie, the prairie areas forming a nearly continuous belt from the towns of Scott and Randolph, in Columbia county, southwestward to Middleton, in Dane county. This high belt breaks down suddenly to the westward, but the escarpment, though quite bold, is without the great cliff-like exposures so characteristic of the Lower Magnesian as it appears along the lower Wisconsin and upper Mississippi rivers. The same is true of the sides of the limestone ridges about the heads of the Catfish river. Along the Wisconsin, however, below Sauk City, the Lower Magnesian crowns the river bluffs often with bold cliffs, the difference being chiefly due to the absence of drift materials. Along the western side of Sauk county, the drift is also absent, and the usual abrupt, ridgy topography of the driftless regions is everywhere apparent, the limestone capping to the ridges being often a mere crest of rock, large fallen masses from which dot the side-hills below.

Whilst in minor details the Lower Magnesian varies much as to its **lithological characters** — even individual horizons not showing any great constancy in this regard — all parts of it have some features in common, which serve to distinguish it from the newer limestone formations of the region. In general, it may be said that the Lower Magnesian is a magnesian limestone, varying in composition from varieties that contain not more than one or two per cent. of insoluble ingredients, to those that are for the most part sand. An analysis has been given, a few pages back, of one of the purest phases, whilst in the detailed descriptions of this chapter, numerous determinations of the quantity and nature of the insoluble ingredients of both pure and impure varieties will be found. These in the purer kinds are exceedingly fine and clay-like, whilst in the less pure they are usually quartz sand of varying degrees of fineness, the constituent grains always much rolled. The analysis above cited, as also others made for the survey, do not show the carbonates of calcium and magnesium in the right proportion to make a true dolomite, the first-named carbonate being always in excess. Older analyses show a nearer approach to the composition of dolomite. The purest kinds have usually a grayish-white color, a minutely crystalline texture, and marked conchoidal fracture. More commonly the white back-ground is blotched with yellow, whilst other layers again occur, in which the buff color is uniform. These are usually characterized by a close, even, granular texture, which may be due to an admixture of sand grains, or may characterize a quite pure limestone.

The bedding of the Lower Magnesian varies much. Usually those layers from 40 to 60 feet above the base are the heaviest, the individual layers running sometimes to a thickness of 4 to 6 feet, whilst the bedding lines are exceedingly indistinct. In the upper and lower portions of the formation, the layers are usually much thinner, and more distinct, although commonly quite irregular, very rough-surfaced and internally porous, with drusy cavities that are lined with calcite and dolomite crystals. Occasionally, however, the lower layers are exceedingly regular, being obtainable in large, smooth-surfaced, compact, and finely granular slabs. Highly concretionary layers, some of which appear even to have a brecciated structure, occur at many different horizons in the formation, the structure sometimes affecting in the highest degree a layer not more than a foot thick, whilst above and below, for many feet, no trace of a concretionary structure is apparent. In other cases much greater and less well-defined thicknesses are affected in this manner. One of the most prominent features of the formation is the rough-weathering seen on nearly all outcrops, in some cases due to the concretionary structure of the rock.

Chert occurs very abundantly throughout the Lower Magnesian, and of three or four different kinds. In many places above the Madison sandstone there is to be seen a thin layer of greensand, and above this a thinner one, one to ten inches in thickness, of a pure white, oölitic, chert, which, on examination under the microscope, appears to consist of egg-shaped aggregations of fine glassy quartz grains, embedded in a still finer silicious matrix. This layer is very persistent in the country about Madison. A sample from the Madison quarries yielded: silica, 98.01; alumina, 0.52; iron peroxide, 0.73; lime, 0.67; magnesia, 0.21; water, 0.24=100.38. The same oölitic chert occurs disseminated through the layers of limestone in the lower beds, to the whole mass of which it often gives the appearance of an oölitic structure. The older writers on Wisconsin geology all speak of oölitic *limestone* as characterizing the lowest portions of the Lower Magnesian; so far as my observation goes, the limestone is not oölitic itself, but carries disseminated oölitic chert. Higher up, beginning usually some 30 feet above the Madison sandstone, a more compact chert comes in, increasing in quantity as the formation is traced upward. This chert is either quite compact and flinty, occurring in irregular layers or nodules, or is more or less cavernous, the cavities being lined with drusy quartz. Associated with the greyish-white beds of the least silicious limestone, is a chert occurring in well-marked layers and rows of nodules, which, in external shape and soft silicious coating, resemble closely the flints of the Chalk, whilst within they are often beautifully banded and jasper-like. Still higher in the formation, about 100 feet above its base, the thin layers of limestone are often replaced bodily, for considerable thicknesses, by a compact iron-stained chert.

Black dendritic markings are very common in the Lower Magnesian, but occur in the greatest abundance and beauty in those layers that are fine-granular and buff-colored, and not more than 30 to 40 feet above the upper surface of the Madison sandstone. The mineral causing these markings is supposed to be the black oxide of manganese.

In **stratigraphical arrangement,** the Lower Magnesian appears to show but little persistent regularity. An attempt to make out a thoroughly reliable and detailed scheme of the stratigraphy of this formation, meets with two considerable difficulties. The first of these lies in the fact that, although exposures are very numerous, it is only rarely that any considerable thickness can be seen at one place; so that numerous small, often somewhat distant, exposures have to be thrown into place by means of aneroid observations, a not very satisfactory guide. The other difficulty arises from the irregular nature of the upper surface of the formation, which is due to erosion before the deposition of the St. Peters sandstone, and as a result of which the Lower Magnesian varies from 50 to 250 feet in thickness. From this it follows that all determinations of horizon within the Lower Magnesian, made by measuring from the base of the St. Peters sandstone downwards, are worthless. Varying so greatly as it does in thickness, beds immediately underneath the St. Peters may, in fact, be nearer the base than the summit of the formation.

In the region around Madison, the Lower Magnesian has usually a thickness of about 70 to 80 feet, though it may run from 50 to 100. feet. The following outline scheme of the succession of its layers in this region is an abridgement of a more elaborate one, which accompanied the annual report on the field work of 1874, to which was also attached a large chart of grouped sections. These are not here reproduced, because the work of later seasons proved them to have only a local value. The numbers in the scheme are from below upwards, on account of the uncertainty as to any measurements from above, downwards. The exposures cited are only single instances out of many representing the different layers.

		Ft.	*In.*
VII.	Concretionary, brownish-yellow layers, which at times are quite sandy, and at others contain not more than 3 to 4 per cent of fine aluminous impurities; Veerhusen's quarry, Sec. 25, Westport; Williams' quarry, Sec. 33, Madison. Thickness about	10	..
VI.	Heavy. indistinctly bedded layers, which appear to vary much in character, being sometimes, as at Williams' quarry, Sec. 33, Madison, greyish-white, nearly free from foreign ingredients, minutely crystalline, conchoidal-fracturing and compact, but with small cavities lined with dolomite crystals. Interstratified are continuous seams, and rows, of white surfaced nodules of jaspery chert. At other times, as at Veerhusen's quarry, Sec. 25, Westport, these layers have a greenish-tinted buff color, and a fine-granular texture, containing 30 to 40 per cent. of fine quartz sand, and little or no chert. Thickness, in all, about	15	..
V.	Thin, regularly bedded, greenish yellow, fine-granular layers, with very abundant and large dendritic markings; Veerhusen's quarry	10	..
IV.	Very irregularly bedded, alternatingly heavy and thin, white-and-yellow-mottled, rough-textured, very cherty, layers; Middleton quarry	20	..
III.	Thin, irregular, usually somewhat sandy, brownish layers, including occasionally beds of 1 to 2 feet in thickness. Near the top a very highly brecciated layer, 1 foot thick, often comes in (quarry near the school house, Middleton); whilst below, oolitic chert pervades the limestone, and alternations of more and less sandy layers occur, constituting a passage downwards into the Madison sandstone (Middleton and Madison quarries). In some cases this gradation is not marked, the transition from a		

	Ft.	In.
nearly pure limestone to a nearly non-calcareous sandstone being quite abrupt (cut on Chicago and Northwestern road, Sec. 35, Madison; also, cut on same road at Mendota Station, Westport). Thickness	15	..
II. White oölitic chert layer (Madison quarries)	..	6
I. Greensand layer (Madison quarries)	..	6
Total	71	..

The bold bluff that rises from the mouth of Honey creek, Sauk county, has already been cited as giving an unusually complete section of the upper part of the Potsdam series. It shows, also, the largest continuous exposure of the Lower Magnesian that I have ever seen — a vertical cliff over 50 feet in height. The following is a detailed section of this cliff, beginning above:

	Ft.	In.
1. Heavy layer of brown-and-yellow-mottled limestone, which leaves on solution 2.2 per cent. of very fine clayey residue	1	..
2. No good exposure	5	..
3. Heavy layer of very close-textured, nearly white, limestone, with many dendritic markings; residue 9.09 per cent. and clayey	1	2
4. Thin layers, 3 to 4 inches each, of limestone like the last; residue 5.8 per cent., clayey	3	..
5. Thin layers of brown-and-gray-mottled limestone with minute crystal-lined cavities; residue 2.9 per cent., clayey	..	6
6. Heavy layer of light gray, close-textured limestone, with cavities like No. 5; residue 8.35 per cent., clayey	3	6
7. Two heavy layers like No. 6; residue 6 per cent., clayey	5	2
8. Shaly layers of porous, yellow-and-gray-mottled, crystalline limestone; residue 7.2 per cent., clayey	2	3
9. Three layers of yellow-and-gray-mottled, close-textured limestone; residue 18.85 per cent., clayey	3	..
10. Heavy layer of yellowish, sandy limestone; residue 40.17 per cent., fine, gray sand	2	..
11. Heavy non-arenaceous layer, with very indistinct subordinate bedding	3	6
12. Very irregular, brownish, close-textured limestone, occurring in thin broken layers, the cracks being lined with white stalactitic lime carbonate; residue 4.38 per cent., clayey	1	6
13. Two heavy layers of brownish-gray, close-textured limestone; residue 3.42 per cent., clayey	2	6
14. Irregularly thin bedded, very close-textured chonchoidal-fracturing gray limestone; residue 9.3 per cent., clayey	1	4
15. Very indistinctly bedded, nodular-weathering, close-textured, mottled limestone; residue 7.17 per cent., clayey	8	8
16. Very irregularly bedded, rough-surfaced, close-textured, gray limestone; residue 28.97 per cent., fine sand and clay	3	6
17. Thick layer of porous, brecciated, highly-crystalline limestone; residue 13.67 per cent., fine sand and white clay	1	9
18. Thick layer of compact, yellowish brown, granular, smooth-fracturing limestone, with much dendritic manganese oxide; residue 16.65 per cent., clayey	1	7
Total	52	5

The foot of the cliff is evidently very close to the top of the Madison sandstone, whose first exposure, however, is 15 feet below. Although the foreign impurities increase slightly in quantity downwards, we find no distinct evidence of a gradation into the sandstone below. In fact the whole cliff shows a nearly uniform material, the differences being but slight between the several layers.

North of Dane county the Lower Magnesian has the same general characters as described, with some local variations; but no scheme of elementary stratification for these districts has been made out. In the high prairie country of southern Columbia county the formation attains a thickness of 120 to 140 feet or more, the highest beds being generally very cherty, or even replaced bodily by chert. In central and northern Columbia the lowest layers have lost their irregularity of bedding and rough texture, and have become very evenly bedded and closely granular, at the same time showing little or no sandy admixture, and no passage downwards into the Madison sandstone, which itself continues non-calcareous upwards to contact with the Lower Magnesian. Along the western side of the district, in western Sauk county, the same lack of gradation downwards is generally to be noticed. In a large region lying south of the Baraboo quartzite ranges, small pebbles of red quartzite are frequently found in the Lower Magnesian.

The **irregular upper surface** of the Lower Magnesian, already mentioned, is one of the most striking features of the formation. The first demonstration of the existence of such an eroded surface was made by Prof. Chamberlin, in eastern Wisconsin, but since then numerous confirming facts have been collected in other parts of the state. The valley of Sugar river, and its numerous branch ravines, in the towns of Verona, Montrose, Primrose, Springdale and Cross Plains, cut down to the Lower Magnesian, the St. Peters sandstone forming the steep valley sides. At numerous points in these valleys, exposures of the Lower Magnesian are found at higher levels than those of the St. Peters, and under such circumstances that they cannot be regarded as proving a distinct and hitherto unrecognized layer of limestone; for they are often near to large sandstone ledges, which rise continuously from lower to higher levels than those at which the limestone is seen. A still more striking proof is found in the patches of St. Peters sandstone that are to be seen lying directly in the hollows of the Lower Magnesian, in the southern part of the town of Arlington, Columbia county; whilst the evidence is perhaps even stronger in the case of Gibralter Bluff, in the town of West Point, Colnmbia county, where a vertical cliff 135 feet high, of St. Peters sandstone, has its base 40 to 60 feet lower than the exposures of Lower Magnesian in the immediate vicinity. About Madison, in Dane county, the Lower Magnesian is only from 50 to 80 feet thick; just north in the high prairie country on the borders of Columbia and Dane counties, it has thickened to 125 to 140 feet, a fact in itself sufficient to suggest the existence of an eroded upper surface. It is not improbable that some of the swells of this high region are directly due to the irregular surface of the underlying limestone.

The **fossils** of the Lower Magnesian are not common, and when found are but obscure gasteropod and orthoceratite markings in the chert of the uppermost layers. If the two small patches of limestone already alluded to as occurring in the region between the quartzite ranges of the Baraboo be regarded as belonging to this formation, quite an interesting addition is to be made to the hitherto meager list of Lower Magnesian forms. The limestone of one of these small areas has yielded a number of fossils which are regarded by Mr. R. P. Whitfield, as "certainly not lower than the Lower Magnesian," to which formation the composition, lithological character, and position of the rock would also refer them, the difficulty lying in the peculiar conclusions that are thus led to with regard to the Lower sandstone in the vicinity, as explained on a previous page. These fossils are: *Stromatopora*, und. sp.; *Orthis Barabuensis?; Holopea*, n. sp.; *Maclurea Swezeyi*, n. sp.; *Illænus antiquatus*, n. sp.; *Dicellocephalus Barabuensis*, n. sp.; *D. Eatoni*, n. sp.; and triangular sheath-like bodies.

The **economic contents** of the Lower Magnesian are limestone for burning into lime, and building stone. Galena, in small quantities, has been obtained from crevices in the Lower Magnesian, but the only occurrence of this kind known in Central Wisconsin is that near Doylestown, in Columbia county, where a limited crevice in the lower part of the formation has yielded several hundred pounds of this ore. This occurrence is interesting because at such a distance from the productive lead region. I have seen no other indication that the Lower Magnesian is ore-bearing. Lime is burnt from the Lower Magnesian at a great many points, and from quite different horizons. The lime produced is uniformly quite slow in slacking, making, however, a very strong mortar. It is rarely very white. Many of the lower beds are too sandy for lime burning, the best for the purpose being apparently the heavy grayish-white layers 40 to 50 feet above the Madison sandstone. Twenty thousand bushels annually are burnt from these layers, on Sec. 33, T. 7, R. 9 E., the product being widely known as "Madison lime." The Lower Magnesian is in general too roughly or too indistinctly bedded to make good building stone, but the heavy beds just alluded to sometimes take on a different character, becoming fine-granular, and very evenly bedded, and yielding a superior cream-colored stone. Such a stone is quarried at one or two points in the town of Westport, and has been used in the construction of the State Hospital for the Insane, and the United States Court House at Madison.

THE UPPER OR ST. PETERS SANDSTONE.

To the layer of sandstone which, everywhere in Wisconsin, Iowa and Minnesota, is found resting upon the eroded surface of the Lower Magnesian, Dr. Owen gave the name of "Upper" sandstone, to distinguish it from the "Lower" or Potsdam sandstone. He also designated it as the "St. Peters" sandstone, from its prominent exposures on the St. Peters river in Minnesota. Mr. Hall regards the St. Peters sandstone as the equivalent of the Chazy limestone of New York, on account of its stratigraphical position. As to the correctness of this reference, I have not the means of forming an accurate opinion; certainly, however, between the periods of deposition of the Lower Magnesian and St. Peters, there was a long gap, whose record is found in the eroded surface of the first-named formation.

For a purely silicious sandstone, and one only 20 to 100 feet in thickness, the St. Peters has an extraordinarily wide **distribution.** It is known in Wisconsin at points 250 miles apart from east to west, and 180 from south to north, whilst to the west, south and east it extends far beyond the limits of the state. In the last named direction it is known to extend, because a number of Artesian wells at points along the shore of Lake Michigan show it with an unusual thickness. To the westward, in Minnesota, it is recognized for an additional distance of at least 100 miles, whilst to the southward also it is known to extend 100 miles beyond the Wisconsin line. Throughout all this large region, there is no question whatever of the identity of the formation, or of its actual continuity. Moreover, as far south as Missouri, the St. Peters is in all probability represented by the uppermost of the alternations of sandstone and limestone that form a large portion of the Lower Silurian strata of that section. Thus it appears that a nearly purely silicious sandstone of inconsiderable thickness has an unbroken extent over a region whose diameters are 500 and 400 miles.

In the Central Wisconsin district the St. Peters has never a very wide surface extent, forming more commonly narrow bands around the areas of the Trenton limestone. It is wholly confined to Columbia and Dane counties. In the former, it is met with in the northeast corner of the county, in the towns of Randolph and Courtland, with a thickness of only 20 feet, and forming strips not more than a few rods wide around several areas of Trenton limestone. Further south its main area lies altogether east of Columbia county, but it is found again in the southeast,-in the towns of Columbus and Hampden, with the same small thickness and distribution in a narrow belt around an area of Trenton limestone. The St. Peters is absent everywhere else in Columbia county, except in five small patches on the high prairie of Arlington, and in a still smaller area, but with a thickness of 125 feet, in the high peak known as "Gibralter Bluff," in the town of West Point. In Dane county, the St. Peters is found underlying the Trenton on both sides of the Catfish valley, sometimes coming to the surface as a narrow band only, at other times having quite a surface spread, as in Sun Prairie, Medina, Cottage Grove, Deerfield, Fitchburg, Oregon, Montrose, and Verona; these larger areas including a number of small patches of Trenton limestone, which caps the summits. On the west side of Sugar river, though having its full thickness, the St. Peters comes to the surface only in narrow bands, forming the sides of deep and narrow valleys. The same is true of the south side of the valley of Black Earth creek in Cross Plains and Middleton. In Berry, Springfield, and northern Middleton, the St. Peters occurs only in a few limited areas on the highest ground. The whole surface spread of the St. Peters, in Columbia and Dane counties, is not more than 225 square miles, all but 6 or 8 of which is in the latter county.

In eastern Columbia and Dane counties the St. Peters sandstone does not contribute any marked **topographical features** to the country, being comparatively thin and generally drift covered. Where it occurs in narrow bands around the Trenton areas, its place is not uncommonly marked by an abrupt change of level. On the west side of Dane county, however, and especially west of Sugar river, which forms the western boundary of the region of the Glacial Drift, the St. Peters affects the scenery of the country in a marked degree. Here we find it having its full thickness of 80 to 100 feet, and producing, by its friability, abrupt, and not infrequently precipitous and rocky, valley sides, whose summits are capped by the Trenton limestone, whilst the valley bottoms are on the Lower Magnesian. In the valleys themselves, isolated towerlike rocks of the St. Peters occur, of varying size, and occasionally of greater area at top than at bottom. Some of these contain the full thickness of the St. Peters, and are crowned with the lowest layers of the Trenton.

The St. Peters does not usually much affect the soil, since it forms only steep side-hills, or else is buried beneath the drift. Occasionally, however, where it comes near the surface over small level areas, as in part of the Sugar river valley, in the town of Verona, it produces a loose sandy soil.

In **lithological characters** the St. Peters is remarkably uniform. So far as my observation extends, it is invariably formed of a fine, purely silicious, sand, whose constituent grains are much rolled. No sign of crystalline surfaces to the grains has been observed in the many specimens examined with the microscope. The only foreign materials in the St. Peters are the hydrous and anhydrous iron oxides, which occur in all parts of the formation, banding it, or staining it for great thicknesses, with yellow, brown, or red. The iron oxide acts as a cementing material, but is not commonly in sufficient quantity to give the rock any considerable coherence. In the more western development of the St. Peters, it is described as often wholly without the iron oxides, and made up of pure white, entirely incoherent, sand, but this is not common in Central Wisconsin. Greensand layers, like those that occur in the Lower sandstone, are found also in the St. Peters, but none have come under my observation. No gradation downwards or upwards into the adjacent limestones by mingling with calcareous material has ever been noticed. No subordinate division of the St. Peters sandstone exists. It is quite uniform in character throughout. The bedding, however, is usually distinct, the layers being ordinarily very heavy, though sometimes quite thin and shaly. The lines of lamination are often marked by a red and white banding when no planes of separation can be detected. The surfaces of large exposures frequently show the hard, vitrified crust so characteristic of the Lower sandstone. To this induration is evidently due the maintenance of tower-like forms and cliffs in so friable a material.

The older geologists describe the St. Peters sandstone as very uniform in **thickness** placing it at from 70 to 100 feet, with a nearly constant thickness of 80 to 90 feet. According to the results of the present survey, although such constancy probably holds true for southwestern Wisconsin, elsewhere the formation is exceedingly variable in this regard. On the east side of the Catfish valley it is 50, 40 and 20 feet in thickness. Further northeast along its line of outcrop, Prof. Chamberlin has found it but a few inches in thickness, and then suddenly expanding to 80 or 100 feet. The same irregularity is observed along its line of outcrop to the Michigan line.

The St. Peters has been reported hitherto as entirely barren in **fossils,** but recently a few have been found in the Eastern Wisconsin district. No traces of fossils have ever been observed in Central Wisconsin.

The only **economic contents** of the St. Peters are to be found in the sand of which it is made. This can be shoveled out and used for all purposes to which sand is ordinarily applied. Frequently the sand is of such purity and whiteness as to be of excellent quality for glassmaking, but, as already said, this phase of the formation is more characteristic of its development in the western part of the state and along the Mississippi.

THE TRENTON LIMESTONE.

In Wisconsin and the adjoining portions of Minnesota, Iowa and Illinois, the St. Peters sandstone is succeeded by 300 to 350 feet of limestone beds. These are apparently the equivalents of the Trenton series of New York, but comprise two well marked members, the upper one of which has no exact representative among the eastern rocks, whilst the lower and thinner of the two, as indicated by its numerous fossils, represents exactly the Birdseye and Black river limstone. To this lower member exclusively it has become customary in Wisconsin to attach the name of Trenton, the upper being known as the "Galena" limestone, from the fact that it is the main repository of the lead ores of the Upper Mississippi lead region. This nomenclature is retained in the present report.

In the Central Wisconsin district the Trenton limestone has a **surface distribution** of about 220 square miles, being confined wholly to Dane and Columbia counties. In the latter county it occurs in two principal areas, one in the northeast occupying the eastern and central parts of Randolph, and the northeast part of Courtland; the other, in the southeast, covering southern Columbia and southeastern Hampden. In Dane county the formation has a much wider spread. In the towns on the east side of the Catfish valley it covers all the higher grounds, occurring in a number of detached areas of very different sizes. Some of these are quite small, running from a few acres to one or two square miles in extent, as in Medina and Deerfield, where they are very numerous; others, however, cover the greater part of a township, or even two or three townships, as in the case of the large one which occupies nearly all of Christiana and Albion, with considerable portions of Pleasant Springs and Dunkirk. On the west side of the Catfish, in Rutland, Oregon, Fitchburg, Verona and Montrose, are a number of small areas of Trenton, occurring as isolated ridges amidst a lower country occupied by the St. Peters. A large area of Trenton occupies the high ground at the head of Sugar river, in Cross Plains and Middleton, whilst the numerous narrow ridges between the branch streams of Sugar river in Primrose and Springdale are everywhere crowned by this formation, which in the highest ridges is present in its full thickness. The high Trenton area of Middleton and Cross Plains constitutes the divide between the heads of Sugar river and Black Earth creek. On the south side of the valley of the latter stream it breaks down quite suddenly. Further north, in northwestern Middleton, southwestern Springfield and southern Berry, a few very small Trenton areas are met with.

No very distinctive **topographical characters** mark the region occupied by the Trenton limestone. Most commonly the areas underlaid by it are prairie areas, and in some cases the coincidence of Trenton and prairie areas is striking. In all cases the soil derived from it is very fertile. In eastern Dane and Columbia, it occupies areas of gently rolling to level country, whilst on the west side of Dane it forms the rounded summits of steep and narrow ridges. Hardly ever forming natural outcrops of any size, it contributes no especially picturesque features to the scenery.

The **lithological characters** of the Trenton limestone contrast strongly with those of the Lower Magnesian, it being throughout very evenly bedded, commonly close-textured, rarely cherty, and having aluminous (clayey) rather than silicious (sandy) impurities. Moreover, though largely dolomitic, it includes a considerable thickness of non-magnesian limestone, standing, in this respect, alone amongst the Silurian limestones of the northwest. In the lead region, according to Hall and Whitney, only the lower 18 to 20 feet of the Trenton are dolomitic, constituting the "Buff" limestone of their and other reports, whilst above, all of the remaining 50 to 80 feet of the formation are true limestone, into which a small and gradually increasing amount of magnesia enters as the upper layers pass into the overlying Galena. The lower of these divisions, the Buff limestone, with a thickness of 25 feet, is well marked throughout Columbia and Dane counties, as is also the lower portion of the Blue limestone immediately above. The higher portions of the formation, which have for the most part been removed by denudation, and are hence but rarely seen, do not seem to bear out Hall's and Whitney's descriptions, since they certainly include some dolomitic layers, in appearance quite like the Buff beds. The exposures of these higher beds are, however, so infrequent, that I would advance this statement with some doubt, but for the fact that in the Eastern Wisconsin district, where all parts of the formation are well developed, Professor Chamberlin has made out definitely an alternating series, all the beds of which are magnesian. This succession, beginning below, is as follows: *Lower Buff* (the "Buff" of the Lead Region), dolomitic, 23 feet; *Lower Blue*, also magnesian, 23 feet; *Upper Buff*, dolomitic, 55 feet; *Upper Blue*, also magnesian, 15 feet. Only the two lower ones of these are ordinarily seen in the Dane county quarries.

The Buff (or Lower Buff) limestone is a very evenly bedded, bluish to buff-colored, close-textured dolomite, in layers from a few inches to 2 or 3 feet in thickness. Externally the layers are usually a brighter yellow than within, owing to a partial peroxidation of the iron-protoxide contained in the rock. The following analysis is one from the Buff layers only a short distance below the junction with the Blue, from Barth's quarry, in the southern part of the town of Bristol, Dane county:

Carbonate of lime	56.07
Carbonate of magnesia	35.32
Silica	4.45
Alumina	2.08
Iron sesquioxide	.69
Iron protoxide	.58
Water	.46
	99.65

In the upper part of the Buff limestone, purplish-brown, close-textured, conchoidal-fracturing layers occur, which contrast much with the remainder of the stratum. The Buff limestone yields a good building stone and is very frequently quarried.

The Blue (Lower Blue) is to be seen ordinarily only in its lower half, 2 to 10 feet of which are not unfrequently laid bare in quarries on the Buff beds. These lower layers are very thin, nodular-surfaced, and made up of dark bluish-gray, flinty-textured limestone, in which small specks and strings of calcite are thickly scattered, and in which also numerous fossil fragments are imbedded. Included between these layers are seams of a very thinly and regularly laminated, dark brown, fragile, calcareous shale, showing numerous black graptolite-like markings. Of the following analyses of the Blue limestone, No. I is of rock taken from the same locality as the Buff, of which an analysis has just been given, and nearly at the junction of the two. Of the other analyses, added for comparison, No. II is cited from the report of Mr. Moses Strong on the lead region, and is from Sec. 36, T. 5, R. 2 E., whilst No. III is of Blue limestone from near Benton, on the Fever river, and is cited from J. D. Whitney's report on the lead region:

	I.	II.	III.
Carbonate of lime	84.02	85.54	97.92
Carbonate of magnesia	5.33	3.98	1.60
Silica	7.03	6.16	1.10
Alumina	2.21	2.26	
Iron sesquioxide	.83	.95	
Iron protoxide	.39	.95	
Water	.61	.93	.....
	100.42	99.87	100.62

The following list of **fossils** includes all that I have observed in the Trenton beds. The determinations are mostly by Mr. R. P. Whitfield:

Name.	*Horizon at which found.*
Petraia (Streptelasma) corniculum,	Occurs throughout the Buff but most common in the lower part.
Columnaria alveolata,	Lower part of Buff.
Graptolitic markings,	Lower part of Blue.
Crinoidal columns,	Upper part of Buff.
Orthis tricenaria,	Buff.
Streptorhynchus filitextus	Buff.
S. deflectus	Buff.
Strophomena camerata,	Buff.
S. incrassata,	Buff.
Rhynchonella, n. sp.,	Buff.
R. n. sp.,	Blue.
Tellinomya cuneata,	Buff.
Cypricardites ventricosus	Buff.
Raphistoma lenticulare	Buff.
R. Nasoni,	Buff.
Trochonema umbilicatum	Buff.
Murchisonia bicincta,	Buff.
M. tricarinata,	Buff.
Pleurotomaria subconica,	Buff.
Helicotoma planulata,	Buff.
Orthoceras annulum,	Buff.
O. vertebrale,	Buff.
Gyroceras duplicostatum, n. sp.,	Buff.
Oncoceras pandion,	Buff.
Cyrtoceras, und. sp.,	Buff.

Beside these, obscure and fragmentory casts of *Orthoceratites* are very numerous indeed in the Buff, varying greatly in size, some occurring as great as 6 feet in length and 8 inches in diameter. The fossils of the Buff are almost wholly in the state of casts of the interior, or impressions of the exterior. Of those in the list, the most frequently met with are the coral *Petraia,* and the gasteropods, amongst which *Trochonema umbilicata* is the most abundant. These gasteropods are frequently of very large size, their rough casts and impressions filling entirely a two-inch layer, whilst for a number of feet above and below the rock may be entirely barren.

The **economic contents** of the Trenton beds are building stone and limestone for flux. Certain beds of the Blue in the lead region are said to be hydraulic, and the property is probably not entirely confined to the rock in that district. The Trenton limestone is also one of the layers in which the lead ore of the lead region occurs. A small crevice occurs near the base of the Trenton, in the town of Fitchburg, Dane county, from which a few hundred pounds of galena have been taken. For the most part, however, the Trenton is without sign of mineral wealth until the limits of the lead region are reached, in the western towns of Dane county. East of this it occurs usually in such small thickness that it could not be looked to to yield any amount of ore, even if it should be metalliferous, of which, how ever, there is no indication.

The Buff limestone is used for building everywhere where it occurs. It can be obtained in quite even blocks and slabs of suitable thickness both for building and paving, presenting, when laid in wall, a uniform straw color. The thinner layers are also frequently used for stone fences.

The application of the blue or non-magnesian limestone layers as a flux in iron smelting is certainly worthy of attention. For most of the furnaces in Wisconsin and the northern peninsula of Michigan, limestone is brought all the way from Kelley's Island, in Lake Erie, whilst others use unsatisfactory native dolomites. The Kelley's Island rock contains much more magnesia (15–20 per cent.) than the Blue limestone, but is otherwise often purer, carrying almost no earthy or silicious impurities. It is without doubt this purity that makes it prized for smelting the hard silicious ores of Lake Superior. All of the silica, however, in the Blue limestone is in the state of clay, whilst in freedom from magnesia it ranks far above the Kelley's Island stone, and moreover, as shown by the third of the analyses above given, it is at times free also from the earthy impurities.

THE GALENA LIMESTONE.

This formation is found in the Central Wisconsin district only in a few small cappings in the town of Christiana, eastern Dane county, and on the top of some of the narrow ridges of the towns of Springdale and Primrose, on the west side of Dane county. Since it is so unimportant, and at the same time plays so large a part in both the

Lead Region and Eastern Wisconsin districts, in the reports on which it will be found fully described, it is not thought necessary to give it any attention here.

II. Local Details.[1]

PORTAGE, WOOD, CLARK, AND JACKSON COUNTIES.

(ATLAS PLATE XV, AREA F.)

The only one of the Lower Silurian formations occurring in these counties is the Potsdam sandstone, which forms the basement rock of the southern portions of the three first named, the Archæan rocks rising to the surface in their northern portions. In Jackson county only the bed of Black river and a few scattering mounds show the Archæan rocks.

The peculiar irregularities of the line of junction between the two formations, the extension southward along the stream valleys of long strips of the crystalline rocks, the corresponding northward extension, along the divides, of the sandstone, and the difficulties met with in tracing the boundary, have been before alluded to. The facts upon which the junction line for the region covered by the map of Area F. of the Atlas is based, including the location of a number of outcrops, have also been given briefly, and will not be repeated here.

A very large proportion of the sandstone area in these counties is level, and is, to a considerable extent, occupied by large marshes. Towns 21 and 22, ranges 7 and 8 east, Portage county, are almost all included in one great marsh, as are also towns 21, ranges 2, 3 and 4 east, in Wood county, the latter marsh extending also over considerable portions of the towns to the northward, and having a still greater extent into Juneau and Jackson counties on the south. Underneath these marshes, which, to a large extent, have peat bottoms, sandstone is commonly found at shallow depths. On some of the dividing ridges again, the sandstone country becomes considerably elevated, and has more or less a rolling character. Such is especially the case with the divide between the Black and Trempealeau rivers in western Jackson county, which is without drift covering, and is worn into the deeply ravined surface characteristic of driftless regions, The divide between Black and Yellow rivers, in western Wood and eastern Clark counties, is considerably elevated above the surrounding country, but is very heavily coated with glacial materials, and presents therefore a much more even surface.

The larger part of the sandstone area of Portage, Wood, Clark, and eastern Jackson counties, is within the region of heavy timber, chiefly pine. In the southern portions of the three first named, and in a large part of western Jackson, small pines mingle with the small oaks that are characteristic of nearly all of Central Wisconsin, the growth of timber in all of these portions being scant and small, and associated with a loose, sandy soil. On the northern part of the divide between Yellow and Black rivers, however, the sandstone is deeply buried beneath clay drift, as a result of which we find excellent clay soils, and a heavy growth of hard wood timber, for the most part maple.

Usually the sandstone of these counties is but a thin covering upon the crystalline rocks, which appear in all of the deeper stream-valleys. High bluffs of the sandstone,

[1] In the manuscript, this division of the report includes a full description, by townships, of a large part of the country occupied by the Lower Silurian formations, embracing topography, surface features, rock outcrops, etc. It has been found necessary, in order not to exceed the limits originally assigned to this report, to throw out most of this material, and a number of important outcrops are therefore not alluded to. This omission can be, in part, made up for, by any one who wishes further information than given, by a study of the Atlas maps in connection with the lists of altitudes of Chapter I. The whole amount of material thrown out would make about 45 pages of the small type. R. D. I.

however, occur, carrying its thickness up into the hundreds of feet, and bearing witness to the great thickness which once must have existed over all the region.

In Sec. 23, T. 21, R. 8 E., Portage county, on the edge of the great Plover marsh, rises a prominent knob of sandstone, known as **Mosquito Mountain.** The bluff is about 100 feet high, with its main extent east and west. Just west of it, on the west side of the Portage and Stevens Point road, is a second lower knob. Near the base of the main hill, the sandstone, as seen in a quarry (789), is rather fine-grained and light-colored, with brownish spots and laminæ, and very friable indeed. It is composed of grains of limpid quartz, that are all somewhat rolled, but are still subangular in shape, and has a very minute quantity of a brownish cement. The bedding here is very distinct, the layers running from 2 inches to 1 foot in thickness on a quarry face of 15 feet. One hundred yards to the east of the quarry, on the same hill, are ledges of a much coarser and more indurated sandstone (790), which is in places almost like quartzite, having a whitish color, and composed of much-rolled grains of vitreous quartz, closely cemented. A similar rock (791) occurs in small exposures up to the summit of the bluff. On the western bluff a quarry exposes coarse-grained, brownish, moderately firm sandstone (792), having a semi-vitrified appearance on the exterior.

At the foot of **Conant's Rapids**, S. E. corner Sec. 8, T. 23, R. 8 E., 30 feet of horizontally bedded sandstone show in the river bank, overlying gneiss. The lowest layers, in contact with the gneiss, are hard and quartzite-like; but the body of the exposure is thinly bedded, coarse-grained, friable, and of a light-brownish color.

At **Steven's Point,** just below the railroad bridge, on the east bank of the river (Plate IX, of Fig. 12), thin-bedded friable sandstone shows at the top of the bank, the gneiss being exposed below.

On the west side of the river, Sec. 31, T. 24, R. 8 E., is a low outlier of sandstone, rising 51 feet above the river. The sandstone is cut into deeply at the south end of the mound, for the railroad, and this cutting is expanded into a quarry at one point. Another large quarry is worked on the northwest side of the hill. In the cutting, the upper layers are thin-bedded, whilst the lower seven feet is in heavy layers, and shows a light brownish, white, much indurated, rock (774), of a medium grain, and composed of highly glassy, subangular, quartz grains. Fresh surfaces are quite uniform in appearance; weathered surfaces much iron-stained. Strong joints occur trending N. 15° W. and N 50° E. Pieces 4 by 4 by 4½ feet can be obtained easily, also thin slabs fit for flagging, The quarry on the west side of the hill shows a similar stone, taken from higher layers. The topmost layer in the quarry is very beautifully ripple-marked. The stone from these quarries is a valuable one, and is much used in building at Stevens Point.

About four miles north of Grand Rapids, in the town of **Rudolph**, S. E. qr. Sec. 20, T. 23, R. 6 E., Wood county, a large and excellent sandstone quarry has been opened near the summit of the ridge, whose slope for half a mile southward shows sandstone ledges. The quarry face is 20 feet, and shows very plainly bedded layers 1 inch to 2 feet in thickness. These are traversed by very strong joints, trending N. 10° W. and N. 70° to 80° E. Some of the joints are inclined, especially the former set, most of which dip 67° W., and others are vertical. All the stone is tolerably firm, but most of it is not unusually indurated, crumbling easily in the fingers. Certain layers, however, are very highly indurated, and are susceptible of quite a high polish. These are both plain white and white heavily streaked with dark red, are of a rather fine grain, and consist of subangular grains of highly vitreous quartz. Large blocks can be obtained, as also thin flags 10 by 18 feet. The stone is much used at Grand Rapids, and has a considerable value.

Along the Wisconsin river, from Grand Rapids to Point Bass, sandstone is frequently exposed. Several sections in the vicinity of Grand Rapids, showing sandstone overlying kaolin, have already been described.

Near Point Bass, on both sides of the river, heavy ledges of sandstone overlie gneiss (see Figs. 2, 3 and 4). On the east side of the river the sandstone cliff is 30 to 40 feet high. On the west side, near the north line of Sec. 15, on a side channel of the river, dry at the time of our examination, 5 feet of very friable, coarse, brownish sandstone shows in the bank, the upper layer heavy, the lower ones thinner. The bottom of the channel is formed of large flat slabs of the same sandstone, one inch thick. Beneath four one inch layers of this sandstone are two inches of sandstone highly charged with the greenish-tinged iron sulphide, marcasite, which in places almost entirely excludes the sand. Specimens taken out decompose to the sulphate very rapidly. Immediately below, and in contact with the pyr tous layer, is the Archæan gneiss, much decomposed, but retaining still its firmness and bedding.

Three-quarters of a mile east of **Mapleworks**, on the S. E. qr. of Sec. 12, T. 24, R. 1 E., Clark county, is an isolated sandstone bluff 100 feet high, 500 yards in diameter at the base, 100 yards long and 10 wide at top, rising above the general level of the divide. The slopes are covered with clay and fragments of sandstone. At the summit 5 feet of very coarse grained, rather firm, brownish sandstone (982) is exposed, consisting of very much rolled grains of dull white quartz. The layers are 6 to 18 inches in thickness.

About one mile north of **Neillsville**, on the S. W. qr of Sec. 11, T. 24, R. 2 W., 10 feet of cross-laminated, coarse-grained, yellowish sandstone, shows alongside of the road. Clay seams, one to two inches thick, are included between the layers of sandstone. Similar sandstone is seen at the crossing of Black River, one mile west of Neillsville, S. W. qr of Sec. 15, T. 24, R. 2 W. The base of the sandstone is 40 feet above the river; below is a slope 10 feet in height, without exposure, and below this, again, 30 feet of light-colored pinkish granite.

Along Black River, from Neillsville to Black River Falls, T. 21, R. 4 W., Jackson county, sandstone is quite frequently exposed in or near the banks of the river, the bed of which is on the crystalline rocks.

On the S. W. qr of Sec. 3, T. 24. R. 2 W., west of the river, is a sandstone outlier 175 feet high, and about one-third of a mile in length, the upper portions of which are perpendicular ledges of bare rock. The sandstone is heavily bedded, indurated, coarse-grained, and light-colored. From the summit of the bluff a number of other similar outliers can be seen, dotting the country to the west and south, and one or two to the north, in T. 26, R. 2 W.

For half a mile below French's mill, Sec. 25, T. 23, R. 3 W., the Neillsville road follows the west bank of the river, at an elevation of about 30 feet above the water. On the east side of the road, granite is exposed in the river bank, and on the west side a ridge of horizontal sandstone, 30 to 50 feet high. The sandstone is cross-laminated, coarse, yellowish, and made up of much rolled quartz grains, which reach sometimes as much as one-eighth of an inch in diameter.

In T. 21, R. 4 W., and T. 22, R. 4 W., ledges of sandstone form the river bank for long distances, rising 20 to 40 feet from the water, and are in a number of places to be seen overlying, or abutting against, Archæan schists, as heretofore described (see Plate XVII, and Figs. 1, 20 and 21). This sandstone is usually of light yellowish color, coarse, and somewhat indurated, and includes beds of red and green sandy shale. The lowest layers are often affected by a very marked cross-lamination, the thickness so affected being often as much as six to ten feet.

At Black River Falls, sections 15 and 22, T. 21. R. 4 W., the crystalline rocks are largely exposed, the river passing through a gorge in the gneiss and granite. The ground rises rapidly from the river on both sides, especially the western, and on both sides the granite and gneiss are overlaid by sandstone. At the top of the hill on which the High School building stands, wells pass through 80 feet of sand and gravel into sandstone.

Opposite Ledyard's old mill (Fig. 20), in the bend of the river below the village, 25 feet of sandstone overlie the gneiss. The sandstone here is the usual coarse crumbly rock, and includes layers of greenish and reddish shale, the lowest layer being a fino conglomerate, 8 inches in thickness.

Near the railway depot, on the west side of the river, is a quarry in the sandstone layers belonging just above those exposed at the mill. The quarry face is 15 feet high, and traversed by strong vertical joints. The stone (1012) is heavily bedded, much indurated, of a light color, and composed of alternating very coarse and finer grained layers, all being composed of rolled grains of glassy quartz. Some of the layers show cross-lamination. This stone is a valuable one, and resembles that from the quarries already alluded to as occurring near Grand Rapids and Stevens Point.

About a mile southeast of the depot, on Sec. 23, is a very bold sandstone outlier rising about 250 feet above its base. In the lower slopes the sandstone is mostly concealed. Above is a perpendicular-faced, jagged crest, over 100 feet in height, the prevailing rock (1013) on which is a white to buff-colored, fine-grained, firm sandstone, composed of sub-angular to rounded quartz-grains, and containing near the top numerous iron-stained impressions of *Obolella polita*, but no shells.

About one mile west of Black River Falls, on the road westward to the Trempealeau valley, is an exposure of thin-bedded, coarse, brownish, crumbling sandstone (1010), with numerous white fragments of shells of *Obolella polita*, which, in some of the layers, make up most of the rock. Thin clayey layers occur in which a few shells were noticed, one of *Lingulepis pinnæformis*. The outcrop appears to be 130 to 150 feet below the *Obolella* sandstone of the bluff near the depot.

In the various exposures in the vicinity of Black River Falls, we have a total thickness of sandstone of about 350 feet, with two fossil horizons made out, one 200, the other 300 feet, above the gneiss base upon which the pile rests, and both showing *Obolella polita*.

On the west side of the Trempealeau valley, Sec. 2, T. 22, R. 5 W., Jackson county, is a peculiar isolated bluff known as the **Silver Bluff**. At the east end the bluff is 165 feet high, the lower slopes being covered with a talus from the ledges above. Near the summit is exposed a horizontally and very plainly bedded, hard, white quartzite (1011), which rings like steel when struck with the hammer. The layers are alternately thin and thick, and brownish-weathered, and include interstratified layers of friable sandstone. The quartzite shows distinctly lines of lamination, and has a very plain granular texture, being composed of grains of vitreous quartz which appear as if fused together, and is quite highly translucent. It is unlike the quartzite of the Baraboo ranges, or that of the hills near Wausau, Marathon county. It contains very abundant fragments of casts, more rarely perfect casts, of a very large conical fossil which Mr. Whitfield determines as a new species of *Palæacmæa*. Following the bluff along the brow of its southwest face, the quartzite layers are seen to continue for about a third of a mile, when a sudden rise in the bluff of 80 feet exposes thin-bedded, firm, dark reddish-brown, highly ferruginous, sandstone (1016), of a medium grain, and composed of rounded grains of glassy quartz, which are stained both externally and internally by iron-oxide. On the north flank of the hill, at the same elevation as the quartzite on the opposite side, an 8 inch layer of hard, white quartzite is seen, between heavy beds of whitish friable sandstone.

Juneau and Adams Counties.

(Atlas Plates XIV and XVIII, Areas E. and H.)

These two counties constitute a rectangular-shaped district, lying in the very heart of the state, about 42 miles from north to south, by 36 from east to west, and having an area of about 1,475 square miles. Throughout the whole area, except on the small quartzite bluffs at Necedah, and in one or two very small and somewhat doubtful cappings of limestone in the southwestern towns of Juneau county, the Lower sandstone is the surface rock.

The larger portion of the district presents the character of a level plain, which has, for the most part, a surface of loose sand derived directly from the disintegration of the Lower sandstone, but showing many marshes, some of very large size, and occasionally prairies. Except on the marshes, and the few small prairies, this plain is nearly everywhere covered with a growth of stunted oaks, with which, towards the north, small "jack-pines" intermingle. It is traversed centrally from north to south by the Wisconsin river. and is surrounded on all sides by higher ground. The elevation on the north is due merely to the gradual rise of the plain in that direction, the general altitude on the southern edge, along the Lemonweir river, being about 300 feet, that along the north line of Juneau county, 400 feet. The high ground on the east is also due to a steady, but very much more rapid, rise of the plain in that direction, the dividing ridge along the line of Adams and Waushara counties having an altitude of some 200 feet above the Wisconsin. On the south, southwest and west, however, the edge of the plain is very sharply defined by a narrow and much indented dividing ridge, which is especially marked in the southwestern towns of Juneau county, where it has on its western side the deeply carved valley of the Baraboo, with its numerous branch ravines.

Dotting the central plain, and rising quite abruptly from its most level portions, are the isolated mounds and castellated peaks of rock that constitute its most marked and peculiar characteristic. Except the quartzite mound at Necedah, these are altogether of sandstone, being the only portions that have been left from the denudation of the Lower sandstone. Although none of them exceed 300 feet in height, and but few 200 feet, they register a denudation of fully 500 feet; that is to say, over the larger part of this plain there has been at one time a thickness of 500 feet of rock, which no longer exists, and possibly there has been a much greater thickness than this. There are two

FIG. 35.

OUTLINES OF ROCHE A CRIS AND FRIENDSHIP MOUND, AS SEEN FROM PILOT KNOB.
Scale 2,480 feet to the inch.

classes of these remarkable outliers: the larger and more prominent ones, which reach elevations of from 150 to 300 feet, have lengths of from $\frac{1}{16}$ to 1 mile, and show more or less vegetation on top; and the smaller and less conspicuous ones, which are from 30 to 100 feet in height, often of bare rock, and cover comparatively small areas. The larger outliers are few in number, and are, for the most part, quite distant from one another. Two of these are especially prominent, showing from any point on or around the plain high enough to be above the tree tops. These are the Roche à Cris and the Friendship Mound in the southwest part of T. 18, R. 6 E., Adams county. Their prominence is due both to their heights above the plain at their bases and to the comparatively great elevation of the portion of the plain on which they stand. The Roche à Cris is a thin, wedge-shaped mass of rock, without pinnacles, having a length of about $\frac{1}{8}$ mile, and a height of 225 feet above its base, or about 660 feet above Lake Michigan, and standing up like a fragment of a great wall. Friendship Mound is about half a mile south from Roche à Cris, which it exceeds in height by 50 feet, having also a much greater length and thickness and a more rounded contour. The outline of these two bluffs, as sketched from the summit of Pilot Knob, 10 miles east, is given in Fig. 35. Amongst the other large outliers may be mentioned the very large wooded mound, in T.

20, R. 6 E., 13 miles north of Roche à Cris; Petenwell Peak, a very narrow bluff 230 feet high, and with serrated crest, on the west shore of the Wisconsin, Sec. 9, T. 18, R. 4 E.; the group of bluffs 6 to 8 miles south of Friendship; the large wooded bluff 6 miles southeast of Mauston, T. 15, R. 4 E.; and the Elephant's Back, near Kilbourn City. The last two, though high, do not stand out very prominently, as seen from points within the plain, on account of their nearness to the high ground that limits it on the south. The quartzite bluff at Necedah is also quite prominent. Of the smaller sandstone outliers there are a great number and variety. Many of them are simple peaks or towers of rock, having a diameter at base of only a few feet, and 40 to 60 feet in height, in some cases the diameter at base being less than that at the summit. Others are a series of pinnacles or rounded towers joined together, and others again are massive bluffs with wooded summits and perpendicular sides of rock.

The high ground that bounds the plain on the west enters Juneau county on the west side of T. 16, R. 2 E. (Fountain), carrying on the county line a capping of the Lower Magnesian limestone. From here it trends southeastward across the towns of Fountain, Plymouth, Lindina, Wonewoc and Summit, reaching elevations of 500 to 600 feet, and then, veering more to the eastward, across the towns of Seven Mile Creek and Lyndon to the Wisconsin river, where it is cut through by that stream in the gorge known as the Dalles of the Wisconsin. This ridge is very well marked on its northern side, rising abruptly from the plain, towards which it presents a face deeply indented by the streams flowing northward from it, and flanked by isolated outliers of sandstone. Until it nears the Wisconsin, it constitutes the divide between the waters of the Baraboo and Lemonweir rivers. The former of these streams enters Juneau county on the west line of the town of Plymouth, through which, as also through the next town on the south, it passes in a nearly southerly direction to the south line of the county, having all along a narrow rock-walled valley, into which tributary streams come through deep ravines, that set back into the higher ground on each side. Thus throughout all of these southwestern towns of Juneau, the country bears quite a different aspect from that of other portions of the county, being, in general, an elevated region, carved into numerous ravines, and presenting, on the higher portions, a very excellent clay soil, although entirely without the drift area. As the Dalles are approached, the ridge lessens in elevation, and shows on its northern side many sandstone escarpments, which are often worn into fantastic shapes. East of the Wisconsin, the encircling high ground continues, curving rapidly to the northeast and north, through the towns of Dell Prairie Springville, Jackson and New Chester, running thence northward along the east line of Adams county, and reaching elevations of 200 to 300 feet above the Wisconsin river. Its character, however, is now quite changed, the slopes being no longer abrupt nor worn into ravines, whilst the whole surface is heavily drift-covered.

The plain, thus encircled by high ground, would, over the greater part of its area, become covered by water, if the gorge at the Dalles were closed. That such may actually have been the case at some time, is indicated by the general appearance of the plain and its surroundings, by its numerous large marshes, by the finely laminated (lacustrine?) clay deposits that occur in places over it, and by the great bank of rolled pebbles and bowlders of quartzite that flanks the quartzite bluff at Necedah, far within the driftless region.

In the **valley of the Upper Baraboo**, and on the adjoining high ground, in the towns of Fountain, New Lisbon, Plymouth, Lindina, Wonewoc and Summit, Juneau county, the sandstone is frequently exposed. The immediate valley of the river is narrow, and frequently bounded by rock walls, 20 to 120 feet in height, which show generally rather friable, medium-grained, brownish to white, sandstone, without trace of calcareous or dolomitic ingredients. In places, as on the east side of the river at Elroy, near the railroad bridge, firm quarry layers occur. The high ground on either side of the valley rises rapidly from it, 200 to 300 feet, but shows sandstone only, except in one or two places where exceptional elevations are reached. One such place is on the county line in the southwest corner of the town of Wonewoc, just south of which, on the S. E. qr. of the N. E. qr. of Sec. 6, T. 13, R. 2 E., Sauk county, the Lower Magnesian limestone is quarried, at an elevation of 300 feet above the railroad track at the village of Wonewoc, or at a total altitude of 630 feet. Only a small thickness (3 to 4 feet) of limestone is exposed, and immediately below are seen ledges of coarse, brownish, non-calcareous[1] sandstone, intermingled with which, and in the uppermost layers predominating, is a whitish, chert-like material, having somewhat the appearance of a grayish, granular quartzite (1350). Limestone appears also to cap the high ground in Sec. 1 of Wonewoc, and in portions of the corner sections of the three adjoining towns. The limestone was not seen here in place, but on the north side of the ridge large, fallen masses were noticed, showing the ordinary characters of the Lower Magnesian; and the sandstone exposures do not extend to the summit. On the west side of the ridge, where the Mauston and Wonewoc road descends into the valley of a small stream on the north side of Sec. 12, 50 feet of red and pink, friable, finely laminated, non-calcareous sandstone, with firm, white bands (1340) are exposed. The white bands are exceedingly fine-grained, and made up of sharply angular grains of glassy quartz, being in this respect quite different from most of the sandstone of the Potsdam series. *Scolithus* occurs quite abundantly in this rock. On the south side of the stream, sandstone is again exposed of similar character, and rising higher, the uppermost layers containing the peculiar quartzitic or cherty material (1353) mentioned above as occurring just beneath the limestone on Sec. 6, T. 13, R. 2 E. The highest point of this sandstone is about 15 to 20 feet below the summit of the ridge in Sec. 1.

From the lowest exposures along the Baraboo river to the limestone on the tops of the ridges, the whole thickness of sandstone is not less than 300 feet. The peculiar red-and-white-banded and cherty sandstone occurring just beneath the limestone appears to be without doubt in the Madison horizon, but with an unusual thickness. The Mendota limestone was not noticed anywhere in the region, though benches occur on the hills, at the proper elevation, which might be due to its presence. The dolomitic bands that characterize the Upper Potsdam further southward, were also not seen.

Along the northern face of the watershed between the Baraboo and Lemonweir rivers, from Camp Douglas to the Dalles, numerous isolated bluffs and towers of sandstone occur. At **Camp Douglas Junction,** Sec. 28, T. 17, R. 2 E., is a group of these bluffs, and a number more occur within a radius of two or three miles. Target Bluff, a few rods west of the depot, is a flat-topped mass of sandstone about ⅛ of a mile long, and 120 feet high, with nearly vertical sides. The lowest layers are thick, cross-laminated, coarse, non-calcareous, brownish, and exceedingly friable, having almost no coherence. The same characters, except the cross lamination, are persistent nearly to the top, where thin, lighter-colored, medium-grained layers (1353½) are seen, made up of much rolled grains of dull, translucent quartz. It is noteworthy that many of the bluffs in this vicinity have the same elevation, a fact evidently to be attributed to the existence at that elevation of some peculiar layer in the sandstone series.

Immediately south of the village of **Mauston,** on Sec. 13, T. 15, R. 3 E., is a large and very prominent sandstone bluff, about 200 feet high, half a mile long in a north and south direction, and surrounded on all sides by vertical cliffs flanked below with a long talus of loose sand and sandstone fragments. The cliffs are boldest on the eastern face, where they run from 50 to 100 feet in height. One hundred and eighty feet above the base is a flat bench, above which a narrow ridge rises some 20 to 30 feet, carrying the summit of the bluff to a total altitude of about 500 feet. The bench is due, undoubtedly, to the presence of a layer of green and red shale, which is not exposed,

[1] Whenever this adjective is used without qualification, the rock has been directly tested.

but has been reached by a small shaft sunk on the summit of the bluff. The shaft penetrates: (1) sandrock, lower layers thin, white and shaly, 25 feet; (2) green and red shale 2½ feet; and ends in (3) sandrock again, the same as that seen on the cliffs. The green shale appears to be of the same kind as that known at several horizons in the Lower Sandstone in other parts of the state, but is soft and clayey, unusually free from silicious sand, and of a deep green color.[1] The red shale (1342) is soft, slightly sandy, non-calcareous and of a brick-red color. This shaly layer has influenced the denudation of other bluffs seen to the southeast, which have their summits at the same elevation as this bench. It appears probable that the Camp Douglas bluffs may owe their constancy of elevation to the same cause. All the sandstone on the cliffs of the Mauston bluff is non-calcareous, generally moderately coarse, brownish, pinkish and light-colored in different layers, and much of it firm enough to use in building. It is quarried near the south end of the bluff, at the base of the cliff, where firm, heavy layers are obtained of a light-colored, medium-grained rock (1347); and also at the summit of the cliff, near the north end of the bluff. At the latter place, immediately above the quarry beds, and just beneath the green shale, are a few layers of a porous, very friable brownish sandstone, with numerous iron-stained points and cavities and indistinct fossil impressions, which consists of subangular grains of glassy quartz. On the cliff below the quarry the sandstone is penetrated by numerous brownish veins, one-sixteenth to one-half an inch in width, which, on close examination, are seen to be made up of the grains of the sandrock, more glassy than usual, and closely cemented by a small amount of hydrous iron oxide.

In the southern part of the town of **Lyndon**, on Sec. 28, T. 14, R. 5 E., a narrow, ridgy crest rises 200 feet above the general level of the watershed, reaching an altitude of nearly 700 feet above Lake Michigan. At the summit a white, cherty material (1330) resembling that described as occurring on Sec. 12, town of Wonewoc, remains in place. It is peculiar in showing numerous little rounded holes, that give to the mass some appearance of an organic structure. Ten feet below the chert, fine-grained, non-calcareous, whitish sandstone (1332) is exposed, made up of grains of very fine, sharply angular, glassy, quartz, and resembling that seen below the chert on Secs. 12 and 1, town of Wonewoc. The horizon is evidently the same, and is just beneath the base of the Lower Magnesian limestone.

The gorge known as the **Dalles of the Wisconsin** has been briefly described on a previous page. Along the walls of the gorge, which are from 50 to 100 feet in height, the rock is quite uniform in character, being coarse, very friable, light to dark brown in color, non calcareous, and consisting of very much rolled grains of quartz (1443). The most remarkable feature of these exposures, which are nearly continuous for as much as seven miles, is the cross lamination which affects layers as much as 12 feet thick, and is abruptly terminated above and below by horizontally bedded layers. The transverse laminæ themselves are quite thin, and easily separable from one another. They are not plane, but constitute much warped surfaces. The structure is quite well shown in the view represented on Plate 1A, which is taken from one of Mr. H. H. Bennet's excellent photographs. Plate I, also from one of Mr. Bennet's photographs, shows a peculiar erosion form, known as Stand Rock, which occurs well up on the north face of the high ground through which the Dalles are cut, and far above the gorge itself. It illustrates well the way in which much of the lower part of the Potsdam series is worn—thin layers, somewhat more ferruginous and firm than the rest, though still quite friable, protecting the softer, scarcely coherent rock below. Half a mile east of the upper end of the Dalles, on the east side of the S. E. qr. of Sec. 21, T. 14. R. 6 E., the "Elephant's

[1] This green shale has been the object of exploitation as a *copper ore*, a considerable amount of money having been expended in sinking shafts, etc. It is hardly necessary to say that the money is thrown away.

Back" bluff, an isolated sandstone outlier, rises from the general level. From the summit of this bluff to the water in the river a measured section was taken, showing in all a thickness of 310 feet of the sandstone. The following are the details of the section, beginning at the top of the bluff:—

	Ft.	*In.*	*Ft.*
1. Unexposed	20	..	..
2. Fine-grained, porous, friable, light-brownish sandstone (1431); composed of subangular grains of glassy quartz; showing numerous small iron-stained cavities, and larger ones filled with loose ferruginous sand; fossiliferous, containing *Scolithus*, numerous small indefinite trilobite fragments, and the pygidium of a large trilobite, apparently *Dicellocephalus Minnesotensis;* resembling exactly the fossiliferous rock on top of the bluff, and just below the greensand layer, at Mauston; elevation of the Mauston rock, 470, of this rock, 530	0	6	..
3. Unexposed	12	6	..
4. Yellowish sandstone (1432), resembling No. 2; in upper part with a vitrified crust; below, very loose; carrying *Scolithus*	2	..	..
5. Unexposed	15	..	..
6. Same as No. 4	3	..	..
7. Unexposed	5	6	..
8. Rather coarse-grained, dark-brownish, friable sandstone (1433); composed of much rolled grains of dulled quartz; thickly coated on exterior by hydrous iron oxide; containing *Scolithus*, and numerous iron-stained cavities; irregularly bedded	2	6	..
9. Unexposed to foot of steep ascent	27	..	..
Total height of steep ascent			88
10 Unexposed; on flat bench 150 paces wide	..	..	18
11. Heavily-bedded, coarse-grained, friable, brown, ferruginous sandrock, at top of vertical cliff	6	..	..
12. Heavily-bedded, white-and-brown-banded, coarse sandstone; almost without coherence; having in places an exterior hardened crust	22	..	..
13. Alternating layers of pink, brown and white sandstone; medium to fine-grained, saccharoidal; thin pink layers stand out in knife edges from the body of the rock; all affected by a vitrified crust composed of glassy, closely adherent, quartz grains, on removing which the rock within falls to loose sand; the crust is one-thirty-second to one-half inch in thickness, and has an ill-defined inner edge	16	..	..
Total height of cliff			44
14. Unexposed; a long slope one-half mile to top of the cliff at the river bank (Rood's Glen)	..	..	75
15. Thin layers, one-eighth to two inches thick, of light-colored, brownish-tinted, medium-grained, sugary, friable sandstone (1437, 1437½, 1438); composed of much rolled grains of dulled quartz; layers projecting in shelves	14	..	..
16. Heavy, coarse-grained, firm, ferruginous layer	1	..	..
17. Heavy, projecting layer, with under surface ripple-marked, of medium-grained, light-brownish sandstone (1439); grains much rolled	1	7	..
18. Thin layers like No. 17	4	5	..
19. Thin-bedded, coarse, sugary, very friable sandstone (1440); in alternate pink and brownish seams; cross-laminated; the transverse laminæ thin, warped, and abruptly terminated above and below	6	..	..
20. Heavy layers, resembling No. 19; not cross-laminated, grains some-			

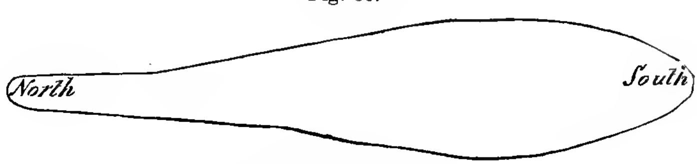
	Ft.	In.	Ft.
times very coarse, giving to the rock an appearance of being made up of grains of rice	6	..	..
21. Alternating thin and heavy layers, light-colored, friable (1441), with some dark brown ferruginous layers (1442); all very coarse and rice-like; some of the thin layers very regular and persistent	54	..	..
Total height of river cliff			85
Top of Elephant's Back above river			310

None of the sandstone of this section has any trace of calcareous or dolomitic ingredients.

On the Wisconsin river, above the Dalles, the sandstone is very frequently seen, both in low mural exposures on the river bank, and also in high isolated peaks. Of these, the most remarkable, as to height, is that known as **Petenwell Peak**, which rises abruptly from the west margin of the river, on Sec. 9, T. 18, R. 4 E., Juneau county. The total height of the peak above the river is 230 feet, the upper 50 to 75 feet being a narrow vertical crest, worn into partly separated crags, not more than 20 to 30 feet wide on top and about 300 feet in length. The rock of this crest is a light-colored, friable sandstone, with a hard, vitrified crust. Below there is a long talus of sand, with exposures of thin crumbly rock at base. The country around is a level sand plain, 40 feet above the river.

The **Roche a Cris**, on the N. E. qr. of the S. E. qr., of Sec. 30, T. 18, R. 6 E., Adams county, has already been mentioned as one of the most striking of the great sandstone outliers of the central plain. It rises abruptly from the surrounding level stretch of sand, a wedge-shaped mass of bare rock, 225 feet high, 1,300 feet long at base, and about 1,100 at the summit, which is a nearly level area 10 to 200 feet in width. The greatest length of the rock lies in a nearly due north and south line. The southern end is a sheer precipice, over 200 feet in height. On the west side there is a steep talus of sand creeping up in places to within 80 feet of the top. On the east there is also quite a long talus, but the cliffs are generally as much as 150 feet high. At the north end the rock is somewhat broken down, making an easy ascent. The summit is without the pinnacles that characterize Petenwell and others of the more western outliers, and is grassed and wooded with a few small pines and scrub oaks. It has the shape and dimensions indicated in Fig. 36, the measurements being made to the edge of the vertical cliff on all sides. The view given in Plate XIV is taken from a photograph by Mr. H. H. Bennett of Kilbourn City, and represents quite accurately the cliff at the southern end of the bluff. From top to bottom of this cliff, the rock is a friable aggregation of rolled quartz grains, showing only slight and somewhat indefinite variations in the different layers. A detailed section along the face of the cliff, beginning above, is as follows:

Fig. 36.



SHAPE OF THE SUMMIT OF ROCHE A CRIS.

Scale 300 feet to the inch.

	Ft.	In.
1. Fine-grained, porous, very friable, light-brown-tinted; composed of sub-angular grains of very glassy quartz; containing numerous small cavities, stained by iron-oxide; weathering with a thin vitrified crust, and occasionally with a brown iron-stain; fossiliferous, containing numerous fragmentary impressions of trilobites and other fossils, the markings being merely thin ferruginous films coating the nearly loose sand; most of the fossils too indefinite and fragmentary to be determined, two species of *Conocephalites*-like trilobites, and *Triplesia? primordialis*, being the only ones made out (1365)	1	6
2. Moderately coarse-grained, much finer than the last, pure white; composed of sub-angular to round grains of limpid quartz, the larger grains very much rolled; weathering in places with dark brown blotches, and everywhere with a hard quartzitic crust; for the most part a solid layer, though lines of bedding are to be seen on weathered surfaces; forming a narrow crest at the summit of the cliff, only 3 or 4 feet wide (1366)	3	4
3. Medium to coarse-grained, moderately firm, brown; constituent grains much rolled; in thin irregular layers 1 to 2 inches in thickness; weathering with a thin vitrified crust (1367)	1	5
4. Resembling No. 2	1	4
5. Medium to fine-grained, moderately firm, brown and reddish-brown; grains glassy, sub-angular to rolled; in the interior a massive bed, but weathering out in places into thin layers (1368)	7	..
6. Fine-grained, friable, yellowish-tinted; composed of much rolled grains of dulled quartz; containing little seams and patches of greensand; irregular shaly layers with rough surfaces (1369)	1	6
7. Medium-grained, rather firm, dirty white; grains glassy and somewhat rolled; one layer, subordinate lamination not apparent (1370)	1	6
8. Medium to fine-grained, brown-and-white-banded; in very thin shaly layers of almost loose sand, without hard weathering; occasionally running into firmer material (1371)	3	..
9. Medium to fine grained, white to yellowish, moderately firm and compact; in one heavy uniform mass without perceptible subdivision into layers; in places a thick quartzitic crust (1372)	21	3
10. Medium to fine-grained, close textured; white, dirty white, brownish; grains all somewhat rolled; hardened crust; in a massive layer without distinct subdivision; top of the layer ripple-marked on a large scale, the summits of the ridges 2 inches apart (1373)	43	..
11. Medium-grained, friable, dark reddish-brown; grains much rolled and stained superficially with hydrated iron-oxide; one layer (1374)	2	..
12. Medium to fine-grained, very friable, brownish and yellowish; weathering into narrow ridgy lines; in some parts, 1 foot thick, cross-laminated; subordinate layers not very well defined, but marked off by different colors.	31	..
13. Medium to fine-grained, friable, dirty white to yellowish; grains rolled and glassy; in places brown-weathered; upper layers thick, lower ones thin and weathering out in ridges (1375)	27	..
14. Very coarse-grained, porous, friable; white with brown-weathering	30	..
15. Medium to coarse-grained; dark-brown, reddish-brown, red, white, and yellow, in irregular bands 2 inches to 1 foot in width, some layers very ferruginous; grains glassy and much rolled (1378)	20	..
16. Very friable, cross-laminated, yellowish layer, constituting a marked horizon in the series, as seen from below	10	..

	Ft.	In.
17. Very fine-grained layers, almost loose sand; in alternating red, white, yellow, pink and brown bands; the bands usually very thin, and on close inspection often divisible into still thinner different colored stripes (1379); near the top the following succession was observed: 2 feet white, streaked below with pink; 1½ feet pink; 3 feet white, streaked with pink; 1½ feet pink, cross-laminated; 5 feet thin pink and white streaks — the lowest portions weathering with a vitrified crust (1380)	20	..
Total height of section	224	10

None of the sandstone of this section shows any sign of calcareous or dolomitic ingredients.

Half a mile south of Roche à Cris, across the valley of the north branch of the Little Roche à Cris creek, is the much larger outlier, known as **Friendship Mound,** which lies in the east part of Sec. 31, stretching southward into the north part of Sec. 6, T. 17, R. 6 E., where its southern end rises abruptly from the northern side of the Little Roche à Cris creek. The bluff is over three-fourths of a mile in length, trending a little west of north, and at base is as much as a third of a mile in width. All around, at an elevation of 150 feet above the base, it presents a marked bench, bounded by sandstone cliffs 50 to 100 feet in height, which are flanked below by a long talus of sand. Above the flat bench rises a wooded crest with several rounded summits, the highest of which is 280 feet above tha base of the bluff, 310 feet above the bridge at Friendship, and about 750 feet above Lake Michigan. The whole of the bluff is wooded with oak and pine, presenting in this regard quite a different appearance from the Roche à Cris, and affording much poorer opportunity for examination of the rock beds. Below the bench the succession of layers appears to be closely like that on the Roche à Cris. At one point on the west side of the mound, just below the edge of the bench, the sand rock is quarried. The quarry rock is moderately firm, uniformly brown-tinted and compact, with distinct lamination lines. The base of the quarry is 20 feet below the top of the bench, and is finely ripple-marked. Similar ripple-marks occur again at a lower level, but neither horizon seems to be the same as that at which similar markings were observed on the Roche à Cris. Above the bench the rock is mostly concealed, but is seen at 40 feet below the summit, where it is coarse, friable, and brown-colored, and intersected by little veins of brown iron-oxide. Exposures occur again at 60 feet below the summit, where the rock is white, friable and *Scolithus*-bearing.

On the south bank of the creek, at the Friendship bridge, thin-bedded, crumbling, brown-and-white-banded sandstone is exposed down to the level of the creek, adding about 45 feet to the Roche à Cris section.

Five to ten miles **south from Friendship,** a number of outliers of sandstone occur. One of these, Rattlesnake Rock, is about five miles south from Friendship, in the southern part of the town of Adams. The bluff is about half a mile in length, is cut into two parts by a central depression nearly to the level of the adjoining low ground, and is mostly grassed and wooded. On each side of the gorge, and on all sides of the bluff, are considerable exposures, the cliff on the west side reaching 50 or even 75 feet in height. A marked bench is 130 feet above the base. Above the bench the bluff rises 90 feet, the summit being 255 feet above the bridge at Friendship, and 655 feet above Lake Michigan. So far as observed, the rock and the succession of layers are the same as in the Roche à Cris section. At the top of the bluff, the rock (1389) is fine-grained, very friable, whitish sandstone, made up of glassy quartz grains, and closely resembling the fossil rock on the summit of Roche à Cris, to which horizon it evidently belongs, as indicated by its having the same altitude, and numero fossil fragments, as well as by its lithological character. The fossils are chiefly trilobite fragments, belonging, so far as can be determined, to the genus *Conocephalites*, and *Scolithus*-borings. Ten feet below the fossil horizon, the rock (1,390) is somewhat the same, but often brownish and containing numerous iron-stained cavities. It is traversed also in every direction by films and veins of dark-brown and reddish black hematite. Some of the veins are as much as an inch in width, and often show an interior cavity or "vug," lined with black, dull metallic-lustred, crystalline plates, which have a distinct cubical cleavage and reddish streak. Amongst the plates are concretionary balls, chiefly of the browner oxide, ⅛th inch in diameter, and made up of concentric shells. The structure of the crystalline plates indicates that the hematite has resulted from an oxidation of pyrite.

One mile southwest from Rattlesnake Rock is another quite remarkable pile of rock, lying in the midst of a large marsh. The summit is a flat, oval-shaped area, about 300 by 1,500 feet in size, the greatest length being in a N. 25° W. direction. The base is about 35 feet lower than that of Rattlesnake Rock, and the summit is 155 feet higher, or about 555 feet above Lake Michigan. On the east face the cliffs are 50 to 75 feet in height; on the west, over 100 feet. At the northern end the rock is exposed for most of the height of the bluff, being worn into towers partly separated from the main rock. A section of the bluff, taken chiefly on the east side, is as follows:

	Ft.	*In.*
1. Very fine-grained, non-friable but porous, yellowish, non-calcareous; dotted with fine shining scales of mica; made up of very sharply angular quartz grains; weathering with a light yellowish smooth surface; thin lamination indicated by fine lines, parallel to which there is a tendency to splitting; filled with minute fragmentary fossil impressions, chiefly of trilobites; among these were determined *Ptychaspis* (n. sp.), *Conocephalites minor*, and *Orthis Barabuensis*; not found definitely exposed, but lying in fragments thickly strewn over the surface of the bluff, which is grassed, the rock being thus concealed; lying about 100 feet lower than the fossil horizon on Rattlesnake Rock, and the same horizon on Roche à Cris; not a mere local layer, because found again with exactly the same fossil contents, and peculiar lithological characters, and occupying the same position, 10 miles eastward on Pilot Knob; not appearing in the Roche à Cris section, where, however, it might easily have been overlooked on some of the less accessible portions of the cliff (1400)........	..	6?
2. Very coarse, friable, reddish brown; weathering into thin layers...........	9	..
3. Very coarse and friable, white-and-brown banded; carrying large ripple-marks at top..	16	..
4. Moderately coarse, friable; uniformly white in color, except on weathered surfaces, which show brown-stained layers 2 inches to 4 inches in thickness,	18	..
5. Finer-grained, very friable, pink-and-white banded, white predominating below..	14	..
6. Coarse-grained, very friable; whitish with dirty colored ridgy projections, which on exposed edges are vitrified; near the base including some pink layers..	19	6
7. Fine-grained, very friable, brown-and-white-banded; thin-laminated......	8	..
8. Not seen in detail	50	..
9. Alternating very coarse and finer sand layers, all very friable; alternating also in color, being banded white and brown; finer layers cross-laminated; coarser ones (1401) very plainly banded, and containing rolled grains up to $\frac{1}{20}$ to $\frac{1}{10}$ inch in diameter; all showing very marked surface vitrification, which in the coarser parts extends in much further than in the finer, the grains being glassy and closely adherent; seen at the foot of the north end of the cliff..	20	..
Height of the bluff..	155	..

