Minneapolis, Minn. Nov 7 1885

To Cornell University

I have the pleasure of presenting, in the name of the board of regents of the University of Minnesota, this copy of the first volume of the *final report on the geological and natural history survey of Minnesota.*

N. H. WINCHELL,

State geologist.

THE UNIVERSITY OF MINNESOTA.

A REPORT

ON THE GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA;
MADE IN PURSUANCE TO AN ACT OF THE LEGISLATURE
OF THE STATE, APPROVED MARCH 1,
1872.

PUBLISHED BY AUTHORITY OF THE STATE.

VOLUME I.


GEOLOGICAL
AND
NATURAL HISTORY SURVEY
OF
MINNESOTA.
N. H. WINCHELL, STATE GEOLOGIST
Scale. 12 miles to an inch.
LAKE OF THE WOODS
RAINY LAKE
Rainy Lake Riv.
LAKE SUPERIOR
Red Lake and Pembina
Indian Reservation
White Earth
Indian Reservation
Hunter's
Island
MESABI RANGE
KITTSON
MARSHALL
POLK
BELTRAMI
ITASCA
COOK
LAKE
ST LOUIS
NORMAN
CLAY
BECKER
HUBBARD
CASS
AITKIN
CARLTON
WADENA
WILKIN
OTTER TAIL
CROW WING
PINE
TODD
MORRISON
MILLE LACS
KANABEC
GRANT
DOUGLAS
TRAVERSE
STEVENS
POPE
STEARNS
BENTON
ISANTI
CHISAGO
BIG STONE
SHERBURNE
SWIFT
ANOKA
KANDIYOHI
MEEKER
WRIGHT
HENNEPIN
RAMSEY
WASHINGTON
LAC QUI PARLE
CHIPPEWA
CARVER
YELLOW MEDICINE
RENVILLE
MC LEOD
SIBLEY
SCOTT
DAKOTA
GOODHUE
LINCOLN
LYON
REDWOOD
NICOLLET
LE SUEUR
RICE
WABASHA
BROWN
PIPESTONE
MURRAY
COTTONWOOD
WATONWAN
BLUE EARTH
WASECA
STEELE
DODGE
OLMSTED
WINONA
ROCK
NOBLES
JACKSON
MARTIN
FARIBAULT
FREEBORN
MOWER
FILLMORE
HOUSTON
MINNEAPOLIS
ST PAUL
Duluth
Stillwater

THE GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA.

N. H. WINCHELL, STATE GEOLOGIST.

1872–1882.

THE GEOLOGY OF MINNESOTA.

VOL I, OF THE FINAL REPORT.

BY N. H. WINCHELL,

ASSISTED BY WARREN UPHAM.

SUBMITTED MARCH 10, 1882, AND PUBLISHED UNDER THE DIRECTION OF THE HON. FRED VON BAUMBACH, SECRETARY OF STATE.

ILLUSTRATED BY FORTY-THREE PLATES,

AND FIFTY-TWO FIGURES.

MINNEAPOLIS, MINN.

JOHNSON, SMITH & HARRISON, STATE PRINTERS.

1884.

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LIST OF PLATES AND THEIR ORDER.

LETTER OF N. H. WINCHELL, STATE GEOLOGIST.

THE UNIVERSITY OF MINNESOTA,
March 10, 1882.

William W. Folwell, President of the University.

I have the pleasure of transmitting the accompanying manuscript report, the same being intended for the first volume of the final report on *the geological and natural history survey* of the state. In tendering this volume, the first of the matured results of the survey, permit me to thank you for courteous consideration in our official intercourse, and personal advice and assistance in many ways during the decade that has passed since the work was begun.

Respectfully,
Your obedient servant,
N. H. WINCHELL,
State Geologist.

LETTER OF PRESIDENT WM. W. FOLWELL.

THE UNIVERSITY OF MINNESOTA, MINNEAPOLIS,
March 12, 1882.

Professor N. H. Winchell, State Geologist.

DEAR SIR: I have the honor to acknowledge the receipt of your favor of the 10th instant, transmitting the manuscript of the first volume of your final report. Permit me to congratulate you upon the successful completion of a considerable portion of the great enterprise in which you are engaged and to express the hope that you may be enabled to carry out your whole plan. The completed work will be a noble testimony to your skill and industry, and to the liberality of the generation which has had the foresight to originate it.

Very respectfully,
Your obedient servant,
WILLIAM W. FOLWELL,
President.

PREFACE.

This volume, the first of the final volumes of *the geological and natural history survey of Minnesota,* needs but few words of introduction. It was with much trepidation, but with unreserved devotion to the work, that the writer began alone, in October, 1872, the geological survey of the state of Minnesota. The fund allowed by the Legislature was one thousand dollars per year, to cover all expenses. This sum was doubled by the next Legislature, and the *salt spring lands* of the state were placed in the hands of the board of regents to defray the expenses of the survey. One half of each year, up to 1878, was given to instruction in the University. The field-work of the summer vacation was described in an annual report, hurriedly prepared in the autumn and early winter of each year. In 1878 the regents made other provision for the work of instruction. In 1879, Mr. Warren Upham was employed, and he has remained an assistant on the survey up to the present time.