Nine miles east from Roche à Cris and Friendship Mound, on the N. E. qr. of Sec. 3, T. 17, R. 7 E., is the outlier known as **Pilot Knob.** This is a narrow jagged crest, 75 feet long, 10 to 15 feet wide, and 80 feet high, resting upon a hill with gentler slopes, and about 400 paces in diameter. A section from above downwards is as follows:

	Feet.
1. Medium to fine-grained, brick-red (1420, 770); composed of rolled grains of quartz, coated externally with red and brown iron oxides; containing some hard curving seams, ⅛ to ¼ inch in thickness, of a dark brown color, made up of glassy quartz grains cemented by much brown iron-oxide, and evidently of a concretionary nature; including some lighter colored brown and even white layers, the latter (1419) porous, friable, medium-grained, and weathering with a very hard vitrified crust; containing near the base about a foot of light reddish, very friable, fine-grained, fossiliferous rock, containing *Ptychaspis Miniscaensis* and other trilobite impressions.........	45
2. White, friable, non-fossiliferous sandstone, to foot of crag............... ...	40
3. Unexposed, on gradual slope	30
4. Fine-grained, non-friable, yellowish sandstone (1421), consisting of fine angular quartz, and containing a few scales of mica; thin-bedded and marked by fine lines of lamination, parallel to which it splits with some readiness; fossiliferous, containing *Ptychaspis*, *Conocephalites* and disks of crinoidal columns; exactly resembling the fossil rock at the summit of the last section given, to which horizon it undoubtedly belongs	1
5. Unexposed, on steep slope..	10
6. White-and-brown-banded, thin friable layers	20
7. Unexposed to base	20
Height of Knob	166

The two fossil horizons of the above section appear to be the same as recognized on Roche à Cris, and the bluffs south of Friendship, though apparently somewhat nearer together. The base of Pilot Knob is 545 feet, the lower fossil horizon 595 feet, the upper fossil horizon 665 feet, and the summit 705 feet above Lake Michigan. These figures indicate a slight rise, about 4 feet to the mile, of the strata between Roche à Cris and Pilot Knob. It is possible that this rise may be exaggerated by unreliable barometrical observations; there is, however, certainly no rise westward between these points.

A mile and a half southeastward from Pilot Knob, the intervening ground being low, on the N. W. qr. Sec. 12, T. 17, R. 7 E., is a long ridge facing northwestward, with rock outcrops on the flanks. The highest outcrop seen is some 20 feet below the top of the ridge, and about 25 feet lower than the summit of Pilot Knob. From this point downwards for 40 feet are seen layers of incoherent white sandstone, with intercalated yellowish calcareous bands, 2 to 6 inches in thickness, and 5 to 15 feet apart. The rock of these bands (1405, 1406, 1407) is rough-textured, porous and moderately firm, but crumbling under the hammer. It has the appearance of being coarse-grained, but on close inspection most of the apparent large grains are seen to be due to the aggregation of smaller ones, and the rock is seen to consist of an admixture of fine, yellowish, angular grains, and larger ones of white and much-rolled quartz, with sparsely scattered greensand grains. On solution in acid, the yellowish matter is entirely dissolved, leaving a residue of not over 40 per cent., which is made up entirely of the white quartz grains. Cleavable calcite is occasionally to be seen by the naked eye, and from the ready effervescence and solution in cold acid, it is judged that the rock is much more largely calcareous than dolomitic. These layers are, beyond doubt, those that are to be seen in more southern counties immediately underlying the Mendota limestone, which possibly exists as a capping on this hill. From the figures given, it will be seen that these layers extend as much as 60 feet lower than the summit of Pilot Knob, which, moreover, is of an entirely different kind of rock. In order that the Pilot Knob layers may pass beneath those across the valley, they must have a descent of at least 50 feet to the mile in that direction, an amount of descent that would be altogether extraordinary in Central Wisconsin.

One mile eastward from the exposures just described, on the N. W. qr. of Sec. 7, T. 17, R. 8 E., Marquette county, is a large isolated bluff capped by the Lower Magnesian limestone. Another similar bluff lies a mile northeast of this on Sec. 4 of the same town. The first named, known as "Glover and Merriman's lime bluff," shows the following section:

	Feet.
1. *Lower Magnesian limestone* (1409): close-textured, very finely crystalline, yellowish-gray to nearly white; holding small cavities lined with brown-tinted dolomite crystals, and others lined with stalactitic lime carbonate; in places marked with fine pencilings of the dendritic oxide of manganese; dolomite—dissolving only in heated acid, with a residue of very fine, white, angular silica, constituting 13.96 per cent. of the whole — but containing no sand whatever; containing little greenish blotches and streaks; weathering with rough surface; occurring in layers 3 to 4 feet thick, some of which are much displaced	30
2. Unexposed	10
3. *Madison sandstone:* coarse, whitish, moderately firm; forming a prominent ledge on the side of the bluff	10
4. Unexposed	40
The following occurs on an outlying hill south of the main bluff:	
5. *Mendota limestone:* lowest layers only seen; brownish and yellowish	10
6. Unexposed	15
7. *Potsdam sandstone:* white, crumbling sandstone, with intercalated yellowish, coarse-textured, calcareous layers (773, 1408), exactly like those seen at the last locality described	10
8. Unexposed to base of bluff	35
Total height of bluff	160

The base of the bluff is 570 feet, and its summit 730 feet, above Lake Michigan. These figures indicate some descent from the locality on Sec. 12, T. 17, R. 7 E., but exactly how much is not ascertainable, from the somewhat indefinite position in the series of the limy layers at the former place. It has been said that Friendship Mound and the Roche à Cris rise respectively to altitudes of 750 and 665 feet above Lake Michigan. Neither, however, shows any sign of limestone at top, or any indication of reaching within 100 feet of its horizon. This might be explained readily enough by supposing a continuation westward of the somewhat rapid rise of the strata that is indicated in the vicinity of the Lime Bluffs. It has been shown, however, that the strata of Pilot Knob indicate not only no *westward* rise, but even a slight *eastward* one.

The occurrence of two limestone outliers as much as 25 miles from the nearest points of the area occupied by the Lower Magnesian is interesting, and of considerable economic importance. That this formation once extended as far north as this is thus rendered certain. Having reached the highest land in the region, it may possibly have had also a still wider spread northward.

MARQUETTE AND WAUSHARA COUNTIES, AND GREEN LAKE COUNTY, NORTH OF THE FOX RIVER.

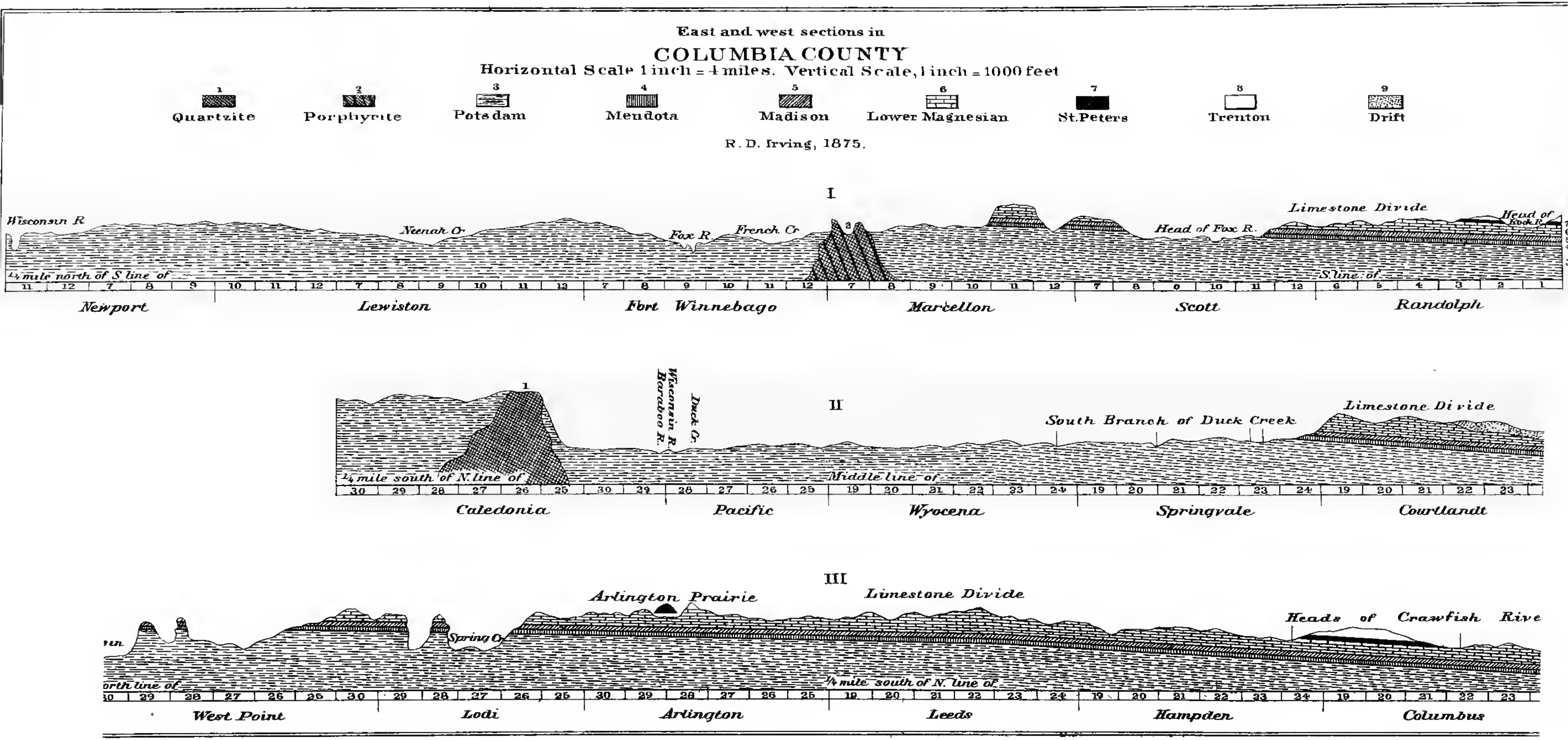
(ATLAS PLATE XIV, AREA E.)

This district lies chiefly to the north and west of the Fox river, towards which it slopes steadily from the summit of the dividing ridge in western Waushara and southern Adams counties. It includes a total area of about 1,239 square miles. Throughout the region the Potsdam sandstone seems to be the surface formation everywhere, except in the few places where the crystalline rocks come to the surface, and in one or two limestone-capped bluffs. The sandstone, however, is not frequently exposed, being for the most part very deeply buried beneath the glacial drift, or Champlain lacustrine clays, the former occurring in portions of the region in a morainic condition, and of unusual thickness. It is not possible to be certain that the superficial deposits do not in places rest directly upon the crystalline rocks without intervening sandstone, but the known facts render such an hypothesis improbable.

This region, though similar in its basement rock and general sandy soil to the central plain of Adams and Juneau counties, differs from it in being without the plain-like character, presenting as it does a steady descent from northwest to southeast of over 300 feet, and a surface in general much roughened by morainic drift. Another striking difference is found in the absence of the castellated outliers that characterize the Adams and Juneau district. A few small ones dot the summit of the high ground in northwestern Marquette county and the adjoining part of Waushara, but these are of rounded shape, comparatively stout, and without the fragile appearance of the more western peaks. Further east, the outliers disappear altogether. The general southeastward descent gives that direction to the many tributaries of the Fox, which, as already described, are large, clear and rapid streams, furnishing many excellent water-powers. In places quite large areas are level, as for instance Burr Oak prairie, in western Waushara county, but these are but small portions of the whole district. In the town of Mount Morris and the adjacent country, northeast of Wautoma, Waushara county, is a small district which owes its irregularity of surface chiefly to subaerial erosion of the rocky strata, presenting the ordinary phenomena of deep and narrow valleys. Southeastern Marquette county includes a small part of the south side of the Fox river basin, in the towns of Packwaukee, Buffalo and Montello. The character of this area is similar to that of the rest of the region, the sandstone outcrops being somewhat more frequent, but the surface in general much heaped up with drift.

The soil of the region is largely sandy. This sand, however, though originally coming, without doubt, from the Potsdam sandstone, is directly derived from the glacial drift, which has also contributed much calcareous and clayey matter. Thus it comes that, although based upon the sandstone, and presenting in many places a very sandy soil, excellent farming land is by no means uncommon in these counties. In the eastern towns of Waushara county, where the red Champlain clays make up the body of the soil, much very excellent land is found. Except in the clay region of eastern Waushara, where hard wood (ash and elm) is plenty, the only timber is for the most part the small oak growth that characterizes most of Central Wisconsin, the oaks becoming mingled with pines towards the north.

From what has been said, it will be seen that the exposures of horizontal strata are not frequent. The lime bluffs of the town of Springfield, in the northwestern corner of Marquette county, have already been described. On Sec. 15, T. 19, R. 11 E., Waushara county, the high ground known as Mount Morris reaches into the limy layers that underlie the Mendota limestone. On top of the hill, 240 feet above Mount Morris post office, are exposed 3 feet of thin layers of coarse-grained, yellowish, firm sandstone


East and west sections in
COLUMBIA COUNTY
Horizontal Scale 1 inch = 4 miles. Vertical Scale, 1 inch = 1000 feet
1 Quartzite
2 Porphyrite
3 Potsdam
4 Mendota
5 Madison
6 Lower Magnesian
7 St.Peters
8 Trenton
9 Drift
R. D. Irving, 1875.
I
Wisconsin R.
Neenah Cr.
Fox R.
French Cr.
Head of Fox R.
Limestone Divide
Head of Rock R.
¼ mile north of S line of
S. line of
Newport
Lewiston
Fort Winnebago
Marcellon
Scott
Randolph
II
Wisconsin R.
Baraboo R.
Duck Cr.
South Branch of Duck Creek
Limestone Divide
¼ mile south of N. line of
Middle line of
Caledonia
Pacific
Wyocena
Springvale
Courtlandt
III
Arlington Prairie
Limestone Divide
Heads of Crawfish Rive
Spring Cr.
¼ mile south of N. line of
West Point
Lodi
Arlington
Leeds
Hampden
Columbus

(1416), alternating with finer-grained, more friable layers (1415). The coarser rock is the most calcareous, consisting of much-rolled grains of dulled quartz, with 30 per cent. of yellow-stained, cleavable calcite (and dolomite?) grains, and dark, smooth-surfaced grains of greensand. The horizon is probably within 25 feet of the Mendota, and is from 600 to 650 feet above Lake Michigan. On the N. W. qr. of Sec. 16, 260 feet below the rock on top of the mount, light brownish, very fine-grained, firm, non-calcareous sandstone (1414½) is exposed. With the exception of Mt. Morris, the lime bluffs of northwestern Marquette county, and a few points in the town of Buffalo, Marquette county, the whole region appears to be eroded well down into the Potsdam series, probably everywhere as much as 100 feet below the Mendota, and in general 200 to 300 feet. Even in the eastern towns of Waushara, just east of which, in Winnebago county, the Lower Magnesian is well down into the low ground, the erosion into the Potsdam has been very considerable, the lacustrine clays reaching a thickness of over 100 feet. At the limestone bluff on Sec. 7, T. 17, R. 8 E., Marquette county, the base of the Lower Magnesian is 700 feet above Lake Michigan. Thirty-eight miles from here, in a N. 10° E. direction, on Sec. 27, T. 19, R. 14 E., Winnebago county, the same horizon is at an altitude of about 200 feet. The total eastward descent thus shown is 500 feet, or about 13 feet to the mile. This descent is, however, by no means uniform, being very much greater in the eastern half of the distance, for the place of the base of the Lower Magnesian at Mt. Morris, as indicated by barometrical observations, is not less than 700 feet above Lake Michigan. These observations were far from any known point of altitude, but allowing all chances for error, the altitude of the Lower Magnesian base, at this place, could hardly be less than 650 feet.

Very good, hard, white sandrock is quarried about 3 miles from Wautoma, in the town of Mount Morris, Waushara county; at a point about the same distance north of Montello, Marquette county; and again near the village of Packwaukee, in the latter county. The stone from all resembles somewhat the sandstone from the Stevens Point, Grand Rapids and Black River Falls quarries, and may be at the same horizon. The **Packwaukee** quarry is opened in the top of a low ridge, on the edge of the Fox river marsh, and a short distance from the shore of Lake Buffalo, N. E. qr. of Sec. 30, T. 15, R. 9 E. The quarry face is 15 feet high, and the rock very regularly bedded in layers from 2 inches to 30 inches in thickness, the heavy layers occurring below, the thin ones at top. Strong, smooth-faced joints intersect the layers, trending N. 75° W., N. 35° W., N. 17° W., and N. 14° E. The top layers are somewhat soft and brownish, the whole quarry face being much iron-stained by weathering. The heavy layers below, however, present a very much indurated, nearly white, fine-grained sandrock (760), made up of grains of sharply angular, glassy quartz, and obtainable in very large, straight-edged, smooth-faced blocks, which dress readily. The rock is a quite unusually good building material.

Sauk and Columbia Counties.

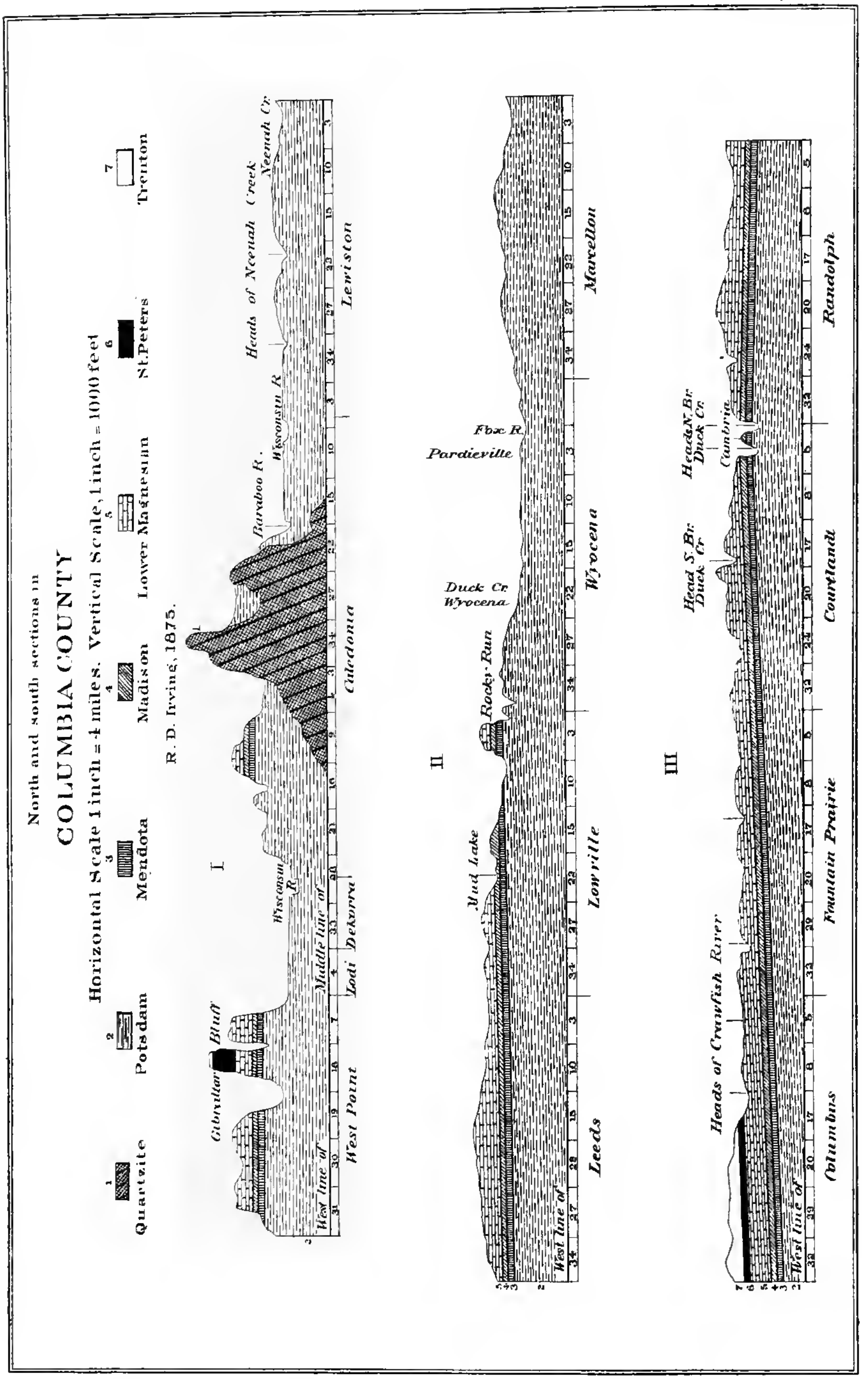
(Atlas Plates XIII and XIV, Areas D and E.)

Those portions of Sauk county lying west of the west line of R. 4 E., are not here included. The remainder of this county, and Columbia, constitute a nearly rectangular area, 54 miles from east to west and 24 from north to south, lying just midway between Lake Michigan and the Mississippi river. Sauk county, in its southern portion, along the Wisconsin, oversteps the limits of the rectangle, adding three entire townships and parts of three others. The whole area of the district, as given by the land-office plats, is 1,351.5 square miles, including 785 square miles for Columbia, and 566.5 square miles for that portion of Sauk county here described, the whole of Sauk county having an area of 796.5 square miles.

The **main topographical features** of the district — the east and west ranges of the Baraboo; the Wisconsin river, which traverses the area centrally from north to south, making a great bow eastward to double the eastern point of the uniting quartzite ranges; the remarkable course of the Fox river, which after flowing southwest directly towards the Wisconsin, turns abruptly north when but one and one-half miles from it, the two rivers traversing a flat sand plain, without dividing ridge, and passing the one into the St. Lawrence, the other to the Gulf of Mexico; the escarpment of the Lower Magnesian limestone, which crosses Columbia county from S. W. to N. E., having its face turned westward and much indented by the head waters of the streams tributary to the Wisconsin; the gentle eastward slope of the country east of the escarpment, with its streams flowing eastward to the Rock river; the sandy plain-like character of the country west of the escarpment; the isolated erosion peaks and outliers that dot the surface of this plain — have all already been more or less briefly alluded to.

The **Lower Magnesian escarpment** enters Columbia county on the southern side of the town of Lodi, projecting in bold points that rise 250 to 300 feet above the valley of Spring creek. Thence it trends northward through the eastern row of sections of that town, with the same character, having on top the elevated prairie land of Arlington. At the northeastern corner of Lodi, it turns nearly at right angles, crossing the northern row of sections of Arlington in an eastward direction. Passing into the northwest corner of Leeds it turns again northward, traversing Lowville from southeast to northwest. In this town, though still well marked, the escarpment is much lessened in boldness and height, because of the increasing eastward descent of the strata, and because also it has in front a wide area occupied by the Madison and Mendota beds, beyond which a second escarpment leads to the lower level occupied by the Potsdam sandstone. From the northeast corner of Lowville it crosses the northwest part of Otsego, not far from the village of Rio, and passing into Springvale about the middle of its south line traverses that town in a northerly direction, projecting westward in long points. In Springvale the Mendota and Madison escarpment is the most marked of the two, it presenting long narrow and bold points projecting westward between the branches of Duck creek, which head in the towns to the eastward. The main branch of Duck creek, in the northern part of Springvale, has the widest valley, and has on each side the longest of the Lower Magnesian points, that on the north side extending all the way to the west line of the town. On this branch of Duck Creek, also, the low ground extends far eastward into the towns of Courtland and Randolph. Across the town of Scott the escarpment presents the same character as in Springvale, the westward projecting points receding eastward, however, in the north part of the town, and having between them the head streams of the Fox river, instead of tributaries of the Wisconsin. The remarkable manner in which the Lower Magnesian escarpment recedes from the Wisconsin after forming for so many miles the southern boundary of the valley of that stream, and the bearing of this upon the former southern discharge of the Fox river system, have been previously alluded to.

Immediately **south and east from the limestone edge**, the country is on a level with its summit, but further south and east sinks gradually with the decline of the strata in those directions. Along the western part of the south line of Columbia county the direction of the greatest descent of the strata is nearly due south: further east and north, however, it veers to the eastward, being at the middle of the east line of the county about due east. Still further north, in the town of Randolph, a northern descent begins to be distinctly perceptible. The surface slopes in general correspond with these changes in direction of the slopes of the strata. The greatest elevations are thus evidently reached towards the southwest, where the escarpment is highest. Thus, the high prairie of Arlington and Leeds reaches altitudes of from 450 to 500 feet, whilst further east, in Columbus and Hampden, the general elevation is 200 to 250 feet less.


North and south sections in
COLUMBIA COUNTY
Horizontal Scale 1 inch = 4 miles. Vertical Scale, 1 inch = 1000 feet
R. D. Irving, 1875.
1 Quartzite
2 Potsdam
3 Mendota
4 Madison
5 Lower Magnesian
6 St. Peters
7 Trenton
I
Gibraltar Bluff
Wisconsin R.
Baraboo R.
Wisconsin R.
Heads of Neenah Creek
Neenah Cr.
West line of
Middle line of
West Point
Lodi
Dekorra
Caledonia
Lewiston
II
Mud Lake
Rocky Run
Duck Cr.
Wyocena
Pardieville
Fox R.
West line of
Leeds
Lowville
Wyocena
Marcellon
III
Heads of Crawfish River
Head S. Br. Duck Cr.
Head N. Br. Duck Cr.
Cambria
West line of
Columbus
Fountain Prairie
Courtland
Randolph

Further ideas as to this structure can best be obtained by examination of the sections of Plates XXII and XXIII, in connection with the map of Area E. In southeastern Lodi, Arlington, Leeds, Hampden, southeastern Lowville, southwestern Otsego, and southern Fountain Prairie, the country above the escarpment is generally rolling prairie, much of it very high. Further north, in northern Otsego and Fountain Prairie, and southern Courtland and Springdale, the prairie belt is broken by a belt of the ordinary oak timber. Still further north again, prairie spreads widely over the limestone country of Courtland, Randolph, Springdale and Scott. Nearly all of the country east of the escarpment shows a most excellent soil, being underlaid for the most part by limestone, which is, however, frequently buried beneath much glacial drift. An exception would be those portions of Fountain Prairie and Otsego where erosion has carried the surface into the horizon of the Madison sand beds, the result being a loose, sandy soil, like that of the regular Potsdam regions. The streams watering this district are mostly small, and all flow eastward towards the Rock river.

Immediately **west of the limestone edge**, there is an abrupt descent of 100 to 300 feet, and, beyond, a more gradual slope of 50 to 100 feet to the Wisconsin river. This area has, in general, the character of a sandy plain, timbered with small oaks, with marshes along the streams, and dotted here and there with isolated bluffs, 100 to 400 feet high, from a few acres to several square miles in area, and generally surmounted by a capping of Lower Magnesian limestone. But very little prairie is met with. Some occurs in the town of West Point, including both low land and limestone outliers. The streams are larger than those on the east of the divide, increasing in size as the escarpment recedes from the Wisconsin. Spring creek, in Lodi, Okee creek, in southern Dekorra and northern Arlington, Rocky run, in northern Dekorra and Lowville, the several branches of Duck creek, in Pacific, Wyocena, Springvale, Courtland and Randolph, and the Fox river in Fort Winnebago, Marcellon, Wyocena and Scott, are the principal streams. The towns of Lewiston, Newport and Fort Winnebago, west of the Fox river, and north of the Wisconsin, are similar to the rest of this sand district in many respects; but are more roughened in surface, the northern portions of the two former rising up to the high land through which the passage of the Dalles is cut.

West of the Wisconsin river we find the topography influenced primarily by the quartzite ranges of the Baraboo, which have already been sufficiently described. For our present purpose it is merely necessary to remember that they are two east and west ranges, some twenty miles in length, uniting at both ends, and thus entirely enclosing the low ground between them. They are made up of Archæan quartzite and quartz-porphyry, but the country around and between them is all occupied by the horizontal formations. Outside of the ranges in the towns of Caledonia, Columbia county, and Fairfield, Merrimack, Prairie du Sac, and Sumpter, Sauk county, the country is in most respects like the level sand district immediately east of the Wisconsin, showing in the more southern portions a few limestone-capped outliers. Farther west, however, we pass beyond the western limit of the glacial drift, and find the topography presenting the usual marked change, being characterized by narrow ramifying ridges and valleys, the former, in the more southern towns, commonly capped by the Lower Magnesian limestone, but in the more northern formed entirely of sandstone. In the southern part of Sauk county, immediately west from the drift limit, the ridges are found frequently worn into narrow, isolated crests, 100 to 200 feet high, and with frequent rock exposures, constituting a very marked and peculiar scenery. Farther west, the ridges are broader, and large areas of limestone occur on the higher levels. In the town of Westfield, west from the ends of the quartzite ranges, the high ground continues, capped now by the Lower Magnesian limestone, and forming the divide between Honey and Narrows creeks. Honey creek enters the Wisconsin about five miles below Sauk City. Following it towards its source, we find it separating, in the northern part of the town of Troy, into two principal branches, the southern one setting back westward nearly parallel to the Wisconsin, and only about six miles from it, the other coming from the south side of the divide in the town of Westfield. Between the wide valley of the south branch and the Wisconsin, is a long line of limestone-capped bluffs, which present a bold front, 200 to 300 feet high, along the north shore of the Wisconsin. North of the Westfield divide the various head streams of Narrows creek are found running northward, with narrow and sharply defined intervening ridges. Narrows creek itself runs in a level valley two to three miles wide. North of it, again, the same narrow limestone-capped ridges are found, until the still broader valley of the Baraboo is reached in the northern part of Reedsburg. Beyond this again the ridgy topography continues, the ridges now altogether of sandstone, and leading up to the high ground which forms the southern rim of the sand plain of Juneau and Adams counties, and through which the Wisconsin passes at the Dalles. On the slope towards the Dalles, in the northeastern part of Sauk county, the small tributary streams of the Wisconsin cut down through narrow rock-walled cañons, similar to the Dalles, though on a smaller scale. The valley of the Baraboo, between the quartzite ranges, is generally higher than the country outside the ranges, and is considerably roughened in surface by the wash from the enclosing ranges towards the Baraboo. The streams watering the district west of the Wisconsin are much larger than those on the east side of that river. The largest of these is the Baraboo river, which, entering Sauk county on the northwest, traverses it in an easterly direction, passing between the two quartzite ranges, and reaching the Wisconsin at the extreme eastern point of its great bend, having in this distance a fall of about a hundred feet. Its numerous tributary streams, dividing into many smaller branches, drain the country for a width of ten miles on each side of the river. South of the southern quartzite range and of the limestone divide in Westfield, the only streams of importance are Honey and Otter creeks. The former is much the larger; separating into numerous small branches, each with its own ravine, it drains an area of about 185 square miles. Otter creek drains a considerable portion of the southern slope of the main quartzite range in the town of Sumpter, and then, taking a due south course towards the Wisconsin, sinks into the sand when within two miles of the river. Except on and about the quartzite ranges, the soil and timber of the district west of the Wisconsin follow the same rule as observed east of the river, *i. e.*, on the lower levels, loose sandy soils, whilst on the higher limestone ground, the soil is clayey and excellent. Good land, however, is sometimes found on the lower levels, as, for instance, on Sauk prairie, where it is due partly to drift materials; in the town of Honey Creek, where stream detritus forms much of the soil, and in the northern part of Excelsior, where no such causes can be assigned. Occasional pine groves are interspersed amongst the ordinary oak timber, whilst amongst the quartzite ranges there is a heavy growth of hard wood, largely maple.

The list of **geological formations** represented in Sauk and Columbia counties includes all of the Central Wisconsin formations, from the Archæan to the Drift, except the Galena limestone. The *Potsdam sandstone* is the surface rock over all the lower levels along the Wisconsin and its many tributaries, besides forming considerable portions of the slopes of the outliers and higher lands. On all sides of the quartzite ranges it is found attaining very considerable altitudes, apparently rising into the horizons of the higher strata, whilst within the circuit of the ranges it occupies all levels, limestone being found in one or two small patches only. Farther north again, in northern Sauk and northwestern Columbia, it occupies all levels, having attained now a much increased altitude by virtue of its general northern rise. The *Mendota and Madison beds* occupy parts of the slopes, or else cap the summits of many of the outliers that flank the limestone escarpment in Columbia county, and of the ridges of western and southwestern Sauk. They also form the surface rock along the slope of the western edge of the limestone country of Columbia county, occasionally, as in the towns of Lowville and Springvale, coming to the surface over a belt of country several miles in width. Even east of the limestone edge, a considerable area of the adjoining portions of Otsego and Fountain Prairie is eroded down to the level of the Madison sand beds, and yet surrounded entirely by the higher formations. Such an effect is a peculiar one, and takes place only where the inclination of the surface bears such a relation to the changing inclination of the strata as indicated in Fig. 37. The *Lower Magnesian* limestone caps many of the outlying bluffs east of the Wisconsin, forms the summit of most of the higher ridges in

FIG. 37.

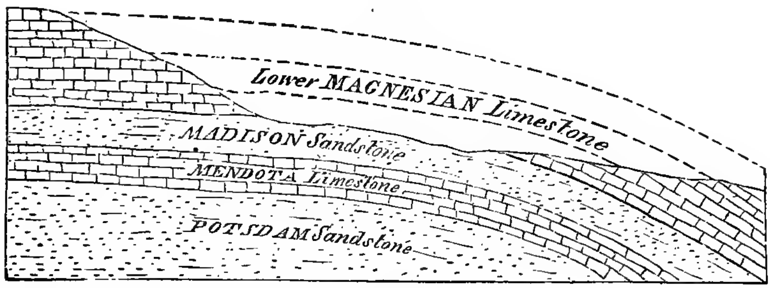


DIAGRAM SHOWING HOW AN AREA OF A LOWER FORMATION MAY BE ENTIRELY SURROUNDED BY A HIGHER ONE.

western and southwestern Sauk, and is the surface rock nearly everywhere in Columbia county, east of the limestone edge. In this latter district, however, it is overlaid by the *St. Peters sandstone* and *Trenton limestone*, in southeastern Hampden, and southern Columbus, over a small area in eastern Fountain Prairie, and over a much larger one in northeastern Courtland and eastern Randolph. The St. Peters sandstone occurs also in several patches in southwest Arlington, lying upon the irregular upper surface of the Lower Magnesian, and forms the upper part of a remarkable bluff in the northeast part of West Point. The characters of the several formations are indicated in the following detailed descriptions. Their thickness, relative positions, etc., are shown by the sections of Plates XX, XXII and XXIII of this volume, and those attached to the Atlas Plate of Area E.

Beginning our detailed descriptions in the northeastern corner of Columbia county, we note first, on Sec. 31, T. 13, R. 12 E., **Randolph**, two quarries on the Mendota and Madison beds, on the walls of a ravine at the head of Duck creek. The quarry on the west wall of the ravine shows the following section:

MENDOTA BEDS.

		Ft.	*In.*
I.	Very fine-grained, yellowish-brown, calcareo-silicious rock (1206); only slightly arenaceous in feeling, but leaving a residue, on treatment with acid, of 69.03 per cent., which consists of exceedingly fine, white, angular quartz; thinly and regularly laminated, the layers running from one to four inches	10	..
II.	Very fine-grained, close-textured, yellow-and-purple-blotched, calcareo-argillaceous rock (1207); the yellow parts like I, the dark-colored a sort of clay-shale, occasionally finely laminated, but not in distinct layers; residue on treatment with acid, 44.53 per cent.; layers, two to eight inches	6	..
III.	Very fine-grained, milk-white, silicious rock, without calcareous admixture; non-arenaceous; similar to II of next section	..	6

	Ft.	In.
IV. Similar to II	11	..
V. Compact, yellowish-brown-and-red-blotched, calcareo-magnesian rock (1210); differing from I in having a very fine crystalline texture, and cavities lined with dolomite crystals; insoluble residue, 41.73 per cent.; layers a foot thick; quarry-rock, used in building at Cambria and other places in the vicinity: obtainable in large well-shaped blocks	4	..
POTSDAM SANDSTONE.		
VI. Greensand layers; moderately firm, rough-surfaced, brownish, speckled with green; calcareous; leaving a residue, on treatment with acid, of fine, sharply-angular quartz, mingled with dark-green grains	2	..
	32	6

The greensand appears without doubt to be that generally recognized as marking the base of the Mendota horizon, which is here more largely silicious than in the typical localities in Dane county, though still sharply contrasting in character with the Madison and Potsdam sandstone layers. A quarter of a mile up the ravine, on its east wall, another small quarry opening shows the following:

MADISON BEDS.	Feet.
I. Fine-grained, brownish, ferruginous, friable sandstone (1226); non-calcareous; composed of rolled grains of dulled quartz; *scolithus*-bearing	4
II. Very fine-grained, firm, pure white, silicious rock (1212); composed of exceedingly fine, sharply angular quartz; non-calcareous; non-arenaceous; containing 97.52 per cent. of silica; close to III of last section; upper layers shaly	3
MENDOTA BEDS.	
III. Similar to II, but stained yellow and pink (1213); very hard and firm; containing 98.12 per cent. silica	3
IV. Reddish-yellow rock similar to I of last section, and apparently the same horizon.	3
	13

At P. Scheasman's quarry, on the west line of the S. W. qr. of Sec. 6, in the same town, a ten-feet quarry face shows below, in thin and very regular layers, a close-textured, buff-colored, nearly pure dolomite (1205), which weathers with a smooth, yellowish surface, is marked finely with dendritic manganese oxide, and is coated in places with white, stalactitic, lime carbonate, and at the top a heavy layer of concretionary, dark-colored dolomite. On the hill above are exposures of the ordinary rough-textured Lower Magnesian, near the base of which formation the quarry layers appear to lie.

In the railroad cutting at Rio, in the northwest corner of the town of **Otsego**, T. 11, R. 12 E., the Madison and Mendota beds are exposed. The following is the section:

MADISON BEDS.	Feet.
I. Brownish, friable sandstone	6
II. Very fine-grained, pure white, firm, silicious rock; non-calcareous; in upper portions slightly arenaceous in texture (1219, close to 1212); lower portions without trace of granular texture; rough-surfaced and pink-tinted (1216, close to 1213); bedding not distinctly seen; composed of exceedingly fine, angular quartz	12
MENDOTA BEDS.	
III. Red-and-yellow-mottled calcareo-arenaceous rock	4
	22

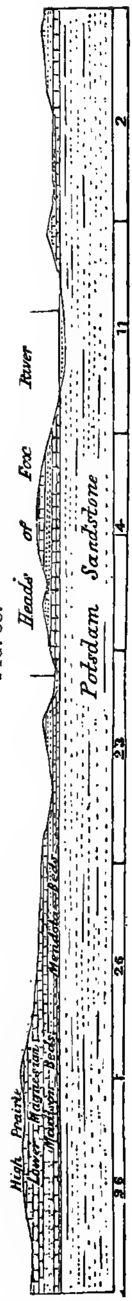


FIG. 38.

NORTH AND SOUTH SECTION IN SCOTT.

Vertical scale 1,000 feet to the inch.

Fig. 38 is a section from south to north along the center line of Secs. 2, 11, 23 and 26, in the town of **Scott**, T. 13, R. 11 E., and serves to give a correct idea of the topography and stratigraphy of that township.

Large ledges of Potsdam sandstone rise on the south side of a small creek in the N. E. qr. of the N. E. qr. of Sec. 3, **Arlington,** T. 10, R. 9 E., a short distance south of the village of Poynette. Here are exposed 15 feet of white, heavily-bedded, friable, non-calcareous sandstone, with some thin greensand layers, the base of the ledge being 60 to 80 feet below the base of the Mendota horizon. Similar but higher ledges occur along the creek in Pine Hollow, in the adjoining parts of Secs. 3 and 4.

The St. Peters sandstone remains on top of the Arlington prairie in five isolated knobs, the highest 70 to 100 feet in height. Three of these are close together on each side of the line between Secs. 28 and 29. The bluff on Spoonam's land, N. E. qr. of the S. E. qr. of Sec. 29, shows large outcrops, in a disturbed condition, of fine-grained, friable, white-and-brown-mottled sandstone (725, 726), composed of glassy quartz grains, the larger ones of which are rolled, the smaller ones angular. Most of the rock is affected by a very hard, vitrified crust, ¼ to ½ inch in thickness, in which the quartz grains appear to possess distinct crystalline surfaces. No trace of calcareous matter is present. Fine-lamination and cross-lamination are plainly perceptible. The knob on Mrs. A. D. Forbes' land has on the south side a vertical cliff, 80 feet in height, of similar but distinctly horizontal and undisturbed sandstone. In the S. W. qr. of the S. W. qr. of Sec. 27, and extending into Sec. 28, and again in the N. hf. of Sec. 34, are other similar bluffs. On the prairie around these sandstone mounds, exposures of the Lower Magnesian limestone are seen at several points whose elevation is greater than that of the base of the sandstone ledges, whilst at least two points, on the south line of Sec. 21 and in the north part of Sec. 29, show the limestone rising as high as the top of the St. Peters. The irregular nature of the upper surface of the Lower Magnesian is thus distinctly proven.

In **Fort Winnebago**, T. 13, R. 9 E., the only formation is the Potsdam sandstone, which, in the middle and western portions, and again in the southeast, rises in isolated bluffs. At T. Coughlin's quarry, N. E. qr. of S. W. qr. Sec. 20, are exposed 10 feet of heavily-bedded, fine-grained, white, porous, friable sandstone (741), which is composed of glassy, sub-angular, quartz grains, and is blotched with ferruginous spots. Rows of little brown-stained pores mark the lamination very plainly. Large fucoidal impressions occur, identified by Mr. Whitfield as *Palæophycus duplex*, and *Palæochoida*, n. sp. Large regular shaped blocks are obtained. The isolated bluff on the adjoining parts of Secs. 25 and 36 shows numerous small exposures of white, crumbling, non-calcareous sandstone, for a thickness of about 90 feet. Fig. 39 is a section from this bluff across the Wisconsin at Portage to the quartzite bluffs of Caledonia. The contour of the section is copied from Gen. G. K. Warren's report on the Fox and Wisconsin rivers.

In **Lodi and Westpoint**, T. 10, R. 8 E., and T. 10, R. 7 E., rock exposures are very frequent along the bluff sides, but only a few prominent points can be described. Kingsley's bluff, on the edge of the high country in the N. E. qr. of Sec. 26, and S. E. qr. of Sec. 23, T. 10, R. 8 E., has the structure shown in Fig. 40. The succession of layers is indicated in the following, beginning above:—

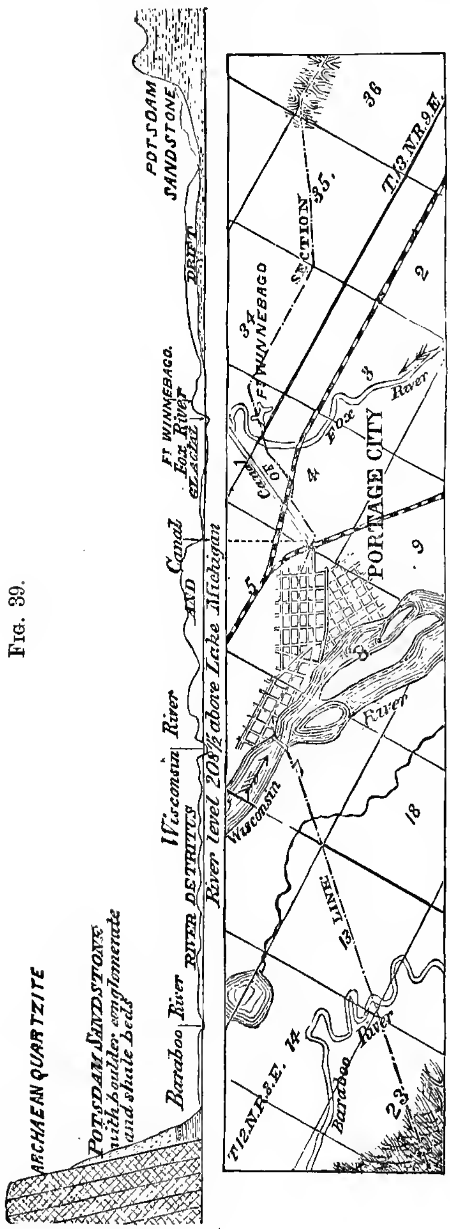


Fig. 39.

Profile-section across the Valley of the Wisconsin, at Portage.
Vertical scale, 400 feet to the inch; horizontal scale 1½ miles to the inch.

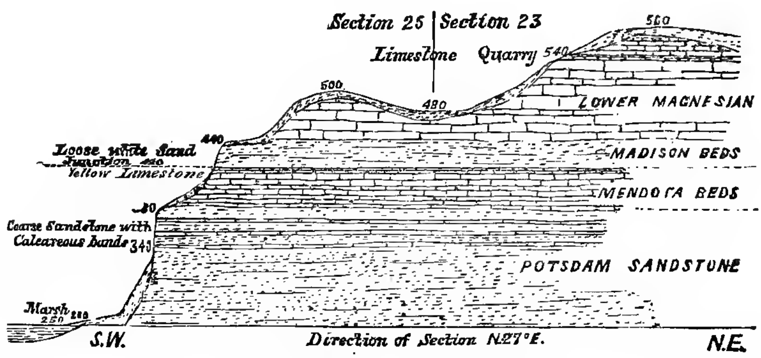
	Feet
I. *Drift-covered slope* without exposure........	20
II. *Lower Magnesian limestone:* in quarry; thin-bedded, top glaciated	5
III. *Drift-covered slope:* without exposure ...	100
IV. *Madison sandstone:* white, incoherent; on the edge of a flat bench in the hillside.	5
V. *Mendota limestone:* yellowish, regularly bedded, fine-grained; containing: silica, 44.57; alumina, 8.68; iron peroxide, 1.18; iron protoxide, 0.22; lime carbonate, 26.69; magnesia carbonate, 17.97; water, 1.28= 99.83; exposed in a small quarry	10
VI. Flat *drift-covered slope* without exposure....	40
VII. *Potsdam sandstone:* white, fine-grained, loose; alternating with harder, yellow, calcareous bands; forming the edge of a bench............	40
VIII. Steep *slope* without exposure, the rock covered by sand from its own disintegration	90
Total	310

The Mendota is quarried again on the side of the hill just west of the depot at Lodi, where it presents the typical yellow color and reddish stains, and is overlaid at the top of the hill by white, incoherent Madison sandstone. Another and much larger Mendota quarry is on the south side of the bluff in the S. hf of Sec. 18, T. 10, R. 8 E. Here are some ten feet of very regularly bedded, yellow, sandy limestone, the layers below heavy, above thin and shaly, with fine large impressions of *Dicellocephalus Minnesotensis.*

The very prominent isolated bluff on the N. E. qr. of Sec. 20, T. 10, R. 7 E., shows the following section at its north end:

	Feet.
LOWER MAGNESIAN.	
1. Grassy *slope*, without exposure	35
2. Coarse, crumbling, brownish *sandstone*	2
3. *Slope* without exposures	18
4. Brownish-yellow, rough, open-textured *limestone*, somewhat crystalline; containing cavities with calcite crystals, numeorous red quartzite pebbles and greensand grains	10
MENDOTA AND POTSDAM.	
5. Coarse, brownish *sandstone*, in perpendicular ledges	10
6. *Slope* without exposure	85
7. Friable, non-calcareous light-colored *sandstone*	15
8. Sand-covered *slope* without exposure	60
Height above road at foot	235

FIG. 40.



SECTION OF KINGSLEY'S BLUFF, LODI.

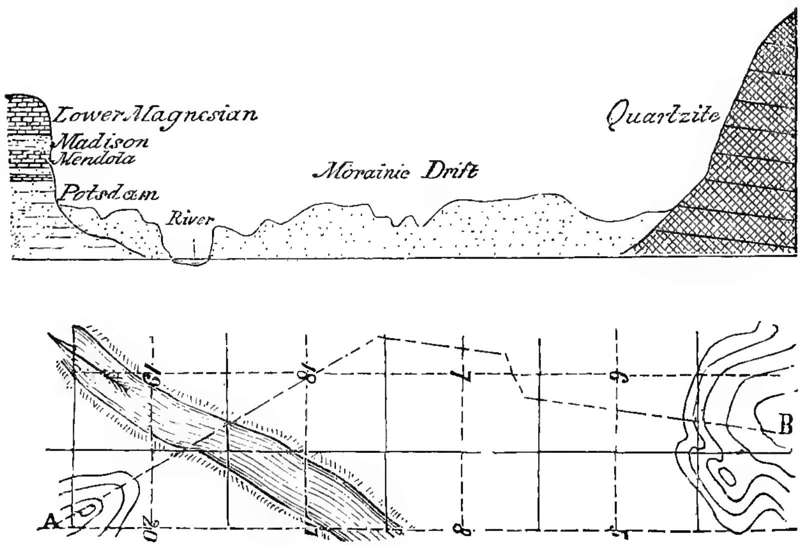
Horizontal scale 1,000 feet to 1 inch. Vertical scale 200 feet to 1 inch. Fignres indicate altitudes in feet above Lake Michigan.

The occurrence of a thin layer of non-calcareous sandstone within the Lower Magnesian is unusual, but this is not an isolated instance. The limestone No. 4 is interesting because of its similarity to the rock from Eiky's and Wood's quarries in the Baraboo valley, the accurate determination of whose stratigraphical position meets with some difficulties, and because of its somewhat peculiar characters as compared with the ordinary Lower Magnesian, the base of which formation there can be no doubt that it marks. From a similar, and equally prominent bluff, on the south side of the same section, the profile of Fig. 41 is taken, running across the Wisconsin to the quartzite range of Merrimac.

Gibralter Bluff is the name given to the bald cliff of St. Peters sandstone which surmounts the western end of a large outlying area of limestone-capped bluffs, in Secs. 17

and 18, T. 10, R. 8 E. The area over which the sandstone is present is not more, probably, than 40 rods in diameter, but the top of the bluff reaches an elevation of about 630 feet above Lake Michigan, or upwards of 450 feet above the adjacent river; so that it constitutes one of the most striking points in the scenery of this part of the valley of the Wisconsin, rising far above all of the immediately surrounding country. Section I,

FIG. 41.

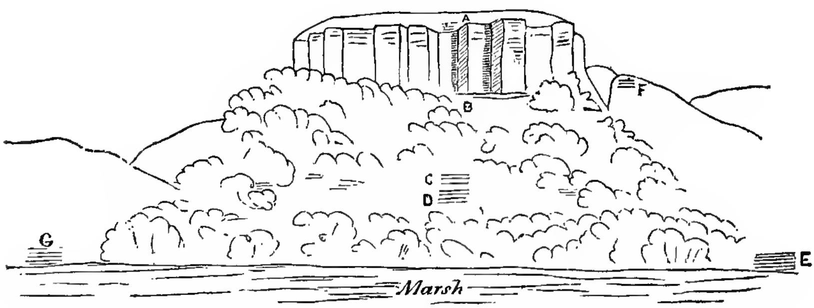


SECTION ACROSS THE VALLEY OF THE WISCONSIN IN WEST POINT AND MERRIMAC.

A B — Line of profile. Horizontal scale 9-10ths inch equals 1 mile. Vertical scale, 400 feet equals 1 inch.

of Plate XXIII, and the north and south section attached to the Atlas Map of Area E, show its relation to the neighboring elevations. Fig. 42 is a rough diagrammatic sketch meant to give some idea of the character of the western face of this remarkable bluff, whose structure is further indicated by the section of Fig. 43, which is drawn to a natural scale.

FIG. 42.

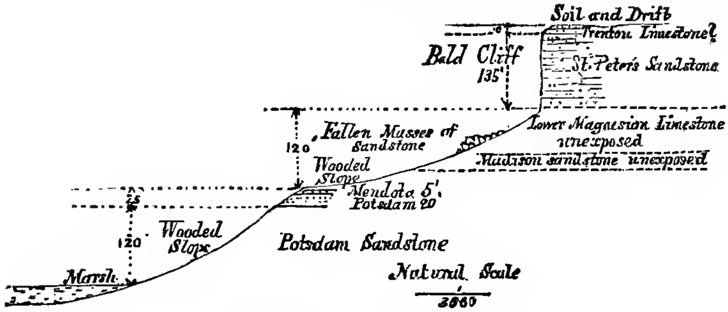


SKETCH OF THE WESTERN FACE OF GIBRALTER BLUFF.

Natural scale, 1:3600.

The western face of the bluff is precipitous in its upper portion for over 100 feet. At the top of the cliff is a rounded summit composed in part of glacial drift, but showing in one place a few broken layers of limestone (736), which are in the proper position, and have the proper characters for the "Buff" or Lower Trenton limestone. The cliff itself is made up of fine-grained, light-colored to nearly white, friable sandstone (735), which is composed of angular and subangular quartz grains, and possesses a hard, vitrified crust. In the uppermost parts of the cliff the horizontal bedding is distinct, the layers being quite thin; below, however, it is not plainly perceptible, whilst the whole has a sort of vertically columnar appearance, due to jointing. On the upper part of the long

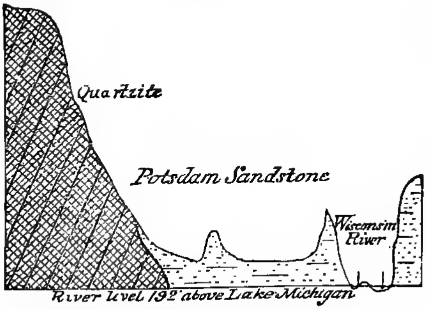
FIG. 43.



SECTION OF GIBRALTER BLUFF.

wooded slope below, are numerous very large sandstone masses, evidently fallen from the cliff. At the lower edge of this slope the Mendota limestone is partly exposed, as shown in Fig. 43, and below it the upper layers of the Potsdam, with intercalated calcareous bands. To the right and left of the line of section, lower non-calcareous sandstone layers are exposed, in low cliffs rising from the edge of the marsh. At the point F, Fig. 42, on top of a bare hill, only a few rods from the sandstone cliff, but at an elevation of 40 feet above its base, is an outcrop of much disturbed Lower Magnesian limestone. Numerous points on the surrounding bluffs also show limestone at elevations above the base of the sandstone of the Gibralter cliff, proving the existence of a very irregular upper surface to the Lower Magnesian.

FIG. 44.



SECTION ACROSS THE VALLEY OF THE WISCONSIN IN SOUTHEAST CALEDONIA.

Vertical scalo, 350 feet to the inch. Horizontal scale, 1⅛ miles to the inch.

For the district west of the Wisconsin river, where both topography and stratigraphy are so largely affected by the quartzite ranges, it will be most suitable to take up in order: the area south of the the quartzite ranges; that west of the ranges; that within them; and that north of them.

South of the quartzite ranges. Fig. 44, which is a section from the top of the quartzite range near the northwest corner of Sec. 2. T. 11, R. 8 E., Caledonia, to the top of a bluff in Dekorra, serves to give an idea of the structure of this part of the Wisconsin valley.

On the flanks of the quartzite in western Caledonia, the Potsdam sandstone rises to altitudes apparently in the horizon of the Lower Magnesian, having then a slight apparent dip southward, or away from the quartzite. This flanking sandstone is well exposed at Dorward's Glen, on the north side of Sec. 18, where it is seen overlying the quartzite, as heretofore described and illustrated in Fig. 27, which is a section along the wall of the glen. This wall shows the following succession of layers, the numbers of the layers being the same as in Fig. 27:—

		Ft.	*In.*
VI.	Yellowish, fine-grained, friable and heavily bedded sandstone	14	8
V.	Pink, fine-grained and thinly bedded sandstone	4	8
IV.	Whitish and brownish, very coarse, heavily bedded sandstone, the constituent grains much rolled translucent quartz	10	..
III.	Similar to the last, but yellowish and finer grained	17	4
II.	Very coarse, like IV.	5	10
I.	Bowlder-conglomerate, almost without matrix, made up of bowlders mostly angular, up to 1 foot in diameter; forms the stream bed	4	2
	Height of cliff	58	8

In the town of **Merrimac**, Sauk county, sandstone at high levels continues to flank the quartzite. This sandstone may be seen at Parphrey's Glen, on the N. E. qr. of Sec. 22, T. 11, R. 7 E., where 20 feet of friable, brownish, *Scolithus*-bearing, regular-bedded sandstone is exposed, including thin layers of a conglomerate of red quartzite pebbles; on the N. E. qr. of Sec. 28, in a high, narrow bluff, which is partly detached from the quartzite; and again, lying directly against the quartzite, on the N. E. qr. of the S. E. qr. of Sec. 20, T. 11, R. 7 E., where it forms a perpendicular cliff directly north of, and across the valley from, the Devil's Nose. The rock at this place is medium to fine-grained, friable, red-and-white-banded, purely silicious, and superficially vitrified, and contains throughout small pebbles of red quartzite, which are, however, aggregated more numerously into two bands, the upper one 2 feet thick, and 25 feet below the summit, the lower one 10 feet thick and 59 feet below the summit. The whole height of the vertical cliff is 210 feet, the whole thickness of sandstone seen, 227 feet. The top of the sandstone has an altitude of 622 feet; its base, one of 397 feet, so that the cliff rises entirely across the horizon of the Lower Magnesian, as indicated by the occurrences of that formation in the country to the south east and west. The sections of Plates XIX and XX show the structure and stratigraphical relations of this cliff.

The isolated knob rising from the west bank of Otter creek, near the center of Sec. 15, T. 10, R. 6 E., **Sumpter**, shows the following section:

		Feet.
I.	*Madison sandstone* in small separated exposures; upper portions very highly ferruginous and firm; near the middle (1227) very fine-grained, lighter colored and slightly calcareous; at the base white, fine-grained, much indurated	25
II.	Unexposed	20
III.	*Mendota limestone;* yellow, shaly, in small quarry-opening	5
IV.	Unexposed	10
V.	*Greensand layer*	1
VI.	Unexposed	15
VII.	*Potsdam sandstone,* upper layers fine, white, friable, banded with calcareous layers, lower portions rising in an abrupt cliff from the bank of Otter creek; heavily bedded, non-calcareous, alternating brown and white	140
	Height of knob	216
	Altitude of summit	416

PLATE, XX

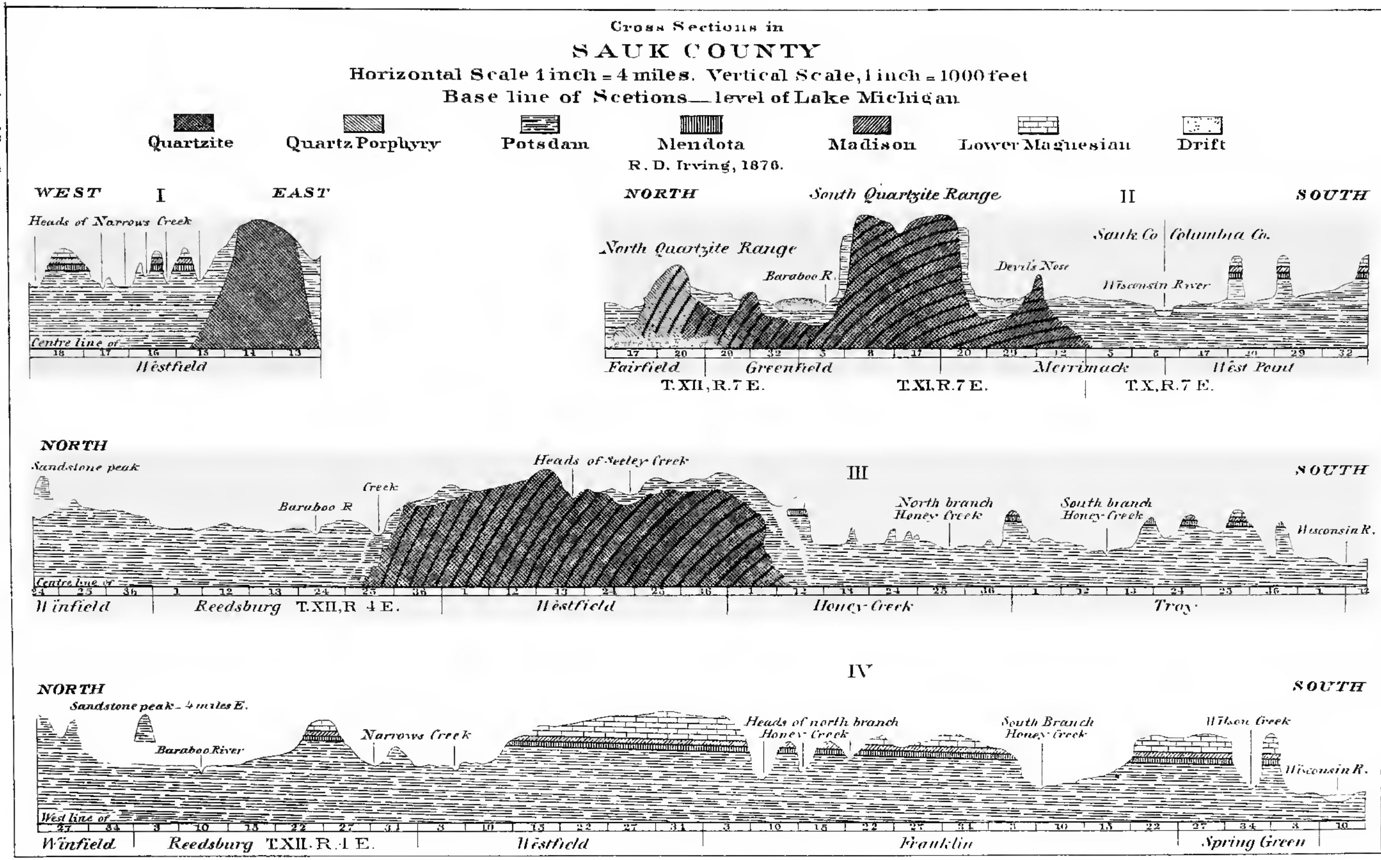


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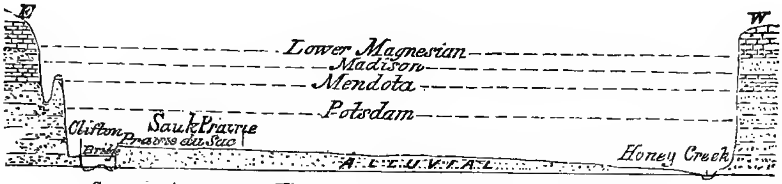
Fig. 45 is a section across the valley of the Wisconsin from the high bluff just west of Rowell's Mill, N. W. qr. Sec. 17, T. 9, R. 6 E., **Prairie du Sac**, in a N. 68° E. direction to the bluffs back of Clifton, Dane county.

Fig. 45.



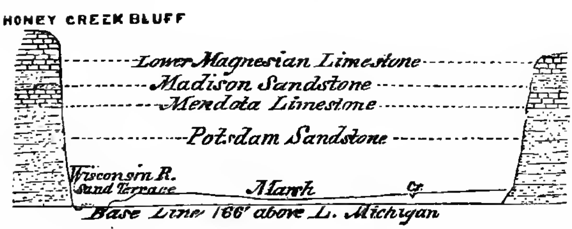
SECTION ACROSS THE VALLEY OF THE WISCONSIN, AT PRAIRIE DU SAC.
Vertical scale 400 feet, 1 inch; horizontal scale 1¼ miles, 1 inch.

The very bold and prominent bluff rising from the bank of the Wisconsin at the mouth of Honey creek, Sec. 21, T. 9, R. 6 E., has already been cited as giving a magnificent section, and portions of this section have been given in some detail in the general descriptions of the formation. Abbreviated, the section is as follows:

	Ft.	In.
1. *Lower Magnesian*, in a vertical cliff facing towards Honey Creek, including subdivisions as given on page 552	52	5
2. *Madison*, including: slope without exposure, 15 feet; white and brown sandstone for the most part non-calcareous, 16.5 feet; slope without exposure, 7 feet; coarse, non-calcareous white and brown sandstone, 2 feet; in all	40	5
3. *Mendota*, including: slope without exposure, 33 feet; brown, earthy, very compact limestone with 34.15 per cent. of white clay, 1 foot; like the last, but with 26 per cent. of clay, 2½ feet; in all	36	6
4. *Potsdam*, including subdivisions as given on page 534; rising abruptly from the Wisconsin	189	3
Total height of bluff	318	7
Altitude of summit	484	..

Fig. 46 is a section across the valley of the Wisconsin, from the bluff just described, 4¼ miles in a southeasterly direction to the bluff on Sec. 1, T. 8, R. 6 E.

FIG. 46.

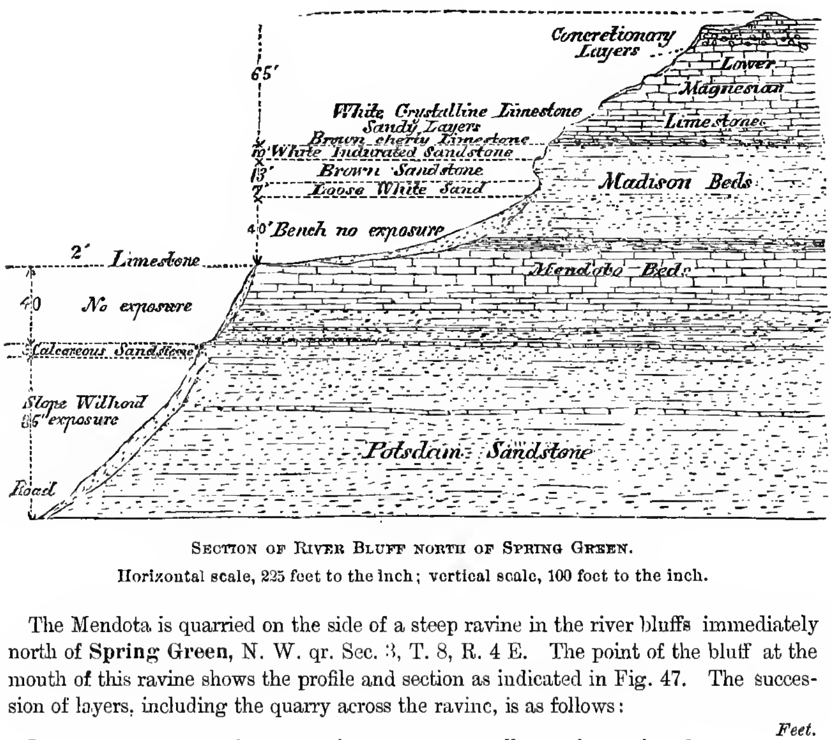


SECTION ACROSS THE WISCONSIN VALLEY FROM HONEY CREEK BLUFF.

Vertical scale 400 feet to the inch; horizontal, 1¼ miles to the inch.

South of the quartzite range, over all of T. 10, R. 4 E., **Honey Creek**, the country is one characterized by numerous high, narrow, branching ridges, which are, for the most part, severed into entirely separate parts, showing frequently walls of bare rock, and often rising into the horizon of the Mendota beds, more rarely into that of the Lower Magnesian. In many cases, the sides of the ridges are worn into bold and fantastic forms of bare rock, whose very plain horizontal stratification renders the effect more striking. On the N. W. qr. of Sec. 17, T. 10, R. 5 E., a narrow, precipitous spur from a higher bluff is worn entirely through, forming a natural bridge of considerable dimensions. The arch is about ten feet thick, its under side being 30 feet from the ground, and the width of the archway 30 to 40 feet. The rock is the upper portion of the Potsdam, containing the usual calcareous bands, and is highly charged with small pebbles of red quartzite. The bases of the cliffs on both sides of the valley of that branch of Honey creek which follows the west line of T. 10, R. 5 E., are made up of a layer 50 feet thick, of white, non-calcareous sandrock, which is rendered very prominent by its strong contrast in color with the darker hued layers at higher levels. Its upper surface appears to be about 155 feet below the Mendota base, and the layer is evidently the same as seen at the foot of the great bluff at the mouth of Honey creek.

Fig. 47.



Section of River Bluff north of Spring Green.
Horizontal scale, 225 feet to the inch; vertical scale, 100 feet to the inch.

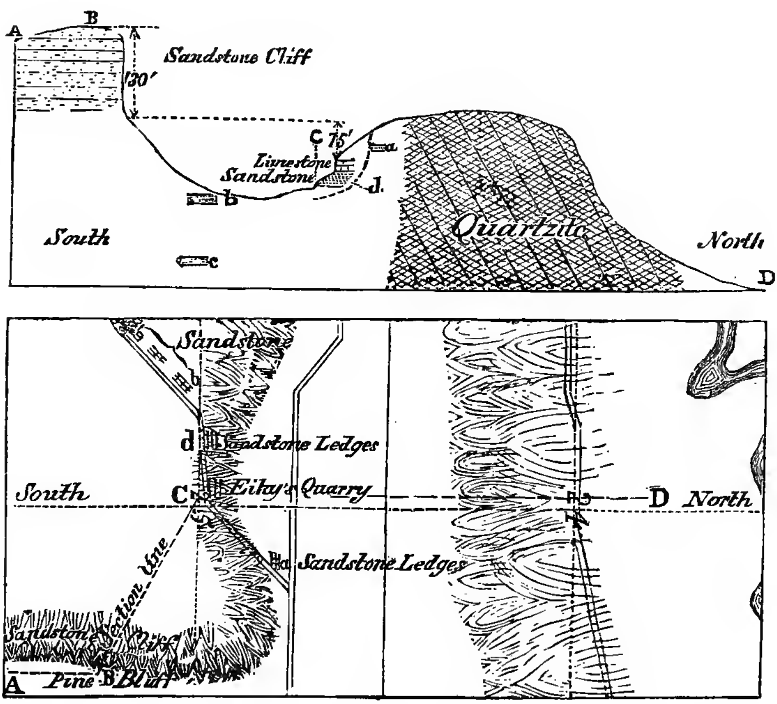
The Mendota is quarried on the side of a steep ravine in the river bluffs immediately north of **Spring Green**, N. W. qr. Sec. 3, T. 8, R. 4 E. The point of the bluff at the mouth of this ravine shows the profile and section as indicated in Fig. 47. The succession of layers, including the quarry across the ravine, is as follows:

	Feet.
I. *Lower Magnesian limestone*: in numerous small, rough-weathered exposures; upper layers concretionary; about midway of the measurement, close-textured, white, crystalline, with chert and a few dolomite-lined cavities; at 20 feet above base, sandy, and including red quartzite pebbles; lowest layers seen, brownish, concretionary, rough-surfaced, with chert and facings to the layers of stalactitic carbonate; at base a greensand layer; exact junction with the next formation seen..........................	65
II. *Madison sandstone:* in perpendicular ledges, including: white, indurated sandstone, with red quartzite pebbles, 13 feet; loose, white, cross-laminated sand, 7 feet; unexposed, about 15 feet; in all	45
III. *Mendota beds*: including: unexposed, about 25 feet; thin, crumbling, limestone layers, 5½ feet; yellow calcareous shale 1½ feet: seven very regular, heavy, yellow, limestone layers, with a 6 inch parting near the base,	

and capable of being split into thin slabs (1292) 10½ feet; unexposed, 10 feet; brownish, red stained, porous limestone, 2 feet; in all about	45
IV. *Potsdam sandstone:* including: greensand layer, 1 foot; unexposed, 20 feet; white loose sand with brownish greensand, bearing calcareous bands (1290), in a perpendicular escarpment, 5 feet; slope to foot of bluff covered with sand, 84 feet; in all about	110
Height of bluff	260
Altitude of summit	465

West of the western end of the quartzite ranges. The sandstone lying at high levels about the quartzite, in the eastern part of the town of **Westfield**, T. 11, R. 4 E., is, without doubt, both in and above the horizon of the Lower Magnesian limestone, as indicated by the exposures of that rock to the westward. Half a mile south of the Mendota quarry, on the point of the ridge in the E. hf. of Sec. 10, the road crossing the same

FIG. 48.



MAP AND SECTION SHOWING THE RELATIVE POSITIONS OF EIKY'S LIMESTONE, AND THE SURROUNDING ROCK EXPOSURES.

Horizontal scale 2 miles to 1 inch. Vertical scale 400 feet to 1 inch. A B C D, line of section.

ridge eastward is cut into brown, friable sandstone, having the proper position and character for the Madison beds. Continuing eastward, the road rises, the ground becoming full of the cherts characteristic of the Lower Magnesian, but on the southeast corner of Sec. 10, non-calcareous, indurated sandstone is again in place, at an elevation of 80 feet above the Mendota in the quarry above named. From this point, sandstone continues in place as the road ascends through the N. W. qr. of Sec. 14 to the center of that section, and beyond, reaching an elevation of 250 feet above the Mendota base. The same thing is to be observed on the road ascending through sections 2, 3 and 11; whilst on the eastern slope of the ridge, towards the valley within the quartzite ranges, sandstone is constantly seen with a great total thickness, lying within and above the Lower Magnesian horizon.

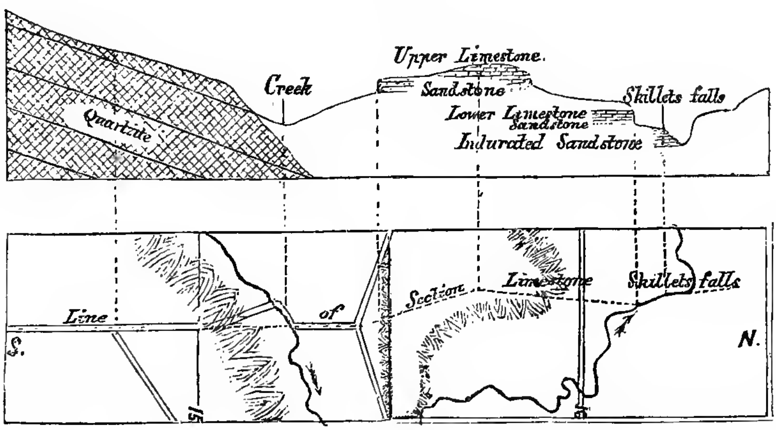
Within the quartzite ranges. In the town of **Caledonia**, Columbia county, more or less of Secs. 27, 28, 29, 30, 31, 32 and 33, T. 12, R. 8 E., lie between the converging ranges, which unite on Sec. 27. The area thus included appears everywhere to be underlaid by sandstone, which is of considerable thickness. In the northern portions of Secs. 28, 29 and 30, the altitude is 500 to 550 feet, as great as that of the northern quartzite range, and wells pass through many feet of sandstone, one near the north line of Sec. 30 penetrating 170 feet of that rock.

Along the east line of Sec. 25, T. 12, R. 7 E. in the town of **Greenfield**, the high sandstone-filled country, just described as occurring on the south flank of the north quartzite range in Caledonia, breaks down suddenly, in a vertical cliff 135 feet high, at the foot of which a slope continues the descent to the Baraboo river, through an additional vertical distance of 275 feet, and a horizontal distance of two miles. In the northern part of Sec. 25, T. 12, R. 7 E. on the south flank of the northern quartzite range, and within half a mile of this cliff, is a small limestone quarry. Fig. 48 gives a map and section showing the relative positions of this limestone and the other rock exposures in the vicinity. The whole thickness of limestone exposed is about 25 feet, the layers running from 1 to 6 inches, but much displaced, and covered by *debris*. The rock (1251) is rough-textured, brownish-yellow, and non-arenaceous, carrying many small cavities lined with calcite crystals, as also much greensand in coarse grains; these much more abundant in the lower layers, at the base of which is a regular greensand layer such as is often to be seen at the base of the Lower Magnesian. The composition of the limestone is indicated by the following analysis, made gratuitously for the survey by Mr W. A. Hover at the State University: lime carbonate, 51.61; magnesia carbonate, 38.51; silica, 5.66; alumina and iron oxide, 2.26; water, 0.40. The uppermost layer in the quarry is finely glaciated, and casts of fossils are found throughout. The following have been identified by Mr. R. P. Whitfield, from a collection made at this place by the late Prof. James H. Eaton: *Stromatopora*, und. sp.; *Orthis Barabuensis? ; Metoptoma*, n. sp.; *Maclurea Swezeyi*, n. sp.; *Holopea*, n. sp.; *Illænus antiquatus*, n. sp.; *Dicellocephalus Barabuensis*, n. sp. Immediately above the quarry, the ground rises rapidly to the northward for 60 feet, without exposure; becoming then nearly level on top of the quartzite range. A short distance along the road which ascends to the eastward, are small exposures ("*a*" of the map of Fig. 48, corresponding *in elevation* to "a" of the section) of brownish, non-calcareous, sandstone, 20 feet higher than the top of the quarry. Down-hill, a short distance to the westward, are ledges of fine-grained, friable, light-colored, non-calcareous, sandstone (746) coming immediately below the quarry layers, some ten feet in height; whilst still farther west, sandstone exposures are seen at different levels (*b*, *c*, of Fig. 48), down to 140 feet below the quarry base, but not continuously. The base of the sandstone cliff lying half a mile southeast across the intervening valley, is 75 feet above the top of the quarry layers. Its lower layers (748) are medium-grained, very friable, brownish, banded sandstone, composed of very much rolled quartz grains; further up, some bands of bright red sandstone are included, whilst near the summit (740, 750) are a number of rapidly alternating, red, white, and yellow bands of quite fine-grained and saccharoidal sandstone, the whole thickness being 135 feet. The determination of the true stratigraphical position of the

Eiky limestone meets with considerable difficulties, and has quite important conclusions depending upon it. This subject is discussed briefly in another place, in connection with facts from other localities bearing on the same conclusion. It is only necessary to say here that the fossils from this limestone are regarded by Mr. Whitfield as certainly not lower than the Lower Magnesian, and that, if we receive this reference, it becomes necessary to believe that the surrounding high-level sandstone, apparently without doubt of the Potsdam series, had been extensively eroded before the deposition of the limestone, and that the latter forms merely a nest lying upon the eroded surface of the older sandstone, as indicated by the dotted line of Fig. 48.

Sandstone is quarried, of excellent quality, at several places near **Baraboo.** One of these is on the south side of a ridge on the N. E. qr. of Sec. 1, T. 11, R. 6 E., just east of the village. The quarry here has a six-feet face, showing heavy and regular beds of moderately fine-grained, white, non-calcareous sandstone (1230), which is marked with fine brownish lamination lines, is made up of glassy, subangular quartz grains, and splits easily into thin slabs. Another and much larger quarry is opened on the "stossed" point of a ridge, southwest of Baraboo, on the N. E. qr. of Sec. 2, T. 11, R. 6 E. The end of the ridge is planed and scratched on a large scale. The total thickness seen is about thirty feet, the sandstone being white, fine-grained, firm, and obtainable in large, well-shaped blocks. In places, a net-work of thin quartz seams is noticeable. This stone, as well as that quarried at other points in the Baraboo valley, is an unusually good sandstone to come from the Potsdam series, much of which is so loose and friable, or badly colored, as to have no value as a stone for building.

FIG. 49.



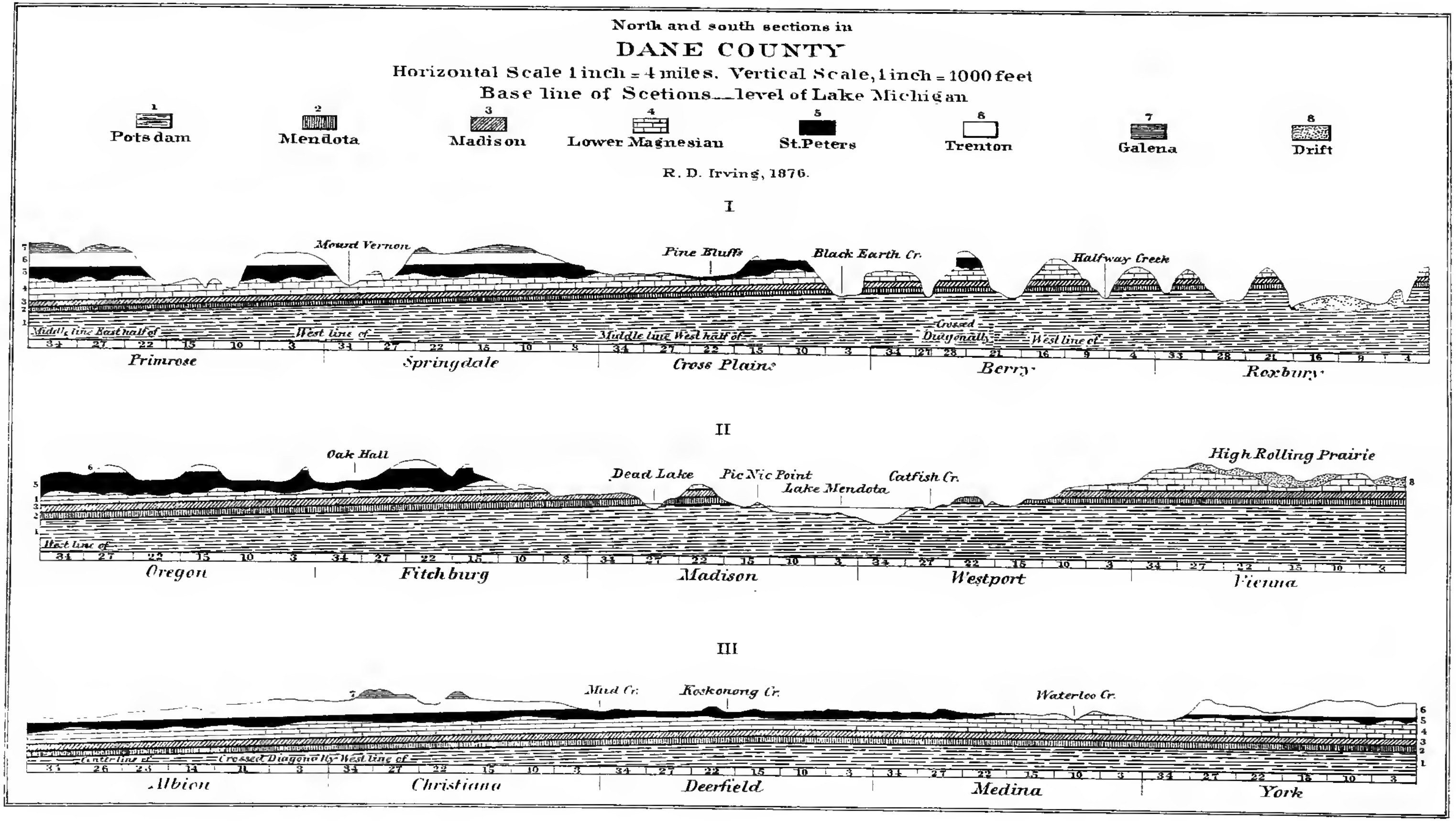
MAP AND SECTION SHOWING THE RELATIVE POSITIONS OF THE ROCK OUTCROPS AT WOOD'S, NEAR BARABOO.

On the N. W. qr. of the S. W. qr. of Sec. 10, T. 11, R. 6 E., on Mr. Joseph W. Wood's land, is a small quarry, on the point of a ridge, of limestone closely like that at Eiky's quarry in Greenfield. The rock (1260) is brownish, porous, rough-surfaced, and minutely crystalline, with, in places, a concretionary structure, and contains only 9.03 per cent. of insoluble ingredients, which are aluminous rather than silicious. In places an indistinct columnar, coral-like structure is noticeable, but no undoubted fossils were observed. On the south face of the same ridge, and on the south line of Sec. 10, is a long ledge of fine-grained, reddish-brown sandstone (1262), which is composed of rough-surfaced, subangular grains of glassy quartz, and contains many pebbles of red quartzite, numerous *Scolithus* borings, and fine, large impressions of *Dicellocephalus*

Minnesotensis. The top of this sandstone ledge is on a level with the base of the limestone in Wood's quarry, directly beneath which a small exposure of similar sandstone is seen. South of the sandstone ledge, on the south line of Sec. 10, as shown on the map and section of Fig. 49, is the valley of Skillet's creek, and south of this, again, rises the southern quartzite range. About ⅓ mile north from Wood's quarry, and 40 feet below its base, in the high bank of Skillet's creek, is an exposure of yellowish, rough-surfaced limestone (1263), which closely resembles the typical Mendota rock, leaving on solution 23.68 per cent of a very fine aluminous residue. The exposure is somewhat broken, but a thickness of about 15 feet is seen. At the foot of the bank, sandstone is in place. This yellowish limestone would appear to be the rock alluded to by Dr. B. F. Shumard in Owen's *Geological Survey of Wisconsin, Iowa and Minnesota*, p. 522, as occurring "in the bank of a small stream ¾ths of a mile south of the Baraboo." He refers it to the "encrinital bed of F. I," the same as the Mendota horizon of the writer's reports. It will be noticed that the quarry limestone, the sandstone carrying *Scolithus* and *Dicellocephalus*, and the yellowish limestone on Skillet's creek, have the proper relations and characters for the Lower Magnesian, Madison and Mendota beds. The upper limestone has just about the same altitude as that at Eiky's quarry, and appears beyond question to belong to the same horizon. Below the Mendota normally there is always found loose, fine-grained sandstone, with some calcareous matter, and narrow, brownish, calcareous bands, this character holding for a thickness of 40 to 60 feet. Below the lower limestone on Skillet's creek, however, we find no such layers, but at the falls, a few rods down stream, are seen fifteen feet of very regular beds of much indurated, entirely non-calcareous, sandstone having a slight slant southward, and bearing no resemblance whatever to the ordinary infra-Mendota layers. Do the two limestone layers, with the intervening sandstone, form a patch lying upon an eroded surface of much older sandstone, represented by the indurated rock at the falls, as suggested already in the case of the limestone of Eiky's quarry?

A short distance northeast of Devil's Lake, on the east line of the N. E. qr. of Sec. 13, T. 11, R. 6 E., on the south flank of a projecting point of the south quartzite range, are numerous large masses of fossiliferous sandstone, evidently near home. The rock is medium-grained, friable and brownish, containing many *Scolithus* markings, and other fossil fragments, chiefly of trilobites, among which casts of large cephalic shields of *Dicellocephalus Minnesotensis* are most readily made out Prof. A. Winchell identified and described also the following, in specimens from this place, sent him a number of years ago: *Orthis Barabuensis; Straparollus (Ophileta) primordialis; Pleurotomaria? adrena; Dicellocephalus Pepinensis; Ptychaspis Barabuensis.* The altitude at which these sandstone masses occur is 520 to 560 feet, or 70 to 110 feet above the limestone at Wood's and Eiky's quarries, and 110 to 155 feet above the Mendota-like rock in the banks of Skillet's creek, Sec. 10, T. 11, R. 6 E. Across the ravine on the north side of which these fossils are found, are bowlder-conglomerate and sandstone beds seen lying directly upon the quartzite, as previously described and figured. These occur at the north point of the east cliff of Devil's Lake, a north and south section through which is given on Plate XIX of this volume. The summit of the cliff, which for some distance is a mere crest, rises rapidly southward, horizontal sandstone layers flanking it on the side away from the lake, and rising with it to an altitude of over 600 feet. The sandstone cliff immediately opposite the Devil's Nose, shown also in one of the sections of Plate XIX, has already been described as extending between the altitudes of 391 and 622 feet, or from 50 feet below Wood's quar y, to 175 feet above it, and as extending far above any apparently possible horizon of the Lower Magnesian. The same appears to be true of the sandstone in all of the region about Devil's Lake. At the south end of the west bluff, for instance, are horizontal sandstone ledges at an altitude of over 700 feet.

PLATE, XXIV


North and south sections in
DANE COUNTY
Horizontal Scale 1 inch = 4 miles. Vertical Scale, 1 inch = 1000 feet
Base line of Scetions — level of Lake Michigan
1 Potsdam
2 Mendota
3 Madison
4 Lower Magnesian
5 St. Peters
6 Trenton
7 Galena
8 Drift
R. D. Irving, 1876.
I
Mound Vernon
Pine Bluffs
Black Earth Cr.
Halfway Creek
Middle line East half of
West line of
Middle line West half of
Crossed Diagonally
West line of
Primrose
Springdale
Cross Plains
Berry
Roxbury
II
Oak Hall
Dead Lake
Pic Nic Point
Lake Mendota
Catfish Cr.
High Rolling Prairie
West line of
Oregon
Fitchburg
Madison
Westport
Vienna
III
Mud Cr.
Koskonong Cr.
Waterloo Cr.
Center line of
Crossed Diagonally West line of
Albion
Christiana
Deerfield
Medina
York

On the eastern side of the north and south quartzite range in **Westfield**, T. 11 R. 4 E., in the eastern row of sections of that town, sandstone similar to that just described occurs with a considerable thickness. Certain layers at high levels are peculiar in being charged with the red and brown oxides of iron, which are at times in quantity sufficient to constitute an iron ore. This ore is to be seen in a pit on F. W. Schulte's land, S. W. qr. of the S. E. qr. of Sec. 13, with a thickness of about 10 feet. It is plainly stratified, and is a more or less sandy admixture of the red and brown oxides of iron, the former occasionally showing metallic surfaces, and greatly predominating. The inner part of the purer fragments presents a dark-colored, compact appearance, yielding a red streak. Occasional stalactitic portions are to be seen, and some of the layers are almost without iron oxide, consisting then of greyish sand with some greensand (glauconite) grains. The following analysis (1269) is from a sample averaged from the ore pile outside, and covers all degrees of richness except the nearly pure sandstone layers: Silica, 19.59; alumina, 3.60; iron sesquioxide, 70.24; manganese oxide, 0.54: lime, 0.76; magnesia, 0.04; phosphoric acid, 0.17; sulphur, a trace; water, 5.19 = 100.33: metallic iron, 49.30. Much of the ore of the pile is better than shown by the analysis, which itself represents an ore of some value. The locality is worthy of close investigation, the indications being that a considerable quantity of a good "soft hematite" might be obtained.

North of the quartzite ranges the Potsdam is everywhere the surface rock, making frequent exposures, many of which are very interesting, but the space is not available for their description.

Dane County.

(Atlas Plate XIII. Area D.)

Dane is one of the largest counties in the settled portions of the state, having a total **area** of 1,237.84 square miles. Its shape is that of an almost perfect rectangle, the northwestern corner of which is cut off by the Wisconsin river. From north to south it measures 30 miles, including towns 5, 6, 7, 8 and 9; from east to west, 42 miles, including ranges 6, 7, 8, 9, 10, 11, 12; thus embracing 34 entire townships and one fractional one. The western tier of townships, range 6, is included within the area of the lead region, and will be found described in the report of Mr. Moses Strong. The balance of the county has an area of 1,080 square miles.

Dane county has a **position** just about midway in the width of the state, its eastern line being 57 miles from Lake Michigan, and its western, 63 miles from the Mississippi. Its southern line is 24 miles north of the Illinois state line.

With the exception of an area of about 120 miles, in the northwest, that drains towards the Wisconsin, the **drainage** of the whole county is shed southward and eastward through different channels into Rock river. This result is due to the fact that nearly the whole area lies on the south side of the limestone dividing ridge that limits the valley of the Wisconsin on the south. This ridge enters the county on the north side of the town of Vienna, trends thence south of west across Dane, and then, bending more to the south, passes through the adjoining portions of Roxbury, Berry, Springfield, Middleton and Cross Plains, and leaves the county on the west side of the last named town. The ridge has a general altitude of 500 to 600 feet, and a width sometimes of a whole township, but on both sides is rendered quite irregular by erosion, the northern side especially projecting in long, bold points into the valley of the Wisconsin. The summit of the ridge is largely occupied by prairie — a continuation of the prairie belt that characterizes the same ridge in its passage across Columbia county — and has always, except in Middleton and Cross Plains, the Lower Magnesian as the surface rock. In these towns it rises into the St. Peters and Trenton horizons. In the northern portions of Middleton, Cross Plains, Berry and Mazomanie the dividing ridge is cut entirely through by a valley half a mile to a mile in width, 18 miles in length, and 100 to 200 feet in depth — which connects the ground about the west end of Lake Mendota with that bordering the Wisconsin. The highest point of the valley is 85 feet above Lake Mendota, and in it are streams running in either direction. Black Earth river — the larger of the two — which runs westward to the Wisconsin, heads within three miles of Lake Mendota, and at only 80 feet above its level. It has been suggested by Gen. G. K. Warren in his report on the Fox and Wisconsin rivers, that this valley indicates a former outlet, westward to the Wisconsin, of the Madison system of lakes. It is not impossible that such an outlet may have existed, but there is nothing in the structure of the region to show that we have here anything else than a case where two systems of erosion have approached one another until the dividing ridge has been partially broken down. South of Black Earth river the high ground comes in again, and, taking a turn westward to accord with the changed direction of the Wisconsin river, passes out of the district.

To the north and west, in the towns of Dane, Roxbury and Berry, the dividing ridge presents a very abrupt escarpment, which projects in long bold points into the valley of the Wisconsin. Beyond the escarpment the low ground is occupied by numerous outlying patches of the high country of varying sizes, similar to those already described as occurring in the adjoining towns of West Point, Lodi, etc., in Columbia county.

Southward from the dividing ridge there is a general and much more gradual descent to the south and east, conforming with the descent in those directions of the underlying strata. West of a line drawn centrally north and south through the county, the general descent of both the country-surface and strata is southward only. East of such a line, the line of greatest descent veers more and more to the eastward, until along the northern part of the east line of the county, it is almost wholly in that direction. The drainage system corresponds with this general structure. In the northeast, in the towns of York, Bristol, Sun Prairie and Medina, the drainage is eastward into Waterloo creek. Farther south, in Cottage Grove, Deerfield and Christiana, the drainage is also eastward towards Koskonong creek, which itself has a general southerly direction. In the central part of the county the drainage along the Catfish valley is in a southeasterly direction, whilst farther west, the Sugar river system runs almost exactly southward. In minor detail, of course, the directions of the streams are due to other causes.

The **Catfish valley,** with its chain of lakes, is the central topographical feature of the county. The head-waters of the Catfish are a number of small streams which rise on the south side of the divide in Springfield, Dane, Vienna and Windsor, and come together in the southern part of the town of Westport. From here to the junction with Rock river, the valley has a southeasterly course, a length of 27 miles, and a width from high ground to high ground of from 4 to 9 miles. Its surface lies generally at from 250 to 300 feet above Lake Michigan, but is quite irregular, the irregularity being largely due to considerable accumulations of drift, but also to the occurrence of small rock outliers, and to the projection into the valley on either side of low rock ridges. These have a general northeast southwest trend, and tend to divide the valley into more or less separate, parallel, cross-valleys, which are very marked, and are undoubtedly to be attributed to the movement over the country of glacier ice, to which cause also is to be assigned the linear nature of the topography of all of the eastern part of the county. The several lakes of the region about Madison are expansions of the Catfish into such cross-valleys, the ridges between which here run entirely across the main valley, though not formed throughout of rock material. Lake Mendota occupies two of the cross-valleys, partially separated by the low ridge of Picnic point and McBride's point. Lake Monona lies in one similar valley, which extends far to the southwestward, and holds also the smaller sheet of water known as Dead Lake, or Lake Wingra. Further south, the glacial movement had a more nearly southerly direction, and the directions of the cross-valleys correspond. There is no prairie in the Catfish valley proper. Along the head streams in Springfield, Westport and Burke, the marshes are of considerable extent.

Immediately **east of the Catfish valley** the country lies higher, but soon sinks again, descending with the eastward descent of the strata, this part of the county running from 240 to 400 feet in altitude. Here we find a gently undulating surface, the ridges having a flowing contour, and all topographical features showing the linear direction induced by the glacial movement. Numerous narrow and linear marsh strips are found on the lowest portions, whilst prairies of some size occur on the highest, being for the most part underlaid by limestone.

On the west side of the Catfish valley is a high and hilly belt of country from 400 to 600 feet in altitude, which extends southward from Middleton, along the adjoining parts of Verona, Fitchburg, Oregon and Montrose. Crossing the divide in the **Sugar river valley**, we find ourselves in an entirely different looking country — one where all irregularities are due solely to subaerial erosion, where the ridges are high and bold, and the branch valleys ramifying, narrow, and steep-sided. The two main branches of Sugar river separate on the southern line of the town of Montrose, one setting back in a more westerly direction than the other. Both have numerous branch-streams, each of which has its steep-sided flat-bottomed ravine. Here the ridges rise to 500 or 600 feet in altitude, and are nearly always occupied by fertile prairie, whilst the valley bottoms stand at 300 to 400, are wooded with a growth of small oaks, and show, rarely, narrow strips of marsh.

As to fertility of **soil**, Dane ranks as one of the best counties in the state. The prairies, found for the most part on the higher ground, owe their especial fertility, usually, to the underlying limestone, but the low ground of the Catfish valley, though often on the upper sandy layers of the Potsdam series, has everywhere an excellent soil, which it owes to alluvial depositions, or to the drift materials. A poor soil is seen only on the low grounds adjoining the Wisconsin river, where the sand comes from the Potsdam sandstone. The St. Peters sandstone rarely affects the soil over any considerable area. East of the drift limit, it is buried beneath drift materials, whilst west of the same line it appears only on the steep sides of ravines. The prevailing timber of Dane county is small oak, occurring in patches or groves, constituting what are known as "oak openings."

The Dane county list of **geological formations** includes nearly the whole Wisconsin series. The Cincinnati and Niagara, however, occur only on the Blue Mounds, and in that portion of the county that is not included in the Central Wisconsin district.

The *Archæan* does not come to the surface in Dane county, but the Artesian borings at Madison reach it at some 800 feet below the surface, and 480 feet below the level of Lake Michigan, at which point a dark-grey felsitic rock is struck. Into this one of the wells penetrates for 187 feet, reaching a point 667 feet below Lake Michigan, and 82 below the level of the sea. The *Potsdam sandstone* comes to the surface along the valley of the Wisconsin, and along the bottoms of a number of smaller tributary valleys in Dane, Roxbury, Berry and Cross Plains. It is also at the surface over a considerable area at the head of the Catfish valley, and in the bottoms of branch valleys, in Springfield, Westport, Windsor, Burke, etc.; but in all this area only the uppermost layers of the formation are at surface. The *Mendota and Madison beds* are the surface rocks over a large portion of the Catfish valley, reaching from the south side of Lake Monona to the south side of Lake Kegonsa. These layers are at surface along some of the valley-bottoms of northern Middleton, southern Springfield, and adjoining towns, as also on the flanks of the higher ground and outliers that border the valley of the Wisconsin. The total thickness of the two layers in Dane county is about 70 feet. The *Lower Magnesian limestone* forms the upper part of all the dividing ridge of the north part of the county. It fo ms, also, the flanks of the high ground on both sides of the Catfish valley, whose bottom it becomes in the region south of Lake Kegonsa. It comes up again underneath the low marshy ground that borders Waterloo creek in York, Bristol, Sun

Prairie and Medina, its eastward descent having carried it here far below the altitudes at which it is found on the west side of the county. It lies also at the bottom of the valley of Sugar river and its numerous branch valleys, crowns the outlying bluffs of the Wisconsin valley, and occurs also in several small isolated patches, within the Potsdam area of the Catfish valley. The thickness of the Lower Magnesian in Dane county seems rarely to be more than 80 feet, whilst its very irregular upper surface brings it often into the horizon of the next formation above. The *St. Peters sandstone* occupies a large tract on the east side of the Catfish valley, where it appears to be never more than 50 feet in thickness. It is found, also, forming a narrow band around the Trenton areas of York, Bristol and Windsor. West of the Catfish valley it occupies much of the high ground forming the divide from the valley of the Sugar river. In the last-named valley and its branches the St. Peters forms the lower part of the bluff sides, having its full thickness of 80 to 90 feet. It occurs also in several detached areas in the high country north of Black Earth creek. The *Trenton limestone* occurs in detached areas, mostly of considerable size, capping the high ground on both sides of the Catfish valley. Some of the areas, however, are quite large, covering one or two townships, as in Middleton, York, Christiana and Albion. In Springdale and Primrose the narrow ridges between the streams, carry the whole thickness of the Trenton limestone, being at times capped by the Galena. For the most part, the Trenton areas of Dane county include only the lower part of that formation. The *Galena limestone* occurs only as a capping on the higher parts of the ridges of Springdale and Primrose, and in two or three small areas in Christiana.

Cross sections for Dane county, both north and south, and east and west, are given on Plates XXIV and XXV, showing both the surface contour, and the succession and relations of the several strata. Two other sections through the county, drawn on a larger scale, will be found attached to Plate XIII of the Atlas. These sections, with the colored map, render unnecessary any further general descriptions.

On the east side of the county the lower or Buff portions of the Trenton shows in numerous quarries, many of which yield a good building stone. Amongst many quarries we may list the following: N. E. qr. Sec. 25, York; N. E. qr. Sec. 26, Medina, a large quarry with a 12 feet face; on Secs. 29, 35 and 36, Deerfield; N. E. qr. Sec. 22, N. E. qr. Sec. 24, and N. E. qr. Sec. 23, Christiana, the last one showing 15 feet of regular, heavy layers; N. W. qr. Sec. 2, N. E. qr. Sec. 15, S. W. qr. Sec. 22, N. W. qr. Sec. 27, Albion; S. E. qr. Sec. 30, Dunkirk, where there is a 15 feet face; S. W. corner Sec. 3, N. W. qr. Sec. 4, N. E. qr. Sec. 10, where there are 10 feet of even, heavy layers, S. E. qr. Sec. 13, N. E. corner Sec. 14, N. W. qr. Sec. 35, S. E. qr. Sec. 36, Pleasant Springs; Sec. 4, Cottage Grove; N. W. qr. Sec. 14, N. E. qr. Sec. 23, Sun Prairie; N. W. qr. Sec. 17, N. E. qr. Sec. 30, and in the north part of Sec. 34, Bristol; S. E. qr. Sec. 14, N. E. qr. Sec. 23, Windsor; S. W. qr. Sec. 2, S. W. qr. Sec. 26, N. W. qr. Sec. 35, Burke; N. E. qr. Sec. 14 and N. E. qr. Sec. 11, Windsor.

The quarry on the N. W. qr. Sec. 35, **Pleasant Springs**, is on the western edge of a Trenton area, and shows 15 feet of the lowest part of the formation. The upper layers are thin, whilst the lower six feet are taken up by two very heavy firm layers, between which is a persistent thin seam. 2 inches thick, which affords large regular paving slabs. The limestone is yellowish, much marked by dendritic oxide of manganese, and is easily trimmed into smooth blocks. The thin upper layers show numerous nests of crystals of limonite, pseudomorphous after pyrite, as also large casts of orthoceratites. The top layer is glaciated, the striæ running almost due south. At the bottom of the quarry, the junction with the St. Peters is exposed. A well near by is 58 feet in the latter formation. The quarry is an old one, having been opened 22 years, during which time 4,000 cords of stone have been removed.

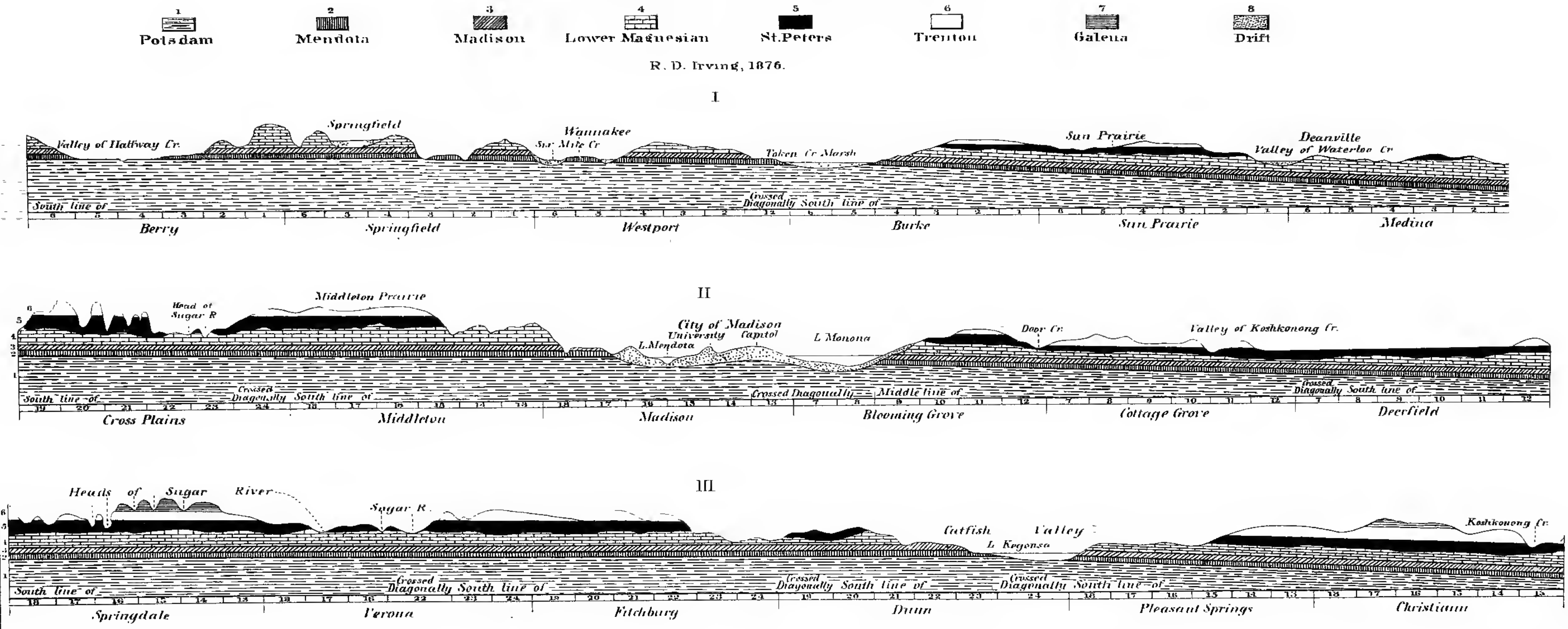
The quarry in the north part of Sec. 4, **Cottage Grove**, shows 20 feet of thin, and

East and west sections in

DANE COUNTY

Horizontal Scale 1 inch = 4 miles. Vertical Scale, 1 inch = 1000 feet

Base line of Sections — level of Lake Michigan

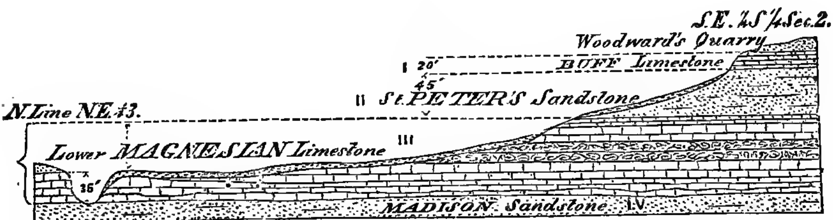


very even-bedded, close-textured, yellowish, limestone, which is much marked by dendritic manganese oxide, and contains the following fossils: *Petraia corniculum*, *Strophomena alternata*, a small *Orthis*, a *Rhynconella*, *Cypricardites ventricosa*, *Trochonema umbilicata*, *Helicotoma planulata*, and fragments of small orthoceratites. The fossils are casts only.

The quarries on Sec. 23, **Sun Prairie**, show in all a thickness of about 20 feet, the upper layers of which are thin, shaly, and bluish in color, and appear to belong to the "Blue" beds, whilst below there are heavy regular layers of buff-colored limestone. Immediately beneath the shaly layers are found layers of a very close-textured, purplish brown, chonchoidal fracturing rock (698), carrying *Columnaria alveolata*. From the buff layers, the following fossils were obtained (697, 698): *Petraia corniculum*, *Orthis trieenaria*, *Strophomena camerata*, *Cypricardites ventricosa*, very large casts of the exterior of *Trochonema umbilicata*, *Raphistoma lenticularis*, a *Muchisonia*, *Orthoceras vertebrale*, *Orthoceras anellum*, *Gyroceras duplicostatum*, n. sp., *Oncoceras pandion*, and crinoidal stems. A strong lime, hard to slack, is made here from the buff beds, but the stone is used chiefly for building purposes.

At the large quarries on the prairie, in the north half of Sec. 34, **Bristol**, are exposed of the Blue limestone about 8 feet, of the Buff about 10 feet. The Blue beds show a dark bluish-gray rock (703), with a flinty-textured matrix, in which are scattered numerous minute strings and patches of calcite. The layers of this rock are about one-half to there-fourths inch in thickness, very rough-surfaced, and show numerous obscure impressions of fossils, of which two brachiopods, *Rhynconella* and *Strophomena*, appear to be most abundant. Between these layers are very thin, regular, fragile, dark brown shaly layers, on which are fine, black, graptolite-like markings. The rough-surfaced blue layers contain: silica, 7.03; alumina, 2.21; carbonate of lime, 84.02; carbonate of magnesia, 5.33; iron peroxide, 0.83; iron protoxide, 0.39; water, 0.61 = 100.42. The Buff beds below are regular heavy layers of yellowish close-textured limestone, including some of a dark purplish brown, chonchoidal-fracturing rock, like that already mentioned as seen on Sec. 14 of the town of Sun Prairie. The buff-colored rock (704), from directly below the junction with the Blue, contains: silica, 4.45; alumina, 2.08; carbonate of lime, 56.07; carbonate of magnesia, 35.32; iron peroxide, 0.69; iron protoxide, 0.58; water, 0.46 = 99.65. The usual fossil casts are found in the Buff beds, including fine ones of *Cypricardites ventricosa* and *Gyroceras duplicostatum*.

Fig. 50.



SECTION ON A LINE RUNNING N. 25° E., FROM THE S. W. QR. OF THE S. W. QR. OF SEC. 2, NEARLY TO THE NORTH LINE OF SEC. 3, BURKE.

Horizontal scale 4 inches, 1 mile; vertical scale 1 inch, 200 feet.

Fig. 50 represents a section obtained in the northern part of the town of **Burke**, showing the small thickness reached by the St. Peters and Lower Magnesian in this part of the county.

In the small quarry on the N. W. qr. Sec. 35, in the same town, a 2 inch layer is crowded with impressions of the exterior, and casts of the interior, of the following fossils (694): *Petraia Corniculum*, *Strophomena camerata*, *S. incrassata*, *Steptorhynchus* *filitexta*, *S. deflecta*, *Orthis tricenaria*, *Rhynconella*, n. sp., *Cypricardites ventricosa*, *Raphistoma lenticularis*, *Pleurotomaria subconica*, *Trochonema umbilicata*, *Murchisonia bicincta*, *M. tricarinata*, *Orthoceras anellum*, *O. vertebrale*.

In the Catfish Valley, the Potsdam, Mendota, Madison and Lower Magnesian are frequently exposed, the last three being quarried at numerous places. A few important points only can be mentioned. O'Malley's and Veerhusen's quarries in **Westport** yield very handsome stone, and one quite different from the general run of the Lower Magnesian. O'Malley's quarry, S. E. qr. S. E. qr. Sec. 10, shows the following section:

	Ft.	*In.*
1. Thin bedded to shaly yellow limestone	6	..
2. Three heavier layers of the same	2	6
3. Broken yellow limestone with much oölitic chert (641) and geodic calcite (642)	4	..
4. Very heavy layers — interstratified with two or three thin layers — of cream-colored, close, granular-textured limestone (640), containing 4.06 per cent. of argillaceous impurities	10	..

From the heavy layers of No. 4, one of which has a thickness of 24 inches, some 2,000 to 3,000 cords have been removed, the stone having been chiefly used in the construction of the State Hospital for the Insane. Mr. Veerhusen's quarry, N. E. qr. of the S. W. qr. Sec. 25, is on the top of a narrow ridge of Lower Magnesian, and has a face of 24 feet, a large amount of stone having been removed. The following is the section, beginning above:

	Ft.	*In.*
1. Rough, brecciated, yellow, fine-granular limestone (629), containing 3.49 per cent. of insoluble ingredients; bedding indistinct	8	..
2. Very heavy layers, some 4–5 feet in thickness, of pale yellow, close-textured, granular limestone (626, 627, 628), which on solution leaves a large residue of fine gray sand, several determinations on specimens from different parts of the face giving 12.14, 13.03, 20.59, 34.74, 35.63, and 40.78 per cents.; quarry layers	15	..
3. Greenish sandy layer (629½); a specimen on solution left 41.17 per cent. of very fine gray sand	1	..
4. Thinner-bedded limestone, like No. 2, but finer-grained, of greenish tint, and profusely marked with dendritic oxide of manganese; below the base of the main quarry; thickness	8	6

The lowest layer is 39 feet above the base of the formation. No. 2 has yielded a very large amount of stone for the construction of the Insane Asylum. The stone is like that from O'Malley's quarry on Sec. 10, and should have much wider use than formerly. It is a much handsomer stone, and endures weathering better than the sandstone used in Madison. The upper and less sandy layers at Veerhusen's have been burned into a good lime. At Westport Station, near the center of Sec. 26, is a long railroad cutting through the western end of the ridge upon which the quarry just described is situated. The deepest part of the cut shows the following section:

	Ft.	*In.*
1. *Lower Magnesian* limestone (636); gray-and-yellow-mottled, porous, moderately thin-bedded, the layers somewhat broken and displaced; contains 11.52 per cent. of argillaceous impurities; at base is a thin layer of white oölitic chert, and another of greensand; in all	20	..
2. *Madison* sandstone, including: thick-bedded, yellowish, fine-grained sandstone (637), with only 2 per cent. of soluble ingredients, 19 feet; lighter colored sandstone, 2 feet 6 inches; and purely silicious, white sandstone, often loose, and composed of much rolled quartz grains, 4 feet; in all	25	6

The quarry on the north side of the marsh, in the N. W. qr. of Sec. 12, **Springfield**, is on the Madison sandstone, whose upper layers here are heavy, regular, buff-colored, contain over 40 per cent. of soluble ingredients, and make a good building stone, resembling that quarried at the same horizon near Madison. Heiny's quarries, on the Lower Magnesian, N. W. qr. Sec. 35, Springfield, are quite extensive. They show the following section:

	Feet.
1. Concretionary and brecciated yellow limestone	5
2. Heavily-bedded white layers with much chert, burnt for lime	10
3. No exposure	25
4. Irregularly thin-bedded, porous, white-and-yellow-mottled limestone (648), with geodic cavities, many black dendritic markings, and 6.11 per cent. of insoluble ingredients	15

The lowest exposure is near the base of the formation.

The Madison sandstone and overlying Lower Magnesian are finely exposed in a large quarry on the edge of the high land, S. E. qr. Sec. 11, **Middleton.** The following section, taken here, is interesting as showing how the great Lower sandstone series graduates upward into the Lower Magnesian; the order is as usual a descending one:

	Ft.	*In.*
LOWER MAGNESIAN.		
1. Very irregular layers, alternatingly thick and thin, of a brownish-gray, close-textured, minutely-crystalline, cherty limestone (591), which leaves on solution 4.39 per cent. of a very fine, clayey residue; 7 feet below the top is a marked concretionary layer, one foot thick	18	4
2. Brecciated layer of sandy, grayish limestone (592), containing 63.89 per cent. of fine gray quartz sand	1	..
3. Thick layer of gray, flinty-textured limestone, with a thin, sandy layer at top	1	1
4. Concretionary, cavity-bearing limestone (593), which leaves on solution 11.03 per cent. of fine, grayish, aluminous residue; the cavities carry dolomite crystals	4	4
5. Yellowish calcareous-sandstone	..	10
6. Yellowish limestone, in places quite sandy	2	..
7. Very close-textured, non-crystalline, yellowish limestone (594), containing 9.19 per cent. of fine, aluminous, insoluble matter, and much marked by dendritic oxide of manganese	2	2
8. Brownish, sandy, porous limestone (595, 652), carrying oölitic chert, numerous crystal-lined cavities, and containing 28.04 per cent. of sand	2	2
9. Yellow-and-gray-mottled, rough-textured, conchoidal-fracturing limestone (596), containing 3.89 per cent. of aluminous impurities	1	..
10. Oölitic chert layer (597; nearly pure quartz, only .01 per cent. being soluble	..	6
MADISON BEDS.		
11. Pure white, exceedingly fine sandstone (598, 651), composed of angular to rolled grains of translucent quartz; often loose sand; the layer very irregular, swelling down and cutting off the layers below; in some places cutting off also the layers *above;* thickness varies from 7 inches to	1	5
12. Light yellow, friable, fine-grained, dolomitic sandstone (599, 650), composed of rolled quartz grains embedded in a crystalline dolomitic matrix; the sand being 63.4 per cent. of the rock; the exact equivalents of the Madison building-stone; thickness	15	7
Total	49	6

The following is the section at MacBride's point, on the north shore of Lake Mendota, N. W. qr. Sec. 1, **Madison:**

	Ft.	In.
I. Heavy-bedded, jointed *Mendota limestone* (634), having a brown color, and close-grained, flinty matrix, and leaving on solution 15.05 per cent. of a fine sandy residue; layers run 2 to 4 feet in thickness; joints N. 87° W., used in construction of old capitol at Madison	21	8
II. Thin-laminated *greensand* layer	1	..
III. Upper layers of *Potsdam sandstone;* fine-grained, light-greenish-tinted, calcareous sandstone, containing 15.5 per cent. of soluble ingredients; thin-bedded, alternate layers, different colors; some more calcareous layers weathering in relief; *scolithus*-bearing	31	..

On the N. W. qr. Sec. 21, and the N. E. qr. Sec. 20, Madison, is a round isolated hill capped by the Lower Magnesian. The top of the hill is almost completely encircled by a large quarry which exposes the Lower portions of the Lower Magnesian and the upper part of the Madison sandstone. The following section includes the quarry face and the record of a well near by:

	Ft.	In.
LOWER MAGNESIAN.		
1. Yellow, fine, granular, close textured limestone (607); thin bedded to shaly; some few layers near the top are burnt for lime	5	8
2. Gray-and-yellow-mottled, porous limestone (603, 611), with large patches of rhombohedral calcite, much dendritic manganese oxide, and 4.1 per cent. insoluble matter; forming one layer	2	..
3. Thin-bedded to shaly yellow limestone, mostly quite sandy	10	..
4. Layer burnt for lime (606) and containing only 2.3 per cent. of insoluble ingredients	..	8
5. Layer of oölitic chert (608); a milk-white material made up of little concretions $\frac{1}{40}$ to $\frac{1}{10}$ inch in diameter, which consist of minute rounded grains of limpid quartz encased in a milk-white powdery matrix; having the following composition: silica, 98.01; alumina, 0.53; iron sesquioxide, 0.73; lime, 0.67; magnesia, 0.21=100.15; thickness, one inch to	..	6
MADISON.		
6. Greensand layer, consisting of a matrix of rounded quartz-grains and dark green grains of glauconite	1	6
7. Light buff-colored sandstone (604); in heavy uniform layers six inches to two feet in thickness; much used as a building stone in Madison: contains 10 per cent. of carbonates of lime and magnesia	12	..
8. Light-colored sandstone, similar to the foregoing but less firm and regular; in the lowest portions at the base of the quarry a loose white sand	5	8
9. Unexposed, below the quarry base	5	..
10. Soft red and brown sandstone in well	14	..
MENDOTA.		
11. Hard yellow limestone, in well	30	..
POTSDAM.		
12 Soft greenish sandstone, in well	20	..
	107	..

The building stone of these quarries is much sought for. It is obtained also from quarries across a small valley, on the N. W. qr., Sec. 21. It was formerly worked to a considerable extent on the side of the hill on sections 17 and 18, and beyond doubt is to be found in the neighboring country at many other fovorably located points. This is a matter of some importance, since in the present quarries the stripping has become a heavy expense.

At Madison, the Mendota is exposed in several small railroad cuttings (622) on the north side of Sec. 22. On the S. W. qr. Sec. 23, on the point of a low ridge projecting into the marsh, is a quarry of some size, showing the lower 10 feet of the Mendota limestone. The upper layers are thin, the lower heavier, and all very irregular. The rock (613) is a dark yellow to brownish, rough-textured, concretionary limestone, containing many red patches of iron oxide, which proceeds, apparently, from the oxidation of pyrite. The composition is: silica, 4.18; alumina, 2.17; iron peroxide, 1.45; carbonate of lime, 55.68; carbonate of magnesia, 35.52; water, 0.58=100.58. Greensand in scattering grains, and light green earthy patches are seen throughout, whilst a regular greensand layer (612) at the bottom of the quarry marks the base of the formation. Towards the side of the ridge the limestone layers have an inclined position due to undermining. This quarry was one of the first points at which the Mendota was recognized, and may be regarded as typical of the lower part of the formation. The rock has many points in common with the Lower Magnesian, being quite as free from sand as that rock.

The Artesian-boring in the Capitol park at Madison has a depth of 1,015 feet, penetrating in its course Glacial Drift, the Potsdam sandstone, and 200 feet of the Archæan rocks. The water in the well comes within some 60–70 feet of the surface, from where it is pumped for use in the boilers at the Capitol and for drinking purposes. It is regarded as a "mineral" water, but is not one, being freer from solid ingredients than ordinary well water, and containing nothing unusual except a small quantity of iron bicarbonate, the iron of which, on exposure to the air, peroxidizes, and produces a brownish sediment. A record of this boring has already been given in the annual report of Dr. Lapham, page 50; the greenish mineral from the rock at the bottom of the well is, however, probably not prehnite, as there given. The Artesian boring at the Milwaukee and St. Paul depot begins at a level 74 feet below the top of the boring in the Capitol park, and brings water to within 7 feet of the surface. The following is an abbreviated register of this boring:

	Feet.
Drift: sand and clay, with bowlders; the lower part nearly all loose sand, so that it is difficult to tell where the drift ends and the underlying sandrock begins; about	70
Potsdam sandstone: specimens from depths of 200, 250, 290, 350, 360, 380 and 390 feet show very fine, white quartz sand, stained here and there with deep brown points of iron oxide, and entirely non-calcareous; some of the sand is a little coarser, and all as seen under the microscope is made up of very much rolled grains, the larger ones of which are almost wholly spherical. Specimens from 600 and 680 feet are also of limpid quartz, but the grains are very much coarser and less rounded. The lowest layer of the formation struck is soft red shale, like that found in the Capitol well. Thickness in all, about	665
Archæan: dark colored rock, like that in the Capitol well	50
Depth of boring	785

The lower layers of the Madison sandstone are quarried on the S. E. qr. Sec. 28, Madison, on the south shore of Lake Wingra, and the same rock is finely exposed (614, 617) with a thickness of 23 feet, largely pure white sand, and overlaid by 17 feet of non-arenaceous thin-bedded Lower Magnesian, in the railroad cutting, S. E. qr. Sec. 35. About 35 feet below the bottom of this cut, 10 feet of Mendota is exposed on the south shore of Lake Monona, near the S. E. corner of Sec. 26. On the south line of the town of Madison, Sec. 33, a large quarry on the Lower Magnesian shows the following, beginning above:

	Ft.	*In.*
1. Concretionary and irregularly bedded, yellowish-gray limestone	10	..
2. Chert layer; sometimes forming a continuous nodular-surfaced layer, at others occurring in a row of separate nodules; internally, the chert (644) is brown-and-white-banded, and jaspery; externally it has a soft, white, silicious coating	..	3
3. Compact, heavily bedded, flinty-textured, gray limestone (644) containing a few geodic cavities lined with dolomitic crystals; composed of silica, 1.09; alumina, 0.44; iron peroxide, 0.43; iron protoxide, 0.63; lime carbonate, 66.82; magnesia carbonate, 30.40; water, 0.35=100.16; thickness	4	..
4. Chert layer, like No. 2	..	2
5. Very heavily bedded limestone, like No. 1	5	..

Throughout the quarry there is a marked local dip of 10° to 15° southward. The quarries have been opened for 20 years, the stone being used altogether for burning into lime, of which about 20,000 bushels are made annually in two large kilns.

On the west shore of Lake Kegonsa, near the center of Sec. 26, **Dunn**, a large exposure shows the following:

	Feet.
I. White sandstone with brownish stains	1
II. Greensand layer	2
III. Light-colored, soft, thin-bedded, calcareous sandy layers, with specks of greensand and geodic calcite	1
IV. Whitish layer, more calcareous than the preceding	2
V. Heavily-bedded, light yellowish sandstone (693); fine-grained, firm, nearly one-half soluble, the residue made up of angular to subangular white sand; in parts cross-laminated	12
VI. Sandy, yellowish, fine-grained limestone	12
	30

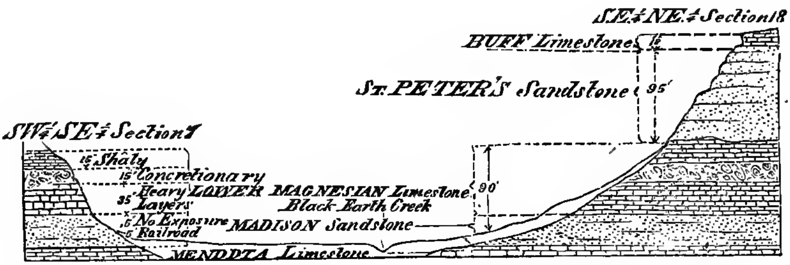
The lowest layers are unmistakably Mendota, which is here much less sharply defined than usual from the Madison. One-half mile north, friable, brownish, entirely non-calcareous, Madison sandstone is seen on the hill side, corresponding to the uppermost layers of the foregoing section. A similar sandrock shows near the roadside on the north line of the N. W. qr. of Sec. 27, at the Town House, on the center of the south line of Sec. 21, and in the field near the middle of the S. E. qr. Sec. 21, the last named lying near to, and about 15 feet below, one of Lower Magnesian. All of these exposures appear to carry the Madison to an unusual thickness, 50 or 60 feet.

On the divide betweem the Catfish and Sugar river valleys, in Middleton, Verona, Fitchburg, Montrose and Oregon, the Trenton is the rock most commonly quarried, being obtained from the tops of isolated ridges whose sides often show large exposures of the St. Peters. Amongst other quarries may be named those on the S. E. qr. Sec. 27 (662, 663, 669), and the S. E. qr. Sec. 35 (664, 665, 666), Middleton; the very large quarries on Secs. 7, 15 and 18, Fitchburg; those on Secs. 13 and 26, Montrose; those on Secs. 4 and 24, Oregon; and those on Secs. 28 and 35, Rutland. All of these are in the Buff beds, generally close to the St. Peters.

In the Sugar river valley and its branch valleys the Trenton is quarried at a few points, but the St. Peters makes very frequent natural exposures of large size. Cliffs and shelving ledges of brownish, friable St. Peter's are frequent on the valley sides, and isolated bluffs and towers of the same rock are to be seen at several places within the valleys themselves. One of these towers, on the S. W. qr. of the S. E. qr. Sec. 11 Primrose, known as the Devil's Chimney, is circular in section, 60 feet high, 50 feet in diameter on the top and 40 feet at the bottom. The isolated bluff on the N. E. qr. of the S. W. qr. of Sec. 28, Springdale, is 100 feet high, 100 yards in diameter at base and 20 on top.

On the Wisconsin river slope the exposures and quarries, which are numerous, are chiefly in the Potsdam, Mendota, Madison and Lower Magnesian. The Trenton is quarried, however, on the N. E. qr. of Sec. 18, Middleton, at the top of a high bluff, showing 90 feet of St. Peters (658) as represented in Fig. 51.

FIG. 51.



SECTION ACROSS THE VALLEY OF BLACK EARTH CREEK.

Vertical scale 200 feet to the inch. Horizontal scale 400 feet to the inch.

The Trenton at this place (659, 660, 661) contains numerous casts of the following fossils: *Petraia corniculum, Strophomena, Cypricardites ventricosus Raphistoma lenticulare, Trochonema umbilicata, Murchisonia bicincta, M. tricarinata, Pleurotomaria Nasoni, Oncoceras pandion,* and *Orthoceras anellum.* The Trenton shows also in a small quarry at the top of the bluff on the N. W. qr. of Sec. 28, Berry, far away from any other Trenton area.

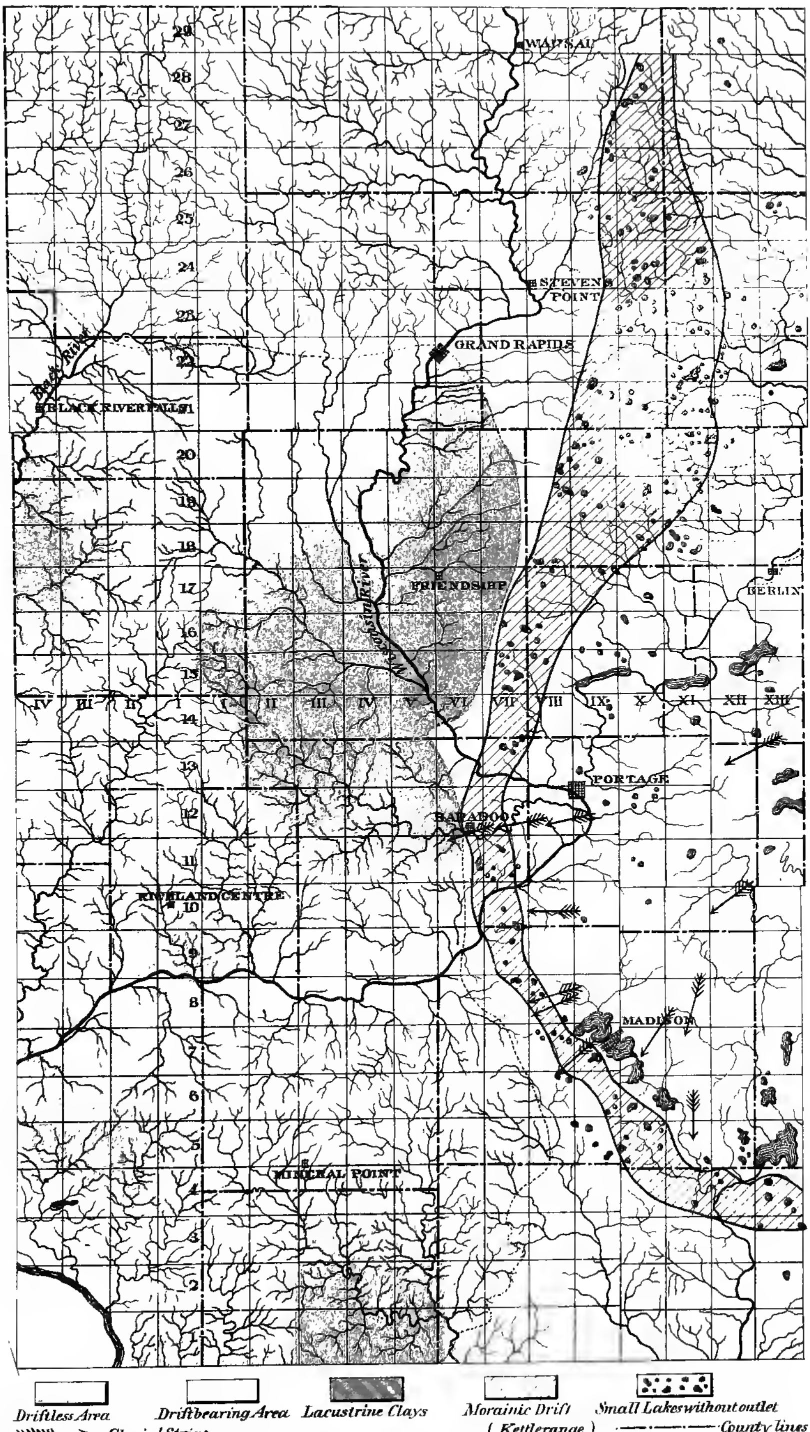
MAP OF PART OF WISCONSIN

designed to show the main facts with regard to the distribution of the

GLACIAL DRIFT

and other

QUATERNARY DEPOSITS. PLATE, XXVA.



Drift limit and moraine, south of Town 5, after Moses Strong and T. C. Chamberlin

The Milwaukee Litho. & Engr. Co.

Plate XXVI shows the boundary of the driftless region for the larger part of its extent in Wisconsin. This line lies chiefly in the Central Wisconsin district, but for the four townships south of Dane county has been copied from the maps of Mr. Strong. Entering Dane county on the middle of the south line of Montrose, T. 5, R. 8 E., it nearly coincides with Sugar river as far as the head of that stream in Cross Plains, T. 7, R. 7 E. Along this portion of its course the heaviest drift deposits are several miles to the eastward of the boundary, which they gradually near to the northward. From the head of Sugar river the divide is crossed to Black Earth river, the northern side of which is followed into the towns of Black Earth and Mazomanie, T. 8, R. 6 E. Thence, bending northward, and crossing the Wisconsin between Sauk City and the mouth of Honey creek, the line pursues a northerly course across Sauk Prairie to the foot of the Baraboo quartzite ranges, morainic drift occurring from half a mile to two or three miles east of it. On top of the quartzite ranges no drift is seen west of Devil's Lake, in whose valley are, however, heavy doposits, and the line appears thus to make a slight bend eastward. North of the ridge, however, it is further west again, for large heaps occur at Baraboo, and bowlders are to be seen two or three miles west of that place.

Beyond the Baraboo, the line continues in a northerly direction to the north line of Sauk county, where it bends out to the westward along the high ground that forms the rim of the sand plain of Juneau and Adams counties, for granitic and other bowlders may be seen all along the road from Kilbourn to Mauston, as far as the N. W. qr. of Sec. 27, T. 14, R. 5 E. Very soon, however, a sharp bend is made to the eastward again, the line following the inner edge of the high ground to the Wisconsin, above the Dalles, and, after crossing the river, in a curving direction through southeastern Adams county. Turning then northward, it lies a short distance west of the east line of that county, until its northern portion is reached, when, curving once more to the westward, it crosses the Wisconsin again near Grand Rapids, in Wood county. A sketch map of the Wisconsin driftless area, given by J. D. Whitney,[1] includes all of Adams and the eastern part of Juneau counties within the drift-bearing area, and shows the limit altogether to the west of the Wisconsin. This portion of the state he does not, however, seem to have mapped from personal investigation. I have never seen any sign of glacial drift in the district specified, and, indeed, the numerous fragile sandstone peaks occurring within it preclude the idea that the glacial forces

[1] Geological Survey of Wisconsin, Vol. I. Albany, 1862.

could ever have acted there. Flanking the north side of the quartzite bluff at Necedah, in Juneau county, is a great bank of gravel and rounded bowlders, but these are wholly of quartzite, derived from the bluff itself, and must hence be regarded as the result of river or lake action upon the quartzite. Clay and sand deposits occur in much of Adams county, as, for instance, around Friendship, but are finely laminated, and appear to be due to deposition from expanded streams or lakes, being wholly without associated gravel. From southern to northern Adams, the drift limit, as marked by the loose materials of the surface, is for the most part directly along the edge of heavy morainic heaps, with numerous bowlders.

Westward from Grand Rapids, the drift limit is not always so well defined, but does not appear to be far from the line of the Green Bay and Minnesota railroad, as far as the crossing of Black river. From here it bends to the northeast, crossing the line of the West Wisconsin road some twelve miles southeast of Eau Claire.

The nature of the **topography of the driftless area,** everywhere most patently the result of subaerial erosion exclusively, is even more striking proof that it has never been invaded by the glacial forces than is the absence of the drift material. Except in the level country of Adams, Juneau, and eastern Jackson counties, it is everywhere a region of narrow, ramifying valleys, and narrow, steep-sided, dividing ridges, whose directions are towards every point of the compass, and whose perfectly coinciding horizontal strata prove conclusively their erosive origin. A glance at the map of Plate XXVI, on which are accurately represented all but the very smallest streams, will serve to give an idea of this feature of the driftless area. Each one of the numerous streams shown has its own ravine, and the ravines are all in direct proportion to the relative sizes of the streams in them. This is well brought out by the colored geological maps of Areas D, E, G and H, in the Atlas. Since the several strata lie nearly horizontal, the colors representing them give really a close idea of the topography. The two first named maps include portions of both drift-bearing and driftless areas, and the different appearances of the geological outlines, stream and marsh directions, etc., on the east and west sides of the maps, are very instructive. It should be said that this difference is due, also, partly, but not mainly, to a change which takes place midway within the districts represented by these maps, from a nearly perfect east and west horizontality of the strata to a small, but gradually increasing, eastward descent. In this connection, reference should also be made to Mr. Strong's excellent contour maps of the lead region.

In the central plain of Adams and Juneau counties, though the ramifying ridge-and-valley topography is wanting, no less indisputable topographical proof is at hand of the immunity of the region from the glacial action in past time; for, dotting the surface of the plain, we find the numerous sandstone towers that have been so often alluded to in this report. The fragile character of these peaks is sufficient evidence that they could never have stood in the path of a glacier.

The **altitude of the driftless area,** as compared with the drift-bearing regions, becomes a matter of some importance in any attempt to explain the absence of the drift phenomena. It has been stated by some writers that the driftless area is higher than the drift-bearing, and was, consequently, not subjected to glacial invasion. It is true that *in general* the eastern half of the state is lower than the western, but from what follows it will be seen that farther than this the statement is inaccurate. From the south line of the state as far north as the head of Sugar river, in Cross Plains, the country west of the drift limit rises rapidly 200–400 feet. Just north of the head of Sugar river, the limit crosses high ground — the western extension of the high limestone and prairie belt of northern Dane and southern Columbia counties — and the altitudes east of the limit are as great as those to the west; whilst in passing from the head of the Catfish river westward, a glacier must have made an abrupt ascent of fully 300 feet. North of Black Earth river, the limit has the higher ground, by 200 feet, on the east. Sauk prairie is crossed on a level, and though higher ground occurs west of the prairie, its topography and the absence of drift show that the glacier never reached so far. Where the quartzite range north of Sauk Prairie is crossed by the limit, it is higher (850 feet above Lake Michigan) than any part of the driftless area except the Blue Mounds, whilst a few miles east a great development of bowlders and gravel is found on one of the highest portions of the range (900 to 950 feet altitude). From the Baraboo north to the Sauk county line, there appears to be no relation between the position of the limit and the altitude of the country. From the north line of Sauk county, in curving, as previously described, to the eastward and northward around Adams county, the limit is on the very crest of the divide. From its position near the middle of the east line of Adams county, the country, for 40 miles to the west, is from 100 to 200 feet lower. From the northwest part of Adams county to the Wisconsin river the limit is in a level country; whilst from the Wisconsin westward the country north of it is everywhere much higher than that to the south, the rise northward continuing to within thirty miles of Lake Superior.

The **surface features of the drift-bearing regions,** so far as they are independendent of the rocky formations beneath, are in strong contrast with those of the driftless area. There is an almost entire absence of the narrow ridge-and-valley topography, or of very steep-sided valleys generally, the contours being everywhere more flowing. The difference is evidently due both to a different method of erosion and to the obliteration of abrupt changes of level by heavy depositions of drift materials Another marked difference is noticed in the entire absence, east of the drift limit, of the fragile castellated outliers that are found further west. Outliers do occur, though not abundantly, but are thick and of rounded contour, and more commonly of limestone. Still another contrast is presented in the linear, and for considerable areas parallel, arrangement of the ridge, valley, marsh, and stream directions, and also of the outlines of the areas occupied by the several formations, as compared with the ramifying arrangement of the driftless region. To these features of the drift-bearing districts are to be added the peculiar appearance due to rounded hills and winding ridges of pebbles and sand, the abundance of circular and serpentine depressions without outlet, and often occupied by lakes of considerable size, and the omnipresent surface erratics — all of which receive especial attention below.

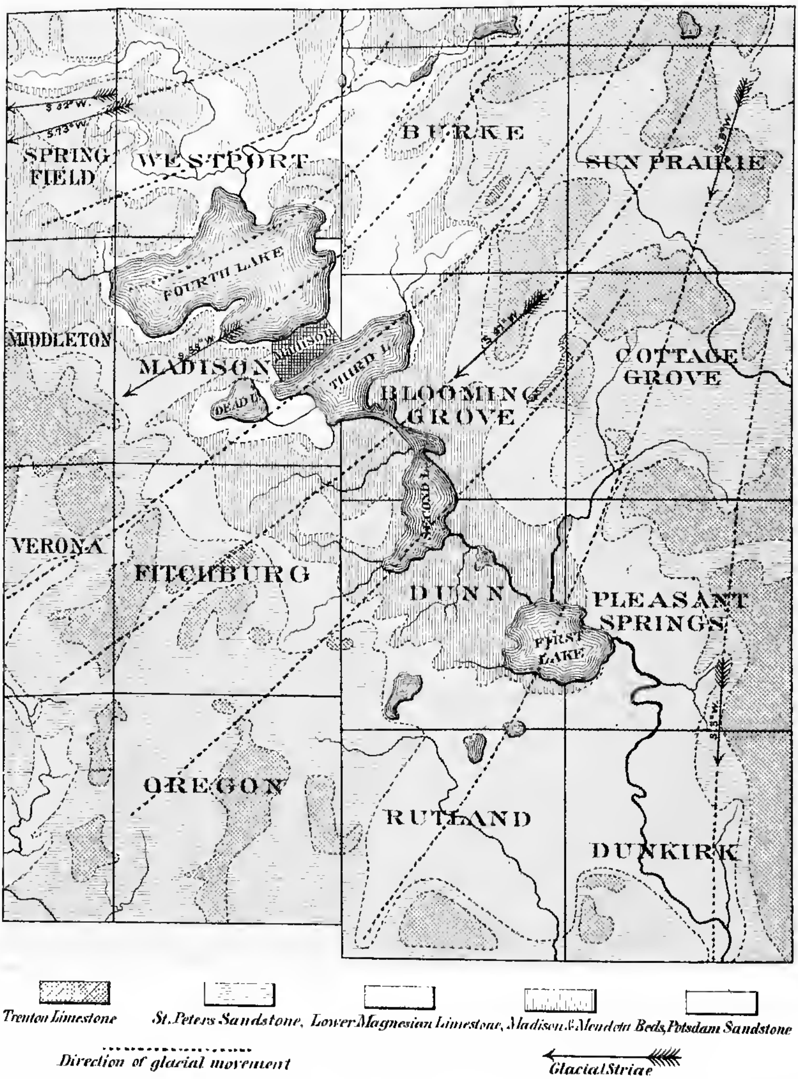
The features thus enumerated are especially to be observed in that part of the state which lies east of the eastern boundary of the driftless area, the region lying immediately north of its northern boundary, though showing in parts considerable quantities of drift material, having apparently not been subjected to so great glaciation. In much of the latter region the drift appears to be quite insignificant, and all surface irregularities as purely the result of subaerial agencies as in the driftless region itself. This is quite evident along both sides of the valley of the Wisconsin from Stevens Point to the north line of the district, and along the valleys of its principal western tributaries. All along the line of the Wisconsin Valley Railroad, between Knowlton and Grand Rapids, wherever the least cutting is made the rock is laid bare. Farther west, on the divide between the Yellow and Black rivers, in Clark and western Wood counties, there is a considerable thickness of drift material, which, however, presents none of the heaped up appearance characteristic of the more eastern drift-bearing regions.

The **linear topography** above mentioned is generally found best marked in the regions east of the belt along which the drift materials have their most marked morainic development. As shown hereafter, this belt lies usually not far east from the western limit of the drift region.

GEOLOGICAL MAP
of the
FOUR LAKE COUNTRY of DANE COUNTY
designed to show the
DIRECTIONS and EFFECTS of the GLACIAL MOVEMENT

R. D. Irving

1876.



The Milwaukee Litho. & Engr. Co.

In the Four Lake Country of Dane county the linear arrangement is finely marked, its directions coinciding with the directions of the glacial striæ on the underlying rocks. Lakes Mendota and Monona, and Lake Waubesa, in part, lie in N.E.—S.W. valleys, the first named occupying two such valleys, which are partly separated by the rock ridge of Picnic and MacBride's points. The valley of Lake Monona extends several miles to the southeastward beyond the lakes, preserving its direction, which, like that of the two valleys of Lake Mendota, is about S. 57° E., or parallel to the direction of the striæ to be seen at the large quarries west of Madison. Numerous other similar valleys of varying size are to be seen in the same country, some occupied by marshes or streams, others entirely dry. Narrow detached ridges, lines of marsh, and the outlines of the formations show the same arrangement, and the same coincidence with the directions of the striæ.

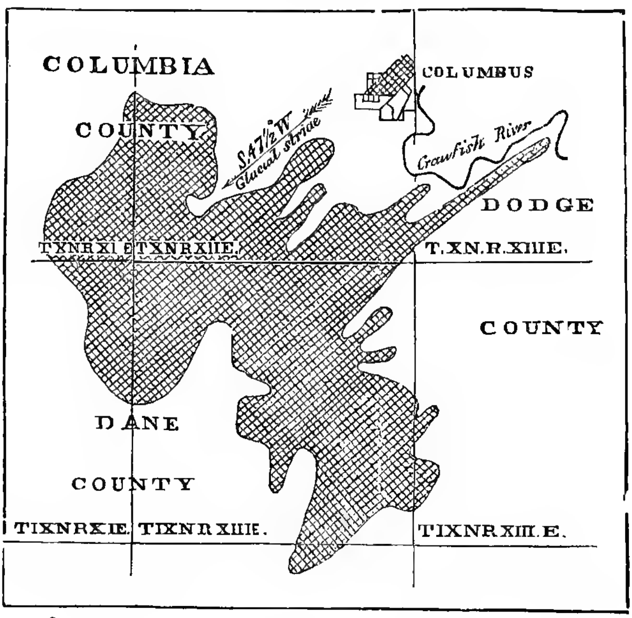
Plate XXVI A is a geological map of the Four Lake Country, and is designed to show especially how the areas of the several formations have been carved out by the glacial forces; since the formations lie one above the other nearly horizontally, the map is also to some extent a topographical one. It gives also the directions of the striæ observed at different points, and the lines along which they indicate the glacial movement to have taken place. It will be observed that the glacial striæ vary in direction from due south at the southeast corner of the map to nearly west at its northwest corner, and that the linear outlines of the formation areas, lake valleys, etc., keep pace with this change in direction. The Atlas map of Area D, which shows also the marsh and stream directions, etc , and is on a larger scale, as well as more accurately drawn, brings this interesting relation out even more strikingly.

It would be instructive to describe in some detail the different linear valleys, ridges and outlines of this district, tracing their varying directions, but the space at command forbids this. It may be mentioned that in the town of Springfield a single narrow valley, carved out in the Lower Magnesian to a depth of 100 feet, is to be observed curving gradually westward to correspond with a slight change in the direction of the striæ on its sides.

Northwestern Dane and eastern Columbia counties are level compared with the district just described, but the linear arrangement is very plainly marked in lines of marsh, streams and geological outlines, as will be seen readily from an inspection of the maps of areas D. and E. Fig. 52 gives the shape of the area of Trenton limestone which occupies the towns of York and Columbus, extending also into adjoining towns on the east and west. A number of short parallel ridges are to be seen in the same region, some of which are rock, and others either altogether of drift or at least with a core only of rock.

Roches moutonees, so characteristic of all glaciated regions where the underlying formation is of the hard crystalline rocks, are not entirely wanting in Central Wisconsin. The bald and smooth rounded summits of quartzite so conspicuous on the high bluffs of Caledonia, Columbia county, show the structure finely. These summits have a direction but little south of west, coinciding with the directions of of the striæ upon them. The scattering knobs of granite and por-

Fig. 52.



Outline of an Area of Trenton Limestone near Columbus.
Scale 4 miles to 1 inch.

phyry which rise through the Potsdam sandstone in Columbia, Marquette, Waushara and Green Lake counties are all distinctly "sheep's backs." The main Archæan region of Central Wisconsin, stretching westward from the Wisconsin to Black river, does not show any distinct "roches moutonées," it being to the west of the region of greatest glaciation. Further east, in Shawano and adjoining counties, these shapes would be expected. The Silurian strata of Central Wisconsin are either too fragile or too susceptible to the solving action of the atmospheric waters, to have received or retained the "roche moutonée" shape.