Although the period of ten years is covered by this volume, it does not embrace all the results of the work of that length of time. In accordance with the general law of the survey, several other departments have been prosecuted. The series of annual reports has been maintained, the General Museum has been established, and investigations of the palæontology and mineralogy of the state initiated. In general the design has been to plan the work systematically and execute it thoroughly, based upon an expectation of final completion. This of course finds, at this time, many lines of investigation still open, and much field-observation still unclassified.

The aim in this volume has been to state facts rather than conclusions. Whenever an attempt has been made to assign a cause to phenomena, it has been so evidently the cause, in the light of the facts stated or universally admitted, that the description of the phenomena would be incomplete without a reference to their obvious cause. Generalization should follow the accumulation of facts, not precede them. In order to give completeness to the survey, these facts ultimately will be grouped, and their true relations set forth. But this cannot be done till the whole state has been surveyed.

At best this is but a preliminary investigation of the geology and geography of the state. It adds definiteness and fullness to the work of Nicollet and of Owen; but it rests on data, appliances, and resources too limited and inexact to warrant the expectation that the future will not find fault with it, and will not be able to extend it by still more thorough and pains-taking study. It is to be hoped, therefore, that in the submission of this work to the scrutiny of the geologist of to-day, and to the verdict of the geologist of the future, they will both scan its pages with due leniency for its errors and imperfections.

It would be useless to attempt to enumerate the individuals and corporations to which the survey is under obligation. Throughout the state its agents, and all its efforts, have been received, with scarcely an exception, with perfect cordiality and coöperation. It has been a constant effort to make the survey *useful*, in every way, and a free avenue of information to the people respecting everything that is included within its scope. This has entailed a voluminous correspondence, but one which often has resulted in benefit to the survey as well as to the inquirer. In the preparation of the historical chapter, however, the generous assistance of Rev. E. D. Neill should be specially mentioned; who placed his rich library of historical works, and several unpublished manuscripts and early maps of the Northwest, unreservedly at the service of the writer. General Q. A. Gillmore kindly superintended the testing of eighty two-inch cubes of building stone. Hon. D. S. Durrie, librarian of the Wisconsin historical society, has loaned several rare books which could not be procured in Minnesota. The gratuitous aid rendered in 1874 by Prof. M. W. Harrington, appears essentially in the reports on three counties.

N. H. W.

Note to the reader. The map of De L'Isle, on page 20, should be accredited to *Neill's Minnesota.* The *sketch of the lead region,* which on page 92 is attributed to Dr. D. F. Weinland, should be accredited to Prof. E. Daniels, who was then state geologist of Wisconsin. The sum of money granted Mr. N. C. D. Taylor by the Legislature in 1865 was one thousand dollars instead of two thousand (p. 97); and professor James Hall dissents from the opinion of the copper prospects of the St. Croix valley attributed to him by Mr. Taylor. The areas of Cass, Crow Wing, Morrison and Wadena counties, as given in the table on page 114, are stated as they would be, had a change of their boundaries, as proposed by the Legislature, been ratified by the inhabitants; but as the change was voted down by the people, their actual areas should be given as follows:

	ACRES.	ACRES.
Cass county,	1,985,316.23 land;	438,814.34 water.
Crow Wing county,	325,343.50 land;	42,494.63 water.
Morrison county,	730,917.20 land;	8,171.77 water.
Wadena county,	339,397.81 land;	8,524.62 water.

Elevations in Houston, Winona and Fillmore counties when referred to sea-level, except the average elevation of townships, should be increased eight feet, and the foot-note on page 241 should be ignored. On page 361, tenth line from the bottom, for "northwestern" read northeastern; and on page 362 for "Racine" read Frankford. The hight of the mounds mentioned in Mower county (page 365) is rarely as much as four feet. The thickness of the strata at Hook's quarry, Mantorville, page 373, amounts to 72 feet 10 inches. Read 143 feet, instead of 134 feet, on page 634, for the hight of the hills south of lake Sakata.

CHAPTER I.

HISTORICAL SKETCH OF

EXPLORATIONS AND SURVEYS

IN MINNESOTA.

BY N. H. WINCHELL.