Drift hills and ridges occur over all of the drift-bearing area of Central Wisconsin. In the region north of the east and west drift limit, in Marathon, Wood, and Clark counties, they do not, however, show any distinct morainic character; but in Dane, Sauk, Columbia, eastern Adams, Marquette, Green Lake, Waushara, Waupaca and Portage counties, they show this character in a marked degree. Moreover, there is, in these counties, a certain belt of country, the western border of which is never very far from the eastern edge of the driftless area, in which the "knobby" drift hills reach an unusual development, the drift materials are thicker than elsewhere, and the surface of the country is dotted with circular or winding depressions, without outlet, of very varying size, and often occupied by ponds or lakes. To these depressions, in certain other parts of Wisconsin, where they are to be recognized on a still larger scale, the name of "potash kettles" has been applied, in allusion to their common shape; and the belt of country in which they occur has been designated as the "Potash Kettle Range," or, more simply, the "Kettle Range." These latter names have heretofore been applied especially to a narrow and very marked range which follows the divide between the valley of Lake Michigan and that in which lie Green Bay, Lake Winnebago, and the head waters of Rock river. Prof. Chamberlin has traced this belt southward to the northeastern part of Rock county, where he finds it bifurcating, one branch running southeastward into Illinois, whilst the other, curving west and northwest, enters the Central Wisconsin district on the south line of Dane county, in the towns of Rutland and Dunkirk.

From the south line of Dane county northward, the "**Kettle Range**" is now recognized for the first time, having been traced for a distance of over 120 miles, as far as the line of the Wisconsin Central Railroad, in Portage and Waupaca counties; beyond which it is known to extend until it becomes merged into the great accumulations of morainic drift which stretch from the head waters of the Wolf and Oconto rivers westward, over a large part of the Archæan region of the north part of the state. The Central Wisconsin "Kettle Range" reaches in parts a much greater width than that of the eastern part of the state, and its inner edge is not so well defined. These differences, however, admit of a satisfactory explanation. Plate XXVI shows the position of the Central Wisconsin Range, whose course and character are described in more detail in what follows.

Beginning on the south, we find, in the towns of Rutland, T. 5, R. 10 E., western Dunkirk, T. 5, R. 11 E., and northeastern Oregon, T. 5, R. 9 E., a considerable development of knolls and ridges of gravel, with a number of depressions occupied by small lakes, one of which, on Sec. 3, T. 5, R. 10 E., is a mile in length. The belt in these towns has a width of about eight miles, and a course west of north. In southwestern Dunn, T. 6, R. 10 E., and Fitchburg, T. 6, R. 9 E., a bow is made to the westward, the convex side of which reaches the northwest part of Oregon, where knolls and large well marked dry kettles are to be seen, and the width is not more than from 4 to 6 miles. In southwestern Madison, T. 7, R. 9 E., the inner edge of the belt reaches the western ends of Lakes Monona and Mendota, where are finely marked mammillary knolls, rising 50 to 75 feet above the lakes, and arranged in lines transverse to the axes of the lake valleys. The western side of this part of the belt is on the high ground of Middleton prairie, where kettles and knolls are to be seen at an elevation of 300 and more feet above the Madison lakes. The same is true of the low ground of northeastern Middleton, where is quite a cluster of water-filled kettles. From Middleton the range passes into Springfield, T. 10, R. 8 E., where the best development is in the northwest corner, and the width is some four miles. The high divide between the Wisconsin and Catfish rivers is crossed in the adjoining portions of Springfield, Dane, T. 11, R. 8 E., Berry, T. 10, R. 7 E., and Roxbury, T. 11, R. 7 E. In Roxbury the belt descends abruptly 200 feet into the low ground of the valley of the Wisconsin. Handsomely shaped and deep kettles are seen in Roxbury, on Sections 8, 9 and 16 in a low area, surrounded by eleven entirely isolated rock bluffs, and two quite large kettle lakes are found on the north side of the town. Columbia county is entered in the town of West Point, T. 12, R. 7 E., where the same characters as observed in Roxbury are continued.

The Kettle Range crosses the Wisconsin river in the northern part of the town of West Point, and continuing northward along the east side of Sauk prairie, reaches the foot of the Baraboo bluffs in T. 11, R. 6 E., and T. 11, R. 7 E., Sauk county. On top of the bluffs immediately north of here it is not well marked, but in the gorge in which lies Devil's Lake, and which makes a complete cut through the range, are very large accumulations of drift materials. The lake itself really occupies a kettle depression, being held in position by immense heaps of entirely unmodified drift at each extremity. These hills rise over 100 feet above the surface of the lake, the southern one falling off on the side away from the lake to over 150 feet, and the northern one fully 100 feet, below its level. The thickness of the drift in the gorge must be nearly, if not more than, 300 feet. It has been shown on a previous page, that in this gorge we have, in all probability, an ancient erosion channel of the Wisconsin river, which, becoming blocked during the glacial times, was never after regained. The Devil's Lake drift appears to lie on the western edge of the Kettle Range, no marked development of which is to be seen on top of the bluff for two miles east, when knolls of limestone, pebbles, and erratics of large size, are met with at the greatest elevations.

Northward from Devil's Lake the Range traverses the Baraboo valley — in which large heaps of unmodified drift occur near the village of the same name — and passing thence through northern Sauk county, crosses the Wisconsin into northwestern Columbia (Newport and Lewiston), and southeastern Adams. Here begins the great development of kettles, both dry and lake-filled, which is continued northward — the width of the whole range at the same time greatly expanding — through northwestern and northern Marquette, Waushara, eastern Portage, and western Waupaca counties, to the line of the Wisconsin Central railroad, and for an indefinite distance in the less settled and unsettled regions beyond. In Waushara county, the Range has attained a width of fully five and twenty miles, the kettles, lakes, knolls and ridges lying thickly spread over the whole surface. As instances of finely marked kettles, may be mentioned those that occur very numerously over the town of Springfield, Marquette county, and in the eastern part of Lincoln, Adams county. These are for the most part dry, often quite perfectly circular, 50 feet in depth and 500 feet in width at top. They occur quite up to the edge of the driftless area, and within a mile of one of the fragile sandstone towers of that district — Pilot Knob. The elevation above Lake Michigan is 550 feet. Excellent illlustrations of lake-filled kettles are to be found in the very numerous lakes of the towns of Marion, Mount Morris, and Springwater, Waushara county. Some of these are of quite large size, as, for instance, Silver lake, near Wautoma, which is over a mile in length. They lie quite often in deep depressions, the water level not unfrequently standing at 25 to 40 feet below the top of the banks, which are wholly of gravel, and very steep, in some cases almost perpendicular. Two or more lakes commonly occur close together, the bank between them having a width on top scarcely enough for a wagon road, and a steep descent to the water on either side. This is finely shown in the case of Silver Lake, already cited, and the nearly as large and partly peat-filled lake immediately north of it. The average elevation of the country in which all of these lakes lie is about 400 feet, and the country between them is everywhere pitted with smaller dry kettles.

Further west, in Waushara county, in the towns of Coloma, Richford, Deerfield and Rose, is a belt of greater altitude, 550 to considerably over 600 feet above Lake Michigan. Here the lakes are less abundant, the drift taking on rather the character of ridges and knolls, though tortuous dry kettles are frequent. This ridge region is the divide between the waters of the Fox and Wisconsin rivers, and the drift depositions within it seem to have suffered little modification since their first formation. The roads running eastward from Coloma, on Burr Oak prairie, pass over parts of this great morainic heap where its structure and nature are seen to great advantage.

For further ideas as to the Kettle Range, its position, varying width, and great numbers of lakes, as compared with the other parts of the state, reference should be made to Plate XXVI. The lakes on this plate are all, except mill ponds, that are given on the township plats of the region mapped, and are accurately placed, although the map is of so small scale. No doubt, others, not on the plats, occur in considerable numbers.

The **materials of the drift** are bowlders, gravel, sand and clay. **Bowlders** are scattered thickly over the whole surface of the drift region. Nearly all are of some sort of crystalline rock, sandstone occurring very rarely, and limestone — except as large sized pebbles — still more rarely. Of the crystalline rock bowlders, those of gneiss of some form or other greatly predominate, making up 50 to 75 per cent. of all. Next in abundance to the true gneiss bowlders, are those of some form of brown-weathering, hornblendic rock, which is generally syenite, and nearly always gneissoid in texture. Of 80 erratics counted within a few rods along the lake shore of the University farm at Madison, 44 were gneiss, 15 gneissoid syenite, 9 granite, 3 diorite, 2 red porphyry, 2 quartzite, 2 sandstone, 1 red felsite, 1 granulite and 1 fine-grained slate. Whilst other rocks are often included, these numbers express, in a general way, what is true for the whole region. The gneiss bowlders vary much in mineralogical composition and closeness of grain, but are nearly always very distinctly laminated, and often much contorted. Occasionally they run into mica slates on the one hand, and gneissoid granite on the other. The granite bowlders vary also, but pink orthoclase granites are most common. All over the region, from Dane northward to Waushara, and probably far beyond, red porphyry and compact red felsite bowlders are very noticeable from their bright red color, although forming only a small proportion of the whole number of erratics. They include kinds in which there is a compact red felsitic matrix, with disseminated hyaline and amygdaloidal quartz; others in which both quartz and felspar are porphyritic; others in which, in addition to these, the red matrix itself develops large crystalline faces; and still others in which the aphanitic matrix constitutes the whole rock.

Quartzite bowlders are not at all common except in one or two limited districts. One of these is in eastern Dane county, in the towns of Medina and Deerfield, where they are abundant, and associated with bowlders of conglomerate, both having beyond doubt come from a mound of quartzite a few miles northeast in Dodge county. It might be expected that the Baraboo quartzite ranges would have had their rock scattered very widely in the country to the southward, but this is not the case. In the Baraboo valley, and still more in the country immediately south of the ranges, quartzite bowlders of large size are very abundant. Further south they occur sparingly as far as the region about Lodi, including talcose quartz-slate, also undoubtedly from the Baraboo ranges. Still further south they are more noticeable for their absence than their presence. It will be seen that this rather unexpected fact admits of a very satisfactory explanation. Sandstone bowlders are rare, not because sandstone is not abundant in the regions over which the drift movement took place, but because of the very friable nature of the rock. Those sandstone bowlders that are found are always either somewhat quartzitic, or, as is more frequently the case, are rendered hard by a large amount of cementing brown iron oxide. Amongst the smaller materials of the drift are sometimes found hard ferruginous concretions which are recognized as coming from the great sandstone region of the heart of the state. That large limestone bowlders should be so very rare appears to be due to the ease with which that rock is worn into smaller sizes.

One of the most interesting substances found in the drift, though hardly attaining the size of a bowlder, is the native copper, which is found in fragments widely scattered over the northwest, from Ohio to Minnesota. These native copper fragments are far more abundant in Wisconsin than elsewhere, and far more abundant there than is commonly supposed. Specimens weighing from a few ounces up to 30, 40, and even 50 pounds, are constantly found in digging. The late Dr. Lapham informed me that the coppersmiths in Milwaukee purchased from finders yearly several hundred pounds of this copper. Ancient implements of copper have been found very abundantly in Wisconsin, the largest collection of such relics in the world now being in possession of the State Historical Society at Madison. It has been argued that these implements prove a high degree of civilization for the races that occupied the northern United States in remote times, since copper smelting is an art unknown to the more barbarous peoples. It is evident enough, however, that there is a direct connection between the abundance of copper implements, and the abundance of drift copper fragments, which in ancient times were probably much more plenty on the surface than now, and which by pounding could yield any and all of the implements ever found. Even a simple melting down was unnecessary, and is directly disproved by the occurrence on the tools of unalloyed silver. Some of the copper for these ancient implements may have been obtained directly from its home in the rock, on the shores of Lake Superior, but this required, of course, no more smelting than the drift fragments.

In size the bowlders vary much, but there is generally a marked break in size between them and the "pebbles," the latter being predominatingly of limestone, the former of crystalline rocks of various kinds. In general the largest bowlders are found farther north. In the southern part of the district the larger ones run, commonly, from two to four feet in diameter, rarely exceeding the latter figure, though occasionally running to as much as 10 feet in one dimension. In Waushara county, especially on the eastern flank of the Kettle Range, bowlders 5 to 10 feet in diameter are very plenty, occurring sometimes in thick clusters, as on the hill immediately north of the village of Poysippi, and in several other places in the neighborhood, where many of one kind are found, giving rise to some doubt as to the possible existence of the rock in place. The largest bowlder observed anywhere in the district lies at the edge of a wood on the S. E. qr. of Sec. 16, T. 18, R. 11 E., Waushara county. It is a red granite, sharp-angled, 13½ feet high, 30 feet long, and 22 wide, measures 110 feet in circumference, is buried in its lower part to an unknown extent, and came from a large outcrop about four miles east. In shape, the smaller bowlders are often very much rounded, the angularity increasing with the size, but depending also much upon composition, hornblendic bowlders always showing more rounding. Scratched and polished bowlders are often seen, but do not form any large proportion, and are generally of the harder and less destructible rocks, such as quartziteand granite.

With regard to the distribution of bowlders, it may be said that, whilst scattered widely over the whole region, they are more plenty in the northern than in the southern portions of the district, and are especially numerous along the inner (eastern) edge of the Kettle Range. The greatest development of bowlders noticed in Central Wisconsin was in eastern Waushara county, and in the adjoining portions of Portage and Waupaca. North of the village of Poysippi, as already stated, the hill is thickly studded with immense bowlders of a coarse, knotty gneiss, composed chiefly of black mica and pink felspar. In the town of Rose, T. 20, R. 10 E., the slope eastward from the high prairie of the next town to the west is strewn with immense bowlders in a very striking manner, and the same thing is to be observed twelve to fifteen miles further north, along the lines of the Wisconsin Central and Green Bay and Minnesota railroads, east of Amherst Junction. Clusters of bowlders are very common, even much further south, as in the central part of the town of Marcellon, Columbia county, and in the S. E. qr. of Sec. 3, Deerfield, Dane county, where the bowlders are scarcely more than ten feet apart, over an area of some 10 to 15 acres. When these clusters occur, they are very apt to be mostly of one kind. Altitude has evidently had no influence whatever on the distribution of bowlders, since they are found on the highest and lowest parts of the country, indifferently. East of Devil's Lake, in the towns of Greenfield and Merrimack, they are found in abundance and of large size on the highest est portion of the Baraboo bluffs, at altitudes of over 900 feet above Lake Michigan. Bowlders are found, also, on the tops of all the isolated bluffs that occur within the drift-bearing area. Very large hornblendic erratics, for instance, are to be seen on the very summit of the limestone bluff of the northwestern part of the town of Springfield, Marquette county. This bluff lies on the top of the divide between the waters of the Fox and Wisconsin rivers, has a height above its base of 200 feet, and a total altitude of 730 feet above Lake Michigan. It lies on the western edge of the Kettle Range, and a mile or two west, in a country 200 to 250 feet lower, the drift has ceased altogether.

Gravel makes up a large part of the drift accumulations, though not so great a proportion as the sand. Two general kinds of gravel may be noted, the coarse and the fine, the former occurring more especially in those regions where the drift appears to take on a true morainic character, forming knolls and ridges, and the sides of many of the depressions of the Kettle Range, whilst the finer gravel is met with commonly in the valleys of streams, or wherever a distinct stratified arrangement of the loose materials is perceptible. The coarse gravel is for the most part of limestone pebbles, with which are mingled some pebbles of white chert, and some of various crystalline rocks, which increase in quantity towards the north. The ordinary limestone pebbles are of a white color, run from three or four to eight or ten inches in diameter, are commonly oblong in shape, much rounded at the ends, and often have one or two sides smoothed and striated. Not unfrequently fossils are contained, indicating the origin of the pebbles, which is also to be inferred from their lithological characters. The coarse unstratified gravel is widely distributed over all the region east of the drift limit and south of the line of the Wisconsin Central railroad, in Portage and Waupaca counties, and also to an indefinite distance further north. It is most abundant in the Kettle Range itself, but is not entirely restricted to it. Even northward, into the region of the Archæan rocks, the gravel is partly of limestone pebbles, which have been brought from the limestone formations to the eastward. In the region north of the driftless area and west of the Kettle Range — including the valley of the Wisconsin as far north as the northern line of Marathon county, and the country lying between the Wisconsin and Black rivers, in northern Wood, and in Marathon and Clark counties — whilst erratics are often seen, sometimes in clusters of very large bowlders, the coarse limestone gravel appears wholly wanting. The fine gravel consists, more largely than the coarse, of pebbles of quartz and various crystalline rocks. It is to be seen, finely stratified, in the drift of stream valleys, and in some places far away from the streams, as, for instance, on the divide between Black and Yellow rivers, where it occurs interstratified with sand and clay to a thickness of over 100 feet.

Sand appears to make up by far the largest part of the drift deposits. It is commonly light-colored and purely silicious, but is often mingled with more or less clayey material, both when in the plainly stratified and the more or less unstratified conditions. Occasionally it is stained brown with hydrous iron-oxide, and when stratified alternates in different colored bands. The explanation of the large preponderance of sand over clay in the Central Wisconsin drift will appear hereafter.

Clay occurs, as already said, to a considerable extent mingled with the sand, over which it sometimes preponderates greatly, forming a firm, tenacious clay, which is stuck full of scratched and polished pebbles and bowlders, and appears to be identical with the "till" of the Scotch geologists. Such a clay, however, is not often to be seen. Something like it appears in the heaps that lie on the high prairies of northern Dane and southern Columbia, but the only places where an apparently true till has been noticed are in the vicinity of Devil's Lake, for a better understanding of whose position reference should be made to Plate XIX, and the descriptions accompanying it. The lake lies in a perpendicularly walled gorge, 500 to 600 feet deep, which passes entirely through the main quartzite range of the Baraboo. This gorge is about three-quarters of a mile in width, and between three and a half and four miles in length. At the northern end its course is nearly due north and south for over a mile, when it turns nearly at right angles, and runs for the rest of its length but little south of east. Devil's Lake lies in the north and south portion of the gorge. At its northern end a hill of drift rises abruptly from the water to a height of 100 feet, falling on the further side as abruptly over 200 feet to the Baraboo river. A short distance beyond the southern end of the lake a similar hill chokes the gorge from side to side, rising 100 feet from the lake level, and on the eastern side sinking rapidly until at its eastern end the bottom of the gorge is full 150 feet below the lake. Through this hill a deep cutting is made for the Chicago and Northwestern Railroad. The sides of the cutting show no sign of stratification, but only a sandy tenacious clay with numerous scratched pebbles and bowlders, the latter including the usual kinds of crystalline rocks, but also a number of quartzite, some of which are much smoothed and striated. The large drift cutting near Baraboo shows something the same sort of material, which is, however, much more sandy, and has traces of a crude stratification. It is quite probable that till-like clays occur somewhat widely in the region of the Kettle Range, but the rare cuttings make this conjectural only. In southeastern Adams county, in the region about Big Spring, quite a large area occurs in which the surface material is a red tenacious clay. No cutting was seen in this clay, and its exact relations and structure are doubtful.

Stratified clays, often fine-laminated, are found in the valleys of most of the streams in the southern part of the Central Wisconsin district, where they are interstratified with fine gravel and sand, and are often utilized for making brick. Such clays are found at a number of places in the Catfish Valley, as, for instance, in the vicinity of Madison, at Oregon, at Stoughton, etc., at times yielding a pure white or cream colored brick, at others, an ordinary red brick. The following analysis is of one of the latter kind, from a pit in the valley through which the Milwaukee & St. Paul railroad passes, on the S. E. qr. of Sec. 17, T. 7, R. 9 E., about one mile west of the University at Madison: silica, 75.80; alumina, 11.07; iron peroxide, 3.53; iron protoxide, 0.31; lime, 1.84; magnesia, 0.08; carbonic dioxide, 1.09; potassa, 1.14; soda, 0.40; water, 1.54; hygroscopic moisture, 2.16=99.56.

These clays contain occasionally small pebbles of limestone which, on being baked in the middle of the brick will subsequently "slack" and cause it to burst open. The clays that produce the light or cream-colored brick contain not unfrequently as much iron as the ordinary red clays, but are very much more calcareous, resembling in this regard the famous Milwaukee brick clay.

The different behaviours of these two classes of clay under heat is evidently due largely to the difference in amount of lime and magnesium carbonates, but is not well understood.

An attempt to study out the system of **arrangement of the drift materials** meets with no little difficulty from the rarity of natural or artificial sections. Enough information can, however, be obtained from the few sections that do occur, and from records of well-borings, to show plainly enough the existence of the two classes of material, the unstratified and stratified. The unstratified condition characterizes always the moraine-like heaps of limestone pebbles, and is in general the condition of the materials occurring on high land, and all along the Kettle Range, where, however, there is often visible, in the sand, a rude sort of bedding, not due to aqueous action, but indicating merely a gradual growth of the deposits. The knobby hills, when not formed of limestone pebbles, are often made up of layers of sand conforming roughly to the outlines of the hills.

Stratified drift is to be seen in the valleys of streams, as also in many not now occupied by streams. A few instances will serve to give an idea of what is a general truth. About a mile east of the Wisconsin, on the side of the road from the village of Knowlton, Marathon county, to the railroad bridge, finely stratified sand and gravel may be seen, at an elevation of over 50 feet above the river. The pebbles are all small, much rounded, and consist predominatingly of granite, with some diorite, quartz, etc., and no limestone. At Montello, Marquette county, in the immediate vicinity of the Fox river, flowing wells are obtained from what appears to be stratified drift. The wells are 50 to 90 feet deep, and pass through a series of layers of sand, gravel, and clay, the gravel layers at different horizons yielding water. A number of railroad cuttings in the vicinity of Madison, and to the southward along the Catfish valley, show finely stratified drift, one of the best points being at Stoughton depot, where a bank 25 feet high shows very regular layers, three to four inches thick, of alternating sand and gravel. On the opposite side of the Catfish, at a lower level, the following alternation occurs:

	Feet.	Inches.
Soil	1	..
Fine gravel	4	..
Cross-laminated sand	4	..
Fine gravel	1	6
Cross-laminated sand	3	..
Horizontally laminated sand	2	2
White brick clay to river level	15	..
	30	6

Of the total **amount of the drift materials**, it is difficult to make a satisfactory estimate, since the thickness is so very variable. The greatest amount of material appears to be in the region of the Kettle Range, and especially in that part of it that occupies Waushara and the adjoining counties. Wells in the town of Oasis, Waushara county, are sunk 140 to 150 feet, without striking rock. The drift hills of the Devil's Lake gorge, described a short distance back, are fully 200 feet thick, and may reach 300. The drift hill on the University grounds, Madison, where the President's house stands, is 107 feet thick to the lake level, 122 feet to rock. The Artesian well at the Capitol Park, Madison, is 180 feet in drift. But the distinctly stratified drift has often also a considerable thickness. It is frequently the case that in valleys, wells sunk close to the rocky side hills will pass through 50 to 100 feet of stratified gravel, sand and clay. Nearly all the valleys have their rock bottoms far below their present surfaces, whilst there are even evidences of entirely obliterated valleys. On the high prairie of Arlington, which is nearly everywhere underlaid, at a shallow depth, by the Lower Magnesian, wells sunk within a few rods of a ledge of St. Peters sandstone, on the S. E. qr., Sec. 28, pass through over 100 feet of loose materials. Even on the summit of the dividing ridge between Black and Yellow rivers, apparently stratified drift has a thickness of over 100 feet. In all of the drift-bearing region, wells commonly pass through 10 to 15 feet of drift before striking rock, and it is probably far within the truth to say that the drift materials are equal to a layer 50 to 60 feet thick, spread over the whole drift-bearing area.

Three kinds of evidence are available with regard to the **directions of the glacial movement:** the courses of the striæ and grooves on the underlying rocks; the directions of the lines of glacial erosion; and the directions of travel of erratics of known origin.

The rocks underlying the drift quite often show *polishing*, *striæ*, and *grooves*, but these markings have not remained over a large portion of the region, either on account of the exceedingly friable nature of the rock on which they have been made, or, if the rock be limestone, because this has suffered from the dissolving action of carbonated water. Moreover, over great areas, the drift conceals the rock basement. The markings observed are most commonly on limestone, which is frequently planed and scratched in a beautiful manner. One observation only has been made on sandstone, and this where the sandstone was unusually hard. The only Archæan rocks on which the markings have been observed, are those of some of the isolated areas within the region of the Potsdam sandstone. In the main Archæan region of the district, no marked evidence of glaciation has been observed. The following is a tabulation of the observations made:

DIRECTIONS, ETC., OF GLACIAL STRIÆ AND FURROWS.

No.	¼ S	S	T.	R.	County.	Directions[1]	Kind of Rock.	Remarks.
1	S W	14	5	12 E	Dane......	S. 35° E.	Trenton Limestone	Striations, 1 set only.
2	NW	35	6	12 E	Dane......	S. 5° W.	Buff Limestone...	Striations, 1 set only.
3	NW	14	8	11 E	Dane......	S. 19° W.	Buff Limestone...	Striations. Fainter lines crossing at small angles.
4	NW	17	7	10 E	Dane......	S. 47° W.	Buff Limestone...	Striations. Fainter striæ S. 40° W.
5	NW	21	7	9 E	Dane	S. 57° W.	Lower Magnesian.	Striations, 1 set only.
6	SE	14	8	8 E	Dane......	S. 73° W.	Lower Magnesian.	Striations, 1 set only.
7	NE	15	8	8 E	Dane......	S. 81° W.	Lower Magnesian.	Striations, 1 set only.
8	SE	23	10	8 E	Columbia...	West.	Lower Magnesian.	Striations. Fainter lines S. 85° W.
9	NE	2	11	6 E	Sauk.......	S. 65° W.	Potsdam sandstone	Grooves very markedly parallel, on the "stossed" end of a ridge.
10	NW	26	12	7 E	Sauk	S. 85° W.	Archæan Quartzite	Grooves, and fine striations, with glassy polished surface.
11	NW	25	12	7 E	Sauk	S. 50° W.	Lower Magnesian.	Striations.
12	NE	26	12	8 E	Columbia ..	S. 85° W.	Archæan Quartzite	Furrows 1′ 6″ wide, 1″-2″ deep; striations in same direction.
13	SE	3	10	12 E	Columbia ..	S. 47.5° W.	Lower Magnesian.	Striations.
14	SE	1	13	12 E	Columbia ..	S. 63° W.	Lower Magnesian	Striations, 1 set only.
15	NE	2	17	11 E	Green Lake	S. 68° W.	Quartz-porphyry...	Striations, very close, parallel, with polished surface.

The *linear topography*, seen in lines of marsh, in the directions of streams, valleys, narrow ridges, and lakes, and in the outlines of the areas of the geological formations, has been described before, as characterizing especially the region of Dane and Columbia counties; and the bearings of these lines have been shown to coincide with the bearings of the glacial striæ. A very brief examination of the table just given, together with Plates XXVI and XXVI A of this volume, and the Atlas Plates of Areas D and E will serve to show the following interesting facts. Beginning on the southeast, in the towns of Albion and Pleasant Springs, and following a curving course northwestward to the country about Lodi in Columbia county, we find the glacial striæ and the linear formation outlines, stream, lake, and marsh directions, etc., undergoing a gradual but steady change from a nearly due south direction to one as nearly due west, and we find this westerly direction continued further northward into the country of the Baraboo

[1] True bearings.

ranges. Moreover, in this change of direction a *constant position is maintained at right angles to the curving course of the Kettle Range.* The southeast bearing observed in Albion is an exception to this statement, but this direction is evidently merely a local one, since in the country immediately east, as I am informed by Prof. Chamberlin, a constant direction to the south or a little west of south is observed. Other exceptions appear in two bearings observed in the country about Baraboo, but these are from places in the valley between the two quartzite ranges, and are evidently due, in some way, to their influence. In going northward through the eastern parts of Columbia and Dane counties, though some increase in westing is seen, the general directions are more nearly southwest. The outline of an area of Trenton limestone that occurs in the adjoining corners of Dane, Columbia and Dodge counties has been given in Fig. 54. North of Columbia county the linear topography continues into Green Lake county, but further west is not marked, nor are striæ often to be observed.

In considering the *origin and directions of travel of the erratics and pebbles* of the drift, we notice at once two classes of these materials, those that have been carried but short distances comparatively, and whose exact place of origin may often be ascertained; and those that have traveled all the way from the Lake Superior country, and whose homes can generally be only roughly guessed at. It is from the first class of bowlders that we can get our best ideas of the directions of the drift movement, not only because of the certainty of their places of origin, but because they have probably moved in more direct lines than those that have come from great distances. The following are a few facts in regard to the first class of erratics. In the eastern sections of the town of Deerfield, T. 7, R. 12 E., Dane county, are many bowlders of a bluish-gray, flinty quartzite, associated with others of a coarse quartzite conglomerate, both having evidently come from the mounds of Archæan quartzite that rise through the St. Peters sandstone on Secs. 34, 35 and 36 of the town of Portland, T. 9, R. 13 E., Dodge county. The distance traveled is from 9 to 14 miles, and the direction of travel S. 25°–30° W., coinciding closely with the directions of the topographical lines. On the top of the hill just west of the depot at Lodi, Columbia county, S. E. qr. of the N. W. qr. of Sec. 27, T. 10, R. 8 E., is a bowlder some eight feet high, of hard, brownish sandstone, having a vitrified or quartzitic weathered crust. Four to six miles due east, on top of the high prairie of Arlington, are five small patches of St. Peters sandstone, the rock of which has characters exactly resembling those of the bowlder at Lodi. Midway between the bowlder and its parent rock, on top of Kingsley's bluff, near the southeast corner of Sec. 23, the Lower Magnesian is observed polished and striated in a due west direction. Several of the valleys of southern Lodi coincide with this direction. It has been stated as a peculiar fact that bowlders of the quartzite that make up the Baraboo ranges are not found, except sparingly, to any distance south of these ranges, although of large size and abundant on both flanks of the main range, and even on its higher portions, as also in the Devil's Lake gorge, and in the valley between the two ranges. The explanation evidently lies in the fact that the east and west trend of the quartzite bluffs has coincided with the direction of the drift movement, which is proved to have been nearly due west by the bearings of the grooves and striæ observed. The little southing that appears in these bearings would not carry the bowlders any distance south before reaching the eastern limit of the driftless region. Bowlders of dark colored quartz-porphyry are found along the road between Montello and Kingston, Marquette county, having traveled 4 to 5 miles a little south of east from the large outcrops on Secs. 2 and 3, T. 15, R. 11 E. In the eastern part of the town of Marion, T. 18, R. 11 E., Waushara county, are several mounds of granite, and in the country for several miles to the west and south of west, bowlders of the same rock are abundant. One of these, of extraordinarily great size, and already mentioned as occurring on the S. E. qr. of Sec. 16, has traveled in a direction of about W. 10° S., three miles from the outcrop on the east line of Sec. 12. A number of angular bowlders of Lower Magnesian limestone on the S. E. qr., Sec. 13, T. 17, R. 7 E., Adams county, have been carried in a similar direction from the isolated limestone bluffs on Secs. 5 and 7, T. 17, R. 8 E., Marquette county. A large bowlder, 30.5 feet in circumference, of very coarse granite, with large surfaces of brilliant felspar, rests on top of the hill at Waupaca, Waupaca county, having been brought eight miles from a mound-like outcrop of the same rock on Sec. 32, T. 23, R. 12 E., in a direction of about S. 60° W.

But these bowlders, whose origin is so near their present positions, are but few in number, compared with those that have come from great distances. Most of the latter have been brought from points 100 to 300 miles to the north, and possibly from places still further north. It appears probable that the region of the northern peninsula of Michigan has afforded a large proportion of them, though it is quite possible that many have come from the north shore of Lake Superior. The native copper fragments we may suppose to have been chiefly brought from Keweenaw Point, for a distance of 300 miles and over. The several kinds of red porphyry erratics are of very doubtful origin. No such rock occurs in the Huronian or Laurentian of North Wisconsin or Michigan, nor am I aware that any occurs in the Copper series of Lake Superior, except in the state of conglomerate pebbles, which have evidently been derived from an older series. The limestone pebbles of the drift have come from all the Silurian limestones of eastern Wisconsin, the Galena and Niagara formations having furnished the larger part. These formations extend in continuous belts from the south to the north line of the state, so that it is not often possible to say in what direction the pebbles have come.

The origin of the sand and clay of the drift may be considered in the same connection, though not affording more than a general idea as to the direction of the drift movement. The great preponderance of sand over the other drift materials, in much of Central Wisconsin, is without doubt to be attributed to the great surface spread of the friable Potsdam sandstone in the region over which the drift has passed. Sand is, however, also found forming most of the drift even far north in the Archæan district, where it is sometimes in quantity sufficient to produce sand barrens. This fact may be regarded as proving a much greater surface extent north and east in the Archæan area of the sandstone formation in preglacial times. The clay has come partly, perhaps, from the limestone formations, and partly from the kaolinization of felspathic erratics, but its principal source would seem to have been the previously kaolinized granites and gneisses of the Archæan region. It is well known that in all southern regions where the drift phenomena are unknown, as for instance along the Blue Ridge from Virginia to Alabama, and in Brazil, the felspathic crystalline rocks are found rotted to great depths. Hunt has drawn attention to the fact that in the region of the Blue Ridge this ceases to be the case north of the southern limit of the glacial drift, whose deposits lie upon the hard, unaltered, and often polished rock surface, and has inferred the removal of the softened rock by the glacial forces. In that small portion of the Archæan region of Wisconsin, in which the drift is insignificant or wanting entirely — as along the valley of the Wisconsin south of Stevens Point, and along Black river south of the crossing of the Green Bay road — decomposed and kaolinized gneiss and granite occur. Over the rest of the Archæan region, on the contrary, the drift rests directly upon the unchanged rock.

No **fossils** of any kind have ever come to my attention as occurring in the drift deposits of Central Wisconsin.

The **economic contents** of the drift are of considerable importance. In many regions of the state where other limestones are either absent or yield only an inferior lime, the pebbles of the drift are profitably burnt. They yield often an excellent white lime, as, for instance, at several points on the Baraboo ranges, and in the sand region of Marquette and Waushara counties. The sand and gravel of the drift are everywhere put to use for the ordinary purposes. The gravel is occasionally transported far into the driftless region for railroad ballasting. The stratified clays of the drift are everywhere used for brick-making, yielding often, as at Stoughton and Oregon, in Dane county, a cream-colored brick fully equal to the "Milwaukee brick."

The facts given in the foregoing pages will warrant a few briefly stated theoretical **conclusions:**

(1) *The drift of Central Wisconsin is true glacier drift;* as is well shown by facts similar to those that are appealed to as proof of the same thing in other glaciated regions, viz.: the unstratified nature of the drift materials, except in stream valleys; the frequent moraine-like drift hills and ridges; the absence of fossils, marine or otherwise; the abundance of well rounded, scratched, and polished bowlders; the existence of a "till" with its striated pebbles; the polished, striated and grooved condition of the underlying rock surface; the linear and parallel erosion outlines; and the entire lack of any evidence of such a submergence of the region as would be necessary for the working of any other distributor of loose materials than a glacier. Moreover, in this special case, there is positive evidence that no such submergence ever did take place. This evidence is found in the sharply defined character and position of the drift limit, which pays no attention whatever to the topography of the country it traverses, having the higher ground now on one side, now on the other, and crossing the highest ridges and lowest valleys indifferently. Only a glacier could have ceased its action along such a line. Had the drift materials been spread by floating bergs, the sea in which these were borne would never have ceased along such an abrupt line, and, moreover, any sea which was deep enough to have floated icebergs over the higher portions of the Baraboo ranges would have carried them westward uninterruptedly to the Mississippi river.

(2) *The Kettle Range of Central Wisconsin is a continuous terminal and lateral moraine.* The mere fact of the existence of such a distinct and continuous belt of unstratified and moraine-like drift, which, in much of its course, lies along the edge of the driftless area, or, in other words, along the line on which the western foot of a glacier must long have stood, would go far towards proving the

truth of this proposition, of which, however, a complete demonstration appears to be at hand. In all the country just inside of the Kettle Range, we find that glacial striæ, lines of glacial erosion, and lines of travel of erratics, all preserve a position at right angles to the course of the range, although that course veers in the southern part of the district from west to north. East of the Central Wisconsin district, as previously stated, the Kettle Range extends eastward and northeastward to the dividing ridge between the valley of Lake Michigan and the valley in which lie Green Bay, Lake Winnebago and the head waters of Rock river, and along this ridge northward into Green Bay peninsula. All along this part of its course, Prof. Chamberlin has found the glacial striæ pointing *east of south*, and towards the Kettle Range, whilst along the middle of the Green Bay valley, he finds the striæ directions parallel to the main axis of the valley, or a little west of south. On the west side of this great valley, and along the eastern border of the Central Wisconsin district, the striæ trend about southwest, whilst still further west they gradually trend further to the west, becoming at last nearly due west, or at right angles to the western Kettle Range.

We have then a most beautiful proof that at one time the Green Bay valley was occupied by a glacier, which was not merely part of a universal ice sheet, but a distinctly separate tongue from the great northern mass. The end of this glacier was long in northern Rock county, its eastern foot on the east Wisconsin divide, and its western on the summit of the divide between the Fox and Wisconsin river systems, as far south as southern Adams county, after which it crossed into the valley of the Wisconsin, and from that into the headwaters of the Catfish branch of Rock river, in the Dane county region. Whilst the main movement of the glacier coincides in direction with the valley which it followed, it spread out on both sides in fan-shape, creating immense lateral moraines. Peculiar circumstances caused the restriction of the eastern moraine to a narrow area, whilst that on the west, having no such restriction, spread out over a considerable width of country, the breadth of the moraine reaching in Waushara county as much as 25 miles. Of course this width of moraine must have been due to the alternate advance and retreat of the glacier foot. Such an advance and retreat appears moreover to be recorded in the long lines of narrow sinuous ridges, each marking perhaps the position of the glacier foot, or a portion of it, during a certain length of time. The intersecting of these winding ridges, which have no parallelism at all with one another, appears to me to have been the main cause of the formation of the kettle depressions. Col. Whittlesey[1]

[1] Smithsonian Contributions to Knowledge.

has supposed that these owe their origin to the melting of ice masses included within the moraine materials, and this may possibly be true with regard to the more regularly circular kettles.

The thickness of the great glacier we can only conjecture. It is easy to see, however, that it was at least a thousand feet, for it was able to accommodate itself to variations in altitude of many hundred feet. Morainic drift occurs on the summit of the Baraboo ranges over 900 feet above Lake Michigan, and on the immediately adjacent low ground 700 feet below.

(3) *The Driftless Region of Wisconsin owes its existence, not to superior altitude, but to the fact that the glaciers were deflected from it by the influence of the valleys of Green Bay and Lake Superior.* Some writers[1] have thrown out the idea that the driftless area is one of present great altitude compared with the regions around it, and that by virtue of this altitude during the Glacial period it caused a splitting of the general ice sheet, itself escaping glaciation. This idea may have arisen from the fact that in the southern part of the area the district known as the "Lead Region" has a considerable elevation; but the facts heretofore given have shown that in reality the driftless area is for the most part *lower* than the drift-covered country immediately around; the greatest development, for instance, of the western lateral moraine of the glacier of the Green Bay valley, having been on the very crown of the watershed between the Lake Michigan and Mississippi river slopes, whilst the driftless region is altogether on the last named slope. Moreover, to the north, towards Lake Superior, and to the west, in Minnesota, the whole country covered with drift materials lies at a much greater altitude. J. D. Whitney, in his report on the lead region of Wisconsin, favors the idea that the driftless district stood, during the glacial times, at a much greater relative altitude than now, and so escaped glaciation. But it is evident that in order that this could have been the case, either (1) a break or bend in the strata must have taken place along the line of junction between driftless and drift-bearing regions; or else (2) the driftless region has since received a relatively vastly greater amount of denudation than the drift-bearing. That no break or bend ever took place along the line indicated is abundantly proven by the present perfect continuity of the strata on both sides of the line, the whole region of Central Wisconsin being in fact one in which faults of any kind are things absolutely unknown. That no sensible denudation has taken place in Wisconsin since the Glacial times, in either drift bearing or driftless areas, is as well proven by the

[1] See Geological Survey of Ohio, Vol. II.

intimate connection with one another of the systems of erosion of the two regions. The valley of Sugar river, for instance, with its branches, is throughout its course worn deeply into the underlying rocks; on its east side it contains morainic drift, proving that it was worn out before the Glacial period, whilst on the west it extends into the driftless regions.

We are thus compelled to believe that during the Glacial period the region destitute of drift had the same altitude relatively to the surrounding country as at present. Before the Glacial period portions of the drift-bearing region may indeed have been somewhat higher, for in it a considerable amount of material must have been removed from one place to another, by the glacial forces. The only satisfactory explanation remaining then for the existence of the driftless region is the one I have proposed. We have already seen that the extent of this region to the eastward was marked out by the western foot of the glacier which followed the valley of Green Bay. That it was not invaded from the north is evidently due to the fact that the glacier or glaciers of that region were deflected to the westward by the influence of the valley of Lake Superior. The details of the movement for this northern country have not been worked out, but it is well known that what is probably the most remarkable and best preserved development of morainic drift in the United States exists on the watershed south of Lake Superior. Here the drift attains a very great thickness, and the kettle depressions and small lakes without outlet are even more numerous and characteristic than in other parts of the state. The watershed proper lies some 30–40 miles south of the lake, and 800 to 1200 feet above it, but the morainic drift extends 25 to 50 miles further southward. On the east side of the state the drift of Lake Superior merges with that of central and eastern Wisconsin, whilst west of the western moraine of the Green Bay glacier, it dies out somewhat gradually, until 125 to 150 miles south of the lake the the drift limit is reached. Much of the country 25 to 75 miles north of the driftless region, though showing numerous erratics, is quite without any marked signs of glaciation; as, for instance, along the valley of the Wisconsin from Grand Rapids north to Wausau. Further west the drift extends more to the southward. The course of the Lake Superior glaciers conveyed them further and further southward as they moved westward.

Future investigations will undoubtedly bring out a close connection between the structure of the Lake Superior valley and the glacial movements south of it. Even the facts now at hand seem to point toward some interesting conclusions. Projecting from the south shore of Lake Superior, we find two great promontories, Keweenaw Point, and the Bayfield Peninsula. Both of these projections have a course somewhat transverse to the general trend of the lake, bearing some 30° south of west. Both have high central ridges or backbones, which rise 1,000 to 1,500 feet above the adjacent lake, and are made up of bedded igneous rocks, sandstones, and conglomerates of the Copper Series. Both of these ridges continue far westward on the mainland, having between them a valley, partly occupied by the lake, which is a true synclinal trough, the rocks of the two ridges dipping towards one another. North of the Bayfield Peninsula, and again south of Keweenaw Point, we find two other valleys running in from the lake shore in the same direction. In all probability each one of these valleys has given direction to a glacier tongue. An inspection of a good map of the northern part of Wisconsin, Minnesota and Michigan will serve to show that the almost innumerable small lakes[1] of these regions are concentrated into three main groups, each group corresponding to a great development of morainic drift, and lying in the line of one of the three valleys just indicated. I suppose that each of the lake groups is a moraine of the glacier which occupied the valley in whose line it lies. The main ice sheet coming from the north met, in the great trough of Lake Superior, over 2,000 feet in depth, an obstacle which it was never able to entirely overcome, and so reached further southward in small tongues composed perhaps of only the upper portions of the ice. These tongues being deflected westward by the rock structure of the country, and having their force mainly spent on climbing over the watershed, left the region further south untouched. The eastern part of the Lake Superior trough is not nearly so deep as the western, and the divide between Lake Superior and the two lakes south of it never attains any great altitude, so that here the ice mass, having at the same time perhaps a greater force on account of its nearness to the head of the ice movement on the Laurentian highlands of Canada, was able to extend southward on a large scale, producing the glaciers of the Green Bay valley and of Lake Michigan.

Although quite crude in its details, I am convinced that the main points of the explanation thus offered for the existence of the driftless region in the northwest will prove to be correct. To obtain a full elucidation of the subject, much must yet be done in the way of investigation, not only in Wisconsin, but over all of Minnesota and the states south, in order that the details of the ice movement for the whole northwest may be fully understood.

[1] Far more numerous in reality than shown on the best maps.

(4.) *The stratified drift of the valleys owes its structure and distribution to the water of the swollen streams and lakes that marked the time of melting of the glaciers.*

(5.) *The depth below the present surfaces of the rock valleys appears to indicate a greater altitude of this part of the continent, during the Glacial period, than at the present time.*

LACUSTRINE CLAYS.

Extending inland from Lakes Michigan and Superior for many miles, and reaching elevations of several hundred feet above the lakes, are stratified beds of loose material, chiefly marly clays, with more or less sand, some gravel and a few bowlders. These are proved to be, with but little doubt, of lacustrine origin, by the manner in which they follow the shores of the lakes, and they register a *depression* of several hundred feet, corresponding to the period subsequent to the melting of the glaciers, when all the lakes and streams of the northern part of the United States were greatly expanded beyond their present limits, and the whole northern part of the continent stood at a lower level.

In the Central Wisconsin district the lacustrine clays have only a small development, most of the district being either too high to have been reached by the lake depositions, or else lying behind the dividing ridges. The eastern towns of Waushara county, however, are underlaid by a considerable thickness of red clay belonging to this formation. The surface elevation of the country here is 160 to 200 feet above Lake Michigan, and the clays 80 to 100 feet and over in depth, as shown by numerous Artesian well borings that yield a flow of water which is obtained from seams of gravel at different horizons in the clay. The clay of eastern Waushara county is part of a large clay area that extends up the Green Bay valley from Lake Michigan.

BOG IRON ORES.

The most recent formations of the Central Wisconsin district are the marsh deposits of peat and bog iron ore. The latter is found on a small scale underlying the peat of many marshes, and also occurring at points not now marshes, but still showing signs of a marsh origin. The large marshes of Juneau, Wood and Portage counties have yielded the best indications of the existence of good bog ore, although the points at which any quantity can be seen are few in number.

At **Necedah,** Juneau county, immediately south of an isolated hill of Archæan quartzite, is a tongue of the great marsh that spreads widely over northwestern Juneau county and into the adjoining counties of Jackson and Wood. Underneath the peat of this marsh tongue, and along the banks of a dry run east of the marsh, bog ore occurs in some quantity. The best ore is found on the S. E. qr. of Sec. 24, T. 18, R. 3 E., on land belonging to Mr. J. T. Kingston, where it lies at about 3 feet below the surface of the marsh, being covered by peat and peaty marsh mud. It is seen in the bottom of a ditch for some 40 rods, and can be raised by the crowbar in large firm blocks. These are very porous, but between the pores show a dark brown, very hard, fibrous, silky-lustred limonite. Immediately over the hard ore, in places, is a sand or shot ore, composed of rolled grains of limonite. The thickness is reported at 2½ feet. The following analysis shows the composition of a sample (1356) averaged from a considerable quantity: silica, 8.52; alumina, 3.77; iron peroxide, 71.40; manganese oxide, 0.27; lime, 0.58; magnesia, trace; phosphoric acid, 0.21; sulphur, 0.02; organic matter, 1.62; water, 13.46 = 99.85: metallic iron, 49.98. Following the stream southward into the N. E. qr. of Sec. 25, the ore grows much leaner, being mingled with sand (1356½). The same sandy ore is seen along the side of a dry run on the N. W. qr. of Sec. 30, T. 18, R. 4 E., an average sample yielding only 16.09 per cent. of metallic iron. Mr. Kingston's ore is certainly an excellent one, and the marsh is well worthy of further investigation.

At **Point Bass,** Wood county, on the west bank of the Wisconsin river, near the center of Sec. 10, T. 21, R. 5 E., on land belonging to the Hon. Moses M. Strong, a porous bedded limonite is exposed in the river bank, 15 feet above the water. The exposure extends along for some 50 feet, and appears to be some 8 feet in thickness, the upper 3 feet being a porous but quite pure ore, containing some 50 per cent. of metallic iron. Two hundred feet down stream a cutting into the river bank shows that the ore does not continue in that direction.

At several points on the east bank of the Wisconsin, **north of Grand Rapids,** on Sec. 4, T. 22, R. 6 E., and Sec. 34, T. 23, R. 6 E., small openings show ore just like that described. At one of these points, on Mr. McGrath's land, the ore is seen with a thickness of 20 inches, very evenly and thinly bedded, and extending over an area of about 75 feet square. The following analysis, made by Mr. Oliver Matthews, a student of the Metallurgical Department of the State University, shows the composition of an averaged sample: silica, 4.81; alumina, 1.00; iron peroxide, 73.23; lime, 0.11; magnesia, 0.25; sulphuric acid, 0.07; phosphoric acid, 0.10; organic matter, 5.88; water, 14.24=99.69: metallic iron, 51.26.

APPENDIX.

MICROSCOPIC LITHOLOGY.

BY CHARLES E. WRIGHT.

[NOTE. — The following descriptions are of a small number of crystalline rocks selected from the large mass of material on hand, as most difficult to determine, or as having a special importance. The numbers are the same as given in the body of the report, and the original specimens will be found in the survey collections, when distributed. A few of Mr. Wright's descriptions have been made use of in the foregoing pages, but the descriptions of crystalline rocks there given are nearly always wholly my own. It is a matter of regret that the funds were not available for microscopic examination of a full suite of the Central Wisconsin rocks. R. D. I.]

501. Silicious Hornblende-Schist. HURONIAN? *Black river, Jackson county, north line Sec. 14, T. 21, R. 4 W.* Light-greenish-black; very fine-grained; crystalline texture; conchoidal fracture; hard and compact. With the lens, minute grains of silica are plainly visible, but the ingredient minerals cannot be distinguished. Under the microscope, in the polarized light, a thin section of the rock presents a very pretty field, and is composed of small fragments of amphibole, minute grains of quartz, and a few scattered leaves of chlorite. From the structure it is evident that the amphibole formed after the quartz, since the former encloses grains of the latter.

757. Granite. HURONIAN? *Village of Montello, Marquette county, S. W. qr. Sec. 9, T. 15, R. 10 E.* Pale flesh-color, dotted with a few dark patches of mica. The facets of felspar are easily recognized. Traversing the specimen is a thin, light-greenish seam of what appears to be epidote. Under the microscope, in the polarized light, the coarse fragments of orthoclase apparently constitute more than one-half the entire section. An occasional twin crystal of felspar after the Carlsbad form may be seen. The grains of quartz are mostly very small and angular, and are frequently enclosed within the felspar. With a power of 500 diameters are visible, in the quartz, fluid inclusions; the absence, however, of any glass or stone-filled cavities will no doubt refer the rock to a metamorphic origin.

758. Argillo-chloritic Schist. HURONIAN? *Village of Montello, Marquette County; S. W. qr. Sec. 9, T. 15, R. 10 E.* Grayish-green; fine-grained texture; partially decomposed; cleaves readily into irregular plates; in the joints it is often ocherous; under the microscope the pale greenish leaves of chlorite are plainly visible; also minute grains of silica and a few scales of hematite.

766. Granite. HURONIAN? *Near Spring Lake, Waushara county, N. E. qr. Sec. 27, T. 18, R. 11 E.* Similar to 757 from Montello. The felspar is more or less decomposed; but this is probably local or accidental.

859 1-2. Hornblende Schist. LAURENTIAN. *Grand Rapids of the Wisconsin, Wood county, S. W. qr. Sec. 8, T. 22, R. 6 E.* Bright greenish-black sprinkled with gray; fine-grained, highly crystalline texture; conchoidal fracture; the fresh surface having a raspy feel; several specks of iron pyrites are strewn along the joints; under the microscope can be easily recognized the amphibole, and considerable orthoclase felspar; also angular grains of quartz and several fluid inclusions, or small liquid-filled cavities. The specimen resembles the hornblende-schist of the Marquette iron district.

897. Hornblende Rock. LAURENTIAN. *Little Bull Falls, Marathon county, Sec. 29, T. 27, R. 7 E.* Dark grayish-green; medium to fine-grained, crystalline texture; uneven fracture and somewhat jointed. The mineral ingredieuts can not well be distinguished with the lens. Under the microscope, however, the amphibole, and plain and striated fragments of felspar, are easily recognized; also, a little chlorite, and a few grains of quartz.

898. Syenite. LAURENTIAN. *Little Bull Falls, Marathon county, Sec. 29, T. 27, R. 7 E.* Greyish-white, spotted with greenish-black; coarse-grained texture; the amphibole and felspar are plainly visible to the naked eye. Under the microscope the felspar appears to be somewhat altered, and a few of the crystals are striated. An occasional fragment of quartz may be seen; also a little chlorite. The former contains fluid inclusions.

898 a. Hornblende Rock. LAURENTIAN. *Little Bull Falls, Marathon county, Sec. 29, T. 27, R. 7 E.* Greenish-black, mottled with grayish-white; medium to coarse-grained; uneven fracture; the felspar and amphibole are plainly visible. It resembles very much a diorite. Under the microscope, the essential minerals are easily recognized. The felspar, owing to the partial decomposition, presents a milky texture, which frequently renders it nearly opaque. The grains of quartz, however, are clear and limpid. The specimen, no doubt, is a coarser variety of 897.

902. Silicious Chloritic Schist (provisional). LAURENTIAN. *Little Bull Falls, Marathon county, Sec. 29, T. 27, R. 7 E.* Very dark greenish-gray, and slightly tinged with bluish-black; weathers to a light drab; fine-grained texture and schistose structure. Under the microscope, the section appears composed of chlorite, small grains of silica, brownish leaves of mica, and a few fragments of amphibole.

905. Chloritic Hornblende Rock. LAURENTIAN. *Little Bull Falls, Marathon county, Sec. 29, T. 27, R. 7 E.* Greenish-black; aphanitic texture; very jointed and apparently schistose; weathers to a dirty drab. Under the microscope can be seen the amphibole and quartz. The felspar is very much altered, but may be recognized by a moment's careful observation. Considerable chlorite is contained, also an occasional scale of mica. It is possible that this rock is a less altered variety of 902, and therefore passing into a silicious chloritic schist.

907. Syenitic Granite. LAURENTIAN. *Big Bull Falls, Marathon county, Sec. 26, T. 29, R. 7 E.* Pinkish, speckled with greenish-black; medium-grained texture; rough, uneven fracture. The felspar is easily recognized. The amphibole and black mica are scarcely to be distinguished from each other, even with a strong lens. Under the microscope this similarity still exists, but the position of the optical bisectrix to the principal crystallographic axis in the hornblende readily separates it from the mica. The former, however, is in excess of the latter. The felspars are mostly twinned, after the Carlsbad form; some of them appear, in the polarized light, to be irregularly banded, which is probably due to an unequal decomposition. Numerous angular grains of quartz are present. The rock is evidently metamorphic.

908. Syenite. LAURENTIAN. *Big Bull Falls, Marathon county, Sec. 26, T. 29,* *R. 7 E.* Gray, thickly speckled with black; fine to medium-grained; rough, uneven fracture; the felspar and hornblende are plainly visible to the naked eye. Under the microscope, each of the above minerals is easily recognized. The felspar fragments are chiefly plain, though a few of them are beautifully striated in one direction. Very little quartz is contained.

910. Syenite. LAURENTIAN. *Big Bull Falls, Marathon county, Sec. 35, T. 29, R. 7 E.* Same as 908, but coarser grained, and some of the grains of quartz contain cavities filled with a salt solution, out of which have crystallized small, transparent cubes of salt. The small bubble and crystals are easily distinguished from each other, even when the corners of the cube are rounded, by the difference of their refractive indices. Scarcely any motion is perceptible in the bubbles, even when heated to 130° C.

915. Silicious Hornblende-Schist. LAURENTIAN. *West bank of Wisconsin river, north line Sec. 26, T. 29, R. 7 E.* Grayish-black; very fine-grained, arenaceous texture; jointed and irregular fracture. Under the microscope, in the polarized light, the section appears composed of a silicious base, interspersed with fragments of amphibole, felspar, and dark colored mica. The felspar is of two varieties, one in small striated fragments, and the other in large plain ones, which are very much altered, frequently so much so that only an indistinct outline remains.

932. Chloro-Silicious-Schist (provisional). LAURENTIAN. *East Bank Wisconsin river, S. W. qr. Sec. 1, T. 29, R. 7 E.* Grayish-green; aphanitic texture; conchoidal fracture; slightly banded. Under the microscope the greenish chloritic base is interspersed with small angular grains of felspar and silica. An occasional patch of calcite may be recognized.

932 a. Very Silicious Marble[1] (provisional.) LAURENTIAN. *East bank Wisconsin river, S. W. qr.* Sec. 1, *T. 29, R. 7 E.* Grayish-green; aphanitic texture; conchoidal fracture; slightly banded. A fragment thrown into acid effervesces briskly, for a time, without disintegrating. Under the microscope it presents an indefinite fringy base, strewn with small crystals of felspar, grains of quartz, and greenish leaves of chlorite.

948. Chloro-Silicious-Schist (provisional). LAURENTIAN. *Falls of Big Rib river, Marathon county, N. E. qr. Sec. 28, T. 29, R. 5 E.* Resembles 932. Under the microscope the base of the rock is composed largely of decomposed crystals of felspar; scattered in this are numerous fragments of amphibole and leaves of chlorite. The rock is apparently an altered hornblende-schist.

948a. Chloro-Silicious-Schist (provisional). *Same place as 948,* to which it is closely similar.

950. Syenite. LAURENTIAN. *Falls of Big Rib river, Marathon county, N. E. qr. Sec. 28, T. 29, R. 5 E.* Light-pinkish-gray, mixed with dark-gray and black; medium to coarse-grained, indefinite texture. A few crystal-facets of felspar may be recognized, but they are mostly too much altered to have preserved their cleavage. This altered condition is very apparent under the microscope, where the section appears thickly strewn with indistinct outlines of the altered crystals, though some are quite fresh. The amphibole is also somewhat changed. A few angular grains of quartz are present, and they show liquid inclusions.

952. Granite. LAURENTIAN. *Falls of the Big Rib river, Marathon county, N. E. qr. Sec. 28, T. 29, R. 5 E.* Grayish-white, spotted with dark-green; medium-grained. With the loupe, small, glassy grains of quartz may be recognized. The felspar is so much decomposed that it shows but little signs of cleavage. Under the microscope the crystals of felspar are grayish and indistinctly outlined. A greenish chlorite is contained,

[1] This rock is merely a phase of the preceding one (932) most specimens of which show no effervescence with acid. R. D. I.

which is very much altered. The grains of quartz appear angular, and contain numerous fluid inclusions.

953. Chloritic Schist (provisional). LAURENTIAN. *Falls of Big Rib river, N. E. qr. Sec. 28, T. 29, R. 5. E., Marathon county.* Light and dark-green; talcose or chloritic texture; warped schistose structure. Hardness about 4. Under the microscope a section of the specimen appears to consist largely of altered crystal fragments of felspar, and grains of quartz, scattered in a greenish chloritic base. The rock is probably a syenitic and hornblende schist ash.

958. Talco-Mica-Schist. ARCHÆAN. *Cutting on the W. V. R. R., three miles north of Junction City, Sec. 24, T. 25, R. 6 E.* Light drab; talcose texture on lamination planes and arenaceous across the grain; cleaves readily into irregular finely-ribbed plates; somewhat altered, and emits a strong clay odor when moistened. Under the microscope the light scales of talc are hardly distinguishable from those of mica, but the dark ones of the latter are more easily recognized. The section is composed largely of small angular grains of silica. The argillaceous odor is due to the numerous decomposed fragments of felspar.

961. Calcareous Mica-Schist. ARCHÆAN. *Cutting on W. V. R. R., two and a half miles north of Junction City. Sec. 26, T. 25, R. 6 E., Portage county.* Dark-green; fine-grained texture. A fracture in the direction of the cleavage glistens with bright, dark greenish-black scales of mica. A lump thrown into acid effervesces briskly, leaving a friable mass. Under the microscope the crystals of calcite are striated showing their usual proneness to twin. The angular grains of quartz and leaves of mica (biolite) are readily distinguished, also opaque crystal cubes of pyrites. The separate mineral ingredients are arranged in bands or layers.

962. Mica-Schist. ARCHÆAN. *From cutting on W. V. R. R., one and a half miles north from Junction City, Sec. 35, T. 25, R. 6 E., Portage county.* Light drab; fine-grained, arenaceous texture across the lamination; slightly shimmering along the schist planes. The minute scales of mica are hardly recognizable to the naked eye. Under the microscope, in the polarized light, a section of the specimen appears brightly colored with angular grains of silica. The base of the rock presents a dirty appearance, and scattered in it are the brownish leaves of mica and a few altered crystal fragments of felspar.

963. Hornblende-Schist. ARCHÆAN. *From a cutting on the W. V. R. R., 3/4 mile north of Junction City, Sec. 35, T. 25, R. 6 E., Portage county.* Dark-green. It is somewhat altered and has a dirty look. The single mineral ingredients can barely be recognized with the naked eye, but under the microscope are plainly visible the amphibole, quartz and mica, also a little chlorite.

964. Hornblende-Schist. ARCHÆAN. *From a cutting on the W. V. R. R., 7 1-2 miles south from Junction City, north part of T. 23, R. 6 E., Wood county.* Dark grayish-green; fine-grained, crystalline-texture; schistose structure and jointed; weathers to a drab. Under the microscope it appears to consist mostly of amphibole. Several small grains of quartz are contained, also a little chlorite.

968. Chloritic Rock. ARCHÆAN. *From east side of Wisconsin river, 5 miles south of Mosinee. T. 26, R. 7 E., Marathon county.* Grayish-green; aphanitic texture; very jointed and apparently schistose. Under the microscope the base of the section presents a moss-like microcrystalline structure, and scattered through it are highly altered crystals of felspar, which are usually very indistinct, only the faint outlines remaining, With a power of 500 diameters the small pale-greenish leaves of chlorite are visible, also numerous minute particles of magnetite.

970. Quartz-Porphyry. ARCHÆAN. *From the bed of Yellow river, 3 miles north of Dexterville, Sec. 3, T. 22, R. 3 E., Wood county.* Light pea-green; massive; resembles some of the quartzites. Several crystal-facets of felspar may be seen, also an occasional small quartz crystal. Under the microscope a section of the specimen appears composed chiefly of felspar, with a few crystals of quartz scattered through it. The quartz resembles that contained in igneous rocks, since some of the crystals enclose, apparently, portions of the matrix. Their richness, however, in fluid cavities, would no doubt preclude such a supposition. The felspar is somewhat altered and presents frequently a fringy texture. A few spherulites of felspar so common to quartz-porphyries may be recognized.

992. **Felspathic-Schist (provisional).** ARCHÆAN. *Cutting on W. V. R. R., 3.7 miles south of Knowlton, Sec. 12, T. 25, R. 6 E., Portage county.* Grayish-drab; fine-grained, indefinite texture. A few minute crystal-facets are visible; emits a strong clay odor when breathed upon. Under the microscope the rock appears very felspathic, and some of the crystals are beautifully banded. Numerous small angular grains of quartz are contained, also brownish leaves of mica, and a fibrous mineral resembling talc.

997. **Actinolite-Schist.** ARCHÆAN. *Cutting on W. V. R. R., 3.7 miles south of Knowlton, Sec. 12, T. 25, R. 6 E., Portage county.* Light-green, medium-grained, crystalline texture. The cleavage facets of the actinolite are easily recognized. It is somewhat decomposed. Under the microscope the actinolite presents a reticulated structure; a little quartz, felspar and chlorite are contained.

1003. **Diorite.** ARCHÆAN. *From bed of Black river, Mormon Ripple, Sec. 3, T. 22, R. 3 W., Jackson county.* Light-and-dark-green; weathers to a light-drab; medium-grained texture, with coarse crystals of amphibole strewn through the mass. Under the microscope the principal mineral ingredients appear to be amphibole and felspar; the latter is of two kinds, plain and striated. An occasional crystal fragment resembling augite is contained, also a little chlorite.

1004. **Quartzite.** ARCHÆAN. *From bed of Black river, Mormon Ripple, Sec. 3, T. 22, R. 3 W., Jackson county.* Light reddish-gray, with streaks of dark-green; quartzose, vitreous texture. Under the microscope appears, in addition to the quartz, a considerable number of slightly altered crystals of orthoclase and greenish leaves of mica or possibly chlorite, though they are apparently the former, since they are strongly dichroitic.

1005. **Felspathic Quartzite, or Granite.** ARCHÆAN. *From bed of Black river, at Mormon Ripple, Sec. 3, T. 22, R. 3 W., Jackson county.* Flesh color; medium-grained texture. On a fresh fracture may be seen numerous bright cleavage facets of felspar. Under the microscope the felspar and quartz appear to be about equally divided. The former are mostly plain crystals, and the latter enclose numerous fluid cavities.

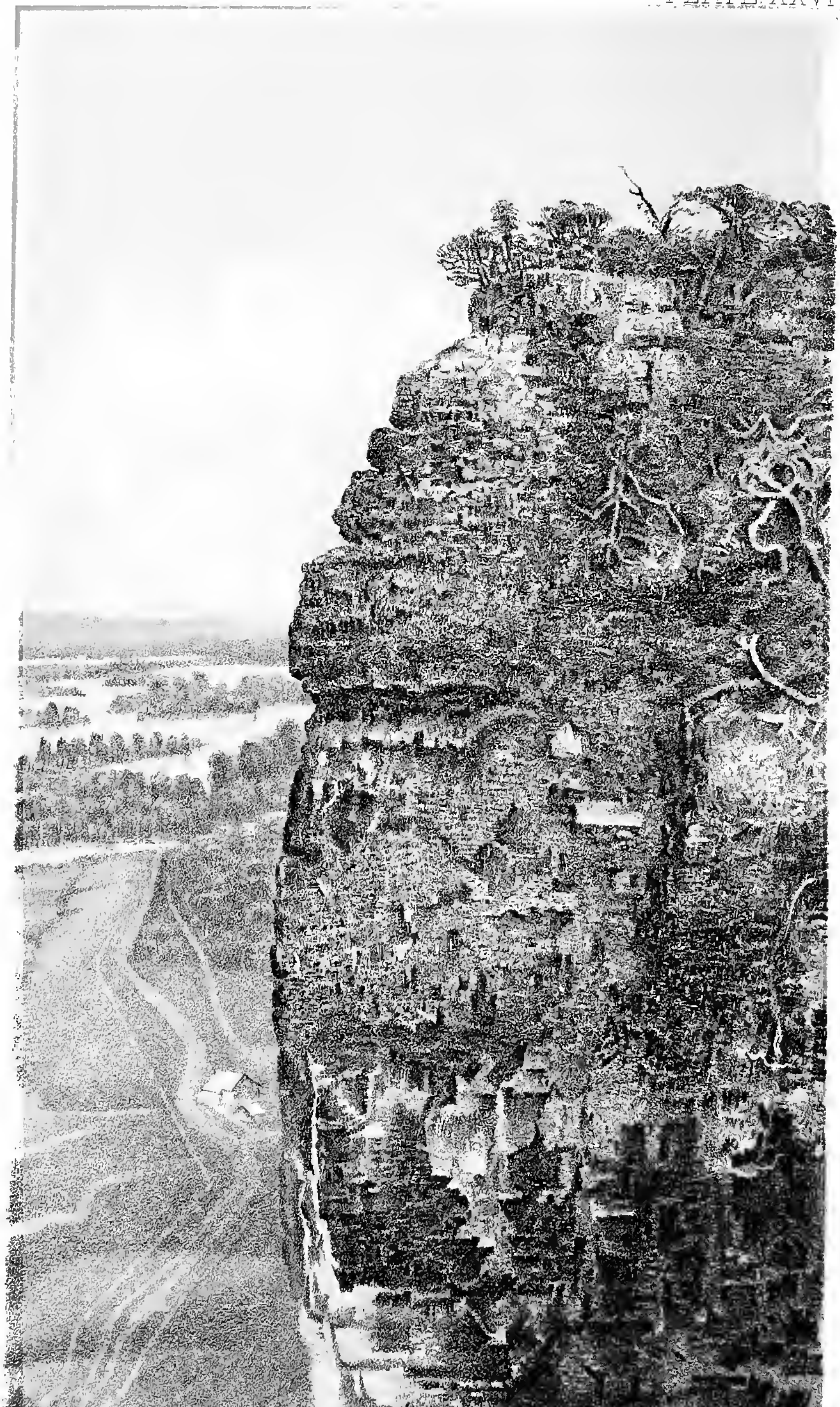
1007. **Micaceous Schist.** ARCHÆAN. *From the bed of Black river, at Mormon Ripple, Sec. 3, T. 22, R. 3 W., Jackson county.* Drab; fine-grained, arenaceous texture; somewhat decomposed and emits a strong clay odor when moistened. Under the microscope a section of the specimen appears to consist largely of altered brownish fragments, resembling mica. Scattered in the base are numerous small angular grains of silica.

1008. **Granite.** ARCHÆAN. *From bed of Black river, at Black River Falls, Sec. 15, T. 21, R. 4 W., Jackson county.* Flesh-color, spotted with dark-green; medium-grained texture. The crystal-facets of felspar and grains of quartz are plainly visible to the naked eye. Under the microscope the felspar appears to be more largely contained than the quartz. But little mica is present.

1412. **Quartz-Porphyry.** HURONIAN? *Pine Bluff, N. W. qr. of the N. E. qr. of Sec. 2, T. 17, R. 11 E., Green Lake county.* Grayish-white; fine-grained texture, and porphyritic with glassy crystals of felspar, which resemble sanadin. Under the microscope, the specimen seems to be an intimate mixture of felspar and quartz. Some of the felspar crystals have an appearance as if, after they were formed, they had been partially dissolved, or replaced in part by crystalized silica; the latter presenting in the polarized light colored patches which have frequently their crystallographic axes all lying in the same direction. On the other hand, many of the quartz grains enclose crystals of felspar, but these may be instances where the felspathic material has been almost entirely replaced by the silica. The quartz resembles vein quartz and contains a few fluid inclusions.

1430. Quartz-Porphyry. HURONIAN? *From head of Lake Buffalo, N. E. qr. of Sec. 8, T. 14, R. 9. E., Marquette county.* Dark reddish-brown; porphyritic texture. The cleavage facets of the felspar are the only mineral ingredients that can be recognized by the naked eye. With the microscope, the base presents a semi-granular moss-like texture, in which are strewn a few crystals of orthoclase and quartz, also numerous small crystal grains of magnetite. To the latter is due the dark color of the rock.

PLATE XXVI.



The Milwaukee Litho & Engr. Co.

VIEW OF BLUFF OF GALENA LIMESTONE,
Near Cassville on the Mississippi.

PART IV.

GEOLOGY AND TOPOGRAPHY

OF

THE LEAD REGION.

BY MOSES STRONG.

GEOLOGY AND TOPOGRAPHY

OF

THE LEAD REGION.

CHAPTER I.

INTRODUCTORY AND HISTORICAL.

Survey of 1873. In accordance with my instructions received from the late Dr. I. A. Lapham, in May, 1873, to make a survey of two lines, with sections of the strata; one north and south, and the other east and west, crossing at or near Mineral Point, work was commenced on the 5th of June, 1873, at Scales Mound, Ill., as being near the southern boundary of the Lead region.

The territory examined during the year 1873 is as follows: Town 29 N., ranges 2 and 3 E., in the state of Illinois; towns 1 to 13 inclusive, in ranges 2 and 3 E., in the state of Wisconsin; towns 4 and 5, on ranges 1 to 6 W., to the Mississippi river; towns 4 and 5, on ranges 1, 2, 3, 4 and 5 E.; towns 6, 7, 8 and 9, on ranges 5 and 6 E., to the Wisconsin river, being in all an area of about 50 townships.

Explorations were chiefly confined to the territory already mentioned; departures were, however, occasionally made for the purpose of visiting localities of geological interest or mineralogical importance. In order to complete the survey of so large a tract of country, it was necessary to traverse an average area of twelve square miles per day. Such an amount precluded anything more than a careful examination of the more important localities, and a general inspection of the rest.

The advantages of this plan of operations were numerous, but chiefly these: that by the examination of a tract of country twelve miles in width, passing through the center of Grant, Iowa and La Fayette counties, a large and comprehensive view of the entire Lead region was secured, so far as its general features were concerned; the details of which, belonging to each separate locality, could be more easily and intelligently obtained in the progress of the survey of this and the succeeding year. Further, it was necessary for topographical purposes to ascertain the elevation of numerous points, which should be readily accessible to the various parts of the region, as will be more fully explained under the subject of Barometrical Observations.

The greater part of the summer of 1873 was devoted to these purposes, and spent within the confines of the Lead region, with the exception of the latter part of July, and two weeks in August, which were passed in the counties of Sauk and Richland, in the examination of the Potsdam and Lower Magnesian formations, and the iron ore deposits incidental thereto.

Survey of 1874. The territory examined in that year was as follows:

Towns 1, 2, 3, 6, 7, 8,	R. 1 W.	Towns 1, 2. 3, 6 to 22 inclusive,	R. 2 W.
" 2, 3, 6, 7,	R. 3 W.	" 3, 6, 7,	R. 5 W.
" 2, 3, 6, 7,	R. 4 W.	" 1, 2, 3, 6, 7, 8,	R. 1 E.
" 3, 6,	R. 6 W.	" 1, 2, 3,	R. 5 E.
" 1, 2, 3, 6, 7, 8,	R. 4 E.	" 1, 2, 3, 4,	R. 7 E.
" 1, 2, 3, 4,	R. 6 E.	" 1, 2, 3, 4,	R. 8 E.
" 1, 2, 3, 4,			R. 9 E.

The townships here enumerated comprise the northern and southern parts of Grant county, the eastern and western parts of La Fayette county, the western part of Iowa county, and that part of it which is drained by Mill creek, the whole of Green county, the western part of Richland county, and some parts of Vernon, Monroe and Jackson counties.

The field work was commenced on the 14th of May, 1874, nearly three weeks earlier than in 1873. The total area examined is equal to sixty-six full townships, being an increase of sixteen over the previous year.