The geographical position of Minnesota is such that for the last two hundred years it has been the *ultima thule* for western travelers and adventurers. Before railroads and highways had made it possible to reach the state from the Atlantic cities easily and quickly, it was the turning-back point for most explorers, traders and adventurers. The route by the great lakes terminated at Fond du Lac, the head of the great system of inland lakes of North America. The route by the Mississippi for canoes either ceased at the Falls of St. Anthony, or, if pushed further, was lost in a labyrinth of small streams and lakes in which the Mississippi has its origin. Westward from the Mississippi, or at least westward from the Red river of the North, and the St. Peter's, extended the boundless prairies of the continent, to cross which, or to enter on which, was, to most travelers, too arduous and too fruitless an enterprise; and few were hardy enough to penetrate so far as the "Shining Mountains," which constituted the next natural goal of the explorer's ambition. Not only the zeal of the missionary, but the cupidity of the fur-trader—*avant coureurs* of American civilization—found in Minnesota a long halting-place. Hence a multitude of published "journals" and "expeditions," or "visits," have made Minnesota widely known throughout both English and French-speaking countries. Many of these volumes are ignored in the following historical synopsis.

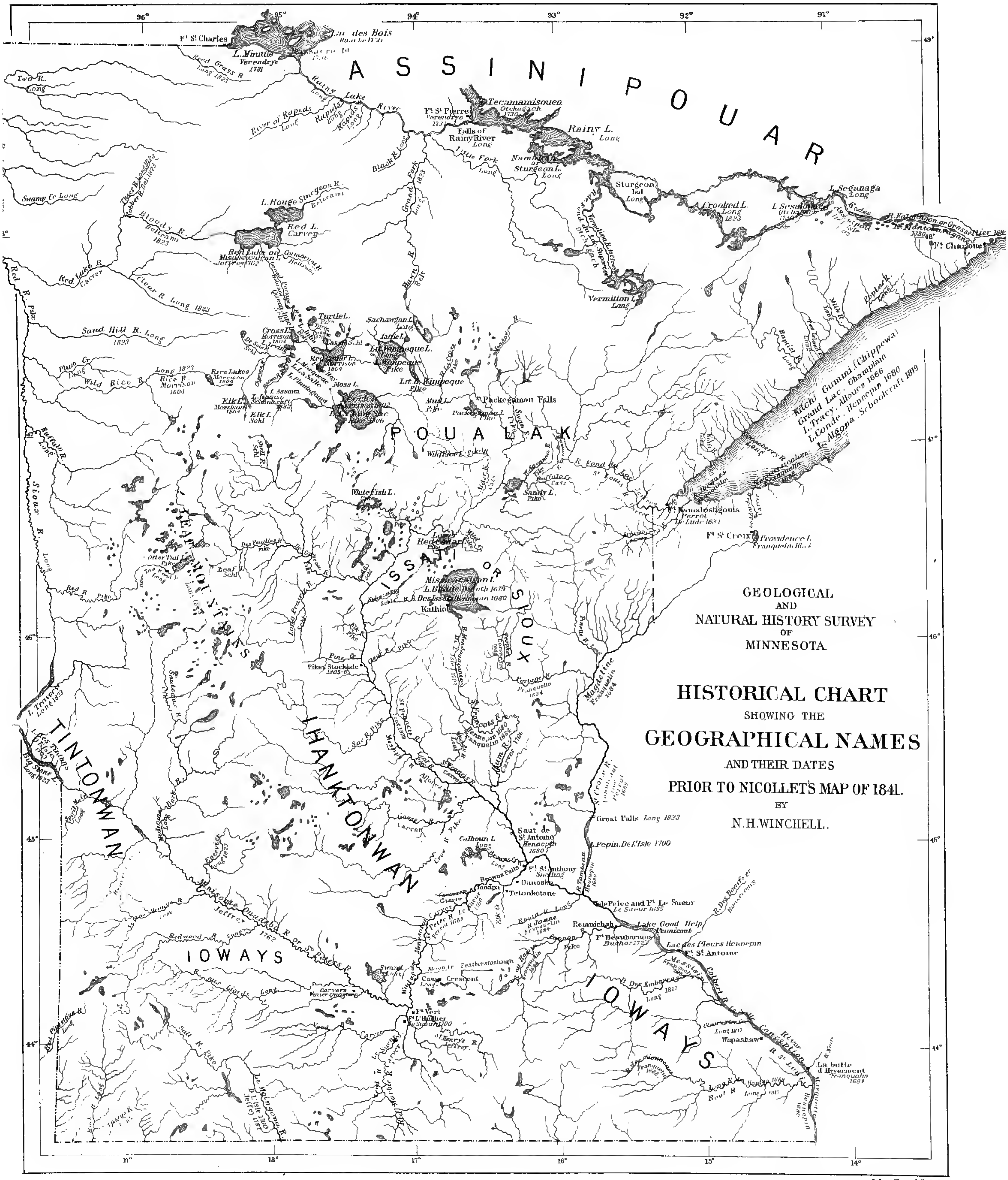
The design has been to note the steps of geographical, as well as geological exploration as authenticated by governmental or semi-official publications.

At the conclusion of peace between Great Britain and France, in 1763, the territory which is now embraced within Minnesota was divided by a line running south from the international boundary to the source of the Mississippi river, and thence southward along the Mississippi. France retained that portion lying to the west of the line, and that to the east was declared subject to the British crown. The name *Louisiane*, which was applied by the French to the lower portions of the Mississippi, was extended northward so as to include all their possessions south of the forty-ninth parallel. That portion of the state which lies east of the division line of 1763 became, in 1783, a part of the original area of the United States, included in the "Territory northwest of the Ohio river." In 1803 France ceded the "province of Louisiana" to the United States. Minnesota was admitted into the Union, as a State, in the year 1858. The history of exploration may hence be divided into three parts: 1. Period prior to 1783; 2. Period of Territorial Exploration; 3. Period of State Exploration and Survey.

I. PERIOD PRIOR TO 1783.

The map of Champlain shows the knowledge he obtained of the western country from the Hurons at the time of his visit to their country in 1615.* This represents the "Grand Lac," which is the French for Kitchi Gummi, the Chippewa name of lake Superior, with a large stream entering it from the south, called "La Grande Rivière." This probably refers to the Mississippi, of which he could have had only a vague idea, and especially since no such stream, commensurate with the importance which he has given this, enters lake Superior from the south. The accident of its being

*The principal authorities consulted on the earliest geographical explorations in Minnesota are the following *Notes pour servir a l'histoire et a la bibliographie et la cartographie de la Nouvelle-France et des Pays adjacents*, 1545–1700; par l'auteur de la Bibliotheca Americana vetustissima. Paris, Librairie Tross, 1872. *The Collections of the Minnesota Historical Society*, four volumes, and the *Publications of the Department of American History*, of the Minnesota Historical Society *Decouvertes et etablissements des Francais dans l'ouest et dans le sud de l'Amerique septentrionale;* by Pierre Margry, Paris Hennepin's *Louisiana*, a translation from the French of Hennepin's first, or Paris, edition of his work on the Mississippi, by John Gilmary Shea, New York. 1880. Neill's *History of Minnesota from the earliest French explorations to the present time;* third edition, 1879, Minneapolis *History of the discovery and settlement of the Valley of the Mississippi, by the great European Powers, Spain, France and Great Britain;* by John W. Monette, two volumes, New York, 1848 By the courtesy of Rev. E. D. Neill, several manuscript copies of documents in the Archives de la Marine, Paris, and tracings of unpublished old maps from the same place, have been consulted. *Journal d'un voyage fait par ordre du Roi dans l'Amerique septentrionale*, par le P De Charlevoix, 1744, 3 tomes, Paris. *Memoire sur les Mœurs, Coutumes et Religion des Sauvages de l'Amerique septentrionale* par Nicolas Perrot, publiee pour la premiere fois, par le R. P. Tailhan. *Historical Collections of Louisiana*, 4 vols, B. F. French. *Histoire de la Louisiane*, par M. Le Page Du Pratz, 1768 *The Works and Voyages o Champlain*, published in English by the Prince Society, Boston, 1880. *The Discovery of the Great West*, Francis Parkman 1869.


GEOLOGICAL
AND
NATURAL HISTORY SURVEY
OF
MINNESOTA.
HISTORICAL CHART
SHOWING THE
GEOGRAPHICAL NAMES
AND THEIR DATES
PRIOR TO NICOLLET'S MAP OF 1841.
BY
N. H. WINCHELL.
ASSINIPOUAR
POUALAK
ISSATI OR SIOUX
IHANKTONWAN
TINTONWAN
IOWAYS
IOWAYS
Lac des Bois
Rainy L.
Rainy Lake
Vermilion L.
Crooked L.
Red L.
Mississippi
Wapashaw
Great Falls Long 1823
L. Pepin. De L'Isle 1700
Saut de St Antoine Hennepin 1680
Pikes Stockade 1805-6
Kitchi Gummi (Chippewa)
Grand Lac. Champlain
L. Tracy. Allouez 1666
L. Conde. Hennepin 1680
L. Algona. Schoolcraft 1819
96°
95°
94°
93°
92°
91°
47°
46°
45°
44°
19°
18°
17°
16°
15°
14°

represented as flowing north instead of south, is no uncommon error for the early geographers who have mapped the rivers of Minnesota and Manitoba; and La Salle, in 1682, applies the same name to the Mississippi. Champlain also had knowledge of the mining of copper in the upper waters of the Saguenay (or St. Lawrence), but he seems not to have had definite knowledge whether the mines were on the south shore of lake Superior or on the "floating island" (Isle Royale) near the north shore.

The *Relations* of the Jesuit missionaries, so far as published, cover the period from 1626 to 1679. The adventurous fathers more frequently mention the savage inhabitants of the country than its geographical features. The Dakotahs are mentioned by Paul le Jeune in 1640, who says they dwelt in the neighborhood of Ouinnipigon (Winnebago), and that they and the Assinipouars (Assiniboines) had been visited by Nicollet, interpreter for the Algonquin and Huron languages for the Messieurs de la Nouvelle France, in their own countries.*

The *Relation* for 1659 thus refers to the Poualak (Assiniboines). "As wood is scarce and very small with them, nature has taught them to burn coal (charbon de terre) in its place, and to cover their wigwams with skins. Some of the more industrious also make cabins of clay (or turf) much in the same way that swallows build their nests."†

GROSELLIERS AND RADISSON.