The first examinations were made in the vicinity of Cassville, proceeding eastward from there to the eastern boundary of Green county, and visiting successively all the mining districts and individual mines, of which a full report will be found in chapter IV. After examining the Mill creek district, the survey next proceeded to range two west, north of the Wisconsin river, including the valley of Knapp creek and the upper Kickapoo, and as far north as the Green Bay & Minnesota railroad. Finally returning from there, the northeastern part of Iowa, and the northern part of Grant counties were examined, together with that part of the valley of the Wisconsin which lies south of the river.

Previous Publications and Surveys. The first geological survey embraced the extensive district lying between the Missouri river and Red river of the North, and included the upper part of the valley of the Mississippi and the mining districts adjacent to that river. It was undertaken in 1834, and completed in 1835, by the general government, and placed in charge of G. W. Featherstonhaugh.

The next survey was also instituted by the general government, and placed under the direction of Dr. D. D. Owen, in the fall of 1839, and completed by him in the same year; its object being to ascertain the geographical position of the Lead region and its value as mineral land. Dr. Owen was afterward engaged in the geological survey of the Chippewa Land District, during 1847–8, of which he published a final report in 1851, accompanied by a general geological map. The exploration of so large a district did not admit of a minute examination of any particular part: thus, the space devoted to the southwestern part of the state, and lying south of the Wisconsin river, is comprised in about twenty pages of chapter I.

The next geological survey was undertaken under the auspices of the state, in 1853, and placed in charge of Prof. E. Daniels, who published in 1854 a pamphlet concerning the Lead region. He was then succeeded by Dr. J. G. Percival, who held the position of State Geologist, until his death, in May, 1856. He published two reports of about 100 pages each, which contain much valuable information, and bear evidence of the careful research which always distinguished his work.

To complete the survey interrupted by the death of Dr. Percival, Profs. James Hall, E. S. Carr and E. Daniels were appointed; and, in 1858, Prof. Daniels published a report of about 60 pages, on the iron ores of Wisconsin. This was succeeded by the report of Profs. Hall and Whitney, in January, 1862. This was by far the largest report that had been published concerning the Lead region. It comprised about 450 pages, of which 300 were devoted to that district. This report was accompanied by a crevice map of the mineral ranges, and a general geological map of the Lead region. The latter, so far as it was made from personal observation, was quite correct; but it still left much to be desired in this department; which deficiencies, it is believed, have been supplied by the present survey.

For ten years the Geological survey was discontinued. The next, being the examinations of Rev. John Murrish, of which he published a report in 1872, in a pamphlet of sixty-five pages.

Topographical and Geological Maps and Sections. A great deal of time has been devoted to the construction of the maps accompanying the report, so as to represent the topographical features of the country with accuracy. The topographical maps herewith published embrace all the Lead region. They comprise the country lying south of town six, and extending from the Mississippi river eastward, to the line between Rock and Green counties, with the exception of town five in ranges 4, 5, 6, 7, 8 and 9 E. The maps are made on the scale of one inch to the mile, and exhibit by contour lines, fifty feet apart (vertically), the elevation of any point above the level of the sea. The elevation of any point not on these lines must be determined by its relative distance from the two contour lines between which it lies. In addition to this feature (not found on any other map), a complete road-map is presented; also a map of the streams and dry ravines, many of the smaller streams having become dry since the original government survey of the country was made. Again, from an inspection of these maps, can be seen the rise of the various streams, and the height of the dividing ridges. This is also of special value in respect to railroad surveys, when the amount of time and money is considered, which is annually spent in ascertaining these points. It is beleived that a tolerably correct idea of the practicability or impracticability of any contemplated route can be obtained by reference to these elevations, and thus a vast amount of preliminary surveying may be dispensed with.

One of the principal objects of the field-work has been the careful delineation of the geology of all parts of the country, and its correct representation on the colored maps which accompany the reports. In addition to the general geological maps of the state drawn on a scale of three miles to the inch, the geology of the Lead region has also been placed upon the topographical maps. The effect of this is to show the dip and thickness of the strata and "the exact position of the mining ground at each locality." The great extent of country which has been examined and mapped, together with the time and means which admitted of only a general survey, in which the contour lines, both geological and topographical, could be sketched only by the eye, preclude that accuracy which is attainable only with the transit and level. For such imperfections and inaccuracies as may be found to exist in the maps, these circumstances must be our apology and explanation.

The geological sections accompanying the maps are chiefly valuable as showing the "dip, number, magnitude, order and relative position of the various strata," as well as the amount of denudation to which the conntry has been subjected. They are located as far as possible in the general direction of the dip, in order to show the structure, arrangement and irregularities of the strata.

Barometrical Observations. Considerable time has been devoted to ascertaining the relative heights of different parts of the country, for the purpose of ascertaining the amount of denudation, and preparatory to making geological sections. These observations consumed a great deal of time, and were made with much care; the plan followed being as follows: A series of repeated observations were made at points about half a mile apart, from the Illinois Central railroad at Scales Mound, to Calamine, on the Mineral Point railroad, and from there to Mineral Point. A similar series was then carried from there to Lone Rock, on the Chicago, Milwaukee and St. Paul railroad, and from there to Lavalle, on the Chicago and Northwestern railway. In the same manner a series was carried from Mineral Point through Lancaster, to Glenhaven, on the Mississippi river, and from Mineral Point east, to Moscow, and thence north, over the Blue Mounds, to Mazomanie; and also from Moscow to Oregon, on the Chicago and Northwestern railway. Starting from these known elevations, repeated observations were taken; and the mean of several series of elevations, differing but little from each other, was assumed to be approximately correct. Then, from the various points on those lines, series of lines were traveled over, embracing observations in all the accessible points in the Lead region.

The instrument used was a three-inch aneroid barometer, imported by Wm. J. Young & Sons, of Philadelphia; a very delicate instrument, and one which indicated differences of elevation with great readiness and accuracy. The accuracy and value of barometrical observations depend greatly on the state of the weather at the time they are made. The summer seasons have been, as a general thing, quite favorable for such observations, and in cases where it was not, allowance has been made in computing the elevations. They may be considered as correct within a few feet. For the extent of this part of the work the reader is referred to the topographical maps, which show what has been done much better than it can be described.

The value of a work of this kind is incalculable. By means of the elevations obtained, we are readily enabled to make sections of any part of the country, in any direction; showing the geological position of the strata, with their dip, thickness, and the amount of denudation at any particular locality. In mining localities this is especially valuable. It shows the position of the strata and openings, with their dip; the elevation of the neighboring streams, and the practicability of drainage, by means of levels; the depth to which shafts must be sunk from any point on the surface, to reach any particular stratum. All these things, and many others of like nature are most readily shown by sections, and these sections cannot be made without elevations.

For particular elevations of streams, roads, hills, section lines, mining grounds, strata, outcrops, etc., reference is made to the maps accompanying this report. From them a few are selected, of general importance, as being well known localities:

Locality.	Elevations above The Sea.	Elevations above Lake Mich.	Locality.	Elevations above The Sea.	Elevations above Lake Mich.
Wyalusing	611	33	Benton	878	300
Glen Haven, P. O.	606	28	New Diggings	792	214
Cassville	608	30	White Oak Springs	928	350
North Andover	838	260	Shullsburg, school house	1018	440
Bloomington	905	327	Linden	1078	500
Patch Grove	1060	498	Union Mills	798	220
Mount Hope	1076	498	Kings Mills	723	145
Little Grant	828	250	Dodgeville, court house	1109	531
Beetown	762	184	Mineral Point, depot	935	357
Potosi	782	204	Calamine, depot	812	234
British Hollow	865	287	Darlington, depot	802	224
Rockville	926	348	Gratiot, depot	783	205
Hurricane Grove	941	363	Fayette	1053	475
Lancaster, court house	1080	502	Adamsville	878	300
Mount Ida	1168	590	West Blue Mound	1729	1151
Homer P. O.	978	400	Blanchardville	758	180
Fennimore	1168	590	Wiota	996	418
Liberty Ridge	1144	566	Martin	865	287
Annaton	849	271	Cadiz	859	281
Ellenboro'	689	111	Argyle	808	230
Dickeyville	934	356	Jordan	858	280
Jamestown, P. O	912	334	Willett	888	310
Fairplay, P. O.	798	220	Farmers Grove	1118	540
Sinsinawa Academy	926	348	Bem	1078	500
Hazel Green	938	360	Perry	1038	460
St. Rose	994	416	New Glarus, P. O.	968	390
Big Patch	817	239	Monticello	858	280
Platteville, P. O.	835	257	Monroe, court house	1018	440
Washburn	841	263	Clarno	935	357
New California	989	411	Twin Grove	988	410
Montfort	1093	515	Juda	821	243
Castle Rock	847	269	Sylvester	865	287
Highland, P. O.	1161	583	Dayton	818	240
Cross Plains (Iowa Co.)	1198	620	Attica, P. O.	978	400
Mifflin	868	290	Brooklyn	828	250
West Platte Mound	1272	694	Albany	818	240
Belmont	828	250	Brodhead	798	220
Elk Grove	898	320	Oakley	918	340
Meeker Grove	835	257			

The following elevations of stations have been furnished by the Chicago, Milwaukee and St. Paul Railroad Company, and were used as a basis of some of the barometrical observations:

	Elevation above Sea.	Above Lake Michigan.
Black Earth	810	232
Mazomanie	773	195
Arena	732	154
Spring Green	722	144
Lone Rock	704	126
Avoca	695	117
Muscoda	687	109
Boscobel	667	89
Wauzeka	638	60
Prairie du Chien	619	41

Finally, it may be said of the elevations, that they are by far the most important and valuable part of the work, inasmuch as they form the ground-work of the whole, and we are entirely dependent on them for definite results. They have been made and computed with the utmost accuracy and care. Lastly, they comprise that portion of the work, which, from its nature, consumes the most time, and makes the least outward show.

In conclusion, I desire to express my thanks for the hearty co-operation which the survey has met at the hands of the citizens of the Lead region, who have willingly furnished all desired information and statistics, often at no small inconvenience to themselves.

My thanks are also due to Mr. Allan D. Conover, of Madison, my assistant during the year 1873; to Mr. George Haven, of Minneapolis, Minn., my assistant during the years 1874–1875, who, by the careful discharge of their duties in the field, have contributed materially to the completeness of the work.

CHAPTER II.

TOPOGRAPHY AND SURFACE GEOLOGY.

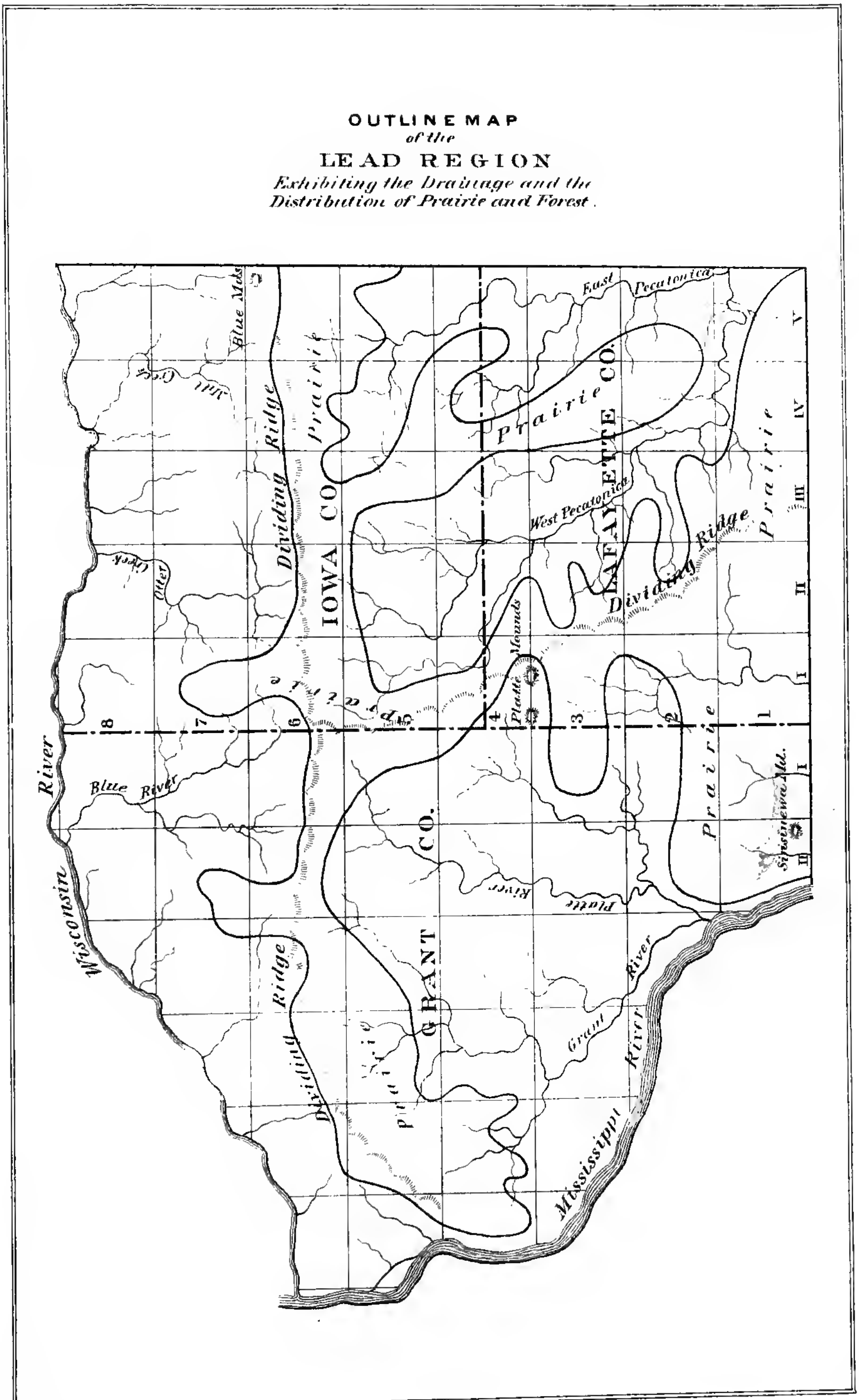
TOPOGRAPHY.

General Features of the Country. Unlike most regions which nature has selected for the reception of metallic ores and useful minerals, the Lead region bears no evidences of any sudden disturbances, or violent action of physical forces. The effects produced by igneous and eruptive agencies are wanting. Faults and dislocations of strata are nowhere found. The only irregularities are slight upheavals, or bending of the strata (and these never of great extent), producing changes of but a few feet from the normal dip.

Between the geological condition and the general surface contour of the country, there is no direct correlation. The existence of a hill or a valley on the surface is not due to a subterranean elevation or depression of the surface, as is by many supposed, and whatever irregularities exist, must be chiefly attributed to the milder natural agencies now constantly at work; such as running water, frost, winds, etc., acting through an immensely long period of time.

Drainage. The most marked and persistent feature of the Lead region is the long dividing ridge, or watershed, which, commencing near Madison, continues almost directly west to the Blue Mounds, a distance of about twenty miles. Here it takes a slight bend to the southwest for fifteen miles, until it reaches Dodgeville, where it resumes its westerly course until it terminates in the bluffs at the confluence of the Wisconsin and Mississippi rivers; its total length is about 85 miles. Two points are noticeable; one is, its general uniform directness of outline (it being subject to but few and unimportant flexures); and the other is its parallelism with the Wisconsin river, so long as the latter holds an approximately westerly course; the summit of the ridge being always about fifteen miles from the river.

The divide maintains an average elevation of about six hundred feet above Lake Michigan, and is seldom less than five, or more than seven hundred, except at the Blue Mounds, where it gradually rises east



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and west, for several miles, until it attains an elevation at the west mound of 1,151 feet. This, however, is an extreme case, and, in fact, the only marked exception to its general level. In the town of Mount Hope, a slight decrease of elevation commences, and continues to the western end of the divide, where the elevation is about 430 feet, at a point within a mile of both the Mississippi and Wisconsin rivers. There are, also, two main branches or subdivisious of the watershed; of these, the western is the ridge which separates the waters that flow into the Platte and Fever rivers, from those which flow into the Pecatonica. It leaves the main divide in the town of Wingville, and passing through the townships of Belmont and Shullsburg, in a southeasterly direction, passes out of the state in the town of Monticello. This ridge is not so conspicuous as the main watershed, either for the directness of its course, or the uniformity of its elevation. The most conspicuous points on it are the Platte Mounds, which appear from a distance to be very high, but are in reality only relatively so, their actual elevation being only about seven hundred feet above Lake Michigan. The ridge appears to slope somewhat, in its approach to Illinois, its average elevation there being about 500 feet.

The easterly subdivision is that which separates the waters of the Pecatonica and Sugar rivers. It may be said to begin at the Blue Mounds, or a couple of miles east of them, and pursuing quite a devious course through the townships of Primrose, Washington and Monroe, it crosses the state line in the town of Jefferson. This ridge is characterized by a much greater want of uniformity in its general course, and by its very irregular elevation. It is much narrower than either of the others, more abrupt in its slopes, and contains quite a large number of hills and low places, especially in the towns of Primrose, Perry, York, and New Glarus, in which towns the streams head within comparatively short distances of each other, on opposite sides of the watershed.

These are the principal elevations of the country affecting the drainage; there are, of course, many minor ones, such as the divides between the Grant and Platte rivers, or the several branches of the Pecatonica; they are, however, merely subordinate ridges, and are but the details of the general plan.

Streams. Having thus given a general outline view of the system of watersheds, a few remarks on the rivers and drainage of the Lead region are necessary to supplement them. As a preliminary remark, it is well to bear in mind, that their present situation was probably never modified or influenced by drift or glacial agencies; the evidence being insufficient to prove that there ever was any drift deposited in the Lead region, the probabilities being rather to the contrary. Premising this, it follows, that the location of streams must have depended on the natural configuration of the country, and the superior advantages of certain strata in certain positions, predisposing them to become the beds of streams. Other things being equal, surface waters would naturally form a channel first in the more soft and easily erosible strata lying along the line of strike of some soft formation, and would cause a river to conform its first channel to its outcropping edge.[1] Simultaneously its tributaries would shape their channels, approximately at right angles to the river, under the following conditions: when the general slope and drainage of the country is not contrary to the geological dip of the formations; which, in the Lead region, does not appear ever to have been the case. The tributaries on one side of the river thus formed would conform themselves to the natural dip of the underlying strata, sloping toward the main river, and would be found wherever there were depressions, or irregularities in the surface, suitable to their formation. These would at their inception approximate to their final length and course, and future changes in them would be confined to the deeper erosion of their beds, and widening of their valleys; the formation of lateral branches; the division of the head of the stream into several smaller sources, and finally, the gradual recession of all the subordinate parts.

With the tributaries on the other side of the principal river, a different order would prevail, as regards their position and growth. They would at first be the merest rivulets, and increase only from erosion; and their beds would lie across the edges of the strata. There would be only a very limited extent of country tributary to the river on this side; the great volume of its water being derived from the tributaries of the other side. The dividing ridge would thus be very near the river, and a second set of long streams, tributary to some other river, would here take their rise and flow away.

In the process of time, the main river would slowly cut its way through the soft formation, in which it had its original bed, into and through those which underlaid it. This might at first be accompanied by a slight recession parallel to the line of strike; such a movement, however, could not be of long duration, but would become less as the valley became deeper; because any such recession would necessitate the removal of all the overlying formations. Finally the small streams flowing across the strata would cut their valley back from the river; the dividing ridge would recede, and their sources would, from the position of the strata, be in steep and precipitous ra-

[1] See Report of Board of Regents of the University of Minnesota for 1872, pp. 46 and 47.

vines. Such, in brief, appears to be the theory of the formation of streams in the Lead region. Its application is easy, and would be as follows:

The Wisconsin river from Mazomanie, to its mouth near Prairie du Chien, is the most conspicuous example and illustration of the foregoing remarks.

Although the surface of the country, in its present condition, does not permit the accurate delineation of the former lines of outcrop, of the paleozoic formations; yet a sufficient number of outliers remain, to show us that they must once have covered the country, far north of where they are at present found. The existence of Niagara limestone, in a thickness of about one hundred and forty feet at the Platte Mounds, and probably the full thickness of the formation at the Blue Mounds, warrants us in supposing that the former outcrop of the underlying Cincinnati group was at least as far north as the present bed of the Wisconsin river.

The valley now occupied by the river, from Mazomanie to Blue river, is very nearly that of the present line of strike of the Lower Silurian formation, and, although from there the strike of the lower members (of which outliers still remain) appears to bear rather more to the northward, yet, observations on the dip of the Cincinnati group, in such occasional outliers as remain, lead me to believe that its original strike was approximately in a southwesterly direction, from Blue river to the Mississippi.

Assuming, then, that the Cincinnati group once had its northern outcrop where the river now runs, or in a line parallel to it, in that vicinity, the surface waters would easily erode a channel in the soft and friable shales which, to a great extent, compose this formation.

In fine, the whole process of formation previously described would take place. On the north side it had, as now, its principal tributary streams, the Kickapoo, Knapp creek, Eagle river, Pine river and Bear creek, in their present localities, and approximately their present length. On the south of the river, however, the principal watershed, already referred to, was probably quite near the river, from which position it has receded to the place it now occupies. The Green river, Blue river, Otter, Mill and Blue Mound creeks were small and insignificant streams; which, by the gradual process of erosion, have increased to their present size and length; but even now, are small when compared to the northern tributaries.

A further effect was to shorten the Grant, Platte, and Pecatonica rivers, by the gradual southwesterly recession of the watershed, and the lowering of the latter by the denudation of the Niagara limestone and Cincinnati groups; except in such localities as were protected by a superior hardness of some part of the formation, as in the case of the Blue Mounds.

The result of the denudation has been to divide the country into two parts, each differing widely from the other in its topographical features. The streams flowing southward from the watershed have eroded the country into gently undulating slopes. This is probably due to the direction of the streams conforming in a measure to the dip of the strata. Abrupt cliffs and steep ravines are the exception, and not the rule, never being found in the immediate neighborhood of the watershed, but rather confined to the small lateral branches. On the other hand, to the north of the watershed, the panorama of bluffs and precipitous ravines is almost mountainous in its aspect. In fact, nothing can be more striking than the contrast which presents itself, from certain points on the divide, in looking from north to south. In nearly all of the ravines leading northward, the fall of the first quarter of a mile is not less than one hundred feet; and, in general, it is true of the streams flowing northward, that three-quarters of the fall takes place in the first quarter of the distance from their sources to their mouth.

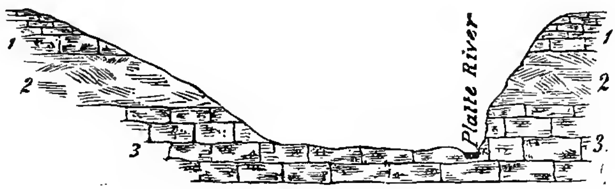
It seems not improbable that these sudden declivities are due to the streams flowing over the edges of the strata, rather than lengthwise along their dip. Again, the streams flowing to the southward become comparatively sluggish in their course, as soon as they cease to be brooks. They have usually a soft muddy bottom, while those tributary to the Wisconsin are clear and rapid streams, flowing over a sandy or gravelly bottom, their valleys being narrow and their sides very steep.

The streams tributary to the Platte, Grant and Pecatonica rivers do not exhibit any marked characteristics on one side that are not shared equally by the other. It may be remarked, however, that the short streams, which flow into the Mississippi river, present much the same topographical characteristics as are seen in the southern tributaries of the Wisconsin, narrow and deep ravines and valleys, being apparently the rule in the western part of Grant county.

The Platte river is frequently found inclosed by hills which are gently sloping on one side, and quite precipitous on the other. This is especially noticeable near its mouth. The river in such cases seems to have encroached on one side of the valley for a long period of time, producing a cliff exposure of Lower Magnesian near the river, and a steep bank of St. Peters, capped with a more retreating slope of the Trenton, as shown in the following section. [See Fig. 1.]

In this connection may be noticed the diminution of water in the Lead region since the early mining times. In comparing the streams at present with those recorded in the government surveys, it will be found that many of the smaller ones are entirely dry, and others nearly so. Numerous springs, which formerly furnished an abundant supply of water, are now dry, and have been replaced by wells, sunk to obtain water from a deeper stratum.

FIG. 1.



GENERAL SECTION OF PLATTE RIVER VALLEY.

1. Trenton Limestone. 2. St. Peters Sandstone. 3. Lower Magnesian Limestone.

In T. 5, R. 6 W., are several streams flowing into the Mississippi river, which present some curious features in common. They vary in length from three to five miles, and take their rise in the Trenton limestone. They occupy quite long and narrow valleys of erosion, and their dry beds may be distinctly traced in them. They are quite large streams, and continue increasing in size for a mile or two from their sources, until they reach certain beds of the Lower Magnesian formation, when they gradually disappear.

The large streams of the Lead region contain a much smaller amount of water than heretofore. Several places were seen where old mills, formerly operated by water-power, had been abandoned, on account of a diminishing and final failure of the supply.

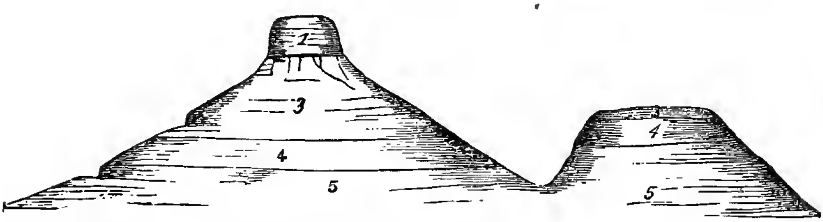
The diminution is not confined to surface water, springs, streams and the like, but is true, to a greater or less extent, of all the mining ground of the region. In many instances this circumstance alone has led to the reopening and profitable working of mines which years ago were abandoned on account of water, with ore "going down" in the crevices.

It is probable that cultivation of the land is the chief cause of this decrease, as a much greater amount of surface is thus exposed, and evaporation takes place more rapidly and in larger quantities. Removal of the timber is, without doubt, another cause of this decrease. The soil of the timbered land contains more moisture than that of the prairie; and in all countries, the removal of the timber has always been followed by a marked decrease of the water supply. This was notably the case in the Hartz mountains, of Prussia, after the fir and hemlock forests were removed. When the mountain sides were again planted with the indigenous trees, by order of the government, their growth was found to be attended by an increase of water in the streams and springs.

Springs and Wells. The Lead region is one of the best watered tracts of country in the state. Springs are very numerous, both about the sources of the streams and frequently in their banks. They are found in all the geological formations, but with the greatest frequency, and of the largest size, between the bottom of the Galena limestone and the top of the St. Peters sandstone. Such springs are usually found flowing along the surface of some layer of clay, and finding a vent in the outcrop of an opening. The clay "openings" most favorable to their formation are, the "Upper Pipe Clay opening," situated on the top of the Blue or Trenton limestone, and separating it from the Galena limestone; the "Glass Rock opening," separating the Blue and underlying Buff limestone; and the "Lower Pipe Clay opening," situated in the lower part of the Buff limestone; the latter however, does not seem to be so persistent a bed as the other two. Springs are by no means confined to these three openings, but occur in many of the beds of the Galena limestone, as well as in the lower formations; usually, however, flowing over an impervious bed of clay, or some layer of rock too compact to admit of the passage of water through it.

In this connection it is desired to call attention to the springs situated about 150 feet below the summit of the west Blue Mound. They have been attributed by many persons to thermal, igneous, and other deep-seated agencies, and by some to hydrostatic pressure. The following facts are offered in regard to these springs: (1) They are found at intervals on all sides of the mound, at a uniform elevation, either as springs or low wet ground, and always on the surface of a stratum of clay impervious to water. (2) They flow most abundantly during and after rainy seasons, and in summer are frequently nearly dry. (3) They are surmounted by the cap of the mound, which is almost a solid mass of flint, and presents a surface of about 100 acres as a watershed. The annual rainfall in the Lead region is about 30 inches, of which about one-quarter is removed by evaporation and the requirements of vegetation, while the remainder finds its way to the springs and streams. On the one hundred acres lying above the springs, there fall annually 10,890,000 cubic feet of water, of which three-quarters, or 8,167,500 cubic feet pass out through these springs, which seems amply sufficient to supply them. (4) The temperature of the Blue Mound springs is the same as that of all other springs in the Lead region, which is about the mean temperature of the earth through which they flow. Were they thermal springs, or of igneous origin, we should expect to find at least some lingering traces of heat, to show us from whence they came. In view of these facts, it seems more logical to look for their origin in the natural and selfevident causes presented, than to attribute them to more complex conditions, imperfectly understood.

Fig. 2.



SKETCH OF THE UPPER PART OF THE BLUE MOUNDS.

1, Flinty cap of the West Mound; 2, Horizon of the springs; 3, Niagara limestone; 4, Cincinnati group; 5, Galena limestone.

In such portions of the country as are not liberally supplied by nature with springs, water is easily and abundantly obtained by means of wells. Their average depth is about twenty-five feet; this, however, depends chiefly on the locality in which they are sunk, those on the ridges and prairies being deeper than the rest. Round wells, of four or five feet diameter, are usually sunk for shallow depths, sometimes being as deep as sixty feet. Wells are sometimes obtained by drilling; such borings being chiefly confined to the prairie, and seldom exceeding sixty feet in depth. They are then furnished with a windmill pump, and supply an abundance of clear water for stock and farm purposes.

Nearly all the water in the Lead region, whether in springs or wells, holds in solution a small portion of lime and magnesia, and a still smaller quantity of sodium, iron, alumina, and silica. The presence of these salts usually gives the water what is called a hard taste which is more noticeable in the limestone than in the sandstone springs, and not infrequently induces persons to believe them possessed of medical properties.

The following analysis, which is believed to be a fair sample of the quality of the water in the springs and wells of the Lead region, is inserted to show the small amount of foreign substances which they contain. The well is situated on the N. E. qr. of Sec. 9, T. 2, R. 9 E., a short distance northwest of the city of Brodhead, on the farm of Mr. Frederick Gomber. It was sunk to a depth of about thirty feet, of which the lower part (probably about ten feet) was sunk in the Lower Magnesian limestone, the rest being in the St. Peters sandstone.

The following analysis of the water, by Dr. Gustavus Bode, of Milwaukee, was furnished by Mr. Gomber:

One gallon U. S. standard measure contains of solid salts, 13.2720 grains, consisting of:

Chloride of sodinm	0.3248	grains.
Sulphate of soda	0.1792	"
Bicarbonate of soda	0.0280	"
Bicarbonate of lime	6.6584	"
Bicarbonate of magnesia	4.8552	"
Bicarbonate of iron	0.2296	"
Alumina	0.1288	"
Silica	0.6888	"
Organic matter	0.1792	"
Total	13.2720	grs.

Dr. Bode remarks of this well as follows: "The total amount of salts is small in comparison with other waters. The salts themselves are the same as those in the Waukesha water, and in the same combination. If the operation of this water depends on the absence of sulphuric acid, and its containing bicarbonates, so the same good and healing results may be expected from your spring."

Prairie and Forest. The prairie area of the Lead region is comparatively small, and seems to be chiefly a continuation of the great prairies of Illinois. The most extensive prairie is that found in the southern part of Grant and La Fayette counties, comprising the townships of Jamestown, Hazel Green, Benton, New Diggings, Shullsburg, Seymour, Monticello and Gratiot. From this there is a branch extending in a northwestern direction (corresponding to the eastern subdivision of the watershed previously alluded to), until it unites with the main watershed; here it branches to the east and west. The western extension forms a prairie in the towns of Glen Haven, Patch Grove, Little Grant, and some parts of Fennimore and Wingville. The eastern prairie follows the main divide already described, the prairie being from six to ten miles in width.

Between the east and west branches of the Pecatonica, there is a prairie, including most of the towns of Fayette, Waldwick and Wiota. In Green county the principal prairie is found in the towns of Monroe, Clarno, Sylvester and Washington.

This, in substance, is the prairie land of the Lead region, although there exist small isolated patches of timber, in the area already described, as well as small prairies, or openings, in the remainder of the region, not included in the prairie area, and which is mostly timbered land. The original area of prairie appears, from the government surveys, to have been somewhat greater. At the present time, the original forests of large timber have been mostly cut down, except about the Wisconsin river bluffs, such timber as is now found, being a second growth, of black, white and burr, oaks, maple, hickory, poplar and elm, the trees being of small size, seldom more than a foot in diameter.

Mounds. The nearest approach to mountains in the Lead region are the Platte Mounds in La Fayette county; the Blue Mounds in Dane and Iowa counties, and the Sinsinawa Mound in Grant county. The former are three in number, about a mile apart, the middle one being very small in comparison with the other two. The east and west mounds are about the same elevation, and are capped with a very hard Niagara limestone to which they doubtless owe their preservation, in the general denudation of the surrounding country. The ground slopes away from them so gently, and blends so gradually with the surrounding high land, that it is impossible to define exactly where the mound proper begins.

Fig. 3.

Sketch of the Platte Mounds.

1 Niagara limestone; 2 Cincinnati group.

The Blue Mounds are two in number; one being in Iowa county, and the other in Dane. The top of the west mound (which is the higher of the two) consists of over a hundred feet of very hard flinty rock, somewhat resembling quartzite; below this is the Niagara limestone. This cap of quartz rock seems to have been removed from the east mound; the top of which is a flat table land under cultivation. These mounds are very conspicuous, and can be seen from any moderately high land in the Lead region.

The Sinsinawa Mound is also a very conspicuous object, in the southern part of Grant county, near the village of Fairplay. It is composed, for the most part, of the Cincinnati group, capped with a small amount of Niagara limestone.

Sinks. Very remarkable features in the vicinity of the Blue Mounds are the numerous sink holes found near their base, and frequently quite high up on their sides. These sinks are usually in groups of three or four, and invariably in nearly an east and west line. One group is near the former residence of Ebenezer Brigham, at the foot of the East Blue Mound, in the S. W. qr. of Sec. 5, T. 6, R. 6 E. There are about a dozen of them, nearly round, varying in diameter from ten to twenty feet, and about five feet deep, all in a line, bearing about 10° north of west. At the West Blue Mound there are several lines of them, about the base and side of the mound. On the center line of Sec. 1, T. 6, R. 5 E. there is a well defined line of them, extending for about a quarter of a mile on each side of the center of the section. There is another range of them near the center of the S. W. qr. of Sec. 1, and a third line near the quarter post of Secs. 1 and 12. The largest of these sinks is an isolated one near the center of the S. E. qr. of Sec. 1, which is as much as fifty feet in diameter, and twenty feet deep. In this one the wall rock of the fissure could be very plainly seen on the south side. From the circumstance of their direction and position coinciding with that of all the mineral crevices in the vicinity, and the fact that the ore is always found in large crevice openings, the inference seems to be that these sinks mark the line of large open crevices in the rock beneath them. It is also reasonable to suppose that the sinks along the center line of Sec. 1, T. 6, R. 5 E. are a continuation of those near the Brigham place, as they seem to point almost directly to one another. It is probable that the water, percolating through the earth into these crevices, has in process of time carried so much of the soil with it as to cause a falling in of the surface, leaving the sinks as the result. In view of the vast quantity of ore which has in former times been obtained from the crevice openings in this locality, it would seem to be worth while to prospect some of these sinks; but nothing of the kind has ever been done.

Sinks do not appear to be confined to the Galena limestone, but seem to be quite as frequent at the Blue Mounds in the Niagara formation. They have been observed in many other localities in the Lead region. The following are cited, to show their occurrence in the several formations. On the S. E. qr. of Sec. 14, T. 5, R. 2 W., are three, situated in a triangular form, in the St. Peters sandstone. This is somewhat exceptional, as the sink holes are usually confined to the limestone formations. On the S. hf. of Sec. 11, T. 6, R. 4 E., are several of these sink holes, from eight to twelve feet deep.

The largest one noticed is situated on the summit of the ridge, on the S. E. qr. of Sec. 29, T. 6, R. 2 E. It lies in the Galena limestone, and is about 200 feet long, by 100 wide, and about twenty feet deep.

SURFACE GEOLOGY.

Soil and Subsoil. The quality of the soil of the Lead region is chiefly dependent on the character of the subjacent formations. The subsoil appears to be derived directly from the decay and disintegration of the strata, of which it is the residuum. South of the principal watershed, the subsoil is clay, almost without exception, having a thickness of from three to six feet, depending on the configuration of the underlying rock formation. This is the average thickness, on comparatively level land; on side hills it is usually much thinner, the greater part having been washed down into the valley below. The clay soils and subsoils appear to consist chiefly of those portions of the overlying Galena limestone, and earthy Cincinnati shales, which being insoluble in water, were not removed by the gradual process of denunation.

The amount of lime, magnesia, and alkaline earths in the subsoil and soil, together with the vegetable mold in the latter, constitute a soil, which, in its virgin state, is unsurpassed for richness and fertility. The number of successive wheat crops which have been raised, without regard to rotation, on some of our prairie farms, attest its native strength; as also the marked decline in fertility of the soil when this has been done, shows the inevitable retribution which follows the practice.

Exceptions to the clay soil, usually found in the country covered by the Galena limestone, are found in the eastern part of La Fayette, and frequently in Green county, where the soil is quite sandy, owing to the disintegration of calcareous sand layers frequently found there in that formation. A few localities are cited below, where the sand was so abundant, that the formation might have been considered a sandstone, were it not for the occasional outcrops of Galena limestone *in place*. In the western part of the town of Jordan, T. 2, R. 6 E., in secs. 2, 11 and 14, the ridges have a great deal of sand contained in the soil. The roads are frequently sandy, similar to those in a sandstone formation. Lying entirely without the limits of the Drift, this circumstance led to a search for and discovery of the original beds.

At the village of Martin, in the S. E. qr. of sec. 32, T. 1, R. 6 E., on the Pecatonica river, at the saw-mill, is a large stone quarry, of which the upper portion consists of Galena limestone in thin beds, containing considerable calcareous sand between the layers. This is the first locality where the sand was found in place.

On the ridge near the quarter-post of 29 and 32, T. 2, R. 6 E., a great deal of sand was seen at an elevation of 150 feet above the top of the St. Peters; numerous concretions of iron were also found, similar to those usually found in the upper bed of that formation. East of the center of sec. 34, T. 3, R. 6 E., is another sandy ridge.

The agencies of the glacial period do not appear to have had anything to do with transporting the component materials of the soil, and although a slight transportation has taken place, it is always merely local. For instance, in the valleys of the creeks which lie in the St. Peters sandstone, the soil is usually a rich clay loam, richer in fact than that of the adjacent ridges, because the best parts of the upland soils have been washed down, and distributed over the surface of the valley.

A similar transportation may be observed in passing up any long, and moderately steep hill, which includes several formations; such hills being very common north of the principal watershed. Let us suppose one, whose summit is composed of Galena limestone, and whose base lies in the Lower Magnesian. Scattered about the base will be seen many loose pieces of Lower Magnesian limestone, mixed with less numerous bowlders of St. Peters sandstone; still less numerous and smaller pieces of the Buff and Blue (Trenton) limestone, while fragments of the Galena limestone will be comparatively rare. On ascending the hill and arriving at the St. Peters, fragments of Lower Magnesian will no longer be seen; while those of the upper formation will become larger and more numerous. On arriving at the Buff limestone, the fragments of St. Peters sandstone will also have disappeared, fragments of Blue limestone will be very numerous and easily recognized by their white color, and their general rounded and worn appearance. On reaching the summit of the hill, no fragments of stone will be found, except such as are derived from the subjacent Galena limestone. One prominent feature of the soil will be the prevalence of flints, which are nearly indestructible, and often form a large component part. From the arrangement of the surface soil and fragmentary rock, it is evident that the rock of any formation is never found above the level from which it was detached.

Peat. While on the subject of surface soil and subsoil, it is desired to report two places in Green county which afford the only approach to this useful article, which has been observed in the Lead region. The first is situated on Jordan creek, in the E. hf. of Secs. 21 and 28, T. 2, R. 6 E., and comprises from one hundred and fifty to two hundred acres. The other locality is on the Little Sugar river, near the center of Sec. 11, T. 3, R. 7 E. As the conditions under which they exist are similar, one description will serve for both.

The turf is underlaid by an impervious stratum of blue clay, which holds the water and nourishes a vegetable growth about four feet thick, which, in this section of the country, is known as peat. When cut and dried, it burns similarly to peat, but with so large a residuum of clay, sand and ashes, as to render it unfit for economic purposes.

Brick Clay. Clay suitable for making brick is found in many parts of the Lead region. Among the localities are Lancaster, Mineral Point and Platteville. The first has two yards in operation, and the latter has one, which commenced operations in the spring of 1874. The clay used is usually of a grayish-yellow color which becomes red on burning. It appears to have been formed in the same manner as other portions of the soil, as already described.

In the Platteville yard an opportunity was found to see the process of manufacture. The clay is dug from an adjacent bank, some selection being necessary. It is then run on small cars to the pug-mills (which are three in number) and ground with water, until it forms a homogeneous paste. After this comes the moulding into bricks, which are spread out on the floor of the yard, dried and piled in a kiln to burn. A kiln of these bricks takes about eight days to burn. It is estimated that about 8,000 bricks per day can be made in this yard.

In the city of Monroe, in Green county, is a brick yard where two kinds of brick are made from the same kind of clay. One is a red brick, similar to all common red brick; the other is a cream-colored brick, of very handsome appearance, closely resembling the Milwaukee brick. From the latter, many of the handsomest buildings in Monroe are constructed. The difference in color is due to the difference in burning, the red color being caused by a greater and long continued heat.

The origin of the clay of which the brick are made is a matter of some doubt. It does not have exactly the appearance of a drift clay; and if not, its situation indicates that it must have undergone some subsequent reärrangement.

Glacial Drift. As has been before intimated, the Lead region is a driftless tract of country; not a single bowlder, pebble or clay of foreign origin being found in its limits, except in three or four isolated cases, which will be hereafter described.

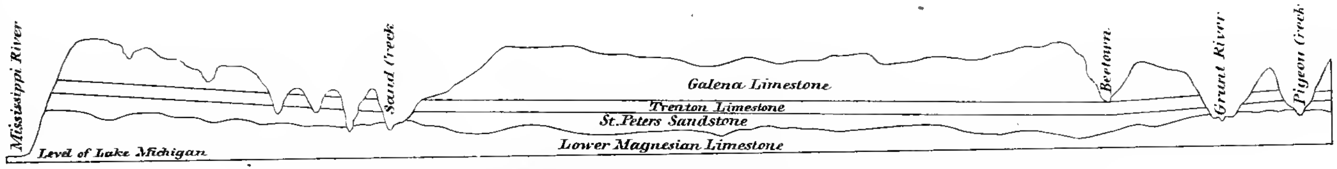
The northern boundary line of the driftless region lies far to the north of the Lead region. The eastern line was found in Green county, and traced out with all possible accuracy. For a particular description of it, reference is made to the geological maps; in brief, however, it is as follows: It commences on the west side of the Pecatonica river, crossing the state line at the southwest corner of the town of Cadiz. From here it proceeds almost in a straight line to the city of Monroe. Thence north, it runs along the divide between the Pecatonica and Sugar rivers, until about two miles south of New Glarus, where it takes a northeasterly course, and passes out of the county about a mile west of Belleville. The course thus indicated is its present line as shown by erratic bowlders lying upon the surface. If the drift deposits originally extended farther westward, no trace thereof now remains. East of the line described, bowlders are found in all parts of the county, with more or less frequency. The boundary line, where bowlders are now found, does not appear to conform at all to the surface features, but crosses the valleys of the streams, and the ridges between them, with equal impartiality.

The different kinds of rock found in the drift are so numerous that it would require quite a catalogue to enumerate them all. It will be sufficient to state that the great bulk of them are granitic, metamorphic, or trappean; the most frequent being varieties of granite and gneiss, and next to them the trappean rocks; chloritic rocks, and those of a schistoze structure, are also quite numerous.

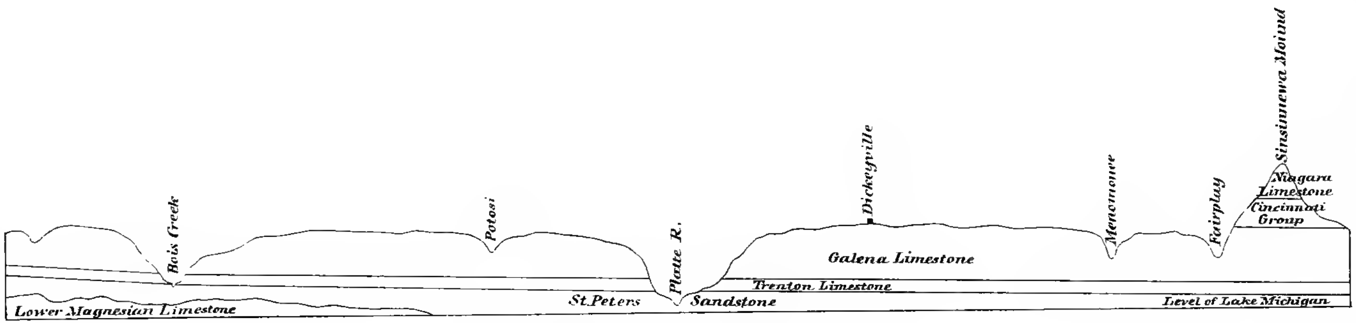
In addition to these there are, in certain places, beds of gravel, sand and clay. The distribution of the bowlders does not appear to be very regular in Green county, in fact, the whole of the county verges so near the western boundary of the drift, that comparatively small deposits were made here, which are quite insufficient to exemplify any general laws of distribution. No difference could be seen in their frequency, between the eastern line of the county and the western line of the drift.

The bowlders are of various sizes, from a few inches to two or three feet in diameter, and are always rounded and worn smooth. They are frequently found quite numerous in one place, and then scattered along at very distant intervals, on the same kind of ground, but do not exhibit any distinctive morainic appearance.

Gravel beds are not very frequent, although they are found in several places in Green county. There is one situated very near the boundary of the drift, on the N. W. qr. of Sec. 4, T. 1, R. 7 E., where there is a bed of gravel about eight feet thick, underlaid by a bed of stratified sand and clay about four feet in thickness. This sand is very fine, and has just enough clay mixed with it to make a good article of moulding sand for iron foundries; it would give a fine impression, and make a smooth casting. A similar bed was found about two miles east of the preceding, in the S. W. qr. of Sec. 2, T. 1, R. 7 E., where the drift sand and gravel have accumulated to a thickness



Section through the Mining Districts of Beetown, Potosi and Fairplay, From the Mississippi at the mouth of the Wisconsin River to the State Line: showing the Denudation



Section continued _ Vert. Scale 800 ft = 1 inch.

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of about twelve feet. A large amount of it has been utilized for railroad ballast. A third bed, like the other two, was observed on the N. E. qr. of Sec. 2, T. 1, R. 7 E., also several others in various portions of the county. Those already described will serve as samples of all.

The amount of drift clay in Green county is comparatively small, it probably having been dissolved out and washed away from the greater portion of the surface. It was only observed in one place, in the N. W. qr. of Sec. 25, T. 3, R. 7 E., where a well had been sunk in the drift. There was here a thickness of about twenty feet of slate-colored clay, full of small pebbles.

Outside of Green county, the indications of drift observed were so few and uncertain, that it seems scarcely proper to attribute them to glacial agencies, and, on the other hand, there is great difficulty in accounting for them in any other manner. They are briefly as follows:

Prof. Whitney describes, on page 137 of the report of 1862, a group of loose blocks of sandstone, which are situated as he represents them in his wood cut. It is referred to in this connection, because I desire to report with it two similar deposits, which have been observed. The first is situated on the road from Mineral Point to Dodgeville, on the S. E. qr. of Sec. 9, T. 5, R. 3 E, as much as three miles from any outcrop of the St. Peters sandstone. The bowlders are from one to two feet in diameter, and lie scattered along the road, and in the adjacent fields, on the south slope of the hill. The bowlders are none of them very large, and it is not impossible that they were hauled there, although it is difficult to understand for what purpose. There are not now, nor have there ever been any houses near them.

The second locality is on the N. E. qr. of Sec. 5, T. 1, R. 2 E., on the ridge between the Strickland and Myers branches. There are here quite a number of blocks of St. Peters sandstone lying on the summit of the ridge. The blocks are of various sizes, some of them weighing several tons. These bowlders are more distant from any outcrop of sandstone than either of the others; the nearest being at "Cook's," about five miles to the northwest, in Sec. 22, T. 2, R. 1 E. It is somewhat singular that these isolated bowlders should always be of sandstone. These several instances have been cited as quite remarkable and singular exceptions to the general driftless character of the Lead region, although we have no very plausible theory to account for their origin.

CHAPTER III.

GEOLOGICAL FORMATIONS.

POTSDAM SANDSTONE.

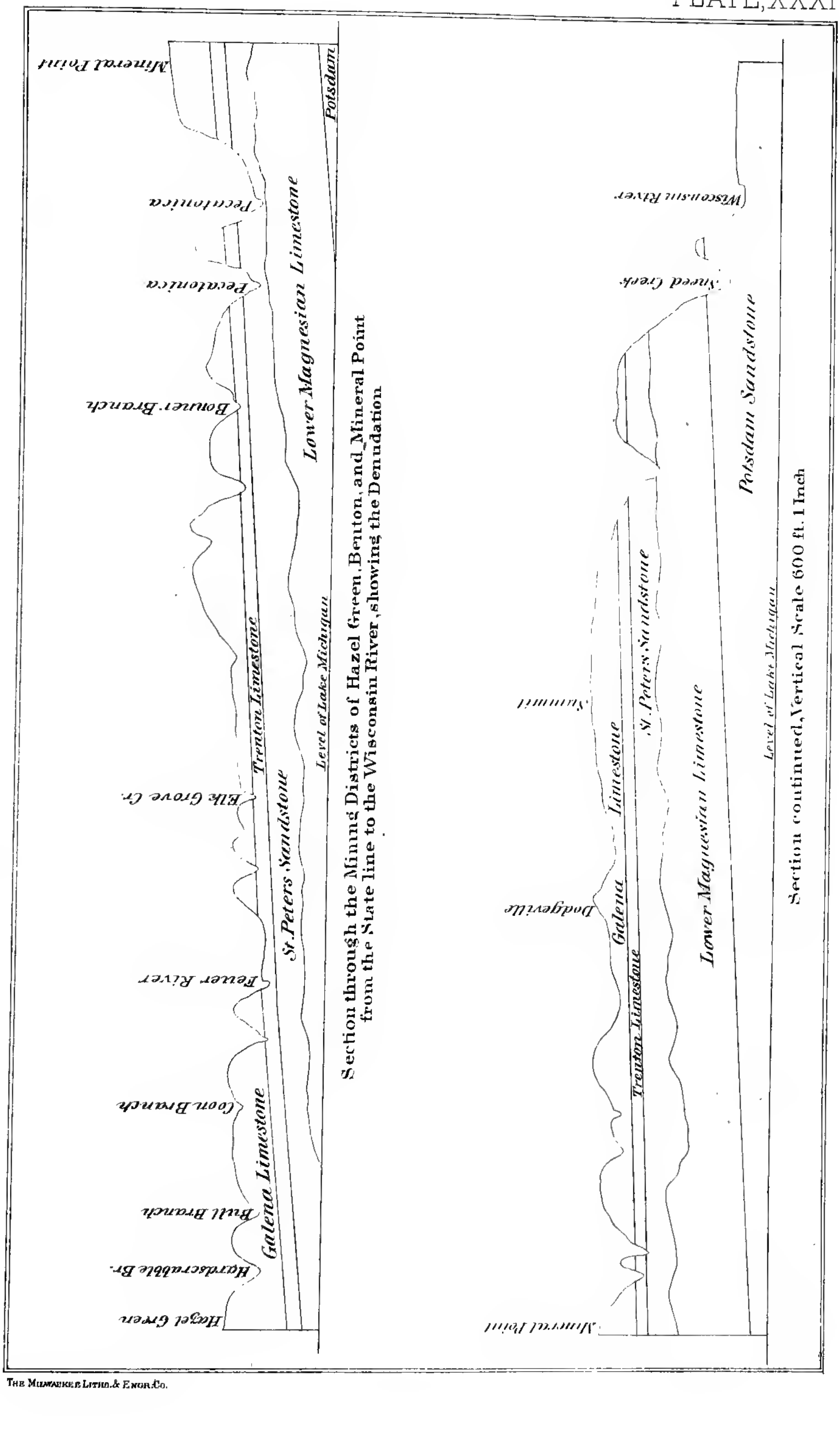
Geographical Boundaries. South of the Wisconsin river it is found as the bed rock of Otter, Mill and Blue Mounds creeks, and their various tributaries, as far south as town 7, on the various ranges. Here it disappears, owing to the southerly dip of the formation, and the sudden rise of the country to the south. The valley of the Wisconsin river also lies in this formation, forming a very level plain from two to three miles wide, and extending from Sauk City to a point about four miles above the mouth of the river. Good natural exposures are seen in the bluffs on each side of the river, in which the various strata may be traced uninterruptedly for miles.

The greatest exposed thickness is seen in the valley of the Wisconsin river, where it is about 300 feet from the water to the bottom of the Lower Magnesian limestone. Examinations north of the Wisconsin river make the entire thickness of the formation about 1,000 feet.

Lithological Characteristics. The following section, taken from a bluff about three miles northwest of Lone Rock, in the N. E. qr. of Sec. 34, T. 9, R. 2 E., will serve as a general guide to the formation:

	Ft.	In.
A. *Lower Magnesian Limestone.*		
1. Irregularly-bedded, white and yellowish Lower Magnesian limestone, containing no flints	60	..
2. Transition beds of arenaceous limestone, in which rounded grains of sand are cemented together by limestone	5	..
B. *Potsdam Sandstone.*		
3. Sandstone, white, very heavy-bedded, containing at the bottom occasional horizontal seams of lime. Friable	45	..
4. Thin-bedded, earthy, straw-yellow shales, containing *Dicellocephalus* and *Lingula*	45	..
5. Very finely laminated blue shale	..	3
6. Thin-bedded, yellow, argillaceous limestone	2	..
7. Earthy material	..	3
8. Very hard and compact brown limestone, building stone	4	..
9. Thin-bedded gray limestone, building stone	9	..
10. Yellow and white friable sandstone, to the valley, mostly unexposed, covered by slope of hill	190	..
Total thickness	360	6

PLATE, XXXI



Section through the Mining Districts of Hazel Green, Benton, and Mineral Point from the State line to the Wisconsin River, showing the Denudation

Section continued, Vertical Scale 600 ft. 1 Inch

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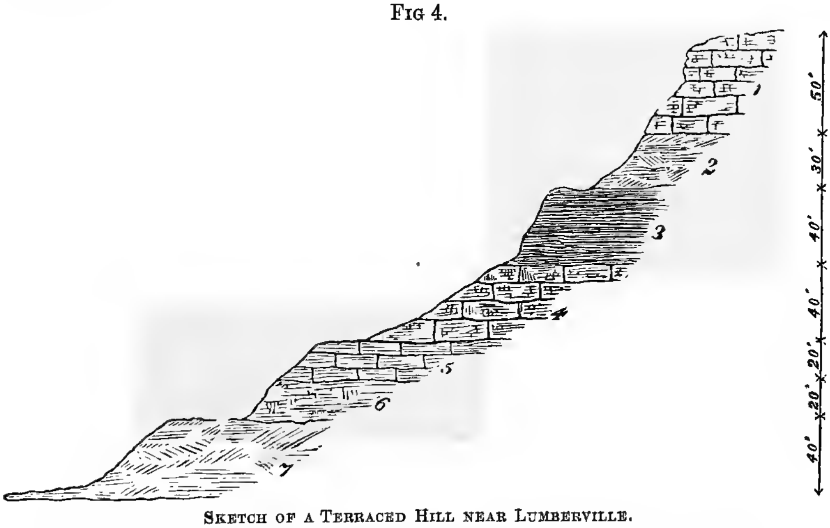
The beds mentioned under Nos. 8 and 9 change to a yellow, arenaceous limestone, which is extensively quarried for building stone at Mazomanie, Black Earth and other towns in the vicinity. It is easily quarried and dressed, and makes a good and durable building stone, which does not undergo much change on exposure to the weather. The sandstone is but little used for building stone, as it is too friable.

The sandstone beds of the Potsdam are usually composed of a very soft and friable sand, frequently crumbling readily between the fingers, especially if it is white. The upper beds are more frequently white than the others, although white beds are not uncommon in all parts of the formation. In general, the lower beds are yellow or brownish in color. The great inequality in the hardness of the several strata of the Potsdam is frequently the cause of the formation of terraces by erosion, which are often a conspicuous feature of the valleys in the vicinity of the Wisconsin river. The following section of a hill near Lumberville, on the Wisconsin, illustrates their appearance.

FIG 4.



SKETCH OF A TERRACED HILL NEAR LUMBERVILLE.

1. Lower Magnesian Limestone. 2. White Potsdam Sandstone. 3. Fossiliferous Shales. 4 and 5. Dolomitic Beds. 6 and 7. Dark-colored Sandstone.

South of the Wisconsin river, about the head-waters of Blue Mounds creek, and Mill creek, the upper bed of the Potsdam consists of a red and very ferruginous sandstone, often containing seams of iron ore, and iron concretions. The coloring matter appears to be partially soluble, and, becoming washed out by the rain, colors the soil in some places to a considerable extent. It is quite conspicuous at Mr. Ruggles' farm, on the road from Dodgeville to Arena. It was found in a tract of land about six miles long, east and west, and about five miles wide, north and south. Another locality where it is very conspicuous is near the center of Sec. 17, T. 7, R. 4 E. In a ditch by the side of the road, it appears as a very dark-red sandstone, streaked occasionally with yellow, and overlaid by a dark-brown, earthy, ferruginous shale.

Along the road for some distance above this outcrop, there is a sandstone containing seams of iron ore. The formation appeared to be about sixty feet thick and unfossiliferous. The country here is so deeply covered with fallen rock, from the overlying formations, that it is difficult to determine the precise horizon of the different beds. The same beds were traced out to the N. W. qr. of Sec. 7, T. 7, R. 4 E., where they present the same appearances. In each of these localities, the thickness of the overlying Lower Magnesian does not exceed 100 feet.

From the results of certain experiments instituted upon the shales designated in the section as No. 4, we are inclined to think they would make a tolerable quality of hydraulic lime, although they are not sufficiently quick-setting to make a good hydraulic cement.

It will be seen from an inspection of the foregoing section, that no sandstone is included in the Lower Magnesian formation which extends to B. Some geologists, however, place the line dividing the two formations between the beds numbered nine and ten under B in the section, p. 668, thus including the *Dicellocephalus* shales and limestones, as well as the upper bed of sandstone, in the Lower Magnesian formation, and beginning the Potsdam with the bed numbered ten. If this arrangement were adopted, the Lower Magnesian would sum up as follows: Limestone above the sandstone bed No. 3 of the section, full thickness, 250 feet; sandstone, 45 feet; shales and limestone, 61 feet, making a total of 356 feet, which is much greater than has heretofore been attributed to the formation. On the whole, it has seemed best, on paleontological grounds, for the sake of perspicuity, and to avoid confusion in comparison with other reports, to respect the old landmarks of subdivision, especially as bed No. 4 contains the characteristic Potsdam fossils.

Paleontology. The fossil remains of this formation seem to be chiefly confined to the calcareous strata and argillaceous shales, described under numbers 4 and 6 of the foregoing section, the most productive being those which immediately overlie the limestone quarry rock. All the quarries from Black Earth to Boscobel were examined, and, in all, more or less specimens were found. The remains consist chiefly of *Lingula aurora* and *Dicellocephelus Minne-*

sotensis, the former being quite small, and usually having the shell remaining; sometimes, however, the shells have been ground up so that only a few fragments are found, disseminated through the shales. The trilobites are seldom or never found entire, but usually the cephalic portion, the pygidium, or still smaller fragments. The various sandstone beds of the Potsdam are usually unfossiliferous. The upper bed of sandstone seldom contains anything but *Scolithus*, which in some localities is very numerous. This fossil is also frequently found in all the sandstone beds.

LOWER MAGNESIAN LIMESTONE.

Geographical Boundaries. South of the Wisconsin river and north of the main watershed, it occupies a tract of land lying about the heads of all the smaller tributary streams, although seldom found so far back as their springs. Passing down any of the streams, such as Otter creek or Mill creek, we gradually pass below its surface; and its outcrops are seen gradually higher in the hills, until, on reaching the Wisconsin river, it forms the cap of all the bluffs from Sauk City to Boscobel, usually appearing in bold and rugged cliffs, lending a very picturesque effect to the scenery of the river. It forms also the valley of the Wisconsin for about four miles above its mouth, and the valley of the Mississippi as far south as Glen Haven, where it passes beneath the surface. Passing south of the divide which separates the waters which flow into the Wisconsin from the Pecatonica, it is found in the branches of the latter stream, as far north as the north line of town 5 in ranges 5 and 6 E. Proceeding westward, it is not again encountered until the Platte and Grant rivers are reached, where it is found as the bed-rock of those streams, and in T 5, R. 3 W., it covers a large portion of the township.

In Green county, there is but one exposure of the formation. It is in the valley of the Sugar river, about three miles above Brodhead. It commences a short distance north of the center of Sec. 15, T. 2, R. 9 E., where it has a width of about half a mile. In passing into town three, it widens to nearly two miles. It then becomes narrower, attains its greatest elevation above the river at Albany, and finally disappears beneath the surface of the river about a mile and a half above that village.

Lithological Characteristics. After passing through the transition beds separating it from the Potsdam sandstone, it assumes all the qualities characterizing dolomite. It is very hard, compact, and close-grained, of a grayish-white color. Beds of flint or chert are contained in all the strata, irrespective of geological position, differing however considerably from the flint found in the Galena limestone, in that they are more regularly segregated, forming layers by themselves, and are not so promiscuously distributed through the formation.

The flint of the Lower Magnesian limestone is much whiter and more liable to decomposition than that of the Galena. There are also frequent geodes and cavities lined with drusy quartz-crystals, which have never been seen in the Galena limestone, but are very adundant in the Lower Magnesian. The crystals are of many colors, white, yellow and rose color predominating, and often affording beautiful cabinet specimens.

A good general idea of the formation may be obtained from the following descriptive section, taken from a bluff at the mouth of Green river, on the Wisconsin, situated on the N. W. qr. of Sec. 22, T. 7, R. 4 W. Upon the summit of the bluff, there was considerable sandstone scattered about, although none could be found in place. It was found in place on the other side of Green river at about the same elevation, consequently we may assume that the top of the bluff is quite near the top of the formation:

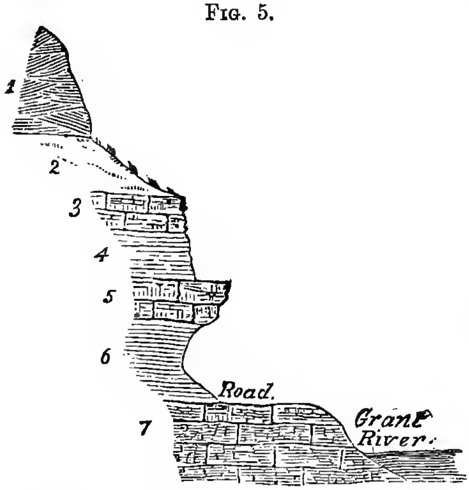
		Feet.
	A. *Lower Magnesian Limesione.*	
1.	Slope of hill (to top of vertical cliff) composed of heavy-bedded, light-gray, Magnesian limestone; stratification quite regular, contains no flints; good building stone	23
2.	Hard, compact, heavy-bedded, light-colored limestone, lines of stratification not distinct; full of irregular masses of flint, which compose about half of the bed; exposed in a vertical cliff	33
3.	Slope of hill covering limestone, not well exposed	23
4.	Coarse-grained limestone, weathering irregularly on exposed surfaces, containing a few flints disseminated through it, and occasional druses of quartz	7
5.	Gray limestone, very hard and compact, regularly stratified, beds from one to two feet thick, containing no flints	29
6.	Crystalline, gray, magnesian limestone, with a few flints irregularly disseminated; beds two feet thick	9
7.	Hard, light-colored limestone, crystalline in texture, weathering but little on exposure; beds about three feet thick; contains no flints	46
8.	Fine-grained, straw-colored, slightly arenaceous, magnesian limestone; beds about one foot thick; stratification quite regular	20
9.	Irregularly bedded, dolomitic limestone, has sometimes an oölitic structure	26
10.	Yellow, arenaceous limestone, transition beds. The sand appears in rounded grains, separate from one another, and cemented together with lime; stratification indistinctly marked	23
	B. *Potsdam Sandstone.*	
11.	Hard and compact sandstone, in beds from two to four feet thick, unfossiliferous,	20
12.	Very coarse-grained, yellow sandstone, weathering in rounded masses; exhibits cross lines of deposition; is very soft and friable	18
13.	Slope of hill probably covering sandstone	15
14.	Steep slope of hill to water in Wisconsin river; this is probably the place of the shaly, argillaceous layers	58
	Total thickness from water to top of the bluff	350
	Total thickness of Lower Magnesian exposed	239

The Lower Magnesian is a formation of extremely variable thickness; the greatest known in the Lead region, is about 250 feet; this, however, is seldom seen. The country in the vicinity of the above section, and Sec. 20, of T. 11, R. 2 W., are two instances where the full thickness prevails. In ranges 4 and 6 E., south of the river, the formation is frequently as thin as one hundred feet, in some localities, and in others, only two or three miles distant, it will attain double that thickness. These sudden variations in thickness are due to an unconformability between the Lower Magnesian and the St Peters sandstone, discovered by Prof. T. C. Chamberlin, and described in another part of this report.

The only change from limestone that was observed was some layers consisting of a very fine calcareous shale[1] with some arenaceous layers and earthy matter interlaminated, about three feet in thickness, which were noticed in the valley of Grant river, in the N. W. qr. of Sec. 22, T. 4, R. 4 W. They were also seen on Pigeon creek, near the center of section 24, in the same township; also in the quarry at Reese's Mill, in the N. E. qr. of Sec. 34, T. 4, R. 4 E., in nearly the same geological position, near the top of the formation.

They were not found occupying this position in other localities. Their presence is due, probably, to local causes alone, and they cannot be considered as constituent beds of the for-

FIG. 5.



SECTION OF CALCAREOUS AND ARENACEOUS SHALES AT GRANT RIVER.

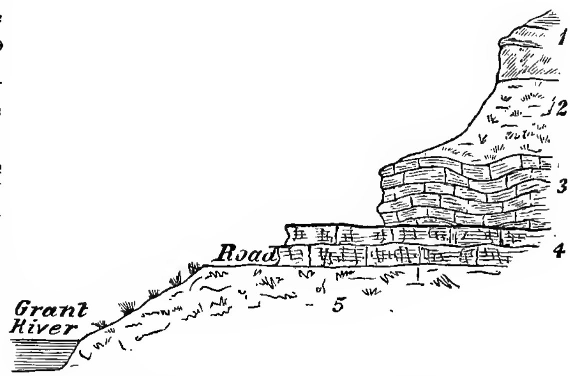
1. St. Peters sandstone. 2. Turfed slope. 3. Limestone bed. 4. Calcareous shales. 5. Limestone bed. 6. Calcareous and arenaceous shales. 7. Lower Magnesian limestone.

[1] The following is an analysis of the calcareous shales, by Mr. E. T. Sweet:

Silica	17.03
Alumina	3.56
Sesquioxide of iron	1.51
Carbonate of lime	42.14
Carbonate of magnesia	34.56
Water	1.28
	100.08

mation. About a quarter of a mile east of the preceding locality, on the opposite side of Grant river, some of the thin layers of the Lower Magnesian are slightly folded and bent, and are underlaid by other and heavier beds which are undisturbed. Their horizon is a little higher than the arenaceous shales, probably near No. 2 or 3 of the preceding section. These flexures are probably due to a slight lateral or horizontal pressure, exerted during the solidification of the rock, which either did not extend to the underlying layers, or which, by their greater compactness, they were able to resist. The level upper surface of the lower beds (4), excludes the idea of unconformability. Fig. 6 is a section taken at this locality. At the Welsh Mill, in Iowa county, a short distance north of the quarter post of Secs. 18 and 19, T. 4, R. 2 E., is a somewhat anomalous occurrence of the Lower Magnesian, as shown in Fig. 7.

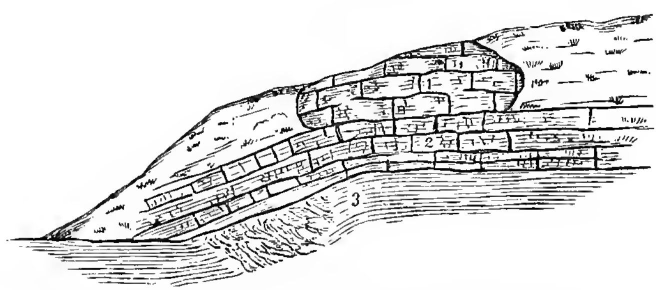
Fig. 6.



Section of Curved Strata at Grant River.

1. St. Peters sandstone. 2. Slope of hill unexposed. 3. Curved strata of limestone. 4. Heavy-bedded limestone. 5. Slope of hill unexposed.

Fig. 7.



Sketch of Lower Magnesian Limestone at the Welsh Mill.

1. Quarry. 2. Curved strata of limestone. 3. West branch of Pecatonica.

The Lower Magnesian appears here on the south side of the stream, for a distance of about a quarter of a mile. It seems to have undergone a slight upheaval subsequent to its deposition. The stream flowing over the sloping beds of the formation has here a considerable fall, which has been utilized as a water power.

Paleontology. The Lower Magnesian limestone is characterized by the extreme rarity of its organic remains. Indeed, it is believed, that up to the period of this survey, no fossils whatever have been reported from the formation in this portion of the state. During the summer of 1873, several places were discovered which establish their existence beyond a doubt. The fossils are usually found imbedded in the drusy quartz, with which the formation abounds, and usually in the form of casts. Some, however, have been found in the limestone.

From several localities, the following are selected, because fossils are more readily found there than elsewhere:

(1) The S. W. qr. of the S. W. qr. of Sec. 4, T. 5, R. 5 E., on the southwestern slope of the hill near the creek.

(2) The S. W. qr. of Sec. 12, and the N. W. qr. of Sec. 13, T. 5, R. 4 W.

ST. PETERS SANDSTONE.

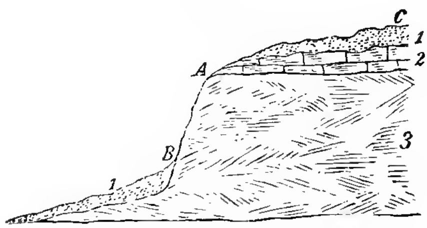
Geological Boundaries. The formation known by the above title in the geological reports of Iowa, Minnesota, Illinois and Wisconsin, was formerly frequently designated as the Upper Sandstone, in contradistinction to the Lower, or Potsdam. It is thought best on account of uniformity, to adhere to the present name. It is found in the valleys of the Grant, Platte and Pecatonica rivers, and their tributaries; and in Green county, it forms the valley of the Sugar river and its branches, this valley being in many places as wide as that of the Mississippi. North of the dividing ridge it is found about the headwaters of the streams which flow into the Wisconsin, having its northern outcrop usually within two or three miles of the river, and as far east as Boscobel, forming a portion of the bluffs which inclose the river valley.

Lithological Characteristics. The formation differs from the Potsdam sandstone, in that it contains no beds of limestone or shales interstratified with it, but presents at any given locality a homogeneous structure through its entire thickness. Its color varies from snow white, through all shades of yellow, to a very dark red, and in texture, from friable crumbling sand, to compact and fine-grained stone. Beneath the microscope the particles of sand appear rounded and waterworn. The same color and texture usually exist through the entire thickness at any given place.

The St. Peters formation frequently impresses upon the surface of the country an appearance of terraces, although no true terraces, such as are formed in river valleys by changes of level, have anywhere been observed. This is most readily seen in those districts where it becomes the surface rock over any extended portion of country.

About the head waters of Grant river, in the towns of Fennimore, Lancaster and Mount Hope, the country is an undulating prairie, where the hills are sandstone, capped with a little Buff limestone, the greater part of that formation having been denuded. Here the St. Peters can be seen, its upper beds jutting out in low ledges, which may be traced by the eye continuously for long distances, about the heads and sides of the small valleys.

FIG. 8.



SKETCH OF A HILL IN THE TOWN OF MT. PLEASANT.
1. Soil and clay. 2. Buff limestone. 3. St. Peters sandstone.

Such exposures are very frequent in Green county, where, in addition to the continuous exposures, small hills are frequently seen, with flat tops, which have been denuded nearly down to the St. Peters. The accompanying sketch represents a section of such an exposure, and is taken from a tract of country in the town of Mt. Pleasant, in Green county, lying about the little Sugar river. The characteristics are the cliff exposure at A, the steep slope of the hill from A to B, and the table land of Buff limestone covered with soil at C.

The varying hardness of the upper bed of the St. Peters, some portions, especially the white, being quite soft and friable, and others nearly as hard as quartzite, due, perhaps, to its greater or less impregnation with iron, appears to have caused an unequal resistance to disintegration, which has resulted in the formation of Knobs, as they are called. They are isolated pillars of sandstone, which shoot up in picturesque castellated forms, frequently exposing the entire thickness of the formation, and forming very conspicuous objects in the landscape. They are chiefly found north of the dividing ridge, about the tributaries of the Wisconsin. The following are the most remarkable instances:

(1) The Knobs, situated at the N. W. cor. of Sec. 21, T. 7, R. 4 E. They are two conical hills of sandstone, forming the termination of a ridge extending out from the west. They exhibit the full thickness of the formation, which is here about 100 feet.

(2) Castle Rock, situated in the southwest corner of the town of Blue River. There are here two very high and precipitous hills of

sandstone, about 250 feet higher than the stream which flows along their base.

(3) Pine Knob, on Otter creek, S. E. qr. Sec. 9, T. 7, R. 2 E.

(4) Pompey's Pillar, S. E. cor. Sec. 13, T. 7, R. 1 E. This is one of the most picturesque and precipitous of all.

The peculiarity of the hardness of the upper beds has proved of great assistance in tracing the outlines of the formation, in determining its thickness, and detecting irregularities in the surface contour.

Ripple-marks on the sandstone were only found at one locality. It is at a quarry in the S. W. qr. of Sec. 3, T. 2, R. 5 E., at the grist-mill near the mouth of Whiteside's creek; the top of the sandstone being about 25 feet above the water. The sandstone is very irregularly bedded in thin layers, with many cross lines of deposition, and the upper beds contain many hollow concretions of iron and sand. The ripple-marks were very plainly seen on some of the layers by the side of the road, and were very regular, parallel and well-defined.

The St. Peters sandstone differs very much in its thickness in different localities,[1] although this does not appear to be the case so much in the Lead region as near the northern outcrop of the formation, where it is in some places as thin as 40 feet, and in others, not more than a mile or two distant, it is 100, or even 150, feet thick, and seemingly depends on the varying thickness of the underlying Lower Magnesian limestone. The layers consist of subordinate parts of very various lamination, dipping in various directions.

Many instances were seen of the varying thickness of Lower Magnesian and St. Peters sandstone,[2] from which the following are selected:

(1) In the S. E. qr. of Sec 26, T. 8, R. 1 E., is a dry run in which the Potsdam is seen in outcropping cliffs; passing above the top of this, a clay soil sets in, which indicates the place of the Lower Magnesian, although it is not seen. Next the St. Peters is seen in bold cliffs 120 feet high; the distance from the lower bed of the St. Peters to the top of the Potsdam being nowhere over 100 feet.

(2) In the S. W. qr. of Sec. 13, T. 7, R. 4 W., the St. Peters has a thickness of 150 feet, of which the upper 15 feet consist of a soft, white, friable sand, in which the usual concretions and impregnations of iron are wanting. This is underlaid by 20 feet of yellow sandstone, and this again by a very dark red sandstone.

(3) In the N. E. qr. of Sec. 29, T. 8, R. 2 W., the Lower Magnesian limestone is just 100 feet thick, and the St. Peters sandstone 150 feet.

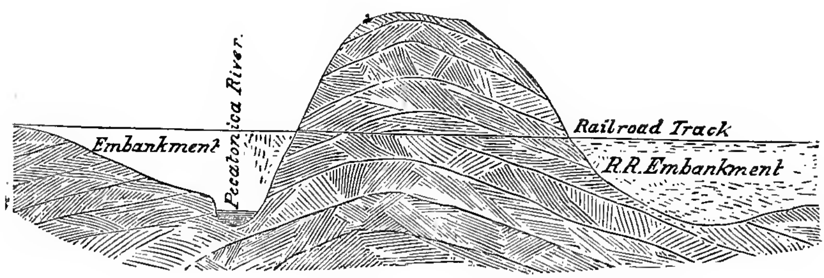
[1] See page 673. [2] See page 673.

(4) In the S. E. qr. of Sec. 8, T. 7, R. 2 W., the Lower Magnesian is 200 feet, and the St. Peters 100 feet thick, its upper surface being nearly horizontal; both formations appear to have about their average thickness.

(5) In the S. E. qr. of Sec. 2, T. 6, R. 3 W., the sandstone is about 70 feet thick, and the Trenton limestones about 50.

There are several new localities which were examined in 1874, where slight upheavals of the formation appear to have taken place. The most marked example of this, known as Red Rock, is situated in the valley of the Pecatonica, in T. 2, R. 4 E. The sandstone emerges from the river near the center of Sec. 20. It reaches it greatest elevation near the quarter-post of Secs. 17 and 18, where it has a thickness of over 100 feet, and disappears again below the river in the S. E. qr. of Sec. 7. The average width of the exposure is about half a mile. It also extends up the valley of a small creek as far as the center of Sec. 8. This exposure covers about one and a half square miles. The following section (Fig. 9) through the railroad cut at this place illustrates the upheaval:

FIG. 9.



UPHEAVAL OF ST. PETERS SANDSTONE AT RED ROCK.

In the northeast part of T. 3, R. 5 E., there is an upheaval of sandstone, beginning at the creek which flows nearly due west, south of Secs. 11 and 12. The disturbance continues north for some distance, as the whole ridge between this creek and the one next north of it lies in the sandstone as far north as the Pecatonica river, in T. 4, R. 5 E. The thickness of the sandstone is here so great that it is hardly probable that it has its normal position. A third disturbance, and the last which will be cited, is in T. 2, R. 6 E. The sandstone on the small branch in Secs. 35 and 36 slopes gently toward Skinner creek, which appears to lie in a slight depression or synclinal valley. Passing over the ridge between Skinner and Jordan creeks, a slight anticlinal ridge was discovered, by means of observations on the top of the St. Peters, which was exposed in numerous small dry runs. The top of the formation was found to be thirty feet higher on the ridge than at either of the creeks. Although disturbances of this kind are extremely rare and infrequent, yet, in these instances the variations from the normal dip are too plain to be mistaken.

Ores and Minerals. The St. Peters sandstone has been carefully examined to find, if possible, any indication of openings, either vertical or flat, such as exist in the Galena limestone. No evidences were seen, except occasional vertical seams and fissures, which contained neither metallic matter, nor minerals and clay, such as are found in veins, and which probably have no connection with the vein system of the Galena limestone. The formation seems to be also perfectly destitute of organic remains.

The only indication of metal seen in this formation is the presence of small concretions of sandstone, cemented by a ferruginous substance. This is due to the decomposition of iron pyrites or marcasite, as is proved by its existence in various stages of decay. These concretions are not confined to any particular part of the formation, but are much more abundant in the upper beds. They are frequently perfectly spherical, and, when they occur in the dark-colored sandstone, are often surrounded by a white ring, about half an inch in width, from which the coloring matter seems to have been absorbed. They have been noticed with more or less frequency in various places, but were found most abundantly in the road near the center of Sec 3, T. 1, R. 6 E. Another place was observed where the concretions were wanting, and their place had been supplied by a different salt of iron; it was in the S. E. qr. of Sec. 25, T. 1, R. 9 E., at the junction of the Buff limestone and St. Peters. The lower bed of the former is full of irregular cavities, and small round holes about one-fourth of an inch in diameter. The upper bed of the sandstone is colored green by some salt of iron, and in it is a seam of greensand and ferruginous matter. It is a peculiarity of this formation that the stone hardens on exposure to the weather. In examining any natural exposure, it is found to consist of an outer indurated shell, and an inner and softer sandstone. This is a valuable quality, causing it to be easily quarried and dressed, and enabling it afterward to withstand the influences of the weather. In addition to this, it is easy to find almost any color that may be desired. Numerous quarries exist in the vicinity of Mineral Point, furnishing a white and yellowish-red stone, which is extensively used in that locality.

Situated on Sec. 17, T. 2, R. 4 E., between the villages of Darlington and Riverside, on the line of the Mineral Point railroad, is the most extensive quarry that has been opened any where in this formation. It is the property of Mr. Wm. T. Henry, of Mineral Point, by whom it was opened in the summer of 1872. The stone in this quarry is of two colors, both a very dark red, but one somewhat lighter in color than the other. It very closely resembles the Lake Superior sandstone in color, and is by far the handsomest building stone that has come under our observation in the Lead region. The railroad passes through the hill, so that the stone can be loaded directly from the quarry on the cars.[1]

TRENTON (BUFF AND BLUE) LIMESTONES.

Geographical Boundaries. It will not be necessary to enter into a detailed description of the ground covered by this formation. It is sufficient to say that it is always found between the lowest bed of the Galena limestone and the top of the St. Peters sandstone, and having an average thickness of about fifty feet.

Lithological Characteristics. The Blue is remarkable as being the purest limestone in the Lead region, and the nearest approach to the Trenton limestone of the eastern states, both in its lithological and paleontological characteristics. A very noticeable feature is its marked division into two parts; one very heavy-bedded, in layers of two or three feet thick, known as the glass rock, which constitutes the lower half; and the other, thin-bedded, in layers of two or three inches, graduating sometimes without much change into the thin-bedded Galena limestone above. It is at this point that the stratum of carbonaceous shale occurs, which is the line of demarkation between the Blue and Galena limestones, and as such, is an unfailing guide. It varies very much in its thickness, being from a quarter of an inch to a foot or more, but wherever a good exposure of the two formations is seen, it has uniformly been found.

The carbonaceous shale attains its greatest thickness in the vicinity of Shullsburg. At the Oakland level on the S. W. qr. of Sec. 5, T. 1, R. 2 E., it varies from one to two feet;[2] and at the grounds of the

[1] The following is an analysis of this stone, by Mr. E. T. Sweet:

Silica	96.74
Alumina	.71
Sesquioxide of iron	1.45
Carbonate of lime	1.24
Carbonate of magnesia	.18
	100.32

[2] Prof. W. W. Daniells, of Madison, has made the following analysis of the shale: carbonaceous matter, 43.60; carbonic acid, 0.88; water, 0.30.

Silverthorn mine on the N. E. qr. of Sec. 31, T. 2, R. 2 E., it has a thickness of seven feet,[1] affording in each of these localities small but handsome crystals of Galenite, having smooth polished faces, which is but seldom the case with crystals of this mineral found at other localities in the Lead region.

The following section taken from the Darlington quarry will give a good general idea of the formation. The quarry is situated on the N. E. qr. of Sec. 3, T. 2, R. 3 E.:

	Ft.	*In.*
Galena Limestone.		
1. Soil and loose rock	2	..
2. Yellowish, hard, compact dolomite, similar to the Buff on the surface, but not blue between the layers, evenly bedded in layers one foot thick	6	..
3. Thin layers two to four inches thick	5	..
4. Carbonaceous shale	..	2
Blue Limestone.		
5. Thin-bedded, very fossiliferous limestone, in layers from two to five inches thick	3	6
6. Heavy-bedded, dark blue limestone, very hard and compact, unfossiliferous except in the shaly partings between the beds [2]	12	..
Buff Limestone.		
7. Heavy-bedded, light blue limestone, weathering to buff on exposure; beds from 4 to 6 feet thick, contains but few fossils, quarry rock	32	..
8. Thin-bedded, fossiliferous limestone, similar to preceding	13	..
9. Unexposed beneath bed of river not less than	10	..
Total thickness	83	8

The Blue limestone has here a thickness of fifteen feet and six six inches, and the Buff not less than fifty-five feet, which is remarkable as being much greater than was seen at any other point. Its average thickness does not exceed thirty feet.

[1] Also the following analysis of the Silverthorn shale:

(1) Carbonaceous matter, 18.31; carbonic acid, 1.85; water, 0.40.

(2) Carbonaceous matter, 15.76; carbonic acid, 0.60; water, 0.32. No. 1 of the Silverthorn shale was quite dark colored, while No. 2 was a light, ash-colored shale.

The specimen from Oakland had been for several years exposed to the weather.

[2] The following is an analysis, by Mr. E. T. Sweet, of the Glass rock from Mineral Point, corresponding to No. 6 of the above section:

Silica	6.160
Alumina	2.260
Sesquioxide of iron	.950
Carbonate of lime	85.540
Carbonate of magnesia	3.930
Water	.930
Phosphoric acid	.055
	99.875

There exists at Mineral Point, at an elevation of about fifty feet above the upper surface of the Buff limestone, or quarry rock, a stratum of compact limestone several feet in thickness, which in color and texture closely resembles the lowest recognized Blue limestone, and contains *Strophomena alternata*, *Leptæna sericea*, *Bellerophon bilobatus*, and some varieties of *Orthis*, all in great profusion, and all of them characteristic of the Blue limestone below. The strata which separate them are not exposed.

It seems probable that this upper stratum may correspond to No. 5 of the preceding section; that Nos. 6 and 7 are the unexposed beds at Mineral Point; and that Nos. 8 and 9 of the Darlington section represent the Blue and Buff limestones at Mineral Point. The relations of the two principal fossiliferous strata are not, however, fully apparent in the Lead region, nor does the upper one seem to be of constant occurrence, whereas the lower one is universally recognized in Iowa, La Fayette and Grant counties.

East of range three east, the presence of the Blue limestone is nowhere so clearly marked as west of this line. It is usually recognized by the outcropping of a quantity of highly fossiliferous fragments, scattered through the soil, having a worn and bleached appearance. East of range three the fossiliferous Blue limestone was not found. It is replaced by a yellowish limestone, containing but very few fossils, and in all respects similar to the Buff limestone. The thickness between the Galena limestone and St. Peters sandstone remains as usual, about fifty feet.

There are two exceptions to the foregoing general statement. A short distance south of the center of sec. 18, T. 1, R. 6 E, the Blue limestone reappears in its full thickness, with all its characteristic fossils, but only covers a small area of ground.

The second exception is situated in the town of Mt. Pleasant, in Green county, in the S. E. qr. of Sec. 11, T. 3, R. 7 E. It is known as the Marble Quarry, so named on account of the fine polish which may be given to the stone. The Blue limestone has here the same thickness, both of the thin and thick beds, as in the western part of the Lead region. All the characteristic fossils are present, and in short, it presents all the usual lithological appearances. It appears to have been deposited in a basin-shaped depression, as the top of the St. Peters was found to be much lower here than any where in the vicinity. Although separated many miles from any other outcrop of the Blue limestone, it is evident that it was deposited under the same conditions, as in other localities. It has been used here for burning lime, of which it always makes a good article. Some small pieces have been polished for paper weights, and other small ornaments. It takes a high polish, equal to marble, although large pieces cannot be obtained.

One other bed has been observed, not mentioned in the descriptive section. It is the line of demarkation between the Buff limestone and St. Peters sandstone. It consists of a greenish blue clay, usually from one to two feet thick. The clay is very finely laminated, and consists of argillaceous and calcareous matter. It might be valuable as a marl, were there not so much of the same constituent parts in the surrounding soil, as to make its application superfluous. It is not a bed of invariable occurrence, but it has been seen in so many localities, over a great extent of country, that it may be regarded as a constituent bed of the formation.

Ores and Minerals. The Blue and Buff limestones are the lowest in which any ores are found in sufficient quantities to repay mining, and the northern and eastern parts of the region in the vicinity of Mineral Point, Linden, Dodgeville, Highland, Centerville, Mifflin, and the Crow Branch Diggings are the most remunerative. It is not to be inferred from this that the formation is barren in the southern and western parts, but rather that it lies so deep that it has not yet been reached in the present system of mining.

Large bodies of lead ore have from time to time been taken from this formation, but it seems to be more especially productive of zinc, both as carbonate and sulphuret. At present the zinc furnished from the localities above mentioned is chiefly derived from it. For statistics of this product, the reader is referred to the latter part of this report, chapter IV.

Organic remains are found in the greatest profusion, and in a very fine state of preservation, the rock in many places being entirely composed of them. In the Buff limestone they usually occur as casts. Without particularizing, reference is made to the general list.

GALENA LIMESTONE. [1]

Geographical Boundaries. This formation is by far the most important in respect to its metallic wealth of all which we have to consider. In it are contained all the mines of the southern and western parts of the Lead region, and whenever mining has been carried on in the underlying Trenton limestones, lead is usually present in the overlying Galena.

[1] In describing this formation the term "Galena limestone," used in other reports, has been adhered to in this, to prevent the confusion arising from several names for the same thing, although strictly speaking it is a dolomite.

The Galena limestone is the prevailing surface rock in the Lead region. Its northern outcrop conforms closely to the main watershed, being parallel to, and always within a few miles north of it. Its surface area is given as follows, for each range in the Lead region:

Range 1 West,	176 sq. miles.	Range 1 East,	190 sq. miles.
" 2 "	137 "	" 2 "	179 "
" 3 "	84 "	" 3 "	189 "
" 4 "	94 "	" 4 "	164 "
" 5 "	108 "	" 5 "	103 "
" 6 "	45 "	" 6 "	144 "
	644 + 969 = 1,613.		969

For a more particular exposition of the surface covered by this formation, reference is made to the maps accompanying this report.

Lithological Characteristics. The Galena limestone is almost invariably a very compact, hard, crystalline rock, of a yellowish gray color, with numerous small cavities, sometimes filled with a softer material, and sometimes lined with small crystals of calcite. The upper portion is usually thick-bedded and free from flints, the layers being from one to four feet thick, while the lower portion almost invariably consists of several feet of layers from one to two inches thick. Good exposures of parts of this formation are frequently to be met with; it may be seen in cliffs and ledges on nearly all the streams in the Lead region. It always weathers irregularly in these natural exposures, leaving the surface full of small cavities due to the removal of the softer parts.

The formation is characterized by layers of flints which however are not constant in their occurrence in the same beds at different localities. In some places there are several beds of flints, which seem to be connected with the openings, and serve as a guide to them, while in others they are either entirely absent or occupying very different geological positions. The flints are sometimes found in separate layers, deposited conformably in the rock, and often in irregular pieces distributed through the strata. They seem to be confined principally to the middle and lower parts of the formation, although not entirely absent from any part.

The general features of the formation will be more readily understood by reference to the following descriptive section taken from a bluff on the Mississippi river, situated on the S. E. qr. of Sec. 28, T. 3, R. 5 W., where the Potosi road leaves the valley:

	Feet.
1. Heavy-bedded, Galena limestone; hard and compact, showing a crystalline structure; stratification very regular; good building stone, contains *Receptaculites*.	26
2. Thin bedded, light yellow limestone, containing flints intercalated, and in layers between the beds....................	6

		Feet.
3.	Beds of limestone three to four feet thick, containing but few flints; good building stone	12
4.	Alternating layers of limestone and flints	9
5.	Beds of limestone 18 inches thick, separated by layers of flint two inches thick	19
6.	Heavy-bedded limestone, layers two feet thick, containing numerous intercalated flints, very hard and compact; stratification quite regular	17
7.	Very close-grained limestone, in beds about four feet thick; good for building stone; contains no flints	29
8.	Slope of the hill to water in the Mississippi river covering Galena limestone	91
	Total thickness	209

The ground rises as it recedes from the bluff, so that there is probably an unexposed thickness of at least 40 feet of Galena limestone above the top of the cliff.

The Galena limestone is in many localities successfully quarried as a building stone. This is chiefly the case in the southern and western parts of the region, where the Buff limestone or St. Peters sandstone cannot be obtained. The chief objection to it is the frequency of cavities and soft places in it which render it difficult to dress, and cause it to weather irregularly. For foundations, or any work where beauty of finish is not the chief object, it is a good and durable stone.

Paleontology. The organic remains of the Galena limestone are quite abundant, but do not exist in such profusion as in the Blue limestone. The characteristic fossil of the formation is the *Receptaculites Oweni* or lead coral, which is found indifferently in all parts of the formation. Next in frequency are the *Streptelasma* (*Petraia*) *corniculum*, and some varieties of small *Orthis*. The most infrequent is the *Maclurea magna*, which is found in the middle beds of the formation. In the upper beds the *Lingula quadrata* is quite frequent, and often found in a fine state of preservation. Other and more infrequent fossils are the *Pleurotomaria lenticularis*, *Bellerophon bilobatus*, *Orthis biforata*, and occasional *Orthocerata*.

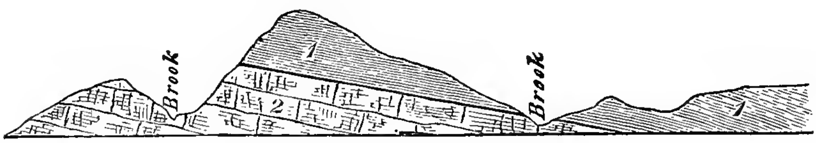
CINCINNATI GROUP.

Geographical Boundaries. This formation was found to cover a much larger area of country than had previously been supposed. It appears in T. 1, R. 2 E., and has an area of about five square miles, contained in the following sections: 21, 22, 23, 24, 25, 26, 27, 28, 34, 35 and 36. In T. 1, R. 3 E., it is found in Secs. 30 and 31, covering about one square mile. It does not occur north of T. 1, on ranges 2 and 3 E.

Near the corner of Secs. 22, 23, 26 and 27, T. 1, R. 2 E., the formation attains an elevation of nearly 600 feet above Lake Michigan; and from here to Scales Mound village it forms a continuous chain of hills, among which the most noticeable is Charles Mound, which is the highest land in the state of Illinois. This mound is capped with about 50 feet of Niagara limestone, and in one place a quarry has been opened, from which specimens of the fossil *Favosites favosa* have been obtained.

The average dip of the strata, in the vicinity of Scales mound is about 22 feet per mile in a southwesterly direction, with indications that it is not perfectly uniform but slightly undulating as represented in

FIG. 10.



SECTION FROM SCALES' MOUND TO THE STATE LINE.
1 Cincinnati Group. 2 Galena Limestone.

The Cincinnati group next appears about the Platte Mounds, in the southern part of T. 4, R. 1 E, and the northern part of T. 3, R. 1 E. In T. 4, R. 1 E., it is found in Secs. 31, 32, 33, 34, 35, 36, covering an area of nearly three square miles, and reaching an elevation of 1,140 feet above the sea.

The formation also exists in its full thickness at the Blue Mounds, but exposures of it either natural or artificial are seldom visible; some of the clay which characterizes the lower part of the formation was found on the Brigham farm at the East Mound.

No exposure of this formation was found at these localities. In passing over the gradual slope of the mounds it is impossible to distinguish any boundary line between the Cincinnati group and the underlying Galena limestone, such as is seen on the level table land south of Shullsburg, which has been formed by the denudation of the soft shales which the harder limestone has to a great extent escaped. The line of demarkation between the shales and the overlying Niagara limestone, is well defined at the West Platte Mound on all sides by the very marked change from the steep slope of the limestone to the comparatively gentle one of the shales. On the north side of this mound, ledges of the Niagara limestone may be seen in place almost to the bottom of the formation.

The Cincinnati group was also found covering about seven square miles of country, about the Sinsinawa Mound, in the following sections: 1, 12, 13, 14, 24, 25, 26, 35, 36, T. 1, R. 2 W. Secs. 6, 7, 8, 16, 17, 18, 19, 20, 29, 30, 31, T. 1, R. 1 W., extending north from the

Sinsinawa Mound, as far as Jamestown. Nearly all the mines on the ridge north and east of Fairplay are sunk through the lower part of the Cincinnati group, and good specimens of *Nucula fecunda* may often be found in the dirt thrown out of the shallow holes, when the clay has not been covered again by the refuse of deeper workings.

Lithological Characteristics. The strata of the Cincinnati group are very regularly and conformably deposited, and do not exhibit any indications of sudden and violent dislocations, faults, or uplifts.

The lower beds of the formation are very finely laminated, and of a dark blue color, in many places becoming green and brown. The upper layers are of a yellowish color, and more or less calcareous and silicious.

The lower and middle members of the group split readily and with a very smooth face, but the upper layers, though quite thin-bedded, present a rough and uneven appearance. This group nowhere presents beds of sufficiently thick and durable stone for building purposes. Only one place was noticed where an attempt had been made to quarry this rock; it had been abandoned as impracticable, after a small amount of work had been done.

Where undisturbed, this group has a thickness of about 125 feet. This is the case only on the mounds, which are still capped with the Niagara limestone, as in all other places it has been more or less removed by denudation.

There is nowhere a good natural exposure of the formation. The rocks throughout the group offer so little resistance to the weather that they do not appear in rugged cliffs, such as are seen in all the formations which underlie them, but usually in gently undulating hills. The best exposure is the one in the cut of the Illinois Central railroad, near Scales Mound Station, of which a very accurate section has already been given in Prof. Hall's report. It is much more accurate than can now be obtained, as the weather has since then so decomposed the friable shales that only a few feet of the lower beds are now visible, as they were originally presented. As a general guide to the formation, we take the liberty of reproducing it:

	Ft.	*In.*
1. Greenish shale, with alternations of calcareous and silicious layers, a few inches in thickness	7	8
2. Green silico-calcareous and argillaceous shales	11	6
3. A silico-calcareous or magnesian band	..	3
4. Greenish shale as above	12	..
5. Concretionary layer, 1 to 3 inches	..	3
6. Shale with *Lingula*	6	..
7. A layer filled with a small *Nucula*, and known as the *Nucula* bed, 4 to 8 inches	..	8

	Ft.	In.
8. A calcareous band cut by open joints or fissures, into which the materials of the layer above have penetrated	..	4
9. Dark olive shales, finely laminated and destitute of fossils	3	4
10. *Nucula* bed, similar to the above, 4 to 6 inches	..	6
Total thickness exposed	42	6

A noticeable feature of the two *Nucula* beds, which are the lowest of the series, is that the floor of each is a thin seam of pyrites of a nodular and crystalline form which rests on the bed below. This was the only metalliferous indication noticed in the formation, and it did not seem to exist in great abundance.

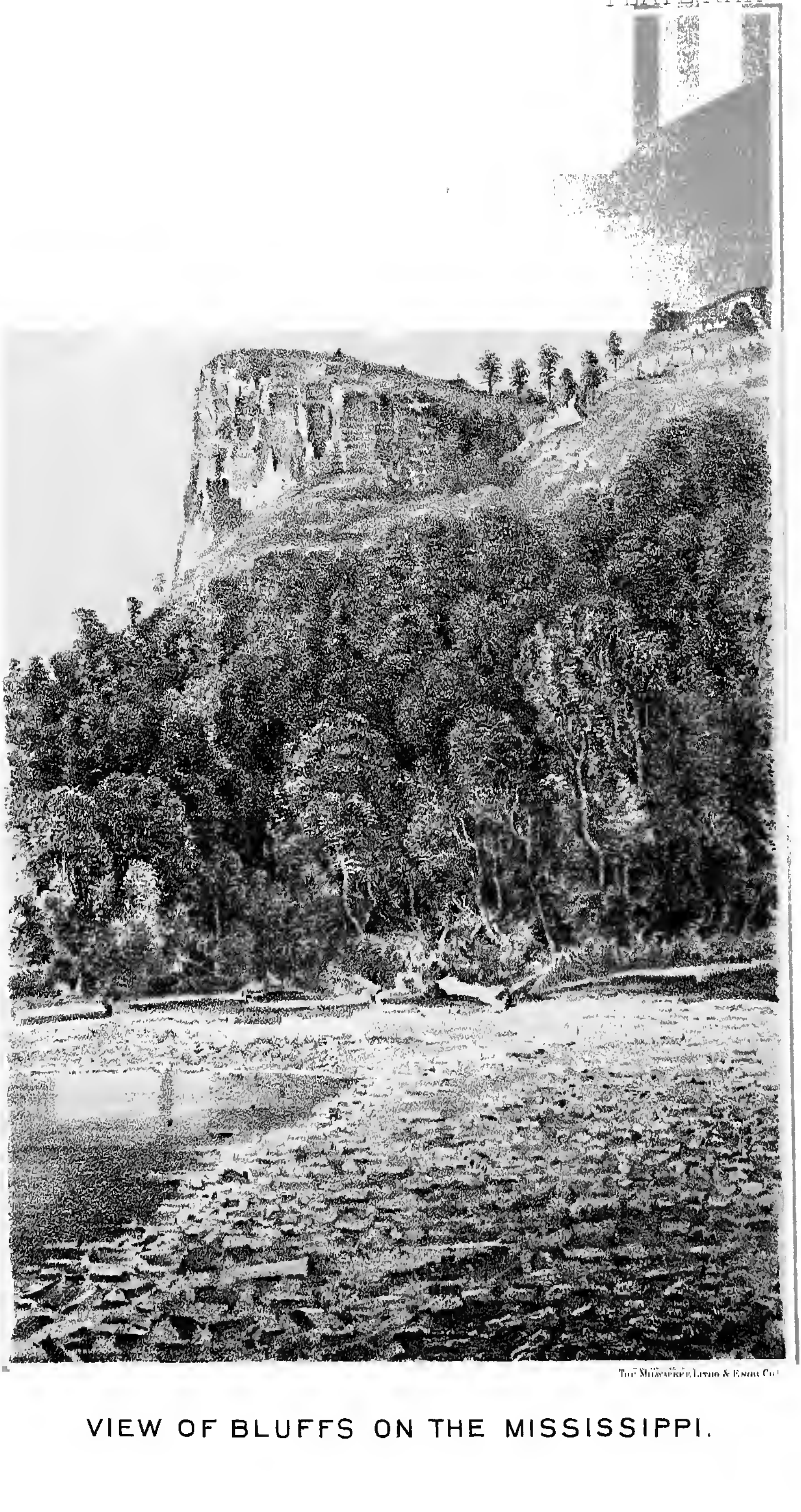
The beds of Galena limestone which underlie this formation are quite regularly stratified in beds about six inches thick. In the west end of the cut, the beds are perfectly horizontal on a course N. 55° W. On a course at right angles to this, the dip was found to be about 50 feet per mile on a S. W. course. It is probable, however, that this is only a local dip.

Nothing of a metallic nature was discovered in the formation, except a few small seams of marcasite in the lower beds.

The best localities for obtaining fossils from this formation are on the sides of the mounds, where the water has partly removed the turf and soil, and formed gullies which are filled with broken fragments of the different beds. Among these may be mentioned the S. E. qr. of Sec. 22, T. 1, R. 2 E., near what is known as the Gratiot place. The lower beds abound with shells of the *Nucula fecunda;* the middle ones with *Rhynchonella increbescens*, *Strophomena alternata*, and stems of *Chætetes*. The upper beds contain a few *Orthocerata*, but they are infrequent.

The lower beds of the Cincinnati group have been exposed in some old diggings in the N. E. qr. of sec. 2, T. 3, R. 1 E., on the road near the Burris place. Specimens of the *Nucula*, and other shells characteristic of the lower beds were here found in great profusion and perfection.

PLATE XXX



The Milwaukee Litho & Engr. Co.

VIEW OF BLUFFS ON THE MISSISSIPPI.

CHAPTER IV.

THE LEAD REGION.

Boundaries and Area. In Wisconsin, the Lead region may be said to be bounded on the north by the northern outcrop of the Galena limestone, running parallel to the main watershed from the Mississippi to the Blue Mounds, as already described; on the west by the Mississippi river; on the south by the state line; on the east by Sugar river. These limits include all of the Lead region which has ever been productive, as well as much that has never as yet proved so. The area thus included which has been, or may hereafter become productive, is necessarily that of the Galena limestone, which is about 1,776 square miles.

Explanation of Mining Terms. For the enlightenment of the readers of this report, who are unfamiliar with mining terms, the following short explanation of expressions most frequently used in the Lead region is offered.

Range. This is probably the most indefinite term in use, and at the same time, one which is universally applied. 1st. A range denotes a single, or several parallel crevices, containing useful ores or minerals; vertical, or approximately so; seldom more than a few yards apart; sometimes, but not necessarily, connected by quartering crevices. Its length may vary from a few hundred feet to a quarter of a mile or more; in short, so far as the crevice or crevices have been connectedly traced, or there is a reasonable probability of such connection. Thus, different parts of the same range often have different names given them before the connection between them is proved. This is a fruitful source of confusion. 2d. The term range is also applied to horizontal bodies of ore, of which there may be one, or several, superimposed upon one another; sometimes, but not necessarily separated by unproductive layers of rock, limited in length in the same way as a vertical range.

Crevice. This term denotes a fissure in the rock, vertical or nearly so, but a few inches in width, of indefinite length, which may or may not be filled with ores or minerals; when a crevice becomes very small, less than an inch in width, it is called a seam.

Vein, is a term little used; it denotes the filling of ore and accompanying minerals, or either, found in a crevice.

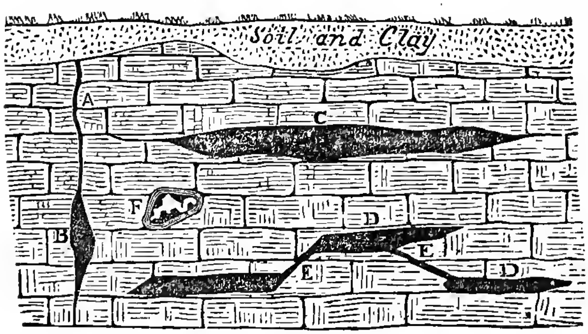
Lode or Lead, are words usually substituted for vein; they are, however, generally applied to ore deposits found either in crevices or openings.

Swither, a metalliferous crevice, making an angle with the principal vein or lode, sometimes called a quartering crevice.

8 o'clock, 10 o'clock, etc, ranges whose course bears toward the sun at those hours of the day.

Openings. They are of two kinds, vertical and horizontal. 1. Vertical openings are known as crevice openings, which are mere enlargements of the crevice in certain parts, these being sometimes coextensive with the vein in length, and sometimes mere local enlargements. There are in the same crevice frequently several openings, situated one above the other, separated by beds of unproductive rock. Crevices vary in width from one to several feet; when very wide and high, they are sometimes called tumbling openings. 2. Horizontal openings are large irregular spaces between the strata which contain the lode. Such openings are usually from one to four feet high, and are frequently superimposed upon one-another, separated by an unproductive rock called a "cap." The "cap" of one opening being frequently the "floor" of the one above it.

FIG. 11.



SECTION OF OPENINGS (ideal).
A, Crevice; B, Crevice opening; C, Flat opening; D D, Flat openings connected by E E, Pitching sheets; F, Pocket with ore.

Pockets are small irregular cavities in the strata in which ore is frequently obtained.

Chimneys are irregularly shaped vertical holes found in crevices; sometimes connecting openings, and at others extending from the surface of the ground to some particular stratum of rock.

Sheet. This is a term usually employed to designate a solid body of ore exclusive of other minerals which may fill a crevice or opening. A sheet is said to "pitch" when it inclines considerably from the perpendicular.

Gouge. This is the soft rock or clay frequently found between the sheet and adjacent wall-rock.

Bar. The term denotes a band or belt of very hard and unproductive rock, crossing the crevices and sheets. In crossing a bar all sheets become less productive, and are sometimes entirely lost, the crevices usually dwindling to mere seams. Their width varies from a few feet to many yards.

Wash-dirt, is the name given to the small ore as it first comes from the mine, mixed with small pieces of rock and clay.

Pipe-Clay. A light colored plastic clay frequently found in the openings and crevices.

Drift. An underground gallery or roadway.

MINERALOGY.

There does not appear to have been any absolute and unvarying order in which the minerals of the Lead region were deposited in the mines. The following conclusions are derived from the inspection of the ore as it occurs in place in the numerous mines visited, and from the examination of a great number of specimens; and it is assumed that when crystals of one mineral are coated or covered with another, the overlying one is the more recent. The minerals appear to have been deposited in the following general order:

GALENITE.
|
SPHALERITE.
|
DOLOMITE, CALCITE.
|
PYRITE, MARCASITE, CHALCOPYRITE.
|
BARITE.
|
CALCITE.
|
CERUSSITE, SMITHSONITE, MALACHITE, AZURITE.

The order above given, however, is subject to very numerous and important exceptions, and is more particularly applicable to crystallized specimens than to heavy ore deposits. Large bodies of ore frequently consist of galenite, sphalerite and pyrite, so mingled together that no order of deposition can be ascertained.

In general it appears that the sulphurets of the metals were deposited first, and that the carbonates have been generally if not invariably derived from them. Carbonate of lead (cerussite), when found crystallized, always occurs in connection with galenite; and carbonate of zinc (Smithsonite) is so frequently found graduating into the sulphuret (sphalerite) as to leave but little doubt of its origin from that mineral.

It seems not improbable that the formation of the carbonate of zinc may even now be taking place in the ground to quite a large extent; especially in such deposits as are not below the water level, or are only periodically submerged. It is a well known fact that the Drybone diggings are usually comparatively free from water, and that the zinc ore below the water level is usually blende (sphalerite) with but little admixture of the carbonate. As the level of the water in the ground becomes gradually lower, and it is a well known fact that it does, the atmosphere, together with surface water charged with carbonic acid, is permitted to act upon the blende, and a transformation from the sulphuret to the carbonate is the result.

The association of calcite with other minerals is such as to indicate that it must have been formed in crystals during at least two different periods. Stalactites of recent origin are found in the mines, which on being fractured show a distinct crystalline structure, and large planes of cleavage.

The following is a list of the minerals known to occur in the Lead region, arranged according to the system adopted by Prof. Dana, in his Mineralogy:

Sulphur. Native sulphur is found but seldom in the Lead region; its presence is usually due to the decomposition of iron pyrites. It is usually found in a pulverulent form. Some pieces weighing as much as an ounce were seen in a cabinet at Hazel Green, which are said to have been obtained from a small sheet in some of the Buncome mines. It is said to be not uncommon in this vicinity. Other localities where it is found are, Mineral Point and the Crow Branch diggings.

Bornite. Variegated or Purple Copper ore. Composition: copper 62.5; iron 13.8; sulphur 23.7. This is quite a rare mineral; a few pieces have been found in the copper diggings near Mineral Point; it has never been found here crystallized, but always massive and in small pieces.

Galenite. Composition: lead 86.6; sulphur 13.4. This is the only ore of lead found in sufficient quantities to be of economic value; it is universally known in the Lead region as "mineral." It frequently occurs in distinct crystals, either as a cube or some modification of it. Octahedral crystals are quite rare, but are occasionally found, especially in the carbonaceous shale of the southern part of the region. Usually, however, galenite occurs massive, with a very distinct cleavage. Freshly broken surfaces have always a bright steel color, which speedily tarnishes on exposure to the air.

Sphalerite. Blende or Black-jack. Composition: zinc, 67; sulphur, 33. This is one of the most abundant minerals in the Lead region, besides being of great economic value as an ore of zinc. It is almost invariably found as an associate vein-mineral in the horizontal deposits of Lead ore. It is usually found massive and compact, of a dark brown or black color, due to a small portion of iron contained in it, and more or less mixed with galenite. The Lead region has never afforded a perfect crystal of blende, although many specimens are found with small and imperfect crystalline faces. The fractured surfaces of such specimens usually have a resinous luster.

Pyrite. Composition: iron, 46.7; sulphur, 53.3. This is the most common vein-mineral found in the mines; it is universally met with in veins, lodes or other deposits of ore, and in many cases impregnates the rock when all other metals are absent. In crevices it frequently appears to have been the first mineral deposited. It is usually found massive, although handsome crystallized specimens are frequently obtained from the mines. In crystals it usually assumes some modification of the cube, the octahedron being quite frequent. It also occurs in radiated and reniform masses. It has never yet been considered of any economic value in the Lead region, and as it is so much mixed with rock, it is doubtful if it could be profitably separated, except by the natural process of disintegration, to which some varieties are liable when exposed to the air. The Crow Branch diggings and the Linden mines afford large quantities and good specimens of this mineral.

Marcasite. Composition: iron, 46.7; sulphur, 53.3, or same as pyrite. The difference between this and the preceding is but slight, and chiefly due to crystalline structure; the former belonging to the monometric and the latter to the trimetric system. It is somewhat lighter colored than pyrite, and decomposes more readily in the air. It is quite a common vein-mineral and occurs in globular and cockscomb shapes. It is abundant in the New Diggings district. It is difficult to preserve specimens of this mineral longer than a few months.

Chalcopyrite. Composition: copper 34.6; iron, 30.5; sulphur 34.9. This is the principal ore of copper in the Lead region, and is most abundantly found in the vicinity of Mineral Point. It usually occurs massive, frequently mixed with pyrite; small and indistinct crystals are occasionally found.

Hematite. Composition: iron, 70; oxygen, 30. Impure arenaceous varieties of this mineral frequently occur, nowhere, however, sufficiently rich or abundant to be of any economic value. It seems to be chiefly due to the decomposition of pyrite, and is most common as the ferruginous sandstone concretions in the upper beds of the St. Peters. It is also frequently found as ocher, with other vein-minerals, especially in the flat openings.

Oxide of Manganese. A substance consisting of oxide of manganese with a little oxide of iron, zinc, and traces of magnesia according to an analysis of Dr. Bode of Milwaukee, is found in crevices in the Trenton limestone, in some diggings situated on Sec. 11, T. 4, R. 1 E. The mineral is as light as cork, color brownish-black, submetallic luster and streak, soils readily, and is infusible. It is very soft, and does not occur crystallized. It has a structure in thin parallel layers resembling wood.

Calamine. Composition: silica, 25.0; oxide of zinc, 67.5; water, 7.5. This mineral is of very rare occurrence in the Lead region. It is found in small, drusy crystals, coating Smithsonite. The crystals are very brittle, colorless, and have a vitreous lustre. It is found near Mineral Point.

Barite. Composition: sulphuric acid, 34.33; baryta, 65.67. It occurs usually white and massive, but sometimes in lamellar and crested forms. The only place where it was found in distinct crystals was in the railroad cut at Scales Mound, where it occurs in small cavities, as small but very perfect transparent crystals, associated with dolomite and pyrite. It is not a very abundant mineral, but is found in several of the mining districts, especially Dodgeville and Mineral Point. The following is an analysis by Mr. E. T. Sweet, of a specimen from the S. W. qr. of Sec. 6, T. 5, R. 3 E., on Van Meter's survey:

Silica	2.24
Alumina	.83
Sesquioxide of iron	.77
Water	Trace.
Barite, sulphate	95.27
Lime, sulphate	1.30
	100.41

Anglesite. Composition: sulphuric acid 26.4; oxide of lead 73.6. Traces of this mineral are reported as occurring in some of the mining districts, but no specimens have as yet been obtained. It probably originates from the decomposition of galenite.

Calcite. Composition: carbonic acid 44; lime, 56. This is a vein-mineral common to all the deposits of ore whether in crevices or openings. It occurs crystallized in modified rhombohedrons and scalenohedrons. The variety known as Dog-tooth-spar is a very frequent form, especially in the Shullsburg and Linden districts which affords very handsome cabinet specimens. The Mineral Point district affords handsome rhombohedrons, and the Linden mine affords handsome twin crystals of calcite set on sphalerite (blende). It also occurs there, rarely, as a pseudomorph after marcasite and has then a radiate or divergent form.

Dolomite. Bitter Spar or Brown Spar. Composition: carbonate of lime and carbonate of magnesia, in slightly varying but nearly equal proportions. It occurs occasionally in small rhombohedral crystals in cavities of the Galena limestone. The best locality for obtaining cabinet specimens is in the railroad cut at Scales Mound.

Smithsonite. Often improperly called Calamine. Composition: carbonic acid, 35.18; oxide of zinc, 64.81. This mineral, commonly known as Drybone, is one of the two ores of zinc found in the Lead region. It is found most extensively in the central and northern parts and usually in connection with blende. It crystallizes in rhombohedral forms; such specimens are, however, rare. It usully occurs massive, having a structure similar to partially decayed bone, from which it derives its common name.

Pseudomorphs, of Smithsonite, after calcite, are sometimes formed. They occur as rhombohedrons, and in the various irregular shapes in which calcite occurs in the Lead region. Perfect crystals, in which the transformation from calcite to Smithsonite is complete, are very rare. It is much more common to find skeleton crystals, or those which have been formed by the deposition of a smooth, light-colored shell of Smithsonite, about a sixteenth of an inch thick, over all the exposed surface of the calcite, followed by a gradual removal of the crystal contained within the shell. The space within the shell is sometimes partially filled with Smithsonite, and frequently planes are formed within, parallel to the cleavage planes of the original crystal. Pseudomorphs are also found in which the imperfect crystallization of sphalerite is very evident. Smithsonite is also found covering crystals of galenite, which are undecomposed.

Cerussite. Composition: carbonic acid, 16.5; oxide of lead, 83.5. Cerussite is occasionally found in small pieces, but never in sufficient quantities to form an object of mining. It occurs in irregular rounded pieces of a yellowish color, exhibiting no crystalline structure. It has been found near Mineral Point, and in former years quite frequently at the diggings near Blue Mounds.

Cerussite is found in small, irregular, translucent crystals of a white or light yellow color, in the mine of Messrs. Poad, Barrett & Tredinnick, near Linden. The specimens seen were large, cubic crystals of galenite coated with pyrite, the crystals of cerussite being formed on both of these minerals. The specimens indicate that the crystals of pyrite had been formed, and many of them broken before the formation of the cerussite.

Hydrozincite. Composition: carbonic acid, 13.6; oxide of zinc, 75.3; water, 11.1. This is a mineral of rare occurrence in the Lead region. It is found at Linden and Mineral Point as a white, finely crystalline, fibrous incrustation on Smithsonite.

Malachite. Composition: carbonic acid, 19.9; protoxide of copper, 71.9; water, 8.2. It is occasionally found in small seams mixed with other ores of copper in the Mineral Point copper mines. Crystals or good cabinet specimens do not occur.

Azurite. Composition: carbonic acid, 25.6; protoxide of copper, 69.2; water, 5.2. It occurs similar to malachite, massive and in seams associated with chalcopyrite. The Mineral Point mines afford very beautiful cabinet specimens of small rhombohedral crystals of dark blue color.

PRESENT CONDITION OF THE MINES IN THE VARIOUS DISTRICTS.

In this subdivision of the chapter, it is desired to present such information in regard to the individual mines as has been collected during the course of the survey up to the time when it became necessary to submit the manuscript for publication. This information has in many cases been procured under difficulties; owing sometimes to temporary suspension of mining operations, sometimes, but not often, to the reticence of owners, and sometimes to petty and vexatious hindrances which are best understood by those who have ever attempted to collect such information. It has been our aim personally to inspect and visit all the mines of any considerable magnitude, or possessing any features of geological or mineralogical interest; and in nearly all cases the owners have been found ready to afford every facility for investigating and obtaining information.

Mining is a business in which change is the rule and not the exception, it is therefore probable that some changes may have occurred since the commencement of the survey which are not here recorded, although it has been our aim to discover and incorporate them in the following report. The mines of the Lead region will be considered under separate districts, as, in fact, they are geographically distributed.

The visitor in the Lead region will constantly hear the terms "Brown rock," "Glass rock," "Pipe-clay opening," etc., used by the miners to designate the different strata in which they work This would be an advantageous system, were it not that the several names are applied to widely different strata by persons in the several districts. The term "Glass rock," for instance, is indiscriminately applied to all the strata in the Buff, Blue and Galena limestones. The following section is given as a general guide in understanding the relative position and thickness of the strata and openings, to which reference will occasionally be made in the subsequent pages. The section, however, will not be found of universal application, but merely shows the strata as their position is now understood by the most intelligent and systematic miners. In practice, the most reliable plan for determining the geological position of an ore bed or mine is, to find the outcrop of some well defined horizon in the vicinity, and ascertain the distance of the bed or mine above or below it, after making due allowance for the dip.

There are numerous openings occurring in all the upper and middle beds of the Galena limestone, none of which appear to be found regularly in all the districts. The section is, therefore, confined to the more persistent openings of the lower beds.

	Feet.
Galena Limestone.	
Green rock	4
Green rock opening	3
Green rock	12
Brown rock	12
Brown rock opening	5
Brown rock	8
Buff and Blue Limestone.	
Upper pipe clay opening	5
Glass rock (Blue limestone)	25
Glass rock opening	6
Buff limestone	12
Lower pipe clay opening	3
Buff limestone	10
St. Peters sandstone	..

BEETOWN DISTRICT.

This is the most westerly district in which any productive mines have been worked. In former years they were very productive, but have gradually become less so. There are several subdistricts, of which the principal ones are Beetown, Nip-and-Tuck, Muscalunge, and Hacketts. The diggings in the immediate vicinity of Beetown are situated north and east of the village, chiefly on Secs. 20 and 29 of T. 4, R. 4 W. There are here on the ridge about a dozen principal old ranges, all nearly parallel, and bearing a few degrees north of west. They vary from half a mile to a mile and a half in length, some of them extending easterly to the Grant diggings. There are no large organized companies at work on them, the principal product being by individual parties in small lots. Lead ore is usually found in this district in two principal openings, known as the 12-foot opening and the 65-foot opening. The first is named from the height of the opening which usually averages about 12 feet. The second derives its name from 65 feet of unproductive rock which separate it from the first.

The following parties are now or have recently been mining near Beetown:

Brown Bros. & Birch. These diggings are situated in the Hull Hollow, about three-quarters of a mile south of the village. They were discovered in 1860 by Walters & Roberts, and were first worked in the twelve foot opening.

There are three parallel east and west ranges situated about nine feet apart. They produce lead ore which is found in flat openings 4½ feet high and 4½ feet wide, lying about 7 feet above the 65-foot opening. The ore has been traced by a level 300 feet west from the discovery shaft. The depth at the working shaft is 60 feet; the greatest depth on the ridge will be 160 feet. Work was commenced in the winter of 1875–6, since which time the product has been 35,000 pounds. The prospects are considered good.

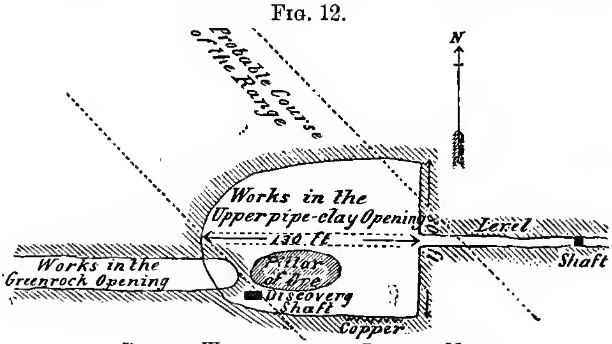
Wilcox Diggings. N. hf. of S. E. qr. of Sec. 32, T. 4, R. 4, W. This ground has been recently bought by Messrs. Henry, Ross, Gundry & Toay, of Mineral Point, by whom it is now operated under the name of the Beetown Mine.

Work was commenced here by Mr. Wilcox in 1868. A level has been run in the ground 500 feet, underlying a flat sheet of blende and Smithsonite, which is in places 36 inches thick. The sheet has been found to extend 80 feet north and south, and 130 feet east and west; its extreme limits are not yet known. On its south side, some copper ore has been found. The sheet lies in the upper pipe clay opening.

About 22 feet above the sheet of zinc ores is one of Smithsonite and lead ore, 150 feet wide, whose length is unknown. It lies in flat and pitching sheets in the greenrock opening.

The ground has produced lead ore to the value of $3,500; also, 45 tons of Smithsonite and 175 tons of blende. Four men are now employed here, and it is intended to work the mine to its full extent. Fig. 12 shows the position of the present workings.

FIG. 12.



PLAN OF WORKINGS IN THE BEETOWN MINE.

Some mining has also been done during this year (1876) on Sec. 27, on the east side of Grant river. The parties are as follows:

Josiah Crossly & Co. Produced about 8,000 pounds of lead ore in the operations of one month.

Crossly & Bass. Situated south of the preceding. Work was carried on for six months, and stopped by the owner of the land; 20,000 pounds of lead ore were produced.

Wilcox & Sons. These parties have been working about a month on a new east and west range. The prospect is considered good.

Pigeon Diggings.

They are situated on the north half of Sec. 20, T. 4, R. 3 W., and consist of several east and west ranges, in which the ore is found in flat openings in the "Brown-rock" division of the Galena limestone. The ground is owned by Messrs. Barber, Dewey & Cox. There are about 50 men employed here, mining chiefly in the old workings, at a depth of 30 to 50 feet below the surface. The annual product of the Pigeon diggings is about 250,000 pounds of lead ore. Mining is chiefly confined to the winter season.

During the last year a sheet of Smithsonite was discovered on the S. E. qr. of Sec. 19, which has produced 60 tons.

Hacketts Diggings.

These mines are situated on Sec. 17, T. 4, R. 4 W. They have been idle for several years. Work has recently been resumed on them by the following parties: Hutchcroft & Pigg, and Whitehead & Co. They have now good paying mines in the 65-foot opening. The annual product is about 30,000 pounds.

Nip and Tuck Diggings.

Situated on the south half of Sec. 25, T. 4, R. 5 W. They consist of several east and west ranges, crossed by north and south ranges. Very little mining is now done here. The parties are Sillick & Co. and Roberts & Co. The annual product is about 20,000 pounds.

Muscalunge Diggings.

Situated on Sec. 26, T. 4, R. 5 W. There are here numerous east and west ranges, from a quarter to a half a mile in length, lying near Rattlesnake creek. More activity is displayed here in mining operations than anywhere else in the district, about half of the ore smelted in the Beetown furnace being obtained here. In addition to the east and west ranges already mentioned, there are a great number of small parallel crevices running nearly east and west, and crossed by various quartering ones, forming a perfect net-work of veins and crevices. The following parties are operating in this vicinity:

Graham Mining Company. This is a Milwaukee company who own and work a large tract of ground comprising the west half of Sec. 26. The workings are all in the 65-foot opening. The following section of the Dewey and Maiden shaft is given, which shows the position of strata from the top of the ridge downward:

	Feet.
Soil and clay	15
Galena limestone	38
Tough, light rock, hard and flinty	2
Opening from 5 to 12 feet high	12
Hard rock with layers of flint	65
Opening (workings)	13
Galena limestone to top of Trenton	35
Total thickness	180

The two openings are seen here to be separated by 65 feet of intervening barren rock. The ground is drained by a level, about three-quarters of a mile long, run on the random of the lower opening, at an expense of $20,000. It empties into one of the adjacent branches of Rattlesnake creek. It could easily be drained to the top of the Blue limestone, by a level in the horizon of the Pipe-clay opening.

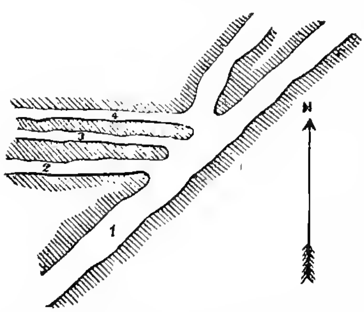
A convenience in hoisting was noticed here which might profitably be adopted in other portions of the Lead region. A six-inch hole had been drilled from the surface to one of the drifts for purposes of ventilation. An Artesian well bucket was then put on, and all small stuff and wash-dirt was removed through the hole, thus saving a long and unnecessary transportation underground to the main shaft. The company has worked continuously here for many years, and now employs about fifteen men. The ground has been very productive; it produced in one year 1,300,000 pounds. Its average annual production for the last nine years is estimated at 300,000 pounds of lead ore.

James Thomas & Co. This company has been working here for the last fifteen years. The ore is found on an east and west range, in the 65-foot opening. The diggings are dry and from 150 to 160 feet deep. Four men are employed here. The average product is 150,000 pounds of lead ore per annum. The land is owned by Mr. Dewey.

Hutchcroft & Thomas. Situated 450 feet south of the preceding, and connected with them underground. They are in the same opening as the preceding, and have been worked continuously many years. During the last year they have been idle, having been sold by the parties who operated them. When worked, their annual product was 150,000 pounds.

Hutchinson, Dewey & Co. Situated on the S. E. qr. of Sec. 26, east of James Thomas & Co., and on the same range and opening. This party has been working here since 1869, and has now a very good prospect. The average depth below the surface is 160 feet; in some cases it is 180 feet. They are connected with the Adkinson diggings by a quartering range. They have produced about 30,000 pounds in the last three years. Three men are now employed.

FIG. 13.



JUNCTION OF EAST AND WEST VEINS WITH A QUARTERING RANGE, ADKINSON DIGGINGS.

1. Northeast or quartering range; 2, 3, 4. East and west veins.

Adkinson Diggings. Situated a short distance east of the preceding and connected with them. Access is gained to these diggings through a level about a quarter of a mile long, emptying into the valley of Rattlesnake creek. The level was run on a northeast crevice, which contained a large amount of ore, and was frequently intersected with east and west crevices, as represented in Fig. 13. These diggings have been worked continuously during the last twenty years. During the last fifteen years the annual product has been 150,000 pounds of lead ore. Four men are now employed here.

Showalter & Payten. Situated a quarter of a mile southeast of the preceding, and near the south line of the Dewey land. These parties commenced two years since, and are now working an east and west range in the 65-foot opening. Two men are now working here, and the prospect is good. During the last two years the product has been 70,000 pounds.

Arthur & Co. Situated 200 feet south of the preceding, on Mr. Arthur's land. This is a new east and west range, discovered in the spring of 1876. A shaft has been sunk 90 feet to the 65-foot opening, and a small amount of ore produced. The appearances in this new range are quite encouraging.

Ritter & Bock. N. E. qr. Sec. 35, T. 4, R. 5 W. Situated on land owned by Mr. Ritter. This is a new east and west range, discovered in the summer of 1875. It is worked on the 65-foot level. It is regarded as a good prospect, and has already produced 20,000 pounds.

Loomis & Co. Situated on the land of the Graham Mining Co., in the southern part. This is also a new east and west range, discovered in August, 1876. It has produced about 12,000 pounds. The mine is now in a condition to yield 1,000 pounds per day.

The Lead ore in the Muscalunge mines occurs in direct contact with the wall rock, usually in vertical sheets, and without any of the associate vein-minerals which are usually found in the other mining districts.

POTOSI DISTRICT.

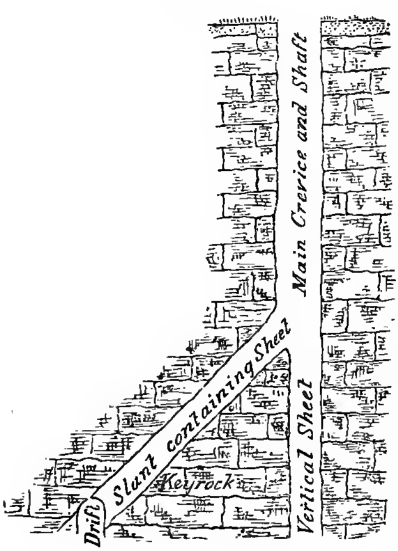
Mining operations here are chiefly confined to the winter season, and furnish employment to about twenty miners.

The old ranges of the Potosi diggings are included in Secs. 33 and 34, T. 3, R. 3 W. Their general course is about N. 70° W., although some bear a few degrees more to the west, and some a few more to the north. They numbered about thirty in all, which were considered as separate and distinct ranges; and in addition there were many smaller crevices not sufficiently important to constitute ranges by themselves.

Among the more important were the Long, Wooley, Gillet, Gilmore, Smith, Polkinghorn and Barbara, some of which were over a mile in length.

The productive portion of these ranges is confined to the middle and lower portions of the Galena limestone, none of the crevices having as yet been proved as low as the Brown rock; the ore is usually found in sheets of varying thickness.

Fig. 14.



Section of the Meredith Mine.

Considerable irregularity exists in the formation of many of the crevices in the Potosi district, by which, they seem to split up in the lower beds of the limestone, forming key-rocks and divergent crevices. An instance in point was seen in the diggings of Mr. Meredith, in the N. E. qr. of Sec. 33, about 300 feet south of the old Wooley range, on the summit of the ridge.

A shaft was sunk on the main crevice which continued without change for sixty feet from the surface. At this point a hard key-rock, as it is called, was encountered, on which the crevice and ore sheets divided, one part continuing vertical, and the other slanting downward at an angle of about 45° for a distance of thirty feet. Here a vary hard and smooth floor was found on which the sheet was followed out by drifting, for a distance of one hundred and thirty feet without reaching the end. No appearance of openings was observed. These diggings were struck about six years ago (1870) and have produced since then about 420,000 lbs.

Rockville Diggings.

There are here a number of east and west ranges with flat openings, which have been worked with but little interruption since 1840, and now furnish employment to about twenty miners. Mining is chiefly confined to the winter season. The following parties are now operating here.

Phillips & Walker. S. W. qr. of S. W. qr., Sec. 13, T. 3, R. 3 W. These parties are working a new east and west range, discovered by them in the summer of 1874. The ore is found at a depth of about 100 feet below the surface, in flat openings from 50 to 60 feet wide, whose length has not yet been ascertained. They have, however, been worked to a distance of 300 feet. The lead ore is found in what is known here as the second opening, which lies about 30 feet above the upper surface of the Blue limestone. Their annual production is 30,000 lbs.

Dilger Mine. N. W. qr. of N. W. qr. Sec. 24. This is a new range discovered in January, 1876. The works are as yet confined to the first opening, which is here 30 feet above the second. It has produced during the past year 40,000 pounds.

Hayward Range. S. W. qr. Sec. 13. This range has been worked continuously every winter since its discovery in 1841, and has yielded in all between four and five million pounds. It is now worked by Messrs. Jackson & Calloway in the second opening, which is here from 30 to 40 feet wide. It produces about 100,000 pounds per annum.

Warfield Range. S. W. qr. Sec. 13. This range has been worked every winter during the last thirty years, and has produced about 2,000,000 pounds. It is now worked by Messrs. White & Dunn in the second opening, which is here from 30 to 40 feet wide. Its annual product is about 100,000 pounds.

Curnow and Pillow Range. S. W. qr. Sec. 13. This range has not been idle during the last thirty years, and is still productive. During the last fifteen years the range has produced over 100,000 pounds per annum. Messrs. Nichols & Stephens are now mining on it, and producing 20,000 pounds per annum.

Emery and Davis Level. N. W. qr. of N. W. qr. Sec. 24. The level was commenced in 1852, and is now 600 feet long, and drains the ground in its vicinity nearly as low as the second opening; its cost was about $20,000. The excavations here were of the nature of a quarry, several flat sheets of lead ore being found interstratified with the Galena limestone. While the level was in operation, the annual product was about 100,000 pounds. The level drains the Langstaff and Willey ranges, which were discovered about thirty years ago, and have been worked continuously ever since. Most of the lead ore is obtained from the first opening; the annual product is 50,000 pounds. These ranges have been worked to the present water level, leaving sheets of ore from 12 to 18 inches thick going down. The level should be run a few rods farther to connect with a north and south crevice; it would then probably drain all the ranges much deeper.

Stone & Bryhon. Situated near the N. W. corner of Sec. 1, T. 3, R. 3 W., on land owned by Mr. Stone, about three miles north of the village of Rockville. The works are in the first opening, which is from eight to ten feet wide. They have been worked in the winter season during the last four years, producing annually between 30,000 and 40,000 pounds. They were formerly worked by Mr. Grusham and were more productive. The mines are dry.

Griswold Diggings. Situated about a quarter of a mile south of the preceding. These are dry diggings worked in the first opening, which is here about six feet high and from ten to thirty feet wide. They have been worked continuously during the last seven years, producing about 65,000 pounds per annum.

Henry Gillilan's Diggings. These diggings are situated about three miles southeast of Rockville, on the Platte river. They are dry diggings, and have been worked during the last four years, in the first opening, which is here thirty feet wide and about six feet high. The annual product is 25,000 pounds.

British Hollow Diggings.

But little mining is now done in these mines. In the winter season about twenty men are employed. The following parties are now mining here:

J. Alderson's Diggings. N. W. qr. Sec. 26, T. 3, R. 3 W. They are situated on the Craig range in the village of British Hollow. This range was worked by a Cincinnati company for three years; they abandoned it two years ago. This company produced about three million pounds during the time of their operations. Mr. Alderson commenced mining here again in July, 1876, with a steam pump, and has sunk four shafts. The workings are about 120 feet deep in the second opening, and in the third, which is about 25 feet below the second. The mine has not produced much yet, as the time has been mostly consumed in preliminary operations.

Peak & Blair. N. W. qr. Sec. 26. These parties have also been working on the Craig range during the past summer (1876). They have a flat sheet of lead ore about five inches thick in the first opening, which here averages 20 feet in width. This range has been worked during the last forty years. The product of the present parties has been about 20,000 pounds.

Dutch Hollow Diggings.

They are situated on the north half of Sec. 36, T. 3, R. 3 W., about two and a half miles east of Potosi. The following parties are now operating here:

Dutch Hollow Level Company. Mining operations have been carried on here continuously for the last six years, excavating a level on or near the upper surface of the Blue limestone. The level is now about half a mile long, and it is expected to reach the main shaft in about a month. When completed, the level will unwater all the Galena limestone above it, which is here about one hundred feet thick. It is expected to unwater the Kendall, and many other old ranges in the vicinity, as deep as the third opening. The level is not producing much now. During the year 1872, it produced 60,000 pounds.

Rup & Son. N. E. qr. Sec. 35. This party has been working during the last six months on a part of the Züg range. The ore is found in the first opening, which is here about 15 feet wide. The production has been 150,000 pounds.

Zug Diggings. This is an east and west range, being the same range and opening as the preceding. It is worked to a depth of 75 feet. The present party has mined here during the last year and a half, and produced 150,000 pounds.

Langstaff & Gillan. Situated three-quarters of a mile northeast of the preceding, on the creek in Sec. 25. The lead ore is found here in a flat sheet in the first opening, near the water level and about 30 feet below the surface. Three men have been working here twelve months, and have produced 60,000 pounds.

The production of the Potosi district, including Rockville, British Hollow and Dutch Hollow, could not be definitely ascertained, as very little record has been kept of it. It is estimated at 80,000 pounds per annum.

Mining in this district is generally abandoned in summer for farming, and resumed again in the winter, in the lack of other employment. In this way a large number of men are at work in the winter, each raising a small amount by prospecting, which forms in the aggregate the total product of the district.

FAIRPLAY DISTRICT.

The only mines in this vicinity which have recently produced anything are those of Black & Co., on the N. E. qr. of Sec. 24, T. 1, R. 2 W., and those of Williams & Co., near the center of Sec. 19, T. 1, R. 1 W.

Black & Co. This property, which comprises in all about two hundred and forty acres, is owned by Messrs. Joseph and Thomas Sparks. It has been known to be rich ground for many years, and to contain, besides the ore, an immense amount of water, which was the chief obstacle to be overcome. Previous to the operations of Mr. Black, it had been attempted by three separate parties, at as many different times, but always with more or less loss.

Mr. Black commenced work on it in November, 1871, by means of pumping, and continued to add pumps, engines, and pumping machinery at intervals. At the time the mine was visited (June, 1874), there were in operation two steam pumps, and two large lift pumps, together with three boilers and two engines, one of them about thirty horse power. The company then contemplated adding a larger engine and machinery. It was estimated that about a thousand gallons of water per minute were being pumped from the mine, and when the lower opening is reached, which is thought to be about fifteen feet deeper, it will become necessary to pump about fifteen hundred gallons per minute.

The mine is in the upper beds of the Galena limestone, which is here present in its full thickness, and indeed the first few feet of the shafts are sunk through the lowest bed of the Cincinnati group, as may be seen from the yellow clay with the characteristic shells in any of the shallow, prospecting holes in the vicinity. The following section of the strata, penetrated in sinking the pump-shaft, will give a correct idea of the formations here represented:

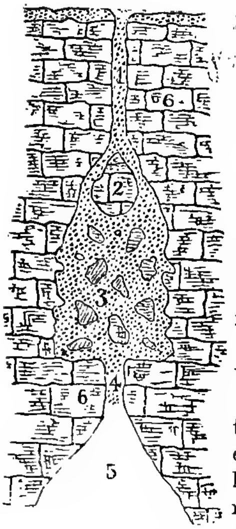
	Ft.	*In.*
Cincinnati Group.		
Soil and clay bed	20	..
Pipe clay	..	10
Bed of black clay	..	4
Shaly layers	..	10
Galena Limestone.		
Galena limestone in thin layers	4	..
Galena limestone cap in layers 4 feet thick, gradually increasing in thickness to the bottom	30	..
Opening containing ore	30	..
Total depth of shaft	86	00

The course of the vein is nearly east and west, and five shafts have been sunk upon it, the deepest of which has reached a point 105 feet below the surface. The opening now presents the appearance of a series of large rooms or caves, from 15 to 20 feet wide and about 15 feet high, for a distance of 600 feet.

The vein was crossed in several places by bars of hard rock, one of which was sixty-five feet in thickness. The bars always caused a decrease in the size of the opening, and sometimes nearly cut off the vein. In other places the opening contracted in width, in which case the ore usually occurred in a solid sheet, sometimes as much as seven feet thick by seven and a half high. In the caves or larger parts of the opening the ore was found in large masses, weighing sometimes several thousand pounds. Two large masses were found which weighed respectively fifty thousand and twenty-seven thousand pounds. With the ore large masses of rock were found mixed with loose dirt and a fine dark clay. The sides of the opening were much washed and worn by water, showing a very regular stratification with no appearance whatever of faults or dislocations. Each of the caves in the opening had a chimney going down, apparently to a second opening, which has never yet been proved or worked. The upper part of the opening was sometimes filled with a large key-rock, having a crevice on each side of it. Sometimes, however, the key-rock was replaced by a flat-cap-rock containing crevices.

The appearance of these caverns as we passed through them was a sight not soon to be forgotten. On the floor lay great masses of rock which had fallen from above, with clay continually moistened from the dripping walls and arching roof, and here and there the feeble light revealed rich masses of glittering ore.

FIG. 15.



The annexed section shows the relative position of the different portions of the vein:

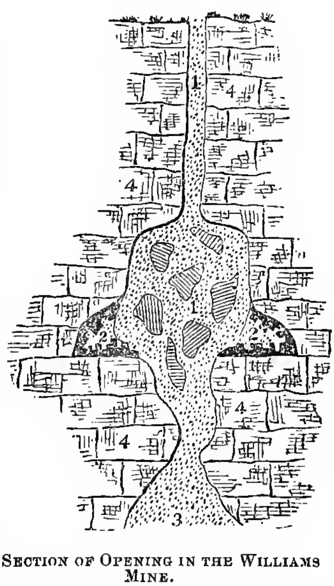
1. Crevice containing lead ore.
2. Key-rock with crevices on each side.
3. Opening containing lead ore with loose masses of rock and clay.
4. Chimney going down to
5. Second opening.
6. Galena limestone.

The vein has not been worked over half the time since its commencement, as frequent stoppages were necessary for the purpose of putting in new pumps and machinery. Work was discontinued here in February, 1876, but it is expected that active operations will soon be resumed.

Mr. Black estimated that he had taken out about one million pounds of lead ore, at an expense of $40,000.

Williams & Co. This mining property is situated about three-quarters of a mile northeast of Black's mine, and was operated by the proprietors, Messrs. Thomas and Jeremiah Williams, and Mr. O'Connor. The water in this ground is not nearly so abundant as in the preceding. It is easily removed with a common lift-pump, worked with a ten-horse power engine; the amount seldom exceeds 250 gallons per minute. Mining has been confined to the upper half of the Galena limestone. The lower clay beds of the Cincinnati group are also found here, but there is not so great a thickness of them as at Black's mine. The pump shaft commences at the top of the Galena limestone, and is sunk to a depth of one hundred and six feet, at which point the top of the second opening is found, after passing through the first opening, which is situated at a depth of forty-seven feet from the surface, and is probably identical with the first opening at Black's mine, which it much resembles in its general appearance. The first opening here consists of a series of large caves or enlargements of the crevice, with chimneys going down to the second opening.

FIG. 16.



SECTION OF OPENING IN THE WILLIAMS MINE.

The ore was found in masses mixed with clay and large pieces of stone which had apparently fallen from the roof or cap. The Lead ore from its greater specific gravity usually occupies the lower part or floor of the opening. The course of the range is very nearly east and west, but bears a little north on its western end. The length of drifts in the top opening amounts to about nine hundred feet. It is about worked out at the western end, but still continues good at the east. Several masses of lead ore were found in this opening weighing from fourteen to fifteen thousand pounds. A singular formation of ore was found in the top opening, as illustrated in the annexed diagram.

1. Opening and crevice filled with loose masses of lead ore and rock, mixed with loose fine clay and sediment. 2. This is a bench about a foot in width on each side of the open-

ing, and extending along the entire length of the cave, a distance of 80 feet, on which shelf, and the sides immediately above and adjacent, the ore was deposited, fastened firmly to the wall, and exposing crystalline faces to the center of the opening. In other portions of the mine this bench was not observed, and the ore was usually attached in sheets to the side of the opening. 3. The lower opening. 4. The Galena limestone.

The mine was discovered and opened in February, 1872, and since then has probably been the most productive and remunerative mine in the district, on account of the comparatively small amount of water to contend with, and the large amount of lead ores obtained, which has been estimated at two and a half million pounds. Work was suspended on this mine in the fall of 1875, and has not since been resumed.

Fairplay Level Co. A company, consisting of Messrs. Merry, Olinger, Rewell, Pier and Notte, having formed a stock company with a capital of $50,000, have been engaged during the last eight years in running a level on land owned by George Siddell & Co. The level is commenced on the E. half of the S. W. qr. of Sec. 26, T. 1, R. 2 W., about three-quarters of a mile below the village of Fairplay. It has been run eastward a distance of 2,200 feet, and thence south 70 feet; and has cost about $30,000. One "shift" of three men is the usual number employed, and it is not expected that the level will be completed for many years. Its greatest depth below the surface is 140 feet, and 48 feet below the natural water level; one mile farther east it will drain about 60 feet below the present water level.

This level will unwater the whole of section 25, and will cut the following ranges in the third opening: The Crabtree, Thompson, Engine, Carns, Bruce, Lost range, Franklin, Seward, and Cave range. The openings in these ranges are vertical; they were formerly worked and abandoned with lead ore in them going below the water. When these ranges are unwatered they will undoubtedly be very productive.

In the vicinity of Fairplay, about fifty men find employment in mining during the winter; in summer the mines are idle. The greater part of the lead ore raised in this district comes from the mines south of the village, and, exclusive of the two large mines previously described, has not exceeded 50,000 pounds per annum for the last six years.

HAZEL GREEN DISTRICT.

The Hazel Green district exhibits considerable activity at present in mining operations; and the reports of smelters in this vicinity show that a large amount of ore is raised here. During the years 1872 and 1873, miners were attracted to other localities by the prospect of higher wages, which caused a temporary decrease in the production of lead ore; the mines, however, remained unimpaired. The miners have now returned, and the mines have regained their normal productive condition.

The most remunerative and continuously productive portion of the district is the property of the Hazel Green Mining Company, otherwise known as Crawford, Mills & Co. It is situated on the N. W. qr. of Sec. 30, part of the S. W. qr. of Sec. 30, part of the N. E. qr. of Sec. 30, part of the S. E. qr. of Sec. 19, the S. W. qr. of Sec. 19, the N. W. qr. of Sec. 19, the W. hf. of the S. W. qr. of Sec. 18, all in T. 1, R. 1 E.; also the N. E. qr. of Sec. 24, and the E. hf. of the E. hf. of Sec. 25, T. 1, R. 1, W., comprising in all eleven hundred and six acres, on which over four hundred and fifty distinct mineral veins have been discovered and worked.

During the early days of mining these grounds were worked from the surface as deep as was then possible, which was only about thirty-five feet, when they had to be abandoned. Pumping was tried on some of the larger bodies of ore, but as a general thing was found to be too expensive to be very remunerative, on account of the vast amount of water which the ground contained. In the year 1862, Crawford, Mills & Co. commenced their level from a point on the Hard Scrabble Branch, and have been working it continuously ever since. Its total completed length is now about four thousand feet.

It is a feature of this ground that it is traversed by several bars or belts of ground which are very hard and impervious to water. As soon as the level is driven through one of them, it unwaters the ground in all directions to the next bar.