The actual exploration of the state proceeded westward from lake Superior. In the year 1659 two Frenchmen, in the interest of commerce, made the next recorded visit to the Nadouessioux at lake Buade (Mille Lacs), where they spent the winter. Returning to France they endeavored to establish trade with the "forty Sioux villages" of that locality, but did not succeed. Groselliers, however, enlisted the English in an expedition through Hudson's bay to Fort Rupert. He seems to have reached lake Superior from Hudson's bay, perhaps by way of the Me-me-si-pi, or Pigeon river, on the international boundary, inasmuch as that river, on several ancient maps of the northwest, is styled *R. Grossillers.*

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*Neill's *Minnesota*, p. 101.

†Such habitations were occupied by the Iowas on the upper Minnesota when the Sioux first came there, and are probably the source of many of the "mounds" seen in the state of Minnesota.

MENARD.

To Marquette has been given the honor of the first discovery of the Mississippi at any point north of the Chickasaw bluff; but it appears that an earlier Jesuit missionary reached it by way of the Wisconsin river in 1661, while in pursuit of his labors, in an attempt to preach the gospel to the wandering Huron nation, twelve years before Marquette and Joliet. He descended either the St. Croix or the Wisconsin, and ascended the Black river, on the headwaters of which the Hurons had chosen a residence; but in making a portage Menard was lost in the wilderness. Marquette descended the Wisconsin and passed down the Mississippi.*

ALLOUEZ.

After the death of Menard, Claude Allouez was appointed, in 1665, to the Mission of the Holy Spirit, at La Pointe. It was probably in 1666 that he visited *Fond du Lac Supérieur,* and there met a number of the Nadouessioux from the country to the west and southwest, and learned for the first time of the great river, which, in his *Relation,* he denominated the *Messipi.* Allouez, however, never saw the great river of which he heard so much; on the banks of which dwelt the strange race of aborigines who were reported to live in a country of prairies abounding in all kinds of game, who cultivated tobacco and lived largely on "marsh rice," spoke a language entirely unknown, used the bow and arrow with great dexterity, and dwelt in cabins covered with deer skins—the Iroquois of the country, as Marquette styled them.†

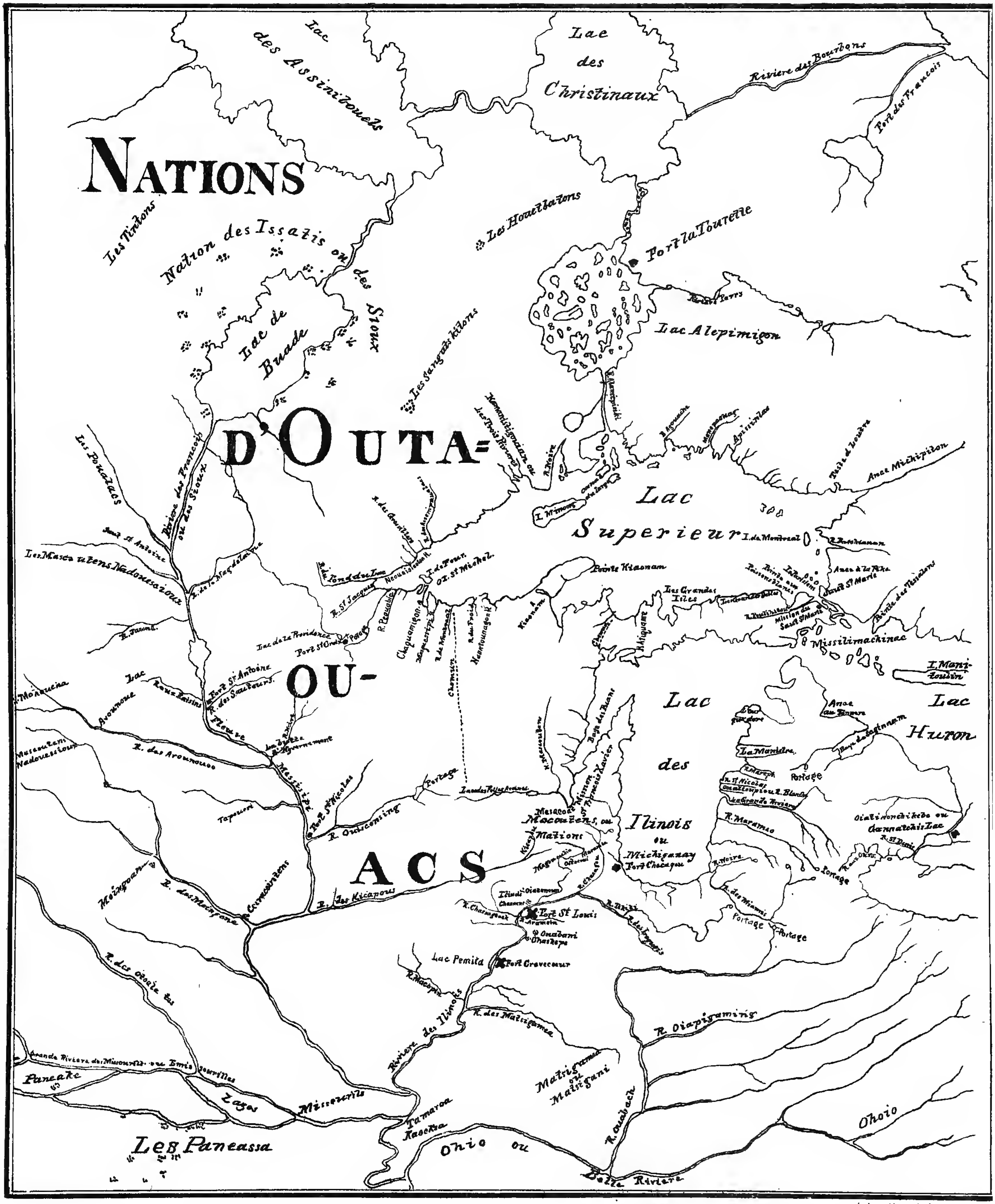
During Marquette's administration the Mission at La Pointe was abandoned on account of the hostility of the Dakotahs, who are described by Marquette as a "certain people called *Nadouessi,* dreaded by their neighbors; and, although they only use the bow and arrow, they use it with so much skill and dexterity that, in a moment, they fill the air. In the Parthian mode, they turn their heads in flight, and discharge their arrows so rapidly that they are no less to be feared in their retreat than in their attack." Although Marquette traveled over much of the western

* Transactions of the Department of American History of the Minnesota Historical Society, E. D. Neill. In French's Historical Collections of Louisiana, Part IV., it is stated, on the authority of the Jesuit Relation of 1639-40, that Sieur Nicollet, in 1639, probably was the first Frenchman on the Mississippi after the visit of DeSoto.

† French expresses the opinion that Allouez visited the Mississippi by way of the Fox and Wisconsin rivers in the year 1670. (Jesuit Relation of 1669-70.) *Hist Coll. Louisiana.*

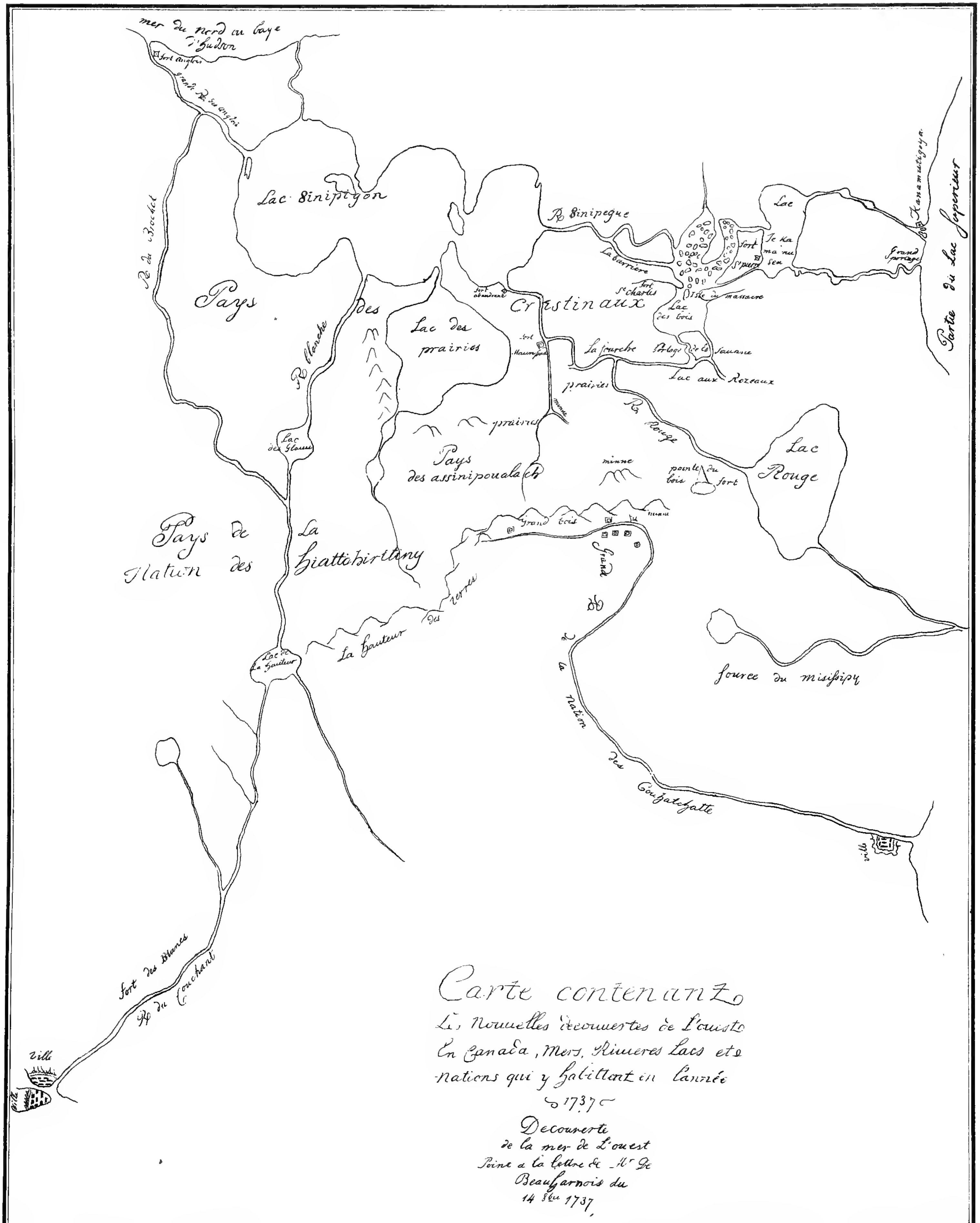
PARTIE D'UNE CARTE DE L'AMERIQUE SEPTENTRIONALE, DRESSÉE PAR J.B. FRANQUELIN DANS 1688, POUR ETRE PRESENTÉE A LOUIS XIV