Sometime in the year 1871, one of those bars was reached which was so hard that blasting with powder made but little impression on it. As an experiment, nitro-glycerine was tried and gave the greatest satisfaction, so much indeed that a factory has been established here, and it is gradually being introduced into the mines. It is at present used in Dubuque, Galena, New Diggings and several other places. It was at first regarded with some dislike and distrust by the miners, but this prejudice is fast being overcome, and nitro-glycerine or some of its compounds will probably supplant gunpowder in the mines at no distant day. The factory at Hazel Green produced, during the first three years, about three thousand pounds of nitro-glycerine, and the demand is steadily increasing.

On account of the position of the bars, it was found necessary to make three branches to the level, one of which is now completed and is gradually draining the western part of the ground. The northern branch when completed will undoubtedly unwater the rest of the ground.

This level is an evidence of what can be done by scientific mining, when carried on persistently and systematically, with sufficient capital, applied with foresight and sagacity. It has cost the company twelve years of time and about $100,000. Its results are, that it has already repaid the outlay of capital by the ore raised from the ground unwatered by it, which would otherwise have been inaccessible. When completed, it will unwater the ground 135 feet below the natural water level on the ridge It furnishes employment to about 80 miners during the mining season, which without it, would hardly exceed half a dozen.

Quite a large and clear stream of water is discharged from the mouth of the level, and is at present used to operate a furnace and three wash-places.

The ore in the Hazel Green mines is usually found in sheets; this is its characteristic mode of occurrence. The ranges are approximately east and west, or north and south, the former being the most productive. Ore is also sometimes found in large bunches or pockets, containing sometimes several thousand pounds, and occasionally in openings. The pockets are often lined with large and very regular cubes, affording handsome cabinet specimens. The total production since the discovery of these mines has been carefully computed from the smelter's accounts at about 126,000,000 pounds. Their present product is about 800,000 pounds per annum.

Mining in this vicinity is confined to the upper half of the Galena limestone, which is here present in its entire thickness, the clay of the lower beds of the Cincinnati group being found near the village, on the road to Galena. A section of the strata from the top of the ridge to the level would present approximately the following features:

Soil and flints	15	feet.
Galena limestone	90	"
Shales or thin layers of limestone	10	"
First clay opening	10	"
Second clay opening	20	"
Flint opening to floor of level	20	"
Total thickness	165	"

The following are the parties who are now engaged in mining on the company's land or have been during the course of the present survey:

Richard Eustice & Co. These parties were working in a new locality, and had, at the time they were visited, one of the handsomest displays of ore ever seen in the grounds. The bottom of the shaft had penetrated an opening filled with soft earth. The sides of the opening were lined with a body of ore which presented an unbroken mass of cubic crystals of various sizes, some of them being as much as six inches on a side, and of very perfect shape, affording very handsome cabinet specimens. There was not less than 10,000 pounds of lead ore in sight, in a place about ten feet long. This body of ore is known to continue several feet deeper to the drift below. These diggings were worked until the fall of 1875, and produced in all 120,000 pounds.

Rowe & Rowe. This is a new range, and was discovered in March, 1874. It is an east and west sheet, in which the ore occurs in a crevice three or four inches wide, at a depth of about 60 feet below the surface, and about 35 feet above the flint opening. Work was suspended here in September, 1876. The total amount produced to that time was 50,000 pounds.

Richard Eustice' Diggings. Situated on the Phelps range, shafts are 90 feet deep, down to the clay openings. Length of drifts about 150 feet. The ore here occurs in a sheet about an inch thick. The diggings were worked from June, 1872, to June, 1875, and produced about 40,000 pounds. Near these diggings, and about ten feet deeper, is an east and west sheet dipping to the north, carrying bunches of blende, which affords quite handsome crystals.

Manwaring and Madison Range. This is an east and west range, and is sometimes known as the Hinch range, from the name of a party who formerly worked it, and by whom it was abandoned in 1858. Since the level has been run, the water has fallen about 50 feet in this ground, and in December, 1873, work was resumed on it by Crawford. Mills & Co., since which time it has produced 40,000 pounds of lead ore. The shaft is down about fifty-five feet, or within six feet of the flint opening. Work was suspended on it in June, 1875.

John Edwards' Diggings. Situated a short distance further west on the same range. A flat sheet of blende is found here in the second opening, at a depth of 80 feet below the surface. The order of deposition here is: 1st, pyrite; 2d, galenite; 3d, blende. During the winter of 1875–6, the product was blende, 10 tons; lead ore, 1,400 pounds.

Bull Pump Range. This range was worked by Jackson & Co. during the years 1873–4–5, producing 90,000 pounds. Work was suspended here in the fall of 1875.

Bininger Range. This range has been worked at intervals since May, 1874. It is now worked by Stephens, Nankivel & Rowe; four men are employed, working with a horse pump in the second opening. During the present year the product has been 30,000 pounds.

Big Pump Range. This range has been worked since October 1, 1876, by Richard Eustice & Co. A small amount of ore has been produced from the first opening.

McCoy Water-Wheel Range. Work was recommenced here about August 1st, 1876, by Rowe & Son, in the first opening.

Oates and Eustice. This party has been working during the last year and a half on a range 200 feet north of the west branch of the level. The lead ore is found in a flat sheet in the second opening. The opening is seven feet high and averages seven feet in width. The sheet is about one foot thick. The product to the present time has been 150,000 pounds.

Clark's Diggings. Two men have been working during the last year in the range next north of the McCoy Water-Wheel range. The ore is found as "chunk mineral" in the second opening, which is here six feet wide. The product has been 30,000 pounds.

Tregenza & Son. Work was commenced by this party in the fall of 1874, on the Drybone range, south of the Badger lot. The works are in the second opening, which is here from 10 to 12 feet wide; and contains a flat sheet about five inches thick, of which the upper part consists of lead ore, and the lower of zinc ores. The product has been, zinc ores 20 tons; lead ore 20,000 pounds. Very handsome specimens of galenite coated with cerusite are obtained here.

W. H. Eustice & Bro. This party commenced work in the fall of 1875 at Crawford's little pump shaft. They worked in the second opening during the winter of 1875–6, and suspended in the summer on account of water. The prospect is good and they expect to resume work this winter (1876). Product 10,000 pounds.

Edwards Estate. On this land there are several old ranges, now drained by the level of Crawford, Mills & Co., in which the following mining has been done:

Peter Skinner, in the winters of 1874–5 and 1875–6, produced 100,000 pounds.

Moffat & Co., in the same seasons, produced 80,000 pounds.

Pierce & Trewather, in the same seasons, produced 70,000. Other parties in the same time, in small amounts, 100,000.

In addition to the parties already mentioned, there are, in the winter season, usually about sixty miners at work on the lands of the Hazel Green Mining Company.

Diggings in the Village of Hazel Green not on the Lands of the Hazel Green Mining Company.

McBreen & Co. This is an east and west sheet, connected with a quartering one averaging about an inch thick, situated on the land of Dr. McBreen, on the N. W. qr. of Sec. 25, T. 1, R. 1 W. The range was worked in 1844, and the ore taken out to the water level. The water having become much reduced by the Hazel Green Company's level, work was recommenced in 1874, since which time about 55,000 pounds of lead ore have been taken out. The diggings are in the upper beds of the Galena limestone, and not down to any opening.

Torneal's Diggings. A short distance southwest of the preceding is a range consisting of twenty parallel crevices, about twenty-five feet apart, and bearing N. 15° E. Work was abandoned on them in 1850, and was recommenced by Mr. Torneal about eight years ago, since which time they have produced 42,000 pounds. Considerable time and labor have been expended in running a cross drift to prove the ground and ascertain the number and position of the crevices. The distance here to water is 80 feet, and the diggings are in the upper beds of the Galena limestone.

Rowe and Vivian. This was formerly known as the Chizzem range, and is situated on Edward Williams' land, in the southwest quarter of Sec. 25, T. 1, R. 1 W., in the southern part of the village of Hazel Green. It is a north and south range, and was worked and abandoned in 1854. Work on it was recommenced by the present parties in November, 1873. Since then it has produced 24,000 pounds. The full thickness of Galena limestone is here present, overlaid by a few feet of clay of the Cincinnati group. The deepest shaft is 106 feet, and the total length of drifts is about 190 feet. Work was suspended here in the spring of 1875.

Williams & Bro. On Edward Williams' land. This party commenced in the fall of 1875, and are now mining in a range a short distance west of the diggings of Eustice & Co., in the village of Hazel Green. They are working on a vertical sheet, and have produced, to the present time, 20,000 pounds.

Chandler's Diggings. These diggings are situated on Mr. Wetherbee's land, and on the Sulphur lot range. Work was commenced two years ago, and continued to the present time. The works are in the second opening, which is from six to eight feet wide, and contain a sheet of lead ore from one to two inches thick, and also large, irregular masses which afford handsome specimens. The mine has produced 500,000 pounds, and is now very good.

Buncome Diggings.

The Buncome Diggings form a sub-district belonging to Hazel Green. They are situated on the Galena river near the mouth of Bull branch. They were formerly very productive diggings, and a few parties are still working in them. They are situated in the Brown rock, which is the lowest bed of the Galena limestone, and is here from twenty to thirty feet thick; and extends down to the creek bed at the State line, where the top of the Blue limestone may be seen. At the mouth of Bull branch the top of the Blue limestone is found to be twenty feet above the bed of the stream. Mining is generally carried on here by drifting into the side of the hill. An example of this is seen on the land of Mr. Gabriel Mills on the N. W. qr. of Sec. 32, T. 1, R. 1 E., where a flat sheet of ore was found on the top of the Brown rock, on which a number of short levels were run. Mr. Mills is now engaged in running a level on the top of the Blue limestone from the center of Sec. 32, westward, to prove the ground for blende, of which ore small quantities have been occasionally found. The Buncome ground is also remarkable as being the only locality in which native sulphur appears in sheet form.

Carpenter & Bennett. These parties are mining on Mr. Mills' land on the N. E. qr. of Sec. 32, T. 1, R. 1 E., on the east side of the Galena river. The workings are as usual in the Brown rock, and produce some lead ore and large amounts of carbonate of zinc and blende. Exactly how much could not be ascertained. They have worked continuously since 1872.

Hicks, Fiddick & Co. Situated on the land of the Edwards estate, on the S. W. qr. of Sec. 29, T. 1, R. 1 E. The diggings are about a half a mile above the mouth of Bull branch, and are also carried on in the Brown rock. They are drained by a level a quarter of a mile long, discharging 100 gallons per minute, which was commenced in 1868. The ore is found in flat and pitching sheets, and sometimes contains a little blende mixed with it. Twelve men are now employed here, and are producing a large amount of Smithsonite. Since the commencement of operations, about 400,000 pounds of lead ore have been produced.

Gabriel Mills Diggings. This ground is on the N. W. qr. of Sec. 29, T. 1, R. 1 E., on the ridge dividing Bull and Hard Scrabble branches, and contained the large lode mentioned in Prof. Whitney's report of 1862, on pages 285 and 286. The ore was discovered here in 1854, and has been worked uninterruptedly ever since, which is somewhat remarkable, as a single range seldom continues uniformly productive through so many years. The property is owned by Mr. Mills, and is now being worked by William, Thomas and James Mills, and R. Pierce. The deepest shaft is 130 feet down to the brown rock, in which the ore is found in flat and pitching sheets. The ore from these diggings is always coated with pyrites, and some Smithsonite is found associated with it.

The ground has produced about eight million pounds of lead ore, their present annual average production is about 50,000 pounds, with no sign of diminution.

Simmons & Sons. N. E. qr. of N. W. qr., Sec. 32, T. 1, R. 1 E. A very fine prospect has recently been discovered by this party on Mr. G. Mills' land. They commenced work about the 1st of September, 1876, with a horse pump. After sinking a shaft 14 feet deep, a flat sheet six inches thick was discovered in the upper pipe-clay opening. The sheet consists of lead ore, blende and pyrites, about half of the thickness being lead ore.

There are also several isolated ranges lying between Hazel Green and Benton, and not properly belonging to either district. They are as follows:

Johns & Harvey. On the N. E. qr. of Sec. 6, T. 1, R. 1 E. The range was struck in 1858, and was worked for some time with an engine and pump, and then abandoned. Work was recommenced by Messrs. Johns & Harvey, in 1869, and they are now working on the natural water-level, at a depth of one hundred and ten feet below the surface, in the middle portion of the Galena limestone. The range bears slightly north of west, and makes ore in tumbling openings, mixed with clay and detached masses of stone. The opening is, in some places, twenty feet wide, but does not correspond in geological position with any of the Hazel Green openings, as it is rather above them. Work was suspended here in the fall of 1874. Their production to that time was 900,000 pounds of lead ore.

Dawson's Diggings are situated on the S. E. qr. of Sec. 32, T. 2, R. 1 E. The general course of the range is east and west, but it is found to pitch in various directions. They are worked about thirty feet below the surface, in the upper measures of the Galena limestone. They were discovered in 1872. Since then they have been worked continuously, and have produced 80,000 pounds.

Drybone Diggings. S. W. qr. Sec. 28, T. 2, R. 1 E. Mining for drybone has now been carried on here by George Hoppenjohn for the last ten years. The diggings are known as the "Bone Patch," and are very shallow, not exceeding twelve or fifteen feet in depth. The Smithsonite occurs in bunches as float, and does not make in any regular sheet or opening. The amount produced is about 50 tons per annum.

Barney Kesson's Diggings are situated about a quarter of a mile southwest of the preceding, on the same quarter section. Work is suspended on them during the summer seasons. They are quite productive diggings and have yielded 50,000 pounds of lead ore per annum for several years.

Anthony & Dixon's Diggings. S. E. qr. Sec. 21, T. 2, R. 1 E. These diggings are about a quarter of a mile south of the village of Jenkinsville, and are worked altogether for blende; although the ore contains a little drybone and lead ore. They are on the top of the Blue limestone, on which a level is now being run, and is completed a distance of 200 feet.

The ore is very close-grained, shows no regular cleavage, and somewhat resembles an ore of iron. It is remarkable by being intersected with thin parallel plates or laminæ of galenite lying very close together, presenting reflecting edges, and being a constituent part of the ore.

The deposit was discovered in 1872, and has been worked continuously since. The production has been 180 tons of blende and 10,000 pounds of lead ore per annum.

Kesting, Hines and others. A short distance southeast of the preceding, on the same quarter section, are three parties at work on some dry bone diggings. There are here several quartering ranges, having a southwest course. The Smithsonite lies from fifteen to sixty-five feet below the surface, and in the lower measures of the Galena limestone; it "makes" in flats, sheets and pitches without much regularity. The ground has been worked about ten years for drybone. The average annual production has been about 225 tons.

Spensley, Winn & Co. Situated about a quarter of a mile southwest of Meeker Grove P. O. The above parties have been working here about five years. The ore is found in an irregular flat sheet in the upper pipe-clay opening. This ground has been worked at intervals during the last twenty years. The water is removed by a horse pump. The production of the last two years is as follows: 1875, blende, 300 tons, lead ore, 20,000 pounds; 1876 to October 1st, blende, 400 tons, lead ore, 20,000 pounds.

Greenwood & Miller. S. E. qr. Sec. 7, T. 1, R. 1 E. This is an east and west range, discovered by Cook, twenty five years since. The present parties became interested in it in 1871. Five shafts from 70 to 90 feet deep have now been sunk, and two drifts of 300 feet each have been run. The ore is found here in a crevice opening, sometimes twelve feet high. The width of the opening is quite variable, as it is crossed by numerous north and south crevices, which usually cause it to expand in width. Bunches of ore are found at the crossings, but no regular sheets. The water is removed from the ground by a two horse pump of 12 inch bore, 6-feet stroke, which pumps about

90 gallons per minute. It is estimated that the ground has produced a million pounds of ore, and its present annual product is about 300,000 pounds.

NEW DIGGINGS DISTRICT.

Considerable lead ore is now being raised in the vicinity of New Diggings, being mostly on the ridge immediately south of the village. The following section taken from the mines south of the village will give a correct idea of the relative position of the several beds and openings:

	Ft.	In.
Soil and clay	14	..
Galena limestone	60	..
Flint bed	1	2
Shale	..	2
First opening (sometimes called crevice opening)	5	..
Limestone cap	2	..
Second opening (sometimes called flat opening)	5	..
Flinty rock	9	..
Third opening (this is the principal flat opening)	4	..
Galena limestone	4	..
"Putty bed."	..	3
Galena limestone	1	8
Fourth opening	6	..
Galena limestone	50	..
Flint opening	3	..
Brown rock to top of Blue limestone	13	..
Total	178	3

Champion Diggings. N. E. qr. Sec. 26, T. 1, R. 1 E., on the New Diggings ridge There are several ranges here having a general east and west course, one of which, known as Champion's old lode, has probably yielded more than any single range in the Lead region. This and the other ranges owned by Mr. Champion are drained by a level half a mile long. This was completed in the year 1865, at an expense of about seventy thousand dollars. It then drained the ground, and in four years, with the labor of eight men, 5,000,000 pounds of ore were taken out, which sold for about $500,000. This ore was contained in an immense opening, in some places forty feet wide by twenty-five feet high. This principal opening is now worked out, but the range still continues productive, and has been worked uninterruptedly for the last ten years. Average product per year, 85,000 pounds.

Work is now being carried on south of the old ranges, at the western end, in the Myers lot; a shaft has been sunk seventy-three feet to the first opening, which is here about 10 feet high, and from 20 to 30 feet wide. There are here three parallel crevices, one of which is about 8 feet wide. Seventeen men are now employed in the Champion Diggings. Mining is carried on continuously, and the annual product is about 200,000 pounds.

Craig Diggings are situated on the New Diggings ridge on the N. E. qr. of Sec. 26 and N. W. qr. Sec. 25, T. 1, R. 1 E. There are here three principal east and west ranges, a few feet apart. The one which is now worked is known as the Simpson Pump range. These ranges were discovered in 1834. In the spring of 1874, a shaft was sunk on one of them, and they are now worked in the second opening. They produce only lead ore, found in a flat opening which is 100 feet wide, and has been worked to a length of 150 feet. They are worked only in the winter; and produce 40,000 pounds per annum.

Craig, Sanders and Campbell. Work was commenced by this party in the fall of 1874, on the east end of the Simpson Pump range. The mining is carried on in the first opening. The product has been 258,000 pounds, the greater part of which was produced this year (1876). The extreme west end of this range has been worked by Craig, Stephens & White, during the past year, but has not yet produced anything.

Craig Level Company. A company consisting of several persons residing in New Diggings and the adjacent towns, and representing an extensive capital, have been engaged for several years in running a level on the south side of the New Diggings ridge, for the purpose of unwatering the extensive east and west ranges on and near the summit of the ridge. It is already so far advanced that it has lowered the water in the mine several feet, sufficient to admit of the production of enough lead ore to more than defray its expenses. Mining is now carried on on Pump range, the Mitchell range, and several others; the company are making several "crosscut drifts" for the purpose of prospecting their ground. The following are the principal mining operations now (Oct., 1876) in progress here.

On the ground owned by Mr. Craig there are two men working the level; two men working south on a cross cut from the pump shaft range; and two men working a cross cut north from the same range.

On the ground owned by Mr. March are four men working westward, and producing lead ore from the pump shaft range, and two men working a cross cut from the same range southward.

On the ground owned by Mr. Bird there are four men prospecting on the eastern part of the Mitchell range, and four men working on an opening of that range, raising ore; also two parties of three men each prospecting on the east end of the pump shaft range.

On the Dutch lot are two men drifting from the Mitchell range southward; two men cross cutting from the same range northward; three men working westward on the range, and producing ore; two men working a sheet of ore on a north and south range.

On the ground owned by Craig and Dunlap are three men working an old east and west range on the ridge; and three men prospecting and raising ore.

The mining operations of the Craig Level company have been very productive of lead ore. The amounts produced previous to 1874 could not be ascertained. During the year 1873 it was 70,000 pounds, and from March, 1874, to October 1, 1876, the product was 2,075,470 pounds.

Brown, Dodge & Co. This party, consisting of four men, have been working on the west end of the Mitchell range, on land owned by Col. S. Scales. The product has been 10,400 pounds, all raised within the last year.

Harper, Hird & Co. Situated on the New Diggings ridge, a short distance west of the Craig diggings, on two east and west ranges, known respectively as the Wiley and Engine, on which the water has been reduced about four feet by the Craig level. They were quite large ranges, and were extensively worked many years since. Work was resumed on them by the above parties in February, 1873. Since then, the product has been 303,000 pounds. The crevice of the Engine range is here about three feet wide, and the ore makes in the first opening; while on the Wiley range the crevice is ten feet wide, and the ore makes in the crevice and not in the opening. The ground is owned by Col. Sam. Scales, and four men are employed.

The existence of lead and zinc ore in the upper pipe-clay opening (upper surface of the Blue limestone) is also known at New Diggings. A mining company, known as the Occidental, was in operation in 1873, by whom a level had been run on this opening, which resulted in the discovery of a flat sheet of blende or lead ore. No work has been done here recently, but the prospect is considered good.

Catchall Diggings. N. W. qr. Sec. 30, T. 1, R. 2 E. These diggings have in former years produced large quantities of ore; exactly how much could not be ascertained. After lying idle for some years, work was resumed on them in 1870, by S. and C. Vickers, J. and T. Peacock and John Henry. They were worked for a year with a horse-pump, and after that with a steam-pump, the former having been insufficient to remove the water. There are here two north and south ranges crossed by several east and west ranges, which produced blende and lead ore. The pump-shaft is located on one of these crossings, and is 48 feet deep. A series of levels was run from here to the New Diggings ridge by which it was ascertained that the top of the ridge was on a level with the bottom of the shaft; which shows that the openings existing at this place are above those at New Diggings, and probably near the middle of the Galena limestone. The Catchall diggings ceased being worked in January, 1873. The pump and engine still remain on the ground. The product during the three years of working is said to have been two million pounds.

Howe & Alderson. S. E. qr. Sec. 15, T. 1, R. 1 E. This ground is situated a short distance north of the Democrat furnace, and belongs to the Leakley estate. The range was discovered and worked about 1847, and work was resumed on it by the present parties about fourteen years since (1862). The general course of the range is east and west; the extent of the drifts is from 300 to 400 feet, in the course of which five flat openings and one crevice opening have been found. The flat openings are not far above the Blue limestone. There are eight shafts going down to the openings, from 30 to 80 feet deep. The ore is generally small with wash-dirt, but little large or "chunk-mineral" is found. The diggings are entirely free from water. During the past fourteen years they have produced about 1,000,000 pounds. Work was suspended here about January 1, 1876.

John Rain & Co. S. E. qr. Sec. 31, T. 1, R. 1 E. The land is owned by Messrs. Hodge & Scales and the Field estate. The course of the range is N. 5° E. It is known as the Raspberry range, from the name of the man who discovered it in 1849, and sometimes as the Dinsell range. The workings are all in the first of the New Diggings opening, although the second has also been reached. There are five shafts down to the opening, and about 500 feet of drift. The opening is quite variable in size, and is sometimes as much as thirty feet wide. The ore occurs as wash-dirt, although large pieces are occasionally found. The diggings have been worked for lead ore during the last seven years, since which time Messrs. Rain & Co. have taken out as follows: 1871, 50,000 pounds; 1872, 100,000; 1873, 75,000; 1874, 75,000. The product for 1875-6 was not learned, but the mine is now productive.

Diggings on the Leakley Estate.

Robbins & Bros. Four men have been employed here during the last year, working an east and west range with a horse pump. The amount raised is not known, but it is understood that the ground yields enough ore to pay good wages.

Hall & Rain. S. E. qr. Sec. 23, T. 1, R. 1 E. This is a new east and west range on the Leakley estate, discovered in 1873. The ore occurs in a crevice opening from 40 to 45 feet below the surface. Four shafts have been sunk in it, and one drift run a distance of 400 feet. About 119,000 pounds have been produced since they were discovered. Work was suspended this year (1876).

E. Ashworth Diggings. S. E. qr. Sec. 24, T. 1, R. 1 E. This is an east and west range on the Leakley estate, discovered in the fall of 1873. The workings at this place are confined by water to the first opening, which is here crossed by numerous quartering swithers from four to six feet apart. The crossings are the most productive parts of the opening, and the ore frequently comes up to the surface clay. At the time they were visited, June, 1874, five shafts had been sunk about 35 feet deep; one of the drifts was about 100 feet long, and there were several of 50 feet each. The product to that time was 4,000 pounds of lead ore, and fifteen tons of drybone. They have been working continuously since, producing small amounts.

Phoenix Lead Mining and Smelting Co. Sec. 13, T. 1, R. 1 E. A great deal of mining has been carried on here since a very early day, and the ground has been very productive of ore. The principal vein, which is known as the Ellis sheet, was discovered by a miner of that name, about thirty-five years since. Its course is N. 20° E., and it has been worked for a distance of about half a mile. The workings so far have been confined to the Galena limestone, of which there is a thickness of 150 feet at the pump shaft, at the summit of the ridge. This shaft has been sunk to a depth of 115 feet, leaving thirty-five feet of the formation unexplored, exclusive of the underlying Trenton limestones, which have here a thickness of about fifty feet. The sheet of ore is nearly perpendicular, and varies from two to eighteen inches in thickness as deep as the shafts were sunk. The same system of surface mining obtained here as at other places, by means of which the ore was extracted down to the natural water level but a short distance below the surface, leaving the main body of ore untouched. In this manner more than 2,500,000 pounds of lead ore were obtained. In the year 1865 a level was commenced with a view to drain the ground, and was prosecuted with slight intermission until 1872. Its present length is 1,700 feet, and when completed it will drain the ground to a depth of 135 feet. Several other large east and west ranges traverse this ground, among which are the Bobineau, and the Dowd & McGinnis, on the W. hf. of the S. E. qr. of Sec. 14, T. 1, R. 1 E., which have yielded heretofore not less than three million pounds.

SHULLSBURG DISTRICT.

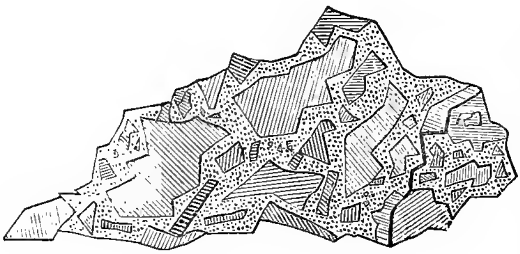
Stopline Diggings. The property is situated on the N. W. qr. of Sec. 28, N. E. qr. of Sec. 29 and S. E. qr. of Sec. 20, all in T. 1, R. 3 E. Although the mine is not in operation, it is in a condition to be worked on very short notice.

The following information in regard to it was obtained from the owner, Mr. Edward Meloy, and personal inspection of the ground. Nearly if not quite the entire thickness of Galena limestone is present at this locality. The northern outcrop of the Cincinnati group is found about a mile to the southwest. The pump shaft has been sunk in a natural chimney to a depth of 112 feet below the surface, and has now reached what is known as the green bed or cap of the Shullsburg openings. The water was removed by an engine and lifting pump discharging 500 gallons per minute. All the water came up in the shaft through the chimney. While the pump was in operation, two springs situated respectively one-half mile east and northwest of the shaft ceased to flow. There are two principal ranges here, one bearing N. 30° E. from the pump shaft and worked for a distance of 800 feet northeast of the shaft, and the other bearing N. 10° E, about 140 feet west of the shaft worked about 500 feet, connected by a quartering range running north of east.

These ranges were struck in 1863, and worked until 1869, and are thought to be a continuation of the Shullsburg elevator ranges. Two shafts, sunk on the range, bearing N. 30° E., have turned out 1,000 pounds to the foot without any drifting and the whole tract within an area which would be embraced within three acres of ground has produced about 600,000 pounds. In every shaft from which ore has been raised, the indications of large bodies below are very strong,

A very peculiar formation was found in sinking on the N. 30° E. range. Commencing at a depth of 35 feet from the surface, a hard brecciated limestone sets in, filled with pyrites, and in some cases with galenite; this formation continues as deep as the shafts were sunk. This was not found on other ranges in this locality, and is a mode of occurrence peculiar to one range.

FIG. 17.



VEIN-STONE BRECCIA, STOPLINE DIGGINGS.

The breccia consists of small, angular pieces of Galena limestone, similar to the adjacent rock of the formation. It appears to have been caused by the undermining and falling in of a portion of the formation, by a previous subterranean drainage. The rubbing and grinding of the sides of the fissure against each other in the course of the movement broke off pieces of various sizes, and the interstices and cavities were subsequently filled with pyrites.

McNulty Mine. In June, 1873, work was recommenced on these old ranges. and considerable capital expended in erecting new machinery and buildings, the old ones having been previously burned. It is now owned and operated by Messrs. J. M. Ryan, of Galena, and M. A. Fox, of Shullsburg.

The mine is situated on the N. E. qr. of the N. E. qr. of Sec. 15, T. 1, R. 2 E., a short distance south of the village of Shullsburg. There is here a thickness of about 200 feet of Galena limestone, or four-fifths of the entire formation. The ore is obtained in the usual opening common to all the mines of the Shullsburg district, between what are known as the green and clay beds, of which the green bed is regarded as the top and the clay bed as the bottom of the opening. In this mine the following stratigraphical information was obtained: Five feet below the clay bed, and 150 feet below the surface is an opening, and a bed of white rock two feet thick, then a layer of hard gray rock three feet. Below this was found a flat sheet of galenite, mixed with pyrites, and indications of an opening below. It is a peculiarity of the mining ground on this ridge, that all crevices south of the Shullsburg branch pitch or dip to the south, about six inches in ten feet, until the summit of the ridge is reached. Here, as in the south shaft of the McNulty, the crevices are vertical. In this shaft the crevice penetrates through the clay floor, and continues on going down, being the only crevice which has done so. Proceeding further south, over the crest of the ridge, the crevices all dip or pitch to the north. Taken together, this system of crevices seems to present a fan-like shape, approaching one another as they descend. In the spring of 1876, a new east and west range was discovered in this mine, south of and parallel to the one already worked. It promises to be very productive of lead ore. The production of this mine from June 1, 1873, to March 1, 1876, is as follows: 1873, 200,000 pounds; 1874, 150,000 pounds; 1875, 75,000 pounds; 1876, 210,000 pounds.

Rickert, Stevens & Co. These diggings are situated on the N. W. qr. of the N. W. qr. of Sec. 14, about 500 feet east of the McNulty mine, and connected with it. Their geological position in respect to strata and openings are almost the same. The ore is found in the usual Shullsburg opening, but in a few instances it runs above it for a short distance, and then drops down again, presenting a saddle-shaped appearance. At the south shaft the rock is very much disturbed and broken, apparently in an area of about 200 feet in diameter. It is in loose masses of all sizes and shapes, containing more or less ore scattered through it, and the fine earthy material known among the miners as sand. The strata pitch in every conceivable direction and degree, from horizontal to vertical, crevices and veins cannot be followed through it with any degree of certainty; but at the borders of this disturbed area, as well as above and below it, the strata have their normal position, which is nearly horizontal. This is merely a local disturbance, and is probably due to the unequal hardness and solubility of the formation. Considerable of the limestone seems to have been removed by currents of water running through the opening, thus permitting large and small irregular masses to fall from above, and filling the interstices with the fine insoluble residuum of sand.

In connection with this irregularity was noticed a remarkable "chimney" about 36 feet long by 20 feet broad, and extending upward further than has yet been followed. It was originally filled with loose masses of galenite rock and sand. In the ground on this ridge the strata dip on both sides toward the north and south line between Secs. 14 and 15, on the west side about four feet in a quarter of a mile, and on the east side one foot in thirty rods. The ground is drained by a horse-pump into a level a short distance below the surface. The mine produces very handsome cabinet specimens of galenite and calcite, in the form of dog-tooth spar.

The following section will serve to convey a general idea of the arrangement of the strata on this ridge:

Soil and clay	6 to 10	feet
Galena limestone	100	"
Flint bed	4 to 8	"
Green bed to clay bed, including the opening	14 to 18	"
Galena limestone to top of Blue limestone	65	"
Total average thickness	195	"

This may be compared with the section taken at New Diggings, and given on page 710 of this report. Reckoning upwards from the top of the Blue limestone to the top of the green bed, or cap of the Shullsburg opening, the distance is found to be about 80 feet, and in the New Diggings section, from the top of the Blue limestone section to the top of the flinty rock, which is the cap of the third or main opening, the distance is 82 feet.

This establishes an identity of geological position of these two points. Measuring downward from the cap in the Shullsburg opening, its average distance is found to be sixteen feet to the bottom of the opening. In the New Diggings section the same distance includes all that lies between the top of the third and bottom of the fourth opening, and finally each is underlaid by about the same thickness of unproductive rock. The correspondence between these openings is thus very distinctly marked. The unproductive beds in the New Diggings openings seem to disappear on going eastward, and finally the openings unite on reaching Shullsburg.

In regard to the production of these diggings, it is estimated that the S. hf. of Sec. 10, and the N. W. qr. of the N. W. qr. of Sec. 14, being an area of one mile long on a course S. 70° E., and three-quarters of a mile wide, including the McNulty and Rickert's diggings, have produced since the commencement of mining operations not less than 100,000,000 pounds.

The preceding information in regard to the mine of Rickert, Stephens & Co. was obtained at the time I examined them in June, 1873. Since then I have recently received the following information concerning them from Mr. John E. Hoover, of Shullsburg, to whom I am also indebted for valuable information relative to the Irish Diggings and the McNulty mine:

"The bearing of the crevice on which we (Rickert, Stephens & Co.) are now working is due east and west. The mineral is found about 12 feet below the green bed or cap, and is mixed with sulphur (pyrites). The rock is different from any before taken out of the mines in this section. It is a dark blue, and mixed with sulphur and flint, and is very hard. In the opening there is copper rust or verdigris mixed with large balls of sulphur. Dog-tooth spar or tiff is also found in large quantities, most of which is attached to the mineral.

"The company commenced work in 1849, and on the present range in May, 1874. They are now operating a steam pump on what is supposed to be a continuation of the South digging range. The product from June 1, 1873, to March 1, 1876, is as follows: 1873, 377,120 pounds; 1874, 201,966 pounds; 1875, 318,690 pounds; 1876, 153,720 pounds."

Silverthorn Mine. N. W. qr. Sec. 32, N. E. qr. Sec. 31, T. 2, R. 2 E. The greatest thickness of Galena limestone found on the ridge was about one hundred feet. The ground is drained by a level run in the carbonaceous shale, on the top of the Blue limestone, which has here a very great thickness, being nowhere less than two feet, and in some places seven and a half feet thick. It seems in this mine to replace the pipe-clay opening. It is very easy to work, and consequently this level has been comparatively inexpensive. This shale, when dried, burns with a bright yellow flame and much smoke until the carbon is exhausted, but owing to the amount of calcareous matter it contains, it is not much reduced in bulk. These diggings produced in 1871, 200,000 pounds, and in 1872, about 100,000 pounds. Their product in previous years could not be ascertained. Work was suspended on them in 1875. An analysis of lead ore from the Silverthorn mine gave the following results: Lead sulphide, 97.06; metallic lead, 84.07; insoluble silicious residuum, 1.76.

Dry Bone Diggings. Situated on the S. W. qr. of the S. E. qr. and the S. E. qr. of the S. W. qr. of Sec. 4, T. 1, R. 2 E. The ranges here run in nearly an east and west direction. The diggings are situated in the lower strata of the Galena limestone; the top of the Blue limestone is found a short distance down the stream. Although shallow, these diggings have been very productive of zinc ore, and are still successfully worked.

Irish Diggings. Sec. 2, T. 1, R. 2 E. These diggings have not been worked for many years on account of water, but were formerly very productive and were abandoned with ore going down in the crevices. The greatest thickness of Galena limestone on this ground is about 150 feet. They could be readily unwatered by means of a level from some point on the Shullsburg branch.

Meloy and Fox. In the early part of the year 1875, that part of the Irish Diggings known as the Findley Cave range was leased by Messrs. E. Meloy and M. A. Fox, of Shullsburg. It is situated on the N. E. qr. of Sec. 2, T. 1, R. 2 E., and comprises 99 acres of land, lying about a mile northeast of the village. The range was worked during the months of April, May and June, 1875, and in November of that year a steam engine and pump were erected, and it has been worked continuously to the present time (November, 1876). The pump shaft is now about 80 feet deep. Water is discharged into an adit connecting with the shaft at 20 feet below the surface, at the rate of 150 gallons per minute. The course of the vein is N. 7° E., having a dip to the eastward of four feet in one hundred. The distance between the walls of the vein or crevice varies from two and a half to seven feet, the space between them being filled with the vein matrix common to this neighborhood. The bottom of the pump shaft is six feet below the top of the flint beds (see section on page 715). The vein appears to continue downwards, the filling of the crevice being loose and allowing the water to pass readily through it.

After sinking the pump shaft, the vein was drifted in, a distance of 60 feet to the northward; in the course of running this drift, 100,000 pounds of ore were extracted.

The foregoing remarks show the condition of the mine in March, 1876. The production since then we have not learned.

This range was worked more than 30 years since, with a two-horse pump, as deep as water would permit, and large quantities of lead ore were obtained. These diggings could be unwatered to a much greater depth by means of a level from some point on the Shullsburg Branch.

Bull Pump Range. Work is still carried on, on this range, which is situated on the Hempstead estate. It is operated by Messrs. Beebe, of Galena, and Wetherbee, of Shullsburg. The amounts produced could not be ascertained.

Oakland Mining Co. The lands of this company are situated in the S. E. qr. of Sec. 6, the N. E. qr. of Sec. 5, the N. W. qr. of Sec. 4, and the S. E. qr. of Sec. 4, all in T. 1, R. 2 E., comprising in all about 565 acres.

This ground includes the old French range, which was discovered as early as 1839, and produced not less than 1.000,000 pounds. It is connected northward by some quartering crevices, and is known as the Earnest and Townsend range.

The thickness of Galena limestone here is about 170 feet. There are six shafts on the range, averaging about 50 feet each. The lead ore is abundant, but dips rapidly to the northwest beneath the water. The range has produced about 400,000 pounds.

The ground is susceptible of drainage from the Shullsburg branch. It is not worked at present.

The company also has a level nearly completed in the S. E. qr. of Sec. 4, which is run on the stratum of carbonaceous shale, or the top of the Blue limestone. At the working shaft there is a thickness of 90 feet of Galena limestone, of which the following section is given:

	Feet.
Clay and soil	18
Yellow flinty limestone	16
Galena limestone containing calcite	20
Blue sandy limestone cap	6
Red ochery clay with lead ore in flat sheets at top and bottom, also diffused through the mass forming wash-dirt	12
Unexplored beds	18
Total thickness	90

Considerable mining has been done in former years in the Blue sandy limestone member of the section, but the main opening appears to be in the red-ochery clay which underlies it, which, so far as explored, has been found to have a thickness of about twelve feet, and to contain a flat sheet of galenite nearly continuous, and of variable thickness, sometimes furnishing pieces of 500 pounds weight.

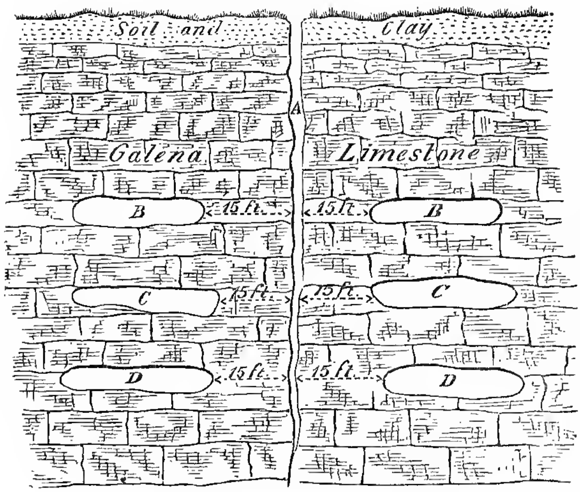
The bearing of the sheet, so far as has been determined, is west of north and east of south, with a slight dip to the southwest. Its area has not been determined, but so far as has been worked there are no indications of the opening, contracting or closing up.

BENTON DISTRICT.

In the immediate vicinity of the village of Benton, there are several parties permanently engaged in mining, besides others who mine only in the winter. The diggings are in the lower beds of the Galena limestone, yet not so low as the brown rock.

The mode of occurrence of the openings in this vicinity is quite remarkable, and is as follows: There are numerous well defined north and south and east and west crevices, which are followed down with shafts until the random of the openings is reached. At this point, instead of the crevice leading into and being connected with the openings, as is usually the case, the crevice usually closes up, and it is necessary to drift at right angles with the crevice for a distance of from ten to fifteen feet on each side, where the openings are usually found. The annexed diagram illustrates the relative position of the openings. A represents the vertical crevice on which the shafts are sunk. The distance from the surface to the top of the first opening is from five to fifty feet, according to the amount of denudation of the ground. B B represents the first opening, which is a flat flint opening four feet high. C C represents the second, which is also a flat flint opening, four feet high. D D represents the third, which is not a flint opening. It is about four feet high, similar to B and C. The distance between the first and second openings is four feet of unproductive cap rock; between the second and third, ten feet of similar rock. The openings are about fifteen feet wide, and sometimes as much as four hundred feet long.

Fig. 18.



Section of the Benton Opening.

Having described the position and mode of occurrence of the ore, the different diggings now in operation will be described.

Bainbridge & Vipord. S. E. qr. Sec. 8, T. 1, R. 1 E. This is an east and west range somewhat near a mile long, which was worked about twenty-two years since and abandoned. Prior to 1854, it produced about one and a half million pounds. About seven years since some work was done on it, and one million pounds were produced. Work was recommenced on the eastern end by the present parties in February, 1874, and has continued to the present time (November, 1876). The annual product is about 20,000 pounds. During the last year and a half they have been worked with a horse pump.

Bainbridge, Mundy & Maighn. This is a quartering southwest and northeast range, about 100 yards north of the preceding. This range was never worked previous to March, 1874. It is now worked only in the winter seasons. It has produced in all about 50,000 pounds. The ore in these diggings and the preceding is found in openings detached from the main crevice.

Metcalf, Harker & Alexander. N. W. qr. Sec. 9, T. 1, R. 1 E. This ground is situated on what is known as the Swindler ridge. It derived its name from the custom which formerly existed among the miners of cutting through and breaking into each other's ground to steal the ore, which the complicated nature of the openings enabled them to do. This range was struck in 1871, and has been worked continuously ever since. The depth to the top of the first opening is fifty feet at this shaft, and on the ridge generally, although the opening is said to dip slightly to the west. Some water is encountered on the ridge, and the present parties have found it necessary to work a two-horse pump. The production to November 1, 1876 has been 600,000 pounds.

Bainbridge Diggings. Situated on the E. hf. of the N. E. qr. of Sec. 4, T. 1, R. 1 E. Work was commenced here by Mr. Thomas Bainbridge, of Benton, in the winter of 1874. In May, 1875, an irregular deposit of lead and zinc ore was discovered about fifty feet below the surface, having a course a little west of south. Three men are usually employed. Its production has been 25 tons of Smithsonite and 25,000 pounds of lead ore.

Harvey's Diggings. Situated on the same ground, and about 250 yards northwest of the preceding. Work was begun here in the winter of 1875–6, and a large flat sheet of Smithsonite was discovered, which has been worked over 200 feet in diameter without reaching unproductive ground. It is found about 50 feet below the surface in the random or horizon of the flat flint openings. The ore is found in flat sheets interstratified with the formation. One hundred tons have been produced.

McElroy Bros. Situated half a mile south of the village of Benton. This is a new discovery, made in the winter of 1875–6. An irregular flat sheet of Smithsonite was found at a depth of 50 feet below the surface, from which in two months, 15 tons of ore were produced. Work was then discontinued during the summer. The above parties intend to work it again in the winter.

M. J. Williams & Co. Situated on the S. W. qr. of the S. W. qr. of Sec. 3, T. 1, R. 1 E. A large flat sheet of lead ore and blende, about one foot thick, was discovered in July, 1876, in the bed of Fever river, soon after a heavy flood which took place at that time. It lies on the upper surface of the Blue limestone, and on account of its situation in the river, but little has been done with it. It is an excellent prospect, and will doubtless be remunerative, as soon as the water can be removed.

McCaffery, Smith & Co. In the middle of October, 1876, these parties commenced work, sinking a shaft on the west line of the forty of M. J. Williams & Co. They found the same sheet of ore as there described. In the space of two weeks they had developed a fine prospect, and had produced about one ton of ore.

Level Company. On the N. W. qr. of Sec. 29, T. 1, R. 1 E., a level is now being run by Messrs. Stevens, Mason, Miller. Robbins, Broderick, Hoover, Thompson, Coltman and Farley, who own and have leased one hundred and thirty-five acres in Secs. 20, 21, 28 and 29. The level was commenced in the spring of 1870, and has now reached a length of one thousand feet. It is being driven on a flint opening near the top of the Brownrock, which is here about fourteen feet above the Blue limestone.

The object of driving the level is to unwater the Drummond range, which runs east and west, and is supposed to be a continuation of the Craw range of Hazel Green, and the Nagle range of New Diggings. It is believed that when the level is completed it will unwater the Drummond range to a depth of forty feet below the present water level.

The level now gives access to two openings in working it, and had, when visited, an inch sheet of lead ore in the working forehead. It may be remarked that these openings are lower than any of the Benton openings, and seem to be identical with those of the Buncome district. The product has been up to the present time 60,000 pounds.

PLATTEVILLE DISTRICT.

The diggings of the Platteville district comprise those situated in the immediate vicinity of the village, the Whig diggings and the Big Patch diggings. The mines near Platteville are all included in Secs. 9, 10, 14 and 15; and of these, the ones chiefly worked are situated on Secs. 9 and 10, a short distance north of the village. The diggings here are very shallow; the deepest shafts are seldom more than thirty feet. The ore occurs in bunches, pockets and small openings in the clay crevices, and often comes up to the surface. Their geological position is about the middle of the Galena limestone. There are no large companies at work in this district, all the mining being done by parties of two or three persons. There are quite a large number of such parties, who form the aggregate production of the district. A few of the more prominent are here given, and their annual production as nearly as could be ascertained.

Stevens & Rowe	40,000 lbs.
Lane & Lawton	60,000 "
Wales & Rowe	50,000 "

C. Cornelius, Jr.	8,000	lbs.
Thompson, Phillips & Colt	12,000	"
Wm. Johnson	5,009	"
Burns & Conley	100,000	"
Sheppard	12,000	"
Leonard Coates	15,000	"
Carlyle, Hendershot & Co.	30,000	"
Other sources in small lots	63,000	"
Total	395,000	lbs.

As most of the mining is done in the winter, none of the above mentioned firms were engaged in mining at the time the district was visited, and we are unable to give a detailed description of the several mines.

Whig Diggings.

This is a small group of east and west ranges in the S. W. qr. of Sec. 7, T. 3, R. 1 W., on the ridge, on the west side of the Platte river, which properly belongs to the Platteville district. More or less mining is done here during all the year. The following informatiou concerning them was obtained from parties now at work there. The diggings are all in the upper beds of the Galena limestone. The principal ranges are as follows:

Gillis Range. This is the longest and largest range in the Whig diggings, being half a mile in length. The shafts are sunk on it from thirty to fifty feet deep, where a crevice opening from three to five feet high is found. There are from three to seven parallel crevices, which were discovered in 1839. Their total product since then has been about five million pounds. The present annual product is 15,000 pounds.

Robbins Range. Situated a short distance north of the Gillis. It was struck in 1840, and produced 500,000 pounds. Work was suspended on it, and resumed in 1866 by Cronin & Stevens, who raised about 300,000 pounds. Less work is now done on it than on any of the others.

Duncan Range. Situated 150 yards south of the Gillis. It is a little more than a quarter of a mile in length. There are here two parallel crevices, and one opening which is from six to twenty feet high, and from five to forty feet below the surface, according to the contour of the ground. It is very hard ground to work, as everything has to be timbered. It still produces a little lead ore and a little Smithsonite, exactly how much could not be ascertained. The total product of the range is said to have been one and a half million pounds.

The relative position of the openings here is as follows:

	Feet.
First opening	6
Unproductive rock	9
Second opening	8
Limestone cap	9
Third opening, height not known.	

Messersmith Range. This range is situated a short distance south of the Duncan, is about a quarter of a mile long, and has but one principal crevice. It is from five to thirty-five feet to the top of the opening; which is from five to ten feet high. The range is now worked out for lead ore, but still produces a small amount of Smithsonite.

Missouri Range. Some work is done on this range at all times. It is situated a short distance south of the preceding, and is about a quarter of a mile long. It has one crevice, and an opening which is about seven feet high. It has produced 650,000 pounds since it was discovered; and its annual yield is about 5,000 pounds.

Dutch Range. The range was discovered in 1840, and has been worked nearly every year since. It is a quarter of a mile long. The ore is found in bunches mixed with blue clay, in the first opening, which is from fifteen to thirty-five feet below the surface. No ore is found in the lower openings. It has produced in all 200,000 pounds, and its present annual average is 5,000 pounds.

Wilkinson and Cronin Range is a quarter of a mile long, and was discovered in 1868. The ore is found partly in the first, and partly in the second openings, which are here eight feet apart. It is from five to thirty feet from the surface to the top of the first opening. There are here two ranges which have produced 300,000 pounds, and the range is now nearly worked out.

Smith Range. This differs from any of the Whig ranges before mentioned, in having its course north and south, instead of east and west. The range is about an eighth of a mile long, and the distance from the surface to the top of the opening is from ten to sixty feet. The sheet was from one to four inches thick, and was worked in one place down to the Blue limestone. The principal bodies of ore were found in the Brown rock opening, which is much lower than the general run of openings at these diggings. The range is said to have produced 200,000 pounds, and is now worked out.

Big Patch Diggings.

The greater part of this group of diggings is situated in section 10, T. 2, R. 1 W. The general course of the range is N. 65° West. The ore is found here in crevice openings, and usually in the first opening. The following parties are now mining here:

Dixon & Coats produced since February, 1876	400,000 lbs.
Casper Linden produced since March, 1876	25,000 "
Tupper & Trowbridge produced during August, September, and October, 1876	12,000 "
Peacock & Co., annual product	18,000 "
Todd & Co., annual product	10,000 "
Haverness & Co., annual product	15,000 "
Spink & Co., annual product	20,000 "

Hawkins, Thomas & Co. S. W. qr. of Sec. 31, T. 3, R. 1 W. This is a discovery of the year 1872. The ore is blende, somewhat mixed with rock, and occurs in a flat sheet on the upper surface of the Blue limestone. The sheet has in some places a thickness of five feet; it lies in the bed of a small stream, and a level to drain it is partially completed. About 27 tons of ore have been produced.

MIFFLIN DISTRICT.

Mining operations here are now chiefly confined to several parallel ranges, having a general northwesterly course, and situated about half a mile south of the village, including the Penitentiary, Dunbar and Owens ranges. The ore is found in flat sheets on the surface of the Blue limestone, in the pipe-clay opening. Some mining is also done on Sec. 10, T. 4, R. 1 E., in the vicinity of the Welsh settlement.

Penitentiary Mine. S. W. qr. of N. E. qr. Sec. 34, T. 5, R. 1 E. This property is owned by Messrs. James, John and Calvert Spensley, Wm. Bainbridge, J. J. Ross, Mrs. Mitchell and N. W. Dean. The mine was opened in 1842, and since then it has been very productive, and has been worked continuously to the present time. The mine is drained by a level containing a tramway on which the rock and ore are carried out of the mine. Sufficient water is removed to operate a large wash place. The distance from the entrance of the mine to the forehead is about 1,700 feet. The average width of the range is about 300 feet, and the thickness of the deposit from six inches to two feet. Fifteen men are now employed here, the average being about twelve. Previous to 1864, the mine was worked chiefly for lead ore, producing in some years as much as 170,000 pounds. It is estimated by Mr. Ross that it produced from 1862 to 1875, 3,000,000 pounds of lead ore and 11,000 tons of blende. The production for 1875 was, blende, 375 tons; lead ore, 35,000 pounds. The production for 1876 was, blende, 600 tons; lead ore, 40,000 pounds.

Jenkins, Miller & Co. These parties have been working during the last two and a half years on the Dunbar range, which is parallel to the Penitentiary, and a short distance north of it. The land is owned by Messrs. Ross & Dean. This range has been worked during the last thirty years, and is drained by the Penitentiary level; the present workings are about 50 feet below the surface. The company produced during the year 1876, to October 1st, blende, 80 tons, lead ore, 8,000 pounds. Their annual average is blende, 80 tons, lead ore, 12,000 pounds.

Rain, Young & Jenkins. These parties are now working on the Blackjack range, which is adjacent to the Dunbar, and sometimes connects with it. The present works are 50 feet below the surface. The ore is found in flat sheets, sometimes 70 feet in width, in the pipe clay opening, the height of the opening averaging five feet. The annual production is from 150 to 200 tons of blende, and from 10,000 to 15,000 pounds of lead ore.

A short distance northeast of the Blackjack is the Owens range. It has not been worked during the last two years, but is considered good mining ground.

CENTERVILLE DISTRICT.

These diggings are like those in the village of Highland, in that they are all situated quite close together, on Sec. 7, T. 6, R. 1 E., on the hill about a quarter of a mile east of the village.

The land is all owned by Messrs. Top, Norndorf & Kroll. The miners are nearly all Germans, from whom the following information was extracted:

The diggings were first worked in 1836, and have been worked continuously ever since, chiefly for lead ore, until within the last ten years, since which time they have been worked for zinc ores. The workings are in the Brown-rock opening, and lie from five to fifty feet below the surface, depending on the amount of denudation. Very little trouble is experienced from water, and during the past two years the ground has been especially dry. The principal parties working here are as follows:

Heller and Parish. These parties are working a southeast and northwest range, 1,200 feet long and 600 feet wide. Their annual product is: Lead ore, 100,000 pounds; blende, 500 tons; Smithsonite, 400 tons.

John Carter and Richard Samuels. On the same range as the preceding. They have worked here two years, and are producing 200 tons of Smithsonite and 5,000 pounds of lead ore per annum. Other parties and their annual products are as follows:

Schock and Flemmer. Blende, 200 tons per annum.

Stepper and Mensing. Blende, 100 tons per annum.

George Wieble. Blende, 200 tons; lead ore, 15,000 pounds.

Blue River Paint Works.

Situated on the S. W. qr. of Sec. 7, T. 6, R. 1 E. At the time this establishment was visited, work had been suspended, and consequently did not appear in as flattering a light as its merits would probably justify. The building and machinery was still standing, in a condition to resume work without delay.

According to the best information obtained, the paint was made from the ocher which is quite abundant in the Centreville diggings, and which furnishes quite a number of shades of yellow in its raw state, and an additional number on being burned. The red paint, however, was derived from the upper bed of the St. Peters sandstone, which was crushed and washed; the red coloring matter being readily dissolved out by the water, from which it afterwards settled on being allowed to stand. The colors after being burned and ground were ready for the market. As many as fifteen different shades of red and yellow were manufactured. Several tons of paint were placed in market, and it was claimed to be a good and durable article. It is unfortunate that the manufacture could not have continued longer, and its qualities been more definitely ascertained and generally known.

HIGHLAND DISTRICT.

The diggings of the Highland district are all situated within a short distance of each other, and about a quarter of a mile north of the village. They are all in the Brown rock, the lower openings never have been proved. Most of the diggings are on what is known as the Drybone Hollow range. The names of parties mining, and the present condition of their diggings, are as follows:

Samuel Hinderleiter & Sons. On the S. W. qr. of Sec. 28, T. 7, R. 1 E., on the Drybone Hollow range. This is an east and west range from one-quarter to one-half mile long, and from two to three hundred feet wide. It was discovered in 1846, and worked entirely for lead ore. It is now divided into small lots of which Mr. Hinderleiter's is one. The work is chiefly confined to going through the old diggings and taking out the Smithsonite left by former miners, no blende being found. The shafts are about twenty-five feet deep, which brings them to the top opening, three feet in height. The ore is found in a flat sheet, about a foot thick, with ocher and clay above and below it. But little water is found here. The annual product of this lot is about thirty tons of Smithsonite.

Mulligan & Francis. These parties have diggings in all respects similar to those already described, on a lot about 150 feet northwest of the preceding.

Maguire, Kennedy & Co. S. E. qr. Sec. 28, T. 7, R. 1 E. This is also on the Drybone Hollow range. The shafts here are from sixty to seventy-five feet deep, according to the surface of the ground. The workings are in the Brown-rock opening, which is here about eight feet high. The lead ore is found in a flat sheet in the bottom of the opening, underlaid by pipe clay.

The blende was discovered in the spring of 1874, and is much mixed with rock. The ore has to be crushed, washed and separated. Water is removed from the diggings by means of a windmill and small pump, and is afterwards utilized to wash ore. The annual product is as follows: Lead ore, 200 pounds; blende, 100 tons: drybone 50 tons.

Blackney, Donahue & Co. This ground is owned by Dr. Stanley of Highland, and is a part of the same range as the preceding, and situated but a short distance northeast of them. The range here makes two well-defined openings separated by a cap-rock. It is irregular in shape, and about sixty or seventy feet wide, with little water.

The following is a section of their principal shaft.

	Feet.
Galena limestone	60
First opening	9
Cap rock	2
Second opening	4

The ore is found in flat sheets, and is Smithsonite, blende, and lead, the former being rather impure. The present parties have been working here for the last seven years. The annual product has been as follows: Lead ore, 11,000 pounds; Smithsonite, 35 tons; blende, 35 tons. The ground here seems to be pretty much worked out, the product being chiefly derived from the old workings.

Spensley & Co. This is also on the land of Dr. Stanley, and is a short distance east of the preceding. It is an east and west range, situated a little north of the Drybone Hollow range. The range is 130 feet wide, so far as has been worked, and may prove to be 200 feet in width each way from the center. The ore makes in pitches, and the sheet varies in size according to the number of feeders coming in from above. The lead ore occurs much mixed with rock, which necessitates crushing and jigging the entire product.

The lot worked by these parties consists of about six acres, of which only about one-sixth has been explored. The ore is blende and lead ore; some Smithsonite is said to be found in the north and northwest portions of the ground, while the blende is found in the southern part. The amount of water here is small, and is all removed by bailing, and hoisting in a barrel containing about 50 gallons.

Three shafts have have been sunk, one of which is down to the Blue limestone, and is 100 feet deep

The company have operated here for six years, with the following product:

Year.	*Blende.* *tons.*	*Lead ore.* *lbs.*
1871	70	60,000
1872	150	120,000
1873	350	150,000
1874	250	160,000
1875	300	257,000
1876	325	300,000

Siddel & Co. They are situated on the same range, worked in the same opening as Spensley & Co., and are located about 150 feet east of them. They are the most easterly of all the diggings in this vicinity. One shaft has been sunk, and the ore has been found to make in the same manner as the preceding, except that this ground already furnishes some Smithsonite from the north side. These parties have been working here for the last five years, during which time the average annual product has been as follows: Lead ore, 70,000 lbs.; Smithsonite, 85 tons; blende, 70 tons.

Flynn, Lynch & Co. On Dr. Stanley's ground, and about 300 feet southeast of Spensley & Co. Their ground is a lot 250 by 350 feet. One shaft has been sunk here 80 feet to the top of the opening, which is here 6 feet high and 100 feet wide. The ground produces lead ore and blende, occurring in a flat sheet, mixed with the top layer of the Blue limestone and some pipe clay. The company has been working about five years, since which time, to October, 1874, they have produced 250,000 lbs. of lead ore and 700 tons of blende.

Robinson's Diggings. Situated about 300 feet southeast of the preceding, on the ground of Mr. Barnard. These diggings are not being worked at present. They were commenced in the winter of 1871-2, and produced 4,500 lbs. of lead ore and about 9 tons of blende in the first two years.

Williams & Edwards. Situated on the land of Mr. Lampe and about 500 feet west of the diggings of Blackney & Co., previously described. They are part of the Spensley and Lynch range.

The works are in the Brown-rock, which here appears to divide into three subordinate openings. A section of their working shaft is as follows, all in the Galena limestone:

	Feet.
Galena limestone	40
First opening	3
Soft, unproductive ground	8
Second opening	3
Soft, unproductive ground	8
Third opening to top of Blue limestone	3

These diggings consist partly of old, and partly of new workings. Cross cut drifts are run through the old works in search of new ground, lead ore being usually found in the lowest opening. These parties have been working since 1870, and their product is as follows:

Year.	Lead ore, lbs.	Smithsonite, tons.
1870	70,000	70
1871	70,000	70
1872	80,000	80
1873	90,000	90
1874	90,000	90

The production of the years 1875 and 1876 was not ascertained.

Harris & Stanley. Situated on the ground of Dr. Stanley, about 300 feet north of the windmill on Kennedy & Co.'s ground, previously described. These diggings are quite dry, being drained by the windmill pump. The range appears to be a branch of the Drybone Hollow range, about 500 feet long, running in a north and south direction. There are two principal openings exhibited in the following section of their working shaft:

	Feet.
Galena limestone	30
First opening	3
Cap rock (limestone)	7
Second opening	6

The ore occurs as usual in this district, in flat sheets. These parties have been working here since September, 1871, since which time to October, 1874, the total product was as follows: lead ore, 40,000 pounds; blende, 35 tons; Smithsonite, 75 tons.

Rowe & Co. Situated on the N. E. qr. of Sec. 28, T. 7, R. 1 E, comprising 160 acres. This is an east and west range, known as the Dunstan, discovered in 1846, and worked continuously since. It is about half a mile long, and 200 feet wide. The range is worked in the Brown-rock opening, chiefly for Smithsonite and lead ore. There are three working shafts from 50 to 75 feet deep. The opening is from 5 to 20 feet high. Their annual product is stated at, lead ore, 50,000 lbs., and Smithsonite, 50 tons.

This was all that could be elicited relative to this ground, as the owners were quite reticent on the subject.

The foregoing comprise all the diggings in the immediate vicinity of Highland, and, with the exception of the last (Rowe & Co.) they are all embraced in a tract of land not exceeding forty acres in extent. The same general geological characteristics prevail in all, and they are nearly all connected together in the workings. The ore in most of them has to be crushed and jigged, and all except Kennedy and Maguire have to haul their wash dirt about a mile and a quarter to water.

In these diggings, the openings below the top of the Blue limestone have never been worked or even prospected. If the several land-owners would take some concerted action, a level might be run up the Drybone Hollow, which would drain them to any depth required. Such a work, however, should be preceded by boring, to ascertain the presence of flat sheets in the lower openings, the existence of which is not improbable.

Mr. Solomon Spensley, who is well informed on the subject, says that the annual average product of the mines is approximately as follows: Lead ore, 1,000,000 lbs.; drybone, 1,350 tons; blende, 1,200 tons. In addition to the preceding, there are some diggings situated south of the village of Highland.

Davis & Co. Situated near the S. E. cor. of Sec. 5, T. 6, R. 1 E. This is a northwest and southeast range, discovered by a Mr. Styles in 1862. It has been proved to a distance of 450 feet, with an average width of 40 feet. The opening is in the Brown rock, and from four to six feet high. There are two shafts, each about 40 feet deep. The ore occurs in flat sheets, and is mostly Smithsonite and blende in about equal quantities, containing little lead ore. The ground was formerly worked chiefly for blende.

The ground is estimated to have produced 2,400 tons of blende, and 1,100 tons of Smithsonite since 1862. Their present annual product is blende, 200 tons, and Smithsonite, 150 tons.

Manning & Delaney. Situated about 600 feet west of the preceding. It is an east and west range which was discovered twenty years since, and has been worked by several different parties, who have proved the ground in the Brown-rock opening for a distance of 600 feet. The present parties have worked it for the past four years, principally for Smithsonite, no blende being found until the spring of 1874. The deepest shaft is only 40 feet; sunk to the top of the Blue limestone, which is here estimated at 25 feet. The St. Peters standstone is plainly seen in the valley a short distance below. The ground produced 600 tons of Smithsonite during the years 1873 and 1874. The diggings are quite dry.

Hornsnoggle Ridge. Situated on the N. E. qr. of Sec. 5, T. 6, R. 1 E. This is an east and west range about half a mile in length, which was discovered about twenty-five years since, and worked for lead ore in the Brown-rock opening; but is now pretty much worked out. The only ore found on the ridge is drybone. The present annual production is about 1,500 tons.

Beginning at the eastern end, and going west, the following parties are working:

Joseph Call. Worked here since 1871, amount produced unknown.

Borey & Newmeyer. Worked since 1872, produced 1,500 tons.

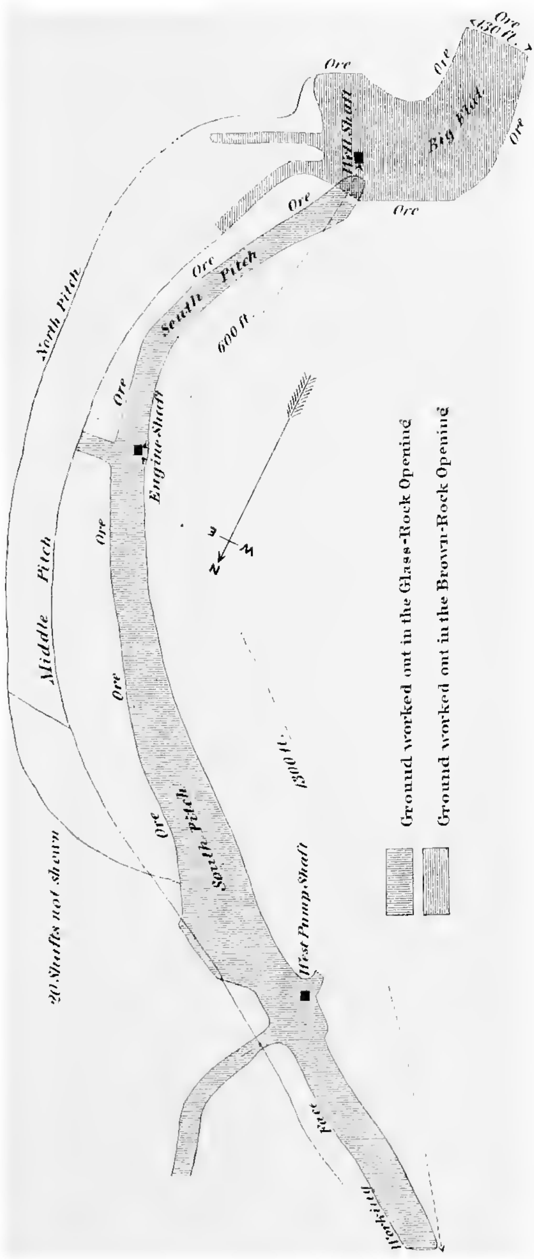
Brinnen & Kelley. Worked on a lot here 20 years, product 1,000 tons.

LINDEN DISTRICT.

The principal diggings in this district are those of the Linden Mining Co., owned by Messrs. J. J. Ross and Wm. T. Henry, of Mineral Point. The property consists of the E. hf. of E. hf. of Sec, 6, W. hf. of Sec. 5, N. E. qr. of S. W. qr. of Sec. 7, N. E. qr. of S. E. qr. of Sec. 7, S. hf. of S. W. qr. of Sec. 8, S. W. qr. of S. E. qr. of Sec. 8, N. W. qr. of N. E. qr. of Sec. 17, S hf. of N. E. qr. of Sec. 17, all in T. 5, R. 2 E., and is situated a short distance west of the village of Linden. They were first opened in 1833, and worked by various parties up to 1853, altogether for lead ore, and in the middle beds of the Galena limestone. Prior to 1853, they are said to have produced 40,000,000 lbs. of lead ore.

In 1853 they were bought by a Pittsburg company, and operated with a water wheel, in the upper and lower pipe-clay openings, also for lead ore. The amount of lead ore produced by them was about 500,000 pounds per annum. The works finally became unprofitable, and were suspended by them in 1866. In this condition they remained until the spring of 1874, when they were bought by Messrs. Ross & Henry, by whom work was resumed in April. They are now operated for blende or blackjack, Smithsonite and such lead ore as incidentally occurs with it. On resuming work the principal operations of the first six months were cleaning out the old shafts and drifts, erecting a new engine of thirty horse power, with a lift pump, together with the necessary buildings, and other machinery. The sheets worked here have a singular complication of "flats and pitches," both in their connection with each other, and in respect to their general course, which can be best understood by reference to Plate XXX. The lines marked North, South, and Middle pitches, are inclined and flat sheets, consisting chiefly of blende, which are now being worked. The shaded portions represent the ground worked out, but leaving along the sides of the workings, and on the unworked portions of the several pitches, a sheet of

PLATE, XXX



THE MILWAUKEE LITHO & ENGR. CO

blende mixed with lead ore and associate minerals, of from one to three feet thick. Attention is here called to the remarkable curvature of the sheets or pitches. Beginning at the well shaft, they take a northeasterly course, curving around to a northwesterly one at the engine shaft, and finally to a westerly one at the west pump shaft. But one parallel case is known in the entire Lead region. It is the Watkins range of the Dodgeville district, situated in the same opening, and worked for the same ore.

Although the blende usually occurs in a large sheet, yet it is frequently connected with two or three parallel smaller ones by veins or "pitches." The sheet often contains detached pieces of the wall or cap-rock, of various sizes, completely surrounded by ore. Large pockets occur in the bed, lined with very handsome crystals of calcite, one of which, recently removed from the mine, measures five feet by two.

Another peculiarity noticed was the fin ing of several pieces weighing from one to five pounds, composed of wall-rock and ore, which were rounded and worn smooth, resembling small drift bowlders. They were found in the lower pipe-clay opening, and had probably been detached from the wall, at its junction with the ore. They must have undergone considerable erosion and transportation, or movement, by subterranean currents of water.

The workings in the vicinity of the engine shaft were first examined. They extend in a westerly direction a distance of 1,300 feet, and have been worked to a width of 45 feet, leaving a sheet of blende on the northern side from one to three feet thick. It has been proved by a cross cut to connect through to the north pitch, a distance of 180 feet. The same sheet has been worked in a southerly direction nearly to the well shaft, a distance of 600 feet, leaving a large sheet of blende on its eastern side. These workings are in the glass-rock opening, and about twenty feet above the St. Peters sandstone.

The following section of the engine shaft will explain their situation:

	Ft.	*In.*
Dump rock, clay and soil	15	..
Galena limestone	72	6
Blue limestone	6	6
Pipe clay	1	..
Glassrock	5	..
Glass-rock opening (workings)	4	..
Buff limestone to bottom of shaft	8	..
Buff limestone to St. Peters sandstone	16	..
Total	128	00

The workings at the well shaft were next examined. They are in the Brown-rock division of the Galena limestone, and about 26 feet above the lower workings. As will be seen on reference to the map, the ground is worked in an irregular shape about 300 feet long, by 150 feet wide

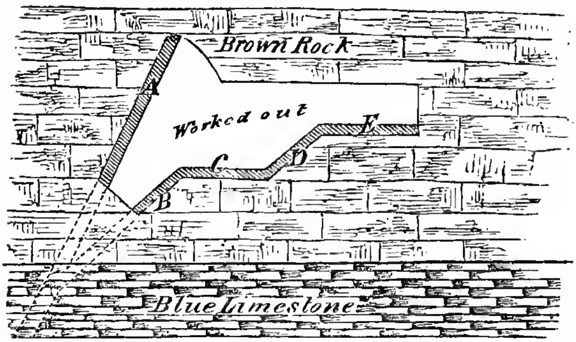
It is estimated that $200,000 worth of ore has been taken, in the course of all operations, from this small, irregular piece of ground. It was full of large flat sheets and pitches, and was worked in some places to a height of 20 feet. It now produces 30 tons of zinc ore per week, and considerable lead ore. This is exclusive of the ore raised by numerous miners working here on tribute.

Fig. 19 illustrates the manner in which the flat and pitching sheets are connected in the ground. It is taken from a point on the south pitch, northeast of the well shaft.

Two sheets were observed. One, A, coming down through the drift, and pitching to the south, and the other coming in from the north on a flat E, making a pitch to D, a second at flat C, and a second pitch at B, through the floor of the drift. At B it is only about three feet distant from the sheet A. It is known from the extension of the works connected with the engine shaft that the two unite below and make a large sheet (as is usually the case), which continues down to the lower opening.

At the west pump shaft a winze[1] was sunk by a former company to a depth of 40 feet in the St. Peters sandstone, with the intention of penetrating through the formation. A small amount of blende is said to have been found, but no regular sheet. Considerable ferruginous matter was also found.

Fig. 19.

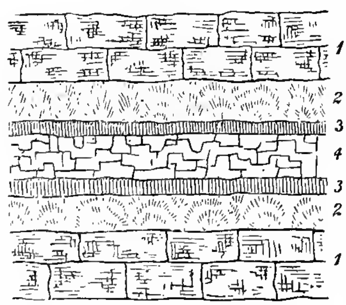


There appears to be no reason why the ground should not continue remunerative for a long time, as it is comparatively easy to work, and the amount of water relatively small. It seems quite likely that these ranges may connect on the north with Morrison's diggings, p. 729, and on the south with the Faul diggings, p. 729; should the latter prove true the mines would all drain into the creek near Linden, and be worked at much less expense.

It is estimated by the owners that during the first six months of their operation, the mine produced ten tons of zinc ores per day; and from that time to the present it has produced twenty tons of zinc per day, and more than 300,000 pounds of lead ore per annum. The value of all ores for the last two years is estimated at $500 per day. The mine now furnishes constant employment to one hundred and eighty miners and other employés. The owners have lately introduced the Ingersoll pneumatic drill with air compressor; and use Rend rock extensively, the explosions being effected by an electric battery.

Poad, Barrett & Tredinnick Bros. S. W. qr. of N. W. qr., Sec. 8, T. 5, R. 2 E. This is a very old mine, the property of Mr. John Heathcock, known as the Robarts mine, on which work had been discontinued for several years, until 1869, when it was again resumed. The present party have been working about four years, and have sunk ten shafts from 40 to 70 feet deep. The water is removed by two horse pumps. To the west of the above parties, and on the same range, are **Kisselbury Bros., Hammerson and Trewatha.** Also on the east end of the same range are the **Poad Bros., Tredinnick, Vial and Geach.**

Fig. 20.



Section of Sheets in the Poad Mine.

1. Galena limestone, cap and floor of opening. 2. Sheet of Iron Pyrites 3 to 4 inches thick. 3. Sheet of Blende 1 in. thick. 4. Sheet of Galenite 1 to 6 inches thick.

The Robarts range has been traced for a distance of a quarter of a mile, the ore being found in flat sheets, 25 feet above the glass rock. The manner in which the ore is deposited is very remarkable, and is shown in the annexed sketch, from which it appears that the order of deposition was, 1st, pyrites; 2d, blende; 3d, galenite. This is one of the few localities in the Lead region from which cerussite is obtained.

[1] A winze is a subterranean shaft which does not extend to the surface.

The three mines on the Robart's range are estimated to produce annually 200,000 pounds of lead ore, and 100 tons of blende.

Treglown & Sons and Capt. Wicks. S. W. qr. of N. W. qr. Sec. 8, on the west side of the Heathcock branch. Wearing & Goldsworthy, owners. This range was discovered about forty years ago, and has been worked continuously ever since. The present company have been working it during the last two years in the glass-rock opening. The ore is found about fifteen feet below the surface; the width of the range is 45 feet, drained by a level 40 rods long. In former years it was worked for Smithsonite at higher levels, and was quite productive. Its present annual production is, lead ore, 5,000 pounds; blende, 100 tons.

Adams & Son and Bowden. These parties are situated about a quarter of a mile southwest of Treglown & Wicks. They have been working during the last seven years on the Morrison range, producing annually about 50 tons of Smithsonite, and 7,000 pounds of lead ore. Water was removed from these diggings by drilling a hole down to the glass-rock opening.

David Morrison Diggings. W. hf. of S. W. qr. Sec. 8. The range is about 700 yards long, 40 feet wide, and has a general north and south course. The range was discovered in 1846, and worked at various times for lead ore to 1874. Mr. Morrison then opened the main sheet of blende, since which time the production has been as follows: in 1874, 90 tons; in 1875, 106 tons. During the present year the mine has not been worked, although it is still good. The range is drained by a level 350 feet long. The ore is found in flat sheets from 7 to 10 inches thick, on the top of the glass rock.

Richards & Faul Bros. These diggings are situated in the village of Linden, near the S. E. corner of section 8, on land owned by Wm. George. The ore is found under the glass rock in a flat sheet from 10 to 12 inches thick, from 15 to 25 feet in width, and from 13 to 30 feet below the surface. The water is removed by a drain about 150 feet long. This mine was discovered in May, 1875. From that time to May, 1876, they produced 80,000 lbs. of lead ore, and 150 tons of blende. During July, August and September, 1876, they have produced 35,000 lbs. of lead ore, and 40 tons of blende.

Thomas Tamblin. Zinc ores were discovered on the N. W. qr. of the N. W. qr of Sec. 10, T. 5, R. 2 E., on the 20th of December, 1875, on the land of Mrs. Thos. Shore. The general course of the range is nearly east and west, and is now worked at an average depth of 10 feet below the surface, and has been proved to a distance of 40 feet. The ore was found as a flat sheet of drybone, cropping out at the foot of a hill; on working into the hill the amount of Smithsonite was found to diminish, and the blende to increase; which seems to be an indication that the Smithsonite is a secondary product, derived from the blende. It is estimated that two miners can produce here 100 tons of zinc ore per annum.

R. S. & W. J. Jacobs. S. E. qr. of S. W. qr., and S. W. qr of S. E. qr. section 7, T. 5, R. 2 E. This mine was discovered in March, 1875. There are here four east and west sheets, from four to six feet wide and from four to six inches thick in the upper pipe-clay opening, separated from each other by six or eight feet of unproductive rock. They are worked about 20 feet below the surface. There is but a small amount of water, which is bailed out. Some very large isolated masses of lead ore have been found here, one of which, weighing 1,527 lbs., was sent to the Centennial Exhibition. Small quantities of zinc ores are also found. The mine produced during the year 1875, of lead ore, 70,000 lbs., and in 1876, 40,000 lbs. The mine has not been worked much during this summer, as the owners are engaged in farming.

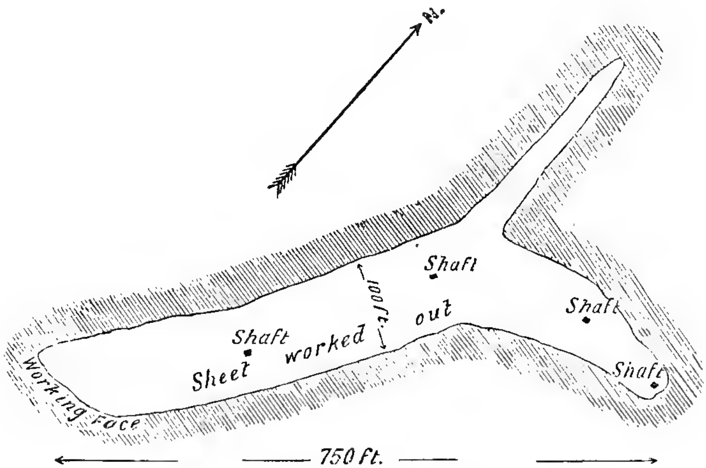
DODGEVILLE DISTRICT.

The mines of this district comprise those in the immediate vicinity of the village; the zinc ore diggings situated about two miles east of the village, and those on Van Meter's survey, about four miles west of the town.

The most productive and profitable are those situated east of the village, worked for drybone, blende and lead ore.

Evan Williams' Mines. S. W. qr. of S. W. qr. Sec. 25, T. 6, R. 3 E. These mines were discovered in 1844, and were worked at intervals until 1853. Since then Mr. Williams has worked them continuously to date. The ore is found in flat sheets about 100 feet wide in the lower beds of the Galena limestone; and the ground is drained by a level a quarter of a mile long. The annexed sketch, made from an underground survey, shows some of the more recent works.

Fig. 21.



Plan of Evan Williams' Diggings.

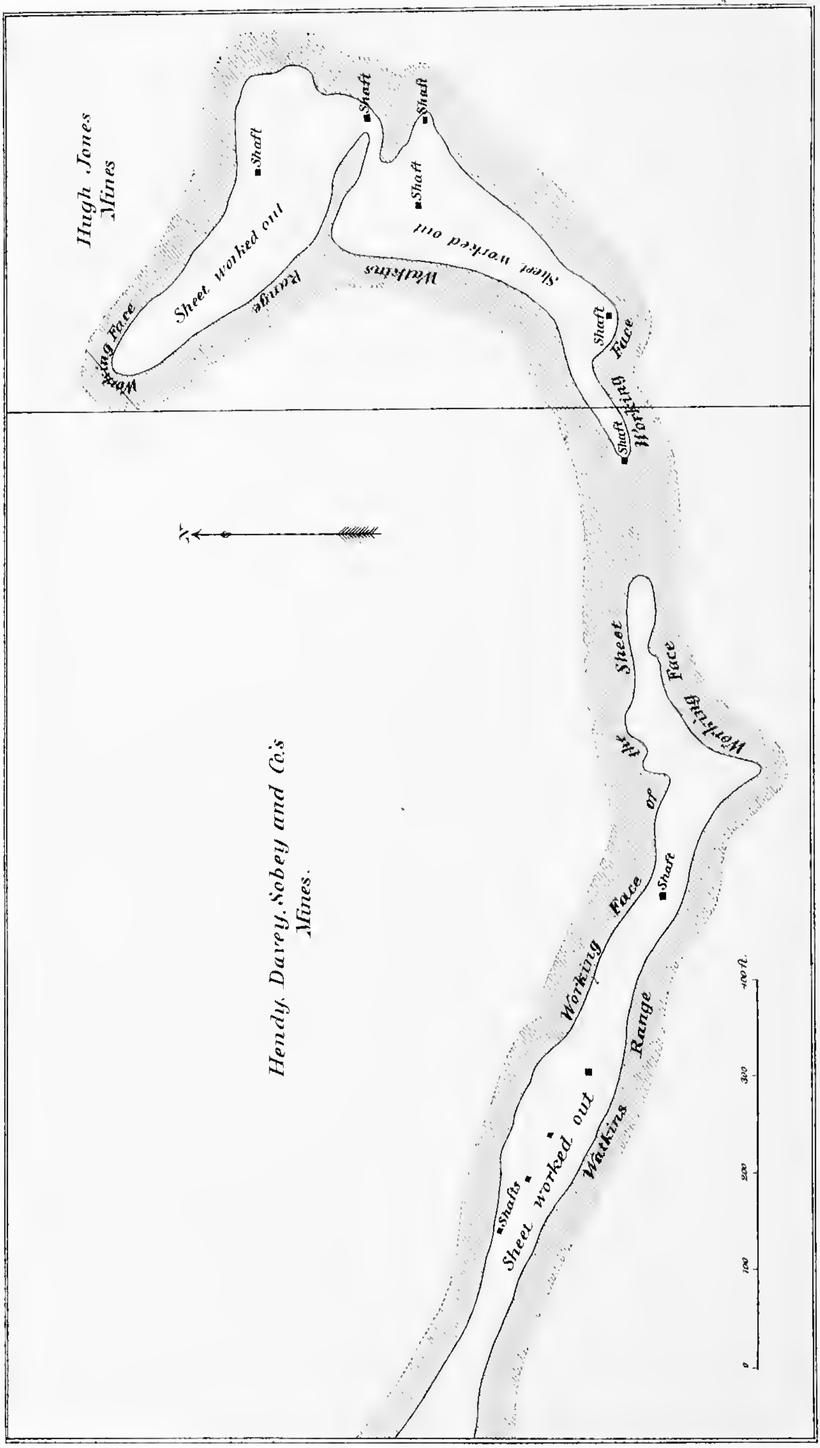
Mr. Williams estimates that this range has averaged 50,000 pounds of lead ore per annum during the last twenty years. Previous to 1863, they were worked exclusively for lead ore. Since then they have averaged 100 tons per annum of blende; the production rising in some years to 200 tons. During the present year (1876) two men have been employed here, and have produced 30,000 pounds of lead ore and 125 tons of blende.

In November, 1875, Mr. Williams commenced working about 700 feet south of the preceding location. A flat sheet was found here at a depth of 90 feet, and has been proved horizontally a distance of 60 feet. This mine in the past year has produced, lead ore 15,000 pounds; blende, 50 tons.

In July, 1876, Mr. Williams sunk a shaft 25 feet deep about quarter of a mile west of the center of Sec. 25, and discovered a flat sheet of blende about five inches thick, from which he has obtained about three tons of blende.

Owens & Powell. On the S. W. qr. of S. E. qr. of Sec. 25 are some small drybone diggings on Mr. Williams' land. Three men are employed here, producing five tons of ore per annum. This is known as Rounds' range.

Jones, Farrager & Owens. S. W. qr. of S. W. qr. of Sec. 25, near the west line of the section on Evan Williams' land. This is an old range which has been worked



The Milwaukee Litho & Engr Co

since its discovery in 1849. The range is drained by a level 300 yards long. The ore is found in flat sheets, from 45 to 80 feet below the surface. Five shafts are now open. These diggings produce only lead ore. The annual product is valued at from $3,000 to $5,000.

Mrddth Evans. N. E. qr. of N. W. qr. Sec. 25, on John Williams' land. These diggings are on Morgan Jones' old range, and have been worked during the last four years for Smithsonite. During the present year (1876) lead ore and blende have been discovered, and 65,000 pounds of lead ore have been produced and considerable blende.

Hugh Jones. N. E. qr. of N. W. qr. Sec. 25. These diggings are on the eastern portion of the Watkins range. They were discovered in 1848. The present party commenced work in 1864. The ore is found in an irregular flat sheet, from 100 to 200 feet wide, in the lower part of the Galena limestone. Its position will be best understood by reference to the diagram of the Watkins range. The annual product of this mine is, lead ore, 25,000 pounds, blende, 150 tons.

Hendy, Davey, Sobey & Co. N. W. qr. of N. W. qr. Sec. 36, T. 6, R. 3 E. These diggings comprise the southern and western portions of the Watkins range. Their position is explained on the annexed map.

Several persons have been engaged in mining here for a number of years. The ore is blende and lead ore, found in a flat sheet in the same opening and position as in the Hugh Jones diggings. The works extend eastward and will ultimately connect with them, the intervening space being about 100 feet. The mine has been and is now quite productive, the exact amount could not be ascertained.

Samuel Clegg. N. E. qr. of S. E. qr. Sec. 26, T. 6, R. 3 E. The land is owned by Mr. A. P. Thompson, of Buffalo. The ore is found in a flat sheet in the glass-rock opening, and is obtained from three shafts, each 100 feet deep. Lead ore only is produced; it was discovered in 1870, and produced in that year 20,000 pounds. Since that time to October 1, 1876 the total product has been 600,000 pounds.

Wm. Carter & Owens. W. hf. of S. E. qr. Sec. 26. Owner of land, A. P. Thompson of Buffalo. This is known as Edward Edwards' range, and was discovered in 1853. The range has a general north and south course, but with some irregularities. It was worked north 500 feet, then west 600 feet, then north; the north and south portions being the most productive of lead ore. The mine is quite wet, but is drained by a level about 2,000 feet long. The number of shafts is nine, the greatest depth below the surface being 70 feet. The length of the drift is 1,250 feet. Mr. Carter has been working this mine for six years. During that time the product of the east and west portion has been 65,000 pounds of lead ore annually, and in the north and south portions 150,000 pounds per annum, with the same expense.

Other parties working in this vicinity are **Nicholas Bailey & Co.** and **John Bosanco & Co.**

Joseph Pearce Diggings. This mine is situated in the village of Dodgeville, a short distance northwest of the court house. It is known as the Lowry range, and was discovered in 1836. It was not worked from 1850 to 1870, when Mr. Pearce commenced work on it, and has worked it continuously ever since. It is worked exclusively for lead ore, which is found in tumbling openings and in flat sheets from 50 to 70 feet wide. The range is drained by a level 800 feet long to a depth of 30 feet below the surface. The deepest shaft is 80 feet.

There is considerable water in the mines, but much less than there was 25 years since. The water is removed by a horse pump worked during the daytime. The length of the range, so far as it has been worked, is 1,000 feet. During the last two years this mine has produced 200,000 pounds of lead ore; previous to this it only paid expenses.

Lambly Range. N. E. qr. Sec. 28, T. 6, R. 3 E. This range has been worked continuously for a great many years, and now gives employment to four men. It produces lead ore to the amount of about 30,000 pounds per annum. Four years ago its annual product was 200,000 pounds.

Porter's Grove Diggings.

These mines are situated in town 6, range 4 east. At present the following mines are in operation:

Union Mine, Wm. Hendy & Co. Situated on the N. E. qr. of the N. E. qr. of Sec. 28. The ore produced is lead, and in tumbling openings, at a depth of 70 feet and on the upper surface of the green rock. From two to five men are employed. The mine is drained by a level one-quarter of a mile long.

Ridgeway Mine, Wm. Hendy & Co. Situated on the S. E. qr. of the S. E. qr. of Sec. 21. This mine is owned and operated by the same parties as the preceding, and is on the same range, which is known as the north and south branch lot. From two to four men are employed. It is also drained by a level a quarter of a mile long. The mode of occurrence of the ore is also the same. The present owners commenced operating them in 1872; since then the product of lead ore is as follows:

	Union Mine.	*Ridgeway Mine.*
1872	300,000 lbs.	44,000 lbs.
1873	35,000 "	44,000 "
1874	16,000 "	63,000 "
1875	38,000 "	44,000 "
1876 to Oct. 1st	22,000 "	17,000 "

Frank, Farwell & Co. S. E. qr. of N. E. qr. of Sec. 28. These parties commenced working on the Wakefield range in Oct., 1875. Previous to that time it had not been worked for twenty years. Most of the workings are at a depth of 35 feet below the surface, although some are as deep as 60 feet. The work is chiefly removing pillars of lead ore which have been left from former operations. The product from Oct., 1875, to Oct., 1876, has been 14,000 lbs.

Other parties mining in this vicinity are **John and Thomas Paull,** of Ridgeway, producing lead ore.

Van Meter's Survey.

On the N. hf. ot the N. E. qr. of Sec. 18, T. 5, R. 3 E., are three very large ranges which have not to our knowledge been reported. Their general course is N. W. and S. E., and they are crossed by numerous north and south crevices. It is at these crossings that the largest bodies of ore are found. The ore is galenite, and is entirely free from any mixture of zinc ores. It is found in the green-rock opening.

The northernmost of the three ranges, known as the Duke Smith, contained an opening in places 50 feet wide, somewhat intersected with bars. It was worked over a quarter of a mile in length, and produced about half a million pounds of lead ore. It has not been worked since 1853.

A short distance south of this is a parallel range which produced over 200,000 lbs. in a distance of about 100 feet. The opening was about 30 feet wide.

The third parallel range, 300 feet south of the Duke Smith range, has been worked since the winter of 1873–4, by Mr. John Hutchinson of Mineral Point. The lead ore occurs in large pockets containing crystalline pieces of from one to five hundred pounds weight. The opening is in the green rock and is from ten to twelve feet high. This range has been the least worked of all, but formerly produced about 100,000 pounds. It now yields ore of the value of $5 per day when worked. None of the ranges have been worked to any great depth, and all were abandoned with ore going down in the crevices. The gradual diminution of water in the country has now made it possible to resume work.

Powell & Co. This party is working on what is known as the Nic Schillen range. Work was commenced in the spring of 1876, and continued for three months. The works are in the glass-rock opening and about 20 feet below the surface. The amount produced was 3,000 pounds.

Richards & Burns. This party is situated south of the preceding, and on land of the Sterling estate. They have been working these during the present year in the green-rock opening, producing about 2,000 pounds per month.

Powell Diggings. They are situated about a quarter of a mile north of Mr. Hutchinson's diggings. This is a new discovery and has been in operation about a year. The production has been 35,000 pounds.

MINERAL POINT DISTRICT.

These mines comprise those in the immediate vicinity of the city, and those of Lost Grove and Diamond Grove. Considerable mining is being carried on at these localities, which are among the oldest and most productive of the Lead region. They are all comprised in towns 4 and 5, ranges 2 and 3 east. In addition to the lead ore, a great deal of zinc ore has been produced within the past ten years, and they now supply a large portion of the zinc ore of the Lead region.

Terrill Range and Badger Range. These ranges are situated on lots 128, 129, 130, 131, 132, 134 of Harrison's survey of the city of Mineral Point. They are old and well known ranges, which have been worked continuously for many years, and are now productive of Smithsonite and galenite. They furnish constant employment to about twenty-five men.

The mines are situated on a high ridge, from which the water drains naturally into the adjacent ravines, leaving the diggings constantly dry. The ore is found in flat sheets and "pitches" (inclined sheets). The ranges are from 150 to 200 feet wide, more than a quarter of a mile long, and contain ore at depths varying from 10 to 60 feet below the surface. There are three principal openings in the lower beds of the Galena limestone. The parties now working on the Terrill range are as follows:

Matt Shields and John Linden. They have been working for three years, at an average depth of 40 feet, producing chiefly Smithsonite from the second opening. The sheet averages about ten inches in thickness.

Pascoe & Collins. They have been working their present mine during the last eight years, producing Smithsonite, blende and galenite from the green rock and the green-rock opening. The Smithsonite is the most abundant, and the lead ore the least so. The workings are from 20 to 60 feet deep, and the ore is found in sheets from one to four inches thick. The blende is found at the greatest depth, and averages about four inches in thickness.

Jacka & Waggoner. These parties have been working here eight years, at a depth of about 50 feet below the surface, but never having reached the lower opening. They estimate their annual production at 15,000 lbs. of galenite and 25 tons of Smithsonite. The range at this point is 200 feet wide.

Hitchins & Terrill. They have been working at various times during the last ten years on the northwest end of the Terrill range, known as the brush lot, producing lead and zinc ore. This was formerly very rich ground. The work at present is confined to prospecting.

Huxtable & Son. These parties are working near the center of the range, and from 20 to 50 feet deep, producing large amounts of lead and zinc ore. This is believed to be one of the best mines on the range.

Parties working on the Badger range are as follows:

Thos. Cox & Sons. These parties are working near the center of the range, and have been mining here during the last ten years. The ore is found in three flat openings. The first is from ten to twenty feet below the surface, and contains chiefly Smithsonite in sheets of three inches thickness. The second opening is ten feet deeper, containing the same ore, mixed with galenite, in sheets of three inches. The third opening is ten feet below the second, and contains chiefly blende in sheets averaging four inches. The description of these openings applies to all the other mines in the range.

Other parties working on this range are **Cox & Co., Jas. Hitchins & Holman,** and **Harris** and partner.

The mining ground on this ridge is owned in small lots by several parties, among whom are Messrs. Ross, Priestly, Tyck and Prideaux. It was found impossible to obtain any information of the amounts of ore produced on this ridge, but it is safe to estimate ore to the amount of $600 per annum for each man, and this is probably much beneath the actual amount.

William Prideaux Mines. S. E. qr. of N. W. qr., Sec. 30, T. 5, R. 3 E. This is a part of the Ashbank range, so called from the decomposed appearance of much of the surface lead ore. It was discovered more than thirty years since, and worked extensively for lead ore. The course of the range is nearly northwest, and its average width about 25 feet. The principal product of the mine is Smithsonite, with some lead ore. The workings are chiefly in the green-rock opening, where the ores are found in flat and pitching sheets, from two to eighteen inches thick. The ground is dry and the workings rather shallow, seldom being more than fifty feet below the surface. In one place, where water was troublesome, it was removed by drilling a hole 54 feet deep, draining it off through a lower opening. During the present year (1876), about 51,000 pounds of lead ore and some blende were obtained in the Brown-rock opening. Mr. Prideaux commenced work in April, 1873, and now employs six men. He estimates that from January 1, to October 1, 1876, the value of ores produced is $6,500, and about the same amount from April, 1873, to January 1, 1876.

A short distance southwest of the preceding, is a parallel range not worked at present, but regarded as a valuable mining ground.

J. Jackson & Co. These diggings are also on the Ashbank range, and a short distance east of Wm. Prideaux. The ores produced are Smithsonite and galenite in nearly equal amounts, found in flat sheets in the green rock, and its opening from 15 to 40 feet below the surface. The range is about 40 rods long and 350 feet wide; ten shafts have been sunk upon it. Work was commenced here in 1868, since which time it has been continuous, the mines proving very productive. No exact amounts could be ascertained, but the owners estimate the value of ores produced since 1868 at $18,000; the present year being the most remunerative.

Mitchell & Pollard. N. W. qr. of S. W. qr. Sec. 30, T. 5, R. 3 E. This range is situated about 60 rods southwesterly from the Prideaux mines. These parties have been working about four years, producing Smithsonite and lead ore. The workings are shallow and dry, similar to the Ashbank range, but not so productive.

Sinapee Diggings. These mines are situated on the N. E. qr. of S. E. qr. of Sec. 30. They were discovered in 1845, have been worked continuously since then, and now furnish employment to several parties, among whom are:

Samuel Prisk and Wm. Paynter. These parties commenced work in the fall of 1875, and have produced during the last year about 50 tons of Smithsonite and some lead ore. The diggings are quite dry and average about 15 feet in depth. The ore is found in flat sheets the principal workings being in the glass-rock opening. Four men are employed here. This mine furnishes fine cabinet specimens of galenite. The range is about 500 feet long, from 100 to 150 feet wide, and has a general east and west course. The ore sheet is from two to four inches thick.

Prisk & Coad. This is a parallel range situated about 300 feet south of the preceding, and having about the same length, width and thickness. The above party commenced work in the fall of 1875, and are now working in the upper pipe-clay opening. This mine is from 50 to 60 feet deep, and formerly produced over a million pounds. Two men are generally employed here, and produced during the last year about 7,000 pounds of lead ore.

Samuel and Wm. Richards. These parties are working a short distance east of Prisk & Paynter. They have been engaged here about a year and a half, producing chiefly blende and lead ore.

Bennett & Brady. Situated near the center of Sec. 29. A large amount of work has been done here, including a level to unwater the ground. They are quite productive of the ores of zinc and lead.

Short & Co. Situated on the N. W. qr. of Sec. 29. Considerable mining has been done by these parties in this vicinity during the last few years.

There are several very profitable mines in the northwestern part of Strong's Addition to the city of Mineral Point, all on land owned by Mr. J. J. Ross. They are as follows:

Bohan & Co. Four men have been employed here during the last four years, producing Smithsonite and lead ore. The range is from 70 to 80 feet wide, has a general east and west course, and is worked to a depth of 70 feet below the surface. There are two openings, separated by about 20 feet of unproductive rock; the lower ore being the glass-rock opening.

Connaughton & Casserly. These parties are working on an east and west range about 300 feet north of the preceding. They have been working here during the last two years, have sunk two principal shafts to a depth of 60 feet, to the glass-rock opening. This is an east and west range, about 60 feet wide, and has been drifted on to a distance of 100 feet. It produces chiefly blende, estimated by the owners at $800 per year.

John Wœgler & Co. Situated about 300 feet northwest of the preceding. These parties are working in the same openings and producing chiefly zinc ores. Until very recently, two other parties were employed in this vicinity, this ridge having for many years been very good mining ground.

Bennett & Co. This party is engaged in mining and prospecting about a quarter of a mile east of the preceding diggings.

Near the corner of towns 4 and 5, ranges 2 and 3 east, are a number of ranges which have been worked for many years. Those situated on section one are the property of the Mineral Point Mining Company; those on the adjacent sections are the property of Mr. John J. Ross.

There are six principal crevices, running nearly parallel, on Secs. 36 and 1. Their general course is S. 70° E., and on entering Sec. 6, they run nearly east and west. The crevices lead down to the opening between the Buff and Blue limestones, known as the glass-rock opening. The ore here is found in a flat sheet about a foot thick, and from 70 to 140 feet wide, which has been worked for a distance of half a mile.

The ores are galenite and blende, and occur associated with barite, and have to be separated before reduction.

The mode of drainage in Mr. Ross' mine is somewhat peculiar. Shafts were sunk at intervals to a depth of six feet below the opening, into the Buff limestone, where a bed is reached through which the water readily passes away. This mode of drainage was accidentally discovered in prospecting for the sheet. No ore of any consequence is found in the upper pipe-clay opening; occasional bunches have been found, probably not over 20,000 lbs. in all. These ranges have been worked at intervals for the last forty years by various parties. Active operations were commenced by Mr. Ross about ten years ago, since which time his ground has produced about 2,500,000 lbs of lead ore, and about 3,500 tons of zinc ores. During the whole time in which these mines have been worked, it is safe to say they have produced not less than eight million pounds of lead ore, and twice as much zinc ores. During the winter of 1874–5, eight men were employed in Mr. Ross' mines and produced ore to the value of $1,600. During the winter of 1875–6, four men were employed, producing ore to the value of $1,000. Work will probably be resumed this winter.

On the lands of the Mineral Point Mining Co. several parties are working on tribute. The amount this ground is producing could not be ascertained.

Goldsworthy & Bro. These diggings are situated on lots 279–280 of Harrison's survey, about a quarter of a mile east of the preceding and on the N. W. qr. of Sec. 6, T. 4, R. 3 E. This is known as the Barber range, and has been worked in the winter season during the last six years.

The ore is Smithsonite, much mixed with pyrites; it is found in the upper pipe-clay opening, in a flat sheet from 8 to 30 feet wide and from 18 to 24 inches thick, being most productive on crossing crevices.

Four men are employed here producing about 20 tons per year.

T. Lutey & Co. This party is working a short distance east of the preceding, on land owned by M. M. Cothren. They have been working on a continuation of the Barber range for about two months (October, November, 1876) and have now a very good prospect.

Most of the lead ore from the Barber range is obtained from the glass-rock opening, but it has never been worked for zinc ore.

Suthers & Co. Situated on the southeast part of Harrison's survey. This is a nearly east and west range, known as the "Walla-walla," and has been worked by the present party since 1865. The range is about 120 feet wide and has been worked in the glass-rock opening to a length of about 1,000 feet, and at a depth of 73 feet below the surface. From three to six men are employed, working in the winter season. The mine produces lead ore and both kinds of zinc ore. The average annual product of lead ore is about 44,000 pounds. The products from January to April, 1876, of all kinds of ore were valued at $900.

J. Arthur & Co. Situated on the S. W. qr. Sec. 6, T. 4, R. 3 E. This is an east and west range, discovered about two years since, and worked continuously to the present. The ores are Smithsonite and lead ore, found in a flat sheet, from six inches to one foot thick, in the glass-rock opening, at a depth of 60 feet from the surface. The range is about 100 feet wide; its length is not yet known. It is situated on land owned by Mr. J. J. Ross. The ground is comparatively dry.

Hoare Bros. Situated about 50 yards east of the preceding, and on the same range, on land owned by Mr. J. Hoare. This party has been working here about two years, producing lead ore and Smithsonite from the glass-rock opening. The diggings are now very good.

Nichols & Holmes. Situated on N. E. qr. Sec. 7, T. 4, R. 3 E., a short distance east of the old zinc works. There are some irregular flat sheets of zinc ore in the glass-rock opening, about 20 feet deep. They have been worked during the last two years and have produced considerable zinc ore.

Harris & Lang. These diggings are situated about half a mile south of the preceding. This is an east and west range situated in the glass-rock opening about 25 feet deep. It has been worked about a year, producing considerable zinc ore.

In the vicinity of the Mineral Point Town Hall, on the N. W. qr. of Sec. 5, T. 4, R. 3 E., are the following diggings:

Prideaux & Henry. This is a north and south range, about 200 yards south of the Town Hall, which has been worked by the present party since 1866. The ores are lead and zinc, found in flat and pitching sheets from 8 to 10 inches thick, in the upper pipe-clay opening, at a depth of from 1 to 60 feet below the surface. The range is from 60 to 70 feet wide, and has been worked to a distance of 350 feet.

Jeffrey & Bro. Situated about 100 yards south of the preceding, and probably on the same range. The range is here 100 feet wide, and produces lead ore, and both kinds of zinc ore, in about equal quantities, and considerable iron pyrites. The work has been chiefly done in the winter season during the last two years.

Short & Foster. Situated about 200 yards west of Jeffrey & Bro., on an old north and south range, sixty feet in width. They have been working during the last two years in the winter season, producing lead and zinc ores from the pipe-clay opening. The diggings are about 40 feet deep.

Mankey & Son. Situated about 150 yards S. E. of Jeffrey & Bro. They have been working during the last twelve years on a north and south range. The product is lead ore found in vertical crevices, and in flat sheets in the green-rock opening at a depth of 40 feet from the surface.

All the diggings on this hill are dry; and most of them are remunerative, but the amounts of ore produced could not be ascertained.

The mining land is owned by Messrs. Henry, Coad, Prideaux and Woodman.

About a quarter of a mile north of this ridge is the Mineral Point Hill, lying directly east of the city. The following parties are mining there:

Vivian & Sleep. This party is working a nearly east and west range, the most southerly of several parallel ranges which cross the hill. The range is about 50 feet wide, and produces zinc ores, chiefly Smithsonite, from the upper pipe-clay opening, which is here about 25 feet below the surface. They have been working here during the last thirteen years, operating during the entire year.

Brown & Cluthers. They have been mining about a year on a parallel range 150 feet north of the one last mentioned. The range is about 50 feet wide; and produces zinc ores, chiefly blende. The ore is found in flat and pitching sheets in the pipe-clay opening.

James Dunn & Son. This party has been working about three years on a range 150 feet north of the preceding. Both kinds of zinc ores are produced from the upper pipe-clay opening, which lies here about 40 feet deep.

Trewilla & Strong. This party has worked about eight years in this vicinity, and one and a half years on their present range, producing zinc ores.

Goldsworthy & Hocks. Situated about one-fourth of a mile east of Vivian & Sleep. They have been mining about a year, producing blende.

The mining land in this hill is owned by Messrs. Hutchinson, Henry, Curry, Gundry and Washburn. The ranges all bear a little north of west and south of east, and have never been worked below the upper pipe-clay opening.

The earliest mining in this vicinity was done on the Mineral Point Hill. The ranges were formerly very productive, and have been worked continuously for many years to the present time. There are a few other parties mining within a few miles of Mineral Point. They are as follows:

Rogers & Mankey. Situated on the N. E. qr. of Sec. 8, T. 4, R. 3 E., on land owned by Mr. Suthers, near Rock branch. This is a new discovery made in October, 1876, being a flat sheet of Smithsonite in the Brown-rock opening.

Jeffrey & May. Situated a short distance north of the preceding. This is also a new discovery made about the same time as the preceding, being a flat sheet of zinc ores in the glass-rock opening. The prospect is very good.

Badcroft Diggings. Sec. 15, T. 4, R. 3 E. Work was begun here in 1872, and has been continued at intervals since. Three men have been employed, chiefly in prospecting, and a small amount of lead ore has been produced. The ore is found in flat and pitching sheets in the pipe-clay opening, about 20 feet below the surface.

Shepard & Co. Situated on the N. E. qr. of the N. E. qr. of Sec. 22, T. 4, R. 2 E. Work was commenced here in August, 1876, on the old Maloney range. This range has a general east and west course, and yields lead ore and blende from the pipe-clay opening, which is here about 25 feet deep. The ore occurs in a flat sheet from 4 to 5 inches thick, the blende forming the top and bottom of the sheet, and the lead ore the central part. The product has been, to December, 1876, lead ore, 1,500 pounds; blende, 3 tons. The ground is dry, and the prospect is considered good.

Clebenstein Diggings. They are situated on the same ridge and a short distance east of the preceding. They are now operated by August Cain, who has been mining about a year. They were operated from 1865 to 1875, by Mr. Clebenstein, and produced large amounts of lead and zinc ores. The ore was found in flat sheets, in the pipe-clay and glass-rock openings.

H. Josephs Diggings. Situated on the W. hf. of the S. W. qr. of Sec. 5, T. 4, R. 3 E. Mining was commenced here in 1871, and continued until the fall of 1874, when it was discontinued on account of water. The ore found here was exclusively blende, which occurred in a flat sheet, in the green-rock opening. The width of the sheet was about 80 feet, its greatest thickness three feet, and it was worked for a distance of 800 feet. The greatest depth below the surface is 70 feet. During the years 1873–4 this ground produced about 1,000 tons of blende.

Diamond Grove Diggings.

These diggings are situated on Secs. 25 and 26, T. 5, R. 2 E. They produce chiefly zinc ores, found in flat sheets in the pipe-clay and glass-rock openings. The following parties are now mining here:

Cain & Read. Situated on the N. W. qr. of Sec. 25. This party has been working on the Rodersdorf range during the winters of 1873–4 and 1874–5. The ore, which is Smithsonite, is found in the glass-rock opening, in a range from 16 to 20 feet wide, and 200 feet long. The production during the first season was 17½ tons, in the second season, 20 tons.

Robert Conley & Sons. Situated on the S. W. qr. of Sec. 25. Mining has been carried on here by the above party during the last ten years on an east and west range. Both kinds of zinc ore and lead ore are found here in the pipe-clay and glass-rock openings, but chiefly in the latter. The range is from forty to sixty feet wide, and has been worked a distance of 150 yards. During the last year and a half the product of lead ore has been 60,000 pounds, and sixty tons of zinc ore during the last two years.

Biddick Diggings. A valuable deposit of lead ore has lately been discovered on the S. W. qr. of Sec. 24, T. 5, R. 2 E., on which four men are now employed running a level. Four flat sheets, from one to four inches thick, are found here situated above one another, in the upper pipe-clay opening. It has not yet been sufficiently worked to determine its actual extent.

Martin Bros. & Cramer. Situated on the S. W. qr. of Sec. 25. This and the preceding are on land owned by Mr. James Spensley. They have been mining here on an east and west range, which was discovered two years since. The ore is Smithsonite; and is found in the glass-rock opening, which is here from ten to thirty feet deep.

Spensley & Brown. Situated on the N. E. qr. of Sec. 26, T. 5, R. 2 E. Six men have been employed here since July 1876 driving an adit in the glass-rock opening. The adit is 200 feet long, and drains an east and west range. The product has been, lead ore, 36,000 pounds, blende, six tons.

Opir & Lancaster. Situated on the N. W. qr. of Sec. 26. This party is working the same range, 450 yards west of the preceding. It is here known as the Lancaster range, and has been worked by the present party about a year. From three to five men are employed, and the product has been 150 tons of blende. It is worked by an adit.

McDermott & Co. Mining has been carried on here by Mr. McDermott for about 26 years, on the McShane & Gray range. The ore is found in flat and pitching sheet, in crevices and crevice openings in the Galena limestone above the flat openings. The diggings now produce lead and zinc ore. The average annual product is about 30,000 lbs. Four men are employed here.

Schlosser & Co. This party has been working four or five years on the east end of the same range as the preceding. The ground is dry, and the lead ore is found about 40 feet below the surface. The annual product is about 10,000 lbs.

Wm. and Thos. Thrasher. This party has worked in this vicinity about fifteen years, on a parallel range situated about a quarter of a mile southeast of Schlosser & Co. The product is chiefly lead ore.

Lost Grove Diggings.

These diggings are situated on land owned by Mr. J. J. Ross, on Sec. 33, T. 5, R. 2 E. Mining is confined here to the winter season. The ground is dry, and the ore is found in flat sheet in the glass-rock opening. The following parties are mining here:

Rigger & Arthur. This party has been working two years on an east and west range, producing lead ore and Smithsonite. The range varies from 25 to 50 feet in width, and lies from 30 to 40 feet below the surface. The product is valued at $1,200 per annum.

Clayton & Co. Situated about a quarter of a mile northwest of the preceding, have been working during the last twelve years on the Jim Brown range. This is an east and west range, from 50 to 60 feet wide, and lying about 70 feet below the surface, producing exclusively lead ore. The product has been about 20,000 pounds per annum.

Garden & Son. Situated about one-fourth of a mile south of the preceding. They have been working about two years and have produced about $400 worth of ore.

Robert Brown & Co. Situated about half a mile east of Clayton & Co., and on the same range. The diggings here are from 25 to 50 feet deep. They have been working about three years and have produced about 30,000 pounds per annum.

Furfer & Co. They have been working on a range near Brown & Co., during the last eight years, producing lead and zinc ore.

CALAMINE DISTRICT.

There are several tracts of land situated on Secs. 18 and 19, T. 3, R. 3 E., which were formerly quite productive; but little work is now done on them. They are situated on the west side of the Pecatonica river, on the ridge which separates the Wood and Bonner branches. The ridge slopes abruptly on all sides but one toward the various streams which nearly inclose it.

On the summit of the ridge there is a thickness of about one hundred feet of Galena limestone, underlaid by fifty feet of the Blue and Buff limestones, below which is the sandstone. All these formations may be distinctly seen in passing from the summit of the ridge to the valley of the Pecatonica.

During the winter of 1876–7 some mining was done here by Mr. Charles Mappes, of Belmont, on an east and west range lying from 30 to 40 feet below the surface. Four men were employed, working on a flat sheet of blende and galenite. The amount produced could not be ascertained. Some Smithsonite is also produced in this vicinity.

Yellowstone Diggings.

Pierce & Son. Some work has been done here during the winter seasons of the last three years, in a range a quarter of a mile north of the Newkirk range, situated on the S. W. qr. of Sec. 14, T. 4, R. 4 E. The lead ore is found in a vertical sheet in a crevice opening about fourteen feet below the surface. In the winter of 1874–5 the product was 18,000 pounds, and in the following winter about 1,800 pounds. No mining is done here in the summer.

WIOTA DISTRICT.

This is a small group of east and west ranges, crossed by north and south crevices, situated in the N. W. qr. of Sec. 19, T. 2, R. 5 E. But very little mining is done here; the annual production of the whole district does not exceed 40,000 pounds. The ore is lead, occurring in the middle portion of the Galena limestone, and there does not seem to be any regular opening. There are several parties here, among whom the principal ones are as follows:

Purcell & Harden. They are at work in the old Hamilton diggings, removing the pillars from the old workings which were abandoned many years since. They are unable to go any deeper, or make any new discoveries, on account of water, which is here quite plentiful. The ground is owned by the Ridgeway Mining Co., of Madison. Messrs. Purcell & Harden have worked here two years, and during that time have produced 20,000 pounds of lead ore.

Smith & Anderson. Situated a short distance north of the preceding, and form the northern part of the Hamilton diggings. This does not appear to form any regular range. The ore occurs in east and west sheets, in very hard rock, and seldom in openings. the diggings have now been worked since January, 1873, and have produced 80,000 pounds.

MONROE DISTRICT.

These are the most easterly diggings in the lead region, and are chiefly interesting for that reason. They are situated about three miles and a half north of the city of Monroe. At present only two parties are at work.

T. H. White & White. Situated on the N. E. qr. of Sec. 14, T. 2, R. 7 E. The ore is found here in a flat sheet, accompanied by pipe clay, about twenty-three feet below the surface. The general course of the sheet is northwest and southeast and produces only lead ore. The ground is quite free from water. The present parties have been working here six years, during which period they have produced 90,000 pounds of lead ore.

Frame & Co. Situated on the S. E. qr. of Sec. 10, T. 2, R. 7 E., on the land of Mr. Henry Wilber. This is an east and west range, about half a mile northeast of the preceding. It was discovered in 1844, and has been proved for a distance of 700 feet. The lead ore is found in both vertical crevices and flat openings. There appear to be three principal vertical crevices, connected in places by horizontal sheets.

They were worked by Mr. John Monahan, from 1870, to February, 1872, chiefly in the winter season, during which time he produced 50,000 pounds. Mr. Frame took the ground in 1874, and produced 4,000 pounds in the first six months. The production since then could not be ascertained. The ground is quite dry, and the workings are about fifty feet below the surface.

It is not probable that any extensive deposits exist in this vicinity. The ground appears rather to be such as, by careful working, will afford moderate wages to a few persons.

COPPER IN THE LEAD REGION.

At present no mining for copper is done in the lead region, nor has there been for several years, except at Mineral Point in the years 1873 to 1876. Indications of its presence are found in many places through the mines, as an associate mineral in the lead veins. The most systematic attempt at copper mining was made at Mineral Point.

Mr. James Toay, who is well acquainted with the past history of the enterprise has kindly furnished the following statement:

"Sometime in the year 1837 or 1838, copper was first discovered on the S. E. qr. of Sec. 32, T. 5, R. 3 E., one mile northeast of the Mineral Point court house. The crevice had a course S. 85° E., and had been traced for over one-third of a mile. This locality has not been worked since 1842. A great amount of copper was obtained.

"It is reported that over one and a half million pounds of copper were taken out, which would include all kinds of ore: 'Smalls,' which would not yield more than ten to fifteen per cent of copper; and the stone or 'Prill' ore, yielding twenty-five to thirty per cent.

"Some of the ore was smelted at the old furnace owned by William Kendall & Co., and some at the new Baltimore furnace, owned by Ansley & Co. About 50,000 pounds was sent to England or Wales for reduction, which indicates that parties here did not at that time understand the proper method of smelting copper.[1]

"Sometime in 1844, S. P. Preston came here, and went into partnership with Kendall & Co., and after that they had no trouble in smelting copper successfully.

"The amount of copper sold from Kendall & Co.'s furnace from 1841 to 1846 was 217,702 lbs. This was about ninety-five per cent. pure copper, and sold for fourteen cents per pound.

"Two other furnaces have been worked; one by Charles Bracken, to what extent I have no knowledge, but know he smelted considerable copper ore from his own land. The other was owned by Curtiss Beach. Here a great amount of copper ore was smelted, taken from the Beach diggings. The greatest amount of ore that Kendall & Co. smelted was taken from the Kendall diggings.

"It is probable that with the increased advantages in the present price of copper; in obtaining coke instead of charcoal for smelting, and in shipping facilities, that copper mining may now be made a profitable business at this place if properly managed."

During the years 1873, 1874 and 1875, about 200 tons of copper ore were produced by Mr. Toay from the mines near Mineral Point. An attempt was also made to smelt it in 1874. No very large amount was smelted, as the common blast furnace was not exactly adapted to its reduction. The ore is a sulphuret of copper. The exact amount produced could not be learned.

The ranges referred to in the foregoing statement of Mr. Toay are situated as follows:

Ansley Range. Course S. 85° E., running from the center of Sec. 32, T. 5, R. 3 E., one-third of a mile long.

Kendal Range. N. E. qr. of Sec. 5, and N. W. qr. of Sec. 4, T. 4, R. 3 E., running from near the quarter post of Secs. 5 and 32, nearly to the center of Sec. 4.; length, about two thousand feet.

Beach Range. E. hf. of Sec. 4, T. 4, R. 3 E. Crossing the center line of Sec. 4 one-quarter of a mile east of the center of the section, and running 600 feet from that point on a course N. 85° W., and 600 feet on a course S. 85° E.

[1] Two specimens of copper ore from the Mineral Point district, S. E. qr. of Sec. 32, T. 5, R. 3 E., were analyzed with these results: No. 1 gave metallic copper, 38.78 per cent. No. 2 gave copper, 4.48 per cent.

Wasley Range. S. W. qr. of the S. E. qr. of Sec. 32, T. 5, R. 3 E. Course S. 85° E.; length, about 1,000 feet.

Ballard Range. S. E. qr of the S. E. qr. of Sec. 32, T. 5, R. 3 E, Course N. 30° E.; length, about 800 feet.

Besides these there are several small north and south ranges on the N. E. qr. of the N. W. qr. of Sec. 5, T. 4, R. 3 E.

Traces of copper ore are also found at many points north of Mineral Point, in the diggings between that city and Dodgeville.

A specimen of ore containing a considerable carbonate of copper was presented by Hon. H. H. Gray, of Dodgeville. It was found about fifteen feet from the surface, on the S. W. qr. of Sec. 22, T. 2, R. 3 E.

Specimens of sulphuret of copper were obtained from some old diggings on the S. W. qr. of Sec. 8, T. 1, R. 5 E. The course of this range is about S. 20° E. Copper was mined here as early as 1838, and two or three loads of ore were brought to Mineral Point for reduction. A specimen from this locality afforded 10.86 per cent. of metallic copper.

STATISTICS OF ZINC ORE.

The statistics of the production of zinc ores are believed to be complete, and to embrace the annual production from the year 1860 (at which time the zinc ores began to be utilized) to October, 1876. The ore is all consumed at La Salle, Ill., by four companies. By far the greatest quantity of the ore is shipped from Mineral Point; the other points are Platteville, Council Hill, and Galena.

The blende is shipped in its crude state, as it comes from the mines; but the carbonate of zinc (drybone) is previously roasted or calcined, by which process it loses its carbonic acid, which constitutes about one-third of its weight, and is decreased in bulk in the same ratio. The small amount of water, which is usually present as a mechanical mixture with the ore, is also driven off.

The ore is calcined in a small and inexpensive furnace, resembling a lime-kiln in its structure and object, capable of containing about sixty tons of raw ore. Such a furnace will roast about twenty-five tons of ore in twenty-four hours, and requires the labor of six men at eight hours apiece (three shifts). From eighty to one hundred pounds of bituminous coal are required for each ton of ore.

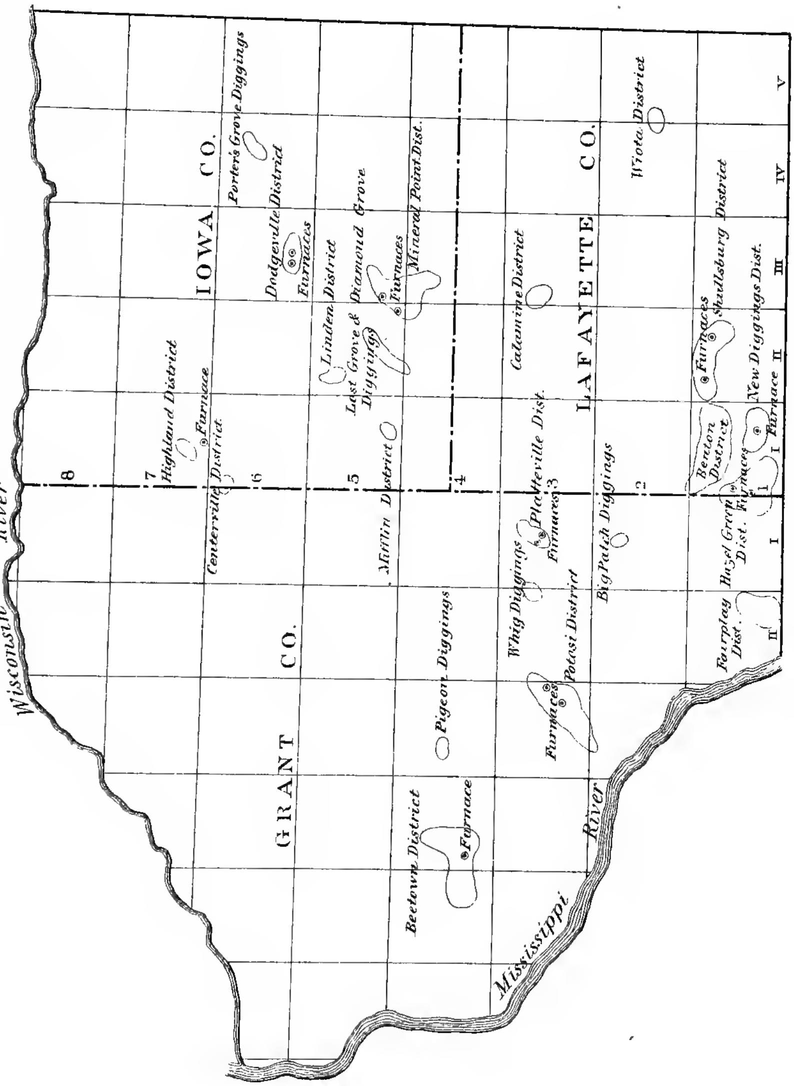
The cost of carrying the ore through this operation is from fifty to sixty cents per ton. The cost of a furnace and requisite tools is about $300.

The following are the amounts of zinc ores produced in the lead region from 1860 to October 1, 1876. The table has been prepared from the books of the four manufacturing companies, to whom I am greatly indebted for their ready coöperation and assistance:

Year.	*Smithsonite, lbs.*	*Blende, lbs.*
1860	320,000	....
1861	266,000	....
1862	....	....
1863	1,120,000	....
1864	3,173,333	....
1865	4,198,200	....
1866	7,373,333	....
1867	5,181,445	841,310
1868	4,302,383	3,078,435
1869	4,547,971	6,252,420

PLATE, XXXII

OUTLINE MAP
of the
LEAD REGION
showing the several Mining Districts and the Furnaces.



The Milwaukee Litho & Engr Co.

Year.	Smithsonite, lbs.	Blende, lbs.
1870	4,429,585	7,414,022
1871	16,618,160	9,303,625
1872	27,694,574	16,256,970
1873	20,538,946	15,089,514
1874	15,123,050	19,500,465
1875	11,878,210	20,538,190
1876, to October 1st	12,168,540	17,181,490
Total	138,953,730	115,456,441

The following statistics of the shipment of ores and metals over the Mineral Point railroad were furnished through the kindness of Mr. C. Spensley, of Mineral Point:

Year.	Lead, lbs.	Zinc Ores, lbs.	Speller, lbs.	Lead, White, lbs.
1857	1,780,490	....	....	....
1858	3,451,539	....	....	....
1859	2,991,925	....	....	....
1860	3,548,335	240,000	....	....
1861	2,360,663	200,000	....	....
1862	2,511,161	....	....	....
1863	2,180,570	840,000	....	....
1864	1,763,769	2,380,000	....	....
1865	2,708,478	3,148,650	....	....
1866	1,837,720	5,380,000	103,400	....
1867	2,854,000	2,660,000	701,210	67,510
1868	2,854,397	4,484,000	630,580	983,010
1869	1,948,000	8,780,000	....	1,317,370
1870	4,352,400	12,740,000	....	1,360,000
1871	3,027,520	21,140,000	....	....
1872	3,577,777	30,900,000	....	....
1873	1,972,230	27,414,000	....	....
1874	3,077,020	28,022,000	....	....
1875	2,632,940	31,538,000	....	....
1876, to October 1,	2,402,000	23,538,000	....	....

These estimates will include the greater part of the pig lead, and the zinc ores produced in the northern, central, and eastern parts of the Lead region; and all the spelter and zinc white produced at the old Mineral Point Zinc Works, which have lately been torn down and sold.

The statement of zinc ores shipped by the railroad is much too small to represent the true production of this part of the Lead region, as no allowance is made for overloading the cars, and for calcination, which would make the amount fully one-fourth greater.

STATISTICS OF THE PRODUCTION OF LEAD ORE

in the Lead Region, from January 1, 1862, to October 1, 1876.

During the progress of this survey, much time and care have been devoted to this portion of the work, in writing to and personally soliciting information from all persons possessed of it, and especially from the smelters. We have sought to prepare a statement of the amount of lead ore produoed annually in each district, and a conbimed estimate of the total amount for the Lead region.

Had it been possible, it would have been preferable to prepare the statement of each district from the mines therein contained; but it is seldom that a written account has been kept by the owners, of the lead ore produced from any range, mine, or diggings, extending back a sufficient number of years to furnish the information required.

Statements of the production of individual mines and ranges have been frequently furnished, and when they were believed to be reliable, they have been incorporated in the preceding part of the report. Such statements, however, are usually based on the memory of the persons who give them, and are therefore somewhat liable to error.

The lead ore produced in each district is seldom exported from it as such, but is usually reduced by the furnaces of that district, and then exported as pig lead. Therefore it was believed that the most accurate statistics could be obtained from the books of the smelters; accordingly circular letters have been sent to each of them, to which in most instances they immediately responded, giving a full and complete statement taken directly from their books, and leaving nothing further to be desired. Some were unable to do so, as their old accounts were lost or mislaid, and some, perhaps, were unwilling to have a detailed statement of their business published. All who did not respond to the circular were personally visited, and a statement giving the general average obtained. Although some of the individual statements herewith submitted may be liable to slight error, yet it is confidently believed that the estimates are, as a whole, rather too small than too large; and that they are as reliable as it is now possible to make them. We are thus enabled to give the products of the separate parts of the district, and a total of the whole.

In presenting these statistics, besides the product of the furnace, some remarks will be added as to the localities of the mines which form its supply, and the number and kind of furnaces.

BEETOWN DISTRICT.

Commencing in the western portion of the Lead region and proceeding eastward, the first is the Beetown furnace, in which is smelted all the ore of the Beetown diggings, together with that of Muscalonge, Nip and Tuck and Hackett's diggings.

The furnace is owned and operated by Hon. Christopher Hutchinson, by whom it was built in 1868. Previous to that time, all of the ore of the above mentioned district was smelted at Potosi. It is a reverberatory furnace, known as a Drummond, with a capacity of 9,000 pounds of ore in twenty-four hours.

It consumes one and three-fourths cords of oak wood, and is operated by two men. The number of pounds of lead ore smelted, from June 19, 1868, to October 1, 1876, is as follows:

Year.	*Pounds of Ore.*	*Year.*	*Pounds of Ore.*
1868	800,000	1873	850,000
1869	1,100,000	1874	1,000,000
1870	1,700,000	1875	800,000
1871	1,300,000	1876	700,000
1872	900,000		
Total			9,150,000

PLATTEVILLE DISTRICT.

Proceeding eastward, the next is the Platteville district, which has two furnaces, both near the village. Here is smelted all the ore raised in the Platteville and Whig diggings; and also that from Big Patch in the town of Smelser:

Year.	Furnace No. 1.	Furnace No. 2.	Total.
1862	800,000	350,000	1,150,000
1863	600,000	350,000	950,000
1864	600,000	350,000	950,000
1865	500,000	350,000	850,000
1866	500,000	350,000	850,000
1867	500,000	350,000	850,000
1868	450,000	350,000	800,000
1869	450,000	350,000	800,000
1870	450,000	350,000	800,000
1871	600,000	350,000	950,000
1872	600,000	350,000	950,000
1873	400,000	200,000	600,000
1874	500,000	....	500,000
1875	504,000	....	504,000
1876	1,044,000	....	1,044,000
Total	8,498,000	4,050,000	12,548,000

The above table gives in round numbers the product of the Platteville district since 1861; it is, however, only an approximation made by the smelters themselves, and believed to be tolerably correct. Furnace No. 1, owned by Messrs. Straw & Spensley, is a blast furnace having two hearths, and is situated about half a mile south of the village.

Furnace No. 2, owned by Mr. Coates, is situated near the railroad depot. It is a blast furnace of two hearths, and has not been worked since some time in 1873. Nothing more than a verbal statement of its annual average could be obtained.

POTOSI DISTRICT.

There have been, at various times since 1861, four furnaces operating in the vicinity, of which only two are now worked. They are as follows, in kind and condition:

Vance's Furnace ceased work in - - 1868
Gibson & Co. ceased work in - - - 1871

A. W. Emery's furnace, situated near Rockville, is a reverbatory, with a capacity of 6,000 pounds to every 24 hours. Thomas Hymer & Co.'s furnace, situated near British Hollow, is a blast furnace of one hearth.

Previous to 1868, all the ore from the Beetown district was smelted at these furnaces, in addition to that which they now smelt, which comprises the mines of Potosi, British and Dutch Hollows, and Rockville.

A detailed statement of the ore smelted at the several furnaces could not be obtained, but from the verbal statements of the several smelters, the following estimate has been prepared which is believed to be nearly correct:

Year.	Pounds of Lead Ore Smelted.	Year.	Pounds of Lead Ore Smelted.
1862	6,050,000	1870	1,900,000
1863	5,120,000	1871	2,230,000
1864	4,500,000	1872	1,400,000
1865	5,200,000	1873	1,500,000
1866	4,400,000	1874	750,000
1867	3,500,000	1875	700,000
1868	2,600,000	1876 to Oct. 1st.	650,000
1869	2,200,000		
Total from January 1, 1862 to October 1, 1876			42,700,000

HAZEL GREEN DISTRICT.

This district embraces all of the mines in the vicinity of the village of Hazen Green, and, indeed, all the ore produced between the Sinsinawa river and the Coon branch of the Galena river.

The furnace is a new blast-furnace of one hearth, and a capacity of 100 pigs (of 70 pounds each), in twenty-four hours. It is owned and operated by Messrs. Crawford, Mills & Co., who furnished the following statement from their books. It is situated on the Hard Scrabble branch, about a mile southeast of the village of Hazel Green.

Year.	*Pounds of Lead Ore smelted.*	*Year.*	*Pounds of Lead Ore smelted.*
1862	2,027,047	1870	1,223,250
1863	1,262,640	1871	1,230,917
1864	837,597	1872	1,278,524
1865	753,821	1873	1,046,626
1866	797,421	1874	830,174
1867	1,334,640	1875	735,395
1868	1,541,670	1876, to October 1st	723,193
1869	1,315,970		
Total from January 1, 1862 to October 1, 1876			16,938,885

NEW DIGGINGS DISTRICT.

This district embraces the diggings in the vicinity of the village; all east of the Coon branch of Galena river as far as T. 1, R. 2 E., and the mines in the vicinity of Benton.

The furnace is a blast of two hearths, and is known as the Democrat furnace. It is situated about two miles north of New Diggings. It was worked from 1864 to 1869 by Mr. Geo. Wilde, of Dubuque, and since then has been worked by T. G. Stevens & Co.

Year.	*Pounds of Lead Ore smelted.*	*Year.*	*Pounds of Lead Ore smelted.*
1862	1,050,000	1870	2,200,000
1863	1,200,000	1871	1,700,000
1864	1,125,000	1872	1,650,000
1865	1,200,000	1873	1,128,000
1866	1,100,000	1874	1,200,000
1867	1,150,000	1875	1,200,000
1868	1,200,000	1876, to October 1st	1,300,000
1869	1,100,000		
Total from January 1, 1862, to October 1, 1876			19,503,000

In addition to this, there was smelted at the Jefferson furnace, by T. G. Stephens & Co., as follows:

Year.	*Pounds of Ore smelted.*	*Year.*	*Pounds of Ore smelted.*
1862	1,098,938	1866	1,073,415
1863	1,326,193	1867	1,050,597
1864	1,112,095	1868	1,429,158
1865	1,078,609	1869	1,515,323
Total			9,684,333

The furnace used was a Drummond, with a capacity of 7,000 lbs. per twenty-four hours.

SHULLSBURG DISTRICT.

The mines embraced in this district are situated in T. 1, R. 2 E., and some in the south part of T. 2, R. 2 E., being not a very large but quite productive district.

There are two furnaces in operation in the district. No. 1 is now operated by Mr. B. Spensley, of Shullsburg, and was formerly owned and operated by Messrs. Quinch & Estey, of that place. It is a blast furnace of two hearths, situated a short distance west of the village, on the Shullsburg branch. No. 2 is also a blast furnace of two hearths, capable of smelting 12,000 pounds of ore in twenty-four hours, with six men. It is also situated near the Shullsburg branch, about four miles below Shullsburg. Prior to June 1st, 1873, it was operated by Messrs. Joseph Hutchinson & Sons. At that time it was leased to Mr. Wesley Spensley, for a term of three years, and is now operated by Messrs. Spensley & Hutchinson. A full account has been furnished of their production.

Year.	*Pounds of Lead Ore smelted at Furnace No. 1.*	*Pounds of Lead Ore smelted at Furnace No. 2.*	*Total.*
1862	1,000,000	800,000	1,800,000
1863	1,000,000	700,000	1,700,000
1864	1,000,000	400,000	1,400,000
1865	1,000,000	1,000,000	2,000,000
1866	1,000,000	1,000,000	2,000,000
1867	1,000,000	1,200,000	2,200,000
1868	1,000,000	700,000	1,700,000
1869	1,000,000	200,000	1,200,000
1870	1,463,986	400,000	1,863,986
1871	1,250,362	400,000	1,650,362
1872	1,146,448	300,000	1,446,448
1873	1,084,221	250,000	1,334,221
1874	1,000,000	700,000	1,700,000
1875	900,000	900,000	1,800,000
1876, to Oct. 1st	625,000	1,000,000	1,625,000
Total	15,470,017	9,950,000	25,420,017

MINERAL POINT DISTRICT.

The ore smelted at the Mineral Point furnaces is derived from all the mines and diggings in the vicinity of the city. Ore is also brought here in many cases from long distances. The ore of the following districts is also smelted here, viz: Mifflin, Linden, Lost Grove, Diamond Grove, Duke's Prairie, and Wiota.

There are two furnaces now in operation. No. 1 owned by Mr. James Spensley is situated one mile west of the city, on the Spensley branch of the Pecatonica. It is a reverberatory, with a capacity of 6,500 lbs. per day. There is also a blast furnace here of two hearths, but it is seldom used, except for smelting slag and large ore.

Furnace No. 2, is situated about a mile above No. 1, on the same stream, and is operated by Mr. John Spensley. There is here a blast furnace of three hearths, and a reverberatory. The latter is the only one now used.

A full statement has been given by Mr. James Spensley of furnace No. 1, and is inserted below, with the exception of the years 1862 and 1863, which have been estimated from an average of the others. The amount of ore smelted at furnace No. 2, from 1863 to 1872 inclusive, is estimated by Mr. John Spensley at 7,273,764 lbs. As the annual product in this district has been comparatively uniform, the average annual product may be estimated at one-tenth of it.

The production of the Mineral Point District will then stand as follows:

Year.	*Furnace No.* 1.	*Furnace No.* 2.	*Total.*
1862	1,264,562	727,376	1,991,938
1863	1,264,562	727,376	1,991,938
1864	956,622	727,376	1,683,998
1865	1,161,682	727,376	1,889,058
1866	1,426,682	727,376	2,154,058
1867	1,316,232	727,376	2,043,608
1868	1,525,334	727,376	2,252,710
1869	1,805,334	727,376	2,532,710
1870	1,464,930	727,376	2,192,306
1871	1,263,296	727,376	1,990,672
1872	934,000	727,376	1,661,376
1873	791,512	727,376	1,518,888
1874	900,000	950,000	1,850,000
1875	900,000	1,100,000	2,000,000
1876, to Oct. 1st	755,350	700,000	1,455,350
Total	17,730,098	11,478,512	29,208,610

DODGEVILLE DISTRICT.

This district comprises all the mines in the vicinity of the village of Dodgeville, Van Meter's survey, and all ore raised north and east of Dodgeville.

There are two reverberatory furnaces here. No. 1 is owned and operated by Messrs. Hendy & Mundy, and has a capacity of 6,000 pounds per day. This furnace commenced work in 1869. No. 2 is owned by Messrs. Bennett & Georges, and has a capacity of 7,500 pounds per day. Both are situated a short distance north of the village. Full statements have been received from furnace No. 1, and from furnace No. 2, with the exception of the last three years, which have been estimated.

Year.	*Furnace No.* 1.	*Furnace No.* 2.	*Total.*
1862	....	1,369,989	1,369,989
1863	....	1,055,441	1,055,441
1864	....	905,511	905,511
1865	....	866,407	866,407
1866	....	1,154,298	1,154,298
1867	....	1,191,939	1,191,939
1868	....	1,046,081	1,046,081
1869	184,000	978,718	1,162,718
1870	435,000	939,617	1,374,617
1871	737,000	1,195,259	1,932,259
1872	934,000	902,320	1,836,320
1873	626,000	815,999	1,441,999
1874	695,000	900,000	1,595,000
1875	340,000	900,000	1,240,000
1876, to October 1st	400,000	700,000	1,100,000
Total	4,351,000	14,921,579	19,272,579

HIGHLAND DISTRICT.

This district comprises the mines in the vicinity of Highland, Centerville, and the Crow Branch diggings. The furnace is a reverberatory. The amount of ore smelted in the district is not very large; exactly how much could not be ascertained. It is about 500,000 pounds per annum, or seven and a half millions since 1862.

From the foregoing statistics, the following general results may be deduced. There are now seven reverberatory or Drummond furnaces in operation, with an average daily capacity of 7,000 pounds of ore each; and five blast furnaces of two hearths, and two of one hearth each, the average capacity per hearth being 100 pigs, or 10,000 pounds of ore per 24 hours. In addition to these there are nine blast furnaces of two hearths each, not at present worked, but nearly all in good repair. Some of them have been supplanted by the reverberatory furnace, which is preferred for fine ore, and some by new furnaces built in adjoining localities.

Combining now the several amounts of lead ore already given as the product of the different districts for the several years since January 1, 1862, we find the total production of the Wisconsin Lead region to have been as follows:

Year.	*Total Product, lbs.*	*Year.*	*Total Product, lbs.*
1862	17,037,912	1870	13,754,159
1863	15,105,577	1871	13,484,210
1864	13,014,201	1872	11,622,668
1865	14,337,895	1873	9,919,734
1866	14,029,192	1874	9,625,174
1867	13,820,784	1875	9,179,395
1868	13,869,619	1876, to Oct. 1st	8,747,543
1869	13,426,721		
Total from January 1, 1862, to October 1, 1876			190,974,784

Besides the smelters already mentioned, there are numerous others operating outside of the Wisconsin Lead region, in Illinois and Iowa. The following information was obtained relative to their production:

The parties smelting in Dubuque are:

J. & W. G. Walters, annual amount	900,000 lbs.
Coates and Brunskill, annual amount	900,000 lbs.
Fern and Simpson, annual amount	650,000 lbs.

Parties smelting in Galena are:

Thomas B. Hughlett, annual average since 1862	1,800,000 lbs.
Spensley's Furnace, present annual average	1,000,000 lbs.

Richard Bowden, or Galena Furnace, smelted as follows:

Year 1874	930,000 lbs.
Year 1875	850,000 lbs.
Year 1876, to October 1st	630,000 lbs.

Hon. Henry Green, of Elizabeth, Illinois, smelted as follows:

Year.	*Pounds.*	*Year.*	*Pounds.*
1873	575,113	1875	615,406
1874	821,720	1876, to October 1st	442,602

Mr. Green remarks that seven years ago the mineral field which supplies his furnace produced three times as much ore as at present.

The amounts smelted by Richards & Co., at their furnace in Warren, Illinois, are approximately as follows:

Year.	*Pounds.*	*Year.*	*Pounds.*
1873	450,000	1875	250,000
1874	300,000	1876, to October 1st	200,000

Inasmuch as no detailed statements could be obtained from any of these parties, or anything more than the foregoing approximations, it is impossible to give a correct and reliable account of the several amounts they have smelted since 1862. By comparing their present product with that of other parties in former years, it is estimated that they have smelted, since January 1, 1862, about one hundred million pounds.

As it is a matter of interest to compare the present production of the mines with the past, I have taken the liberty to reproduce the following statistics of the Upper Mississippi Lead mines, the product being given in tons of metallic lead.[1]

Year.	*Tons.*	*Price per cwt. in St. Louis.*	*Year.*	*Tons.*	*Price per cwt. in St. Louis.*
1823	150	....	1839	11,976	$4.38
1824	78	....	1840	11,987	4.38
1825	297	....	1841	14,150	3.50
1826	428	....			*At Galena.*
1827	2,313	$4.50	1842	13,992	$2.24
1828	4,958	3.30	1843	17,477	2.34
1829	5,957	2.00	1844	19,521	2.82
1830	5,331	2.13	1845	24,328	2.96
1831	5,369	3.00	1846	23,513	2.88
1832	5,401	4.25	1847	24,145	3.17
1833	6,068	4.13	1848	21,312	3.24
1834	7,699	4.25	1849	19,654	3.67
1835	8,469	5.00	1850	17,768	4.20
1836	11,390	5.13	1851	14,816	4.08
1837	9,708	....	1852	12,770	4.12
1838	10,811	....	1853	13,307	5.50

I am also indebted to Messrs. N. Corwith & Co., of Galena, for the following condensed statement of the production of the Upper Mississippi Lead mines:

Years.	*Pigs.*[2]	*Tons.*
1821 to 1831	664,118	23,244
1831 to 1841	1,591,950	55,718
1841 to 1851	6,170,857	215,979
1851 to 1861	4,609,553	161,334
1861 to 1871	2,419,985	84,700
1872	200,000	7,000
1873	200,000	7,000
1874	150,000	5,400
1875	150,000	5,400
To Oct. 1876	125,000	4,500

[1] See Whitney's Metallic Wealth of the United States, 1854, p. 421.

[2] The weight of a pig of lead is about 72 pounds.

CONCLUDING REMARKS.

In the preparation of this report, I have been actuated by many considerations which have to a great extent determined its character and contents. In the first place, the space which can justly be devoted to the Lead region in a report on the entire state is necessarily small, and involves a judicious selection of the material collected and prepared.

In the course of my examinations in the Lead region, I have found in all places, and among all persons connected with the mining interests, a general expression of a desire for information in regard to the condition of the mining industry in those portions of the Lead region more or less remote from the ones in which they reside. To furnish such information is undoubtedly a legitimate object of a work of this kind, and to it, therefore, I have devoted about two-thirds of this report, reserving the remainder for the geological and topographical examinations contemplated by the law.

Among other subjects which I have been obliged to omit is the much-argued question of mining in the Lower Magnesian limestone. No discussion of this question can do it justice which does not take into consideration the origin of the crevices, and the manner of deposition of the ores and associate minerals contained in the mines now operated, since these questions are the only premises from which we can derive any reliable conclusions.

The discussion of this question would have occupied more space in the report than I felt justified in devoting to theoretical questions, at the expense of what appeared to me to be important practical facts.

The subject of drainage in our mines is one of great importance; at present it is effected by pumping, and by levels or adits. Pumping is at best but a temporary expedient, and when steam is employed it is a costly one; it effects the drainage of only a comparatively small area, and when the pump ceases to work, water immediately returns Expensive pumping operations are only warranted where large bodies of ore are known to exist, within a small area of ground.

On the other hand, the drainage effected by a level is permanent and extensive, although the original outlay of capital is large. Our mines have now been worked so long that it is known in each mining locality how many ranges have been worked to the natural water level, and the comparative value of the veins of ore left in them when abandoned. With this foreknowledge it is not difficult to arrange a level that will not only drain the previously known ranges, but will also make it possible to work any others which may afterwards be discovered in its vicinity; a system which is further favored by the well known parallelism of the ranges.

The stratum in which levels can be most rapidly excavated, and with the least expense, is the upper or thin-bedded portion of the Blue limestone (Trenton). There are no interstratified beds of clay above it, and usually nothing to prevent the drainage of all the Galena limestone; but as the strata sometimes contain slight flexures, it is not always possible to drive a level in the same formation. Levels driven in this, the upper pipe-clay opening have the additional advantage of proving one of the most productive openings known in the Lead region.

Judging from the number of levels which have been excavated, and the success which has usually attended them when completed, the system of mining by levels seems to offer the safest field for the employment of capital.

The recent inventions and improvement in pneumatic, or compressed air drills, and in mining explosives, such as dynamite and rendrock, are daily rendering the excavation of levels a much less laborious task.

There is another method by which drainage of mines has sometimes been effected, and which might in many other places be employed to advantage. It is by simply drilling a hole from the bottom of the mine to some of the underlying clay beds of the Trenton. In this way a passage is often effected for the escape of the water, of which it will often avail itself until the opening becomes closed with mud from the mine, when a new hole has to be drilled.

In many portions of the Lead region, but more especially in the southern and centra parts, there is a desire which has often been earnestly expressed to me, that a survey should be made of the ore-bearing ranges both old and new. Such a survey, to be of any practical benefit, should be made with a transit and level, and with the utmost accuracy. It should be made underground when possible, and when not, it should be made on the surface, locating the ranges from the shafts. The survey of each district should be referred to certain fixed points, whose location and elevation should be accurately ascertained. The location of these points with reference to each other could at any time be ascertained by triangulation if thought necessary. The whole should then be mapped on a suitable scale and published with the field notes.

The advantages derived from such a survey are chiefly the following: (1) In ranges which are now worked, it would be easy to reproduce on the surface the areas worked out below, and from the known course of the range the miner could, with considerable certainty, locate his shafts so as to reach the unworked portions, thus effecting a large saving of time, labor and money wasted in prospecting. (2) The surface of the Lead region is rapidly becoming an agricultural country. In many places the old shafts are being filled, the dump piles are being removed, and all surface vestiges of once valuable ranges are becoming obliterated. Many of these ranges were worked many years since for lead ore alone, to the natural water level, and abandoned with valuable bodies of ore still remaining in them; and in view of the increasing production of zinc ore, which is now between three and four times that of lead ore, it is not unlikely that it may become profitable to work them again. From a survey such as is outlined above, the location of old shafts and ranges could at any time be restored. (3) It would conduce to the systematic working of the mines in the future, by forming a basis to which private surveys could be referred, and would indicate the points where levels could be most successfully placed for the drainage of the mines.

These are but a few of the advantages which will occur to persons actually engaged in mining. Probably there is enough money wasted in prospecting every year, which would be saved by such a survey, to carry it on to a successful termination.

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