PLATE 2.



Julius Bien & Co Photo. lith.

Reduced for the Geological and Natural History Survey of Minnesota from a tracing of a map in the Archives des Marines in the possession of the Department of American History of the Minnesota Historical Society



J. Bien, Photo. lith. N.Y.

Reduced for the Geological and Natural History Survey of Minnesota, from a tracing in the Department of American History, of the Minnesota Historical Society

country south of Minnesota, visiting the Mississippi by way of the Wisconsin in 1673, he seems not to have prosecuted his discoveries within the area of Minnesota.

SIEUR DU LUTH.

Under the direction of the Governor of Canada, but probably at the instance of the merchants of Quebec, Daniel Greysolon, the Siéur du Luth, was dispatched with eight men, in 1678, for the purpose of visiting the country to the west of lake Superior, and taking possession of it in the name of the king of France, and securing the trade of the native tribes before the English could reach them. He entered Minnesota in the summer of 1679, having wintered near the falls of the St. Mary's river. In July he caused the arms of the king of France to be set up in the great Sioux village, *Kathio,* which he styles the village of the *Izatys,* which can be no other than the great Nadouessioux settlement at Mille Lacs, to which he gave the name Lac Buade. The next year he reached the Mississippi river by way of the Bois Brulé river (in Wisconsin) and the St. Croix, and encountered Hennepin and his companions, as detailed in his report made to the Marquis of Seignelay in 1685, an extract from which is as follows :*

EXTRACT FROM DU LUTH'S REPORT, MADE IN 1685.

On July 2d, 1679, I had the honor to plant his majesty's arms in the great village of the Nadoecioux, called *Izàtys*, where never had a Frenchman been, no more than at the *Songaskitons* and *Honetbotons*, distant six score leagues from the former, where I also planted his majesty's arms in the same year, 1679.

On the 15th of September, having given the *Agrenipoulak*, as well as all the other northern nations, a rendezvous at the extremity of lake Superior, to induce them to make peace with the Nadouecioux, their common enemy, they were all there, and I was happy enough to gain their esteem and friendship, to unite them together, and in order that the peace might be lasting among them I thought that I could not cement it better than by inducing the nations to make reciprocal marriages with each other. This I could not effect without great expense. The following winter I made them hold meetings in the woods, which I attended, in order that they might hunt together, give banquets, and by this means contract a closer friendship.

The presents which it cost me to induce the Indians to go down to Montreal—who had been diverted by the *Openagaux* and *Abenakis*, at the instigation of the English and Dutch, who made them believe that the plague raged in the French settlements, and that it had spread as far as *Nipissingue*, where most of the *Nipissiriens* had died of it—have also entailed a greater expense.

In June, 1680, not being satisfied with having made my discovery by land, I took two canoes with an Indian, who was my interpreter, and four Frenchmen, to seek means to make it by water. With this view I entered a river which empties eight leagues from the extremity of lake Superior, on the south side, when, after having cut some trees, and broken about a hundred beaver dams, I reached the upper waters of the said river ; and then I made a portage of half a

* Shea's Translation of Hennepin's Description of Louisiana.

league to reach a lake, the outlet of which fell into a very fine river which took me down into the Mississippi. Being there I learned from eight cabins of Nadouecioux whom I met, that the Reverend Father Louis Henpin, Recollect, now at the convent of St. Germain, with two other Frenchmen, had been robbed and carried off as slaves for more than three hundred leagues by the Nadouecioux themselves.

This intelligence surprised me so much that, without hesitating, I left two Frenchmen with these said eight cabins of Indians, as well as the goods which I had to make presents, and took one of the said Indians, to whom I made a present, to guide me, with my interpreter and two Frenchmen, to where the said Reverend Father Louis was, and as it was a good eighty leagues, I proceeded in canoe two days and two nights, and the next day at ten o'clock in the morning I found him with 1,000 or 1,100 souls. The want of respect which they showed to the said Reverend Father provoked me, and this I showed them, telling them that he was my brother; and I had him placed in my canoe to come with me into the villages of the said Nadouecioux, whither I took him, and in which, a week after our arrival there, I caused a council to be convened, exposing the ill treatment which they had been guilty of, both to the said Reverend Father and to the other two Frenchmen, who were with him, having robbed them and carried them off as slaves, and even taken the priestly vestments of said Reverend Father. I had two calumets which they had danced to them, returned to them, on account of the insult which they had offered them, being what they hold most in esteem among them to appease matters, telling them that I did not take calumets from people, who after they had seen me and received my peace presents, and been for a year always with Frenchmen, robbed them when they went to visit them.

Each one in the council endeavored to throw the blame from himself, but their excuses did not prevent my telling the Reverend Father Louis that he would have to come with me toward the *Outagamys*, as he did, showing him that it would be to strike a blow at the French nation in a new discovery, to suffer an insult of this nature, without manifesting resentment, although my design was to push on to the sea in a west-northwesterly course, which is that which is believed to be the *Red Sea* [Gulf of California], whence the Indians who had gone warring on that side gave salt to three Frenchmen whom I had sent exploring, and who brought me said salt, having reported to me that the Indians had told them that it was only twenty days' journey from where they were to find the great lake, of which the waters were worthless to drink.* This has made me believe that it would not be absolutely difficult to find it, if permission would be given to go there. However, I preferred to retrace my steps, manifesting to them the just indignation which I felt against them rather than to remain after the violence which they had done to the Reverend Father and the other two Frenchmen who were with him, whom I put in my canoes and brought them back to *Michelimakinak.*

HENNEPIN'S MOVEMENTS IN MINNESOTA.

That portion of Hennepin's narrative which relates to his movements in Minnesota, and to the natural features of the country, is as follows, as translated from the first, or Paris, edition of his works, by John G. Shea.

The river Colbert† runs south-southwest and comes from the north-northwest; it runs between two chains of mountains, very small here, which wind with the river, and in some places are pretty far from the banks, so that between the mountains and the river there are large prairies, where you often see herds of wild cattle browsing. In other places these eminences leave semi-circular spots covered with grass or wood. Beyond these mountains you discover vast plains, but the more we approach the northern side ascending, the earth did not appear to us so fertile nor the woods so beautiful as in the *Islinois* country.

This great river is almost everywhere a short league in width, and in some places two leagues; it is divided by a number of islands covered with trees interlaced with so many vines as

* There is no such lake in the limits of Minnesota, but this may refer to some of the alkaline lakes of Dakota [N. H. W.]

† Mississippi.

to be almost impassable. It receives no considerable river on the western side except that of the *Otontenta*, and another, which comes from the west-northwest seven or eight leagues from the Falls of St. Anthony of Padua.

On the eastern side you meet first an inconsiderable river, and then further on another, called by the Indians *Onisconsin*, or *Misconsin*, which comes from the east and east-northeast. Sixty leagues up you leave it and make a portage of half a league, and reach the bay of the *Puans* by another river which, near its source, meanders most curiously. It is almost as broad as the river Seignelay, or *Islinois*, and empties into the river Colbert a hundred leagues above the river Seignelay.

Twenty-four leagues above you come to the Black river, called by the *Nadouessions*, or *Islati*, *Chabadeba*, or *Chabaoudeba*. It seems inconsiderable. Thirty leagues further up you find the Lake of Tears,* which we so named because the Indians who had taken us, wishing to kill us, some of them wept the whole night to induce the others to consent to our death. This lake, which is formed by the river Colbert, is seven leagues long and about four wide. There is no considerable current in the middle that we could perceive, but only at its entrance and exit. Half a league below the Lake of Tears, on the south side, is Buffalo river, full of turtles. It is so called by the Indians on account of the numbers of buffalo found there. We followed it for ten or twelve leagues; it empties with rapidity into the river Colbert, but as you ascend it it is always gentle and free from rapids. It is skirted by mountains far enough off in some places to form prairies. The mouth is wooded on both sides and is full as wide as that of the Seignelay.

Forty leagues above is a river full of rapids, by which, striking northwest, [northeast] you can proceed to lake Condé as far as *Nimissakouat*** river, which empties into that lake. This first river is called Tomb river,† because the *Issati* left there the body of one of their warriors, killed by a rattlesnake, on whom, according to their custom, I put a blanket. This act of humanity gained me much importance by the gratitude displayed by the men of the deceased's tribe in a great banquet which they gave me in their country, and to which more than a hundred Indians were invited.

Continuing to ascend this river ten or twelve leagues more, the navigation is interrupted by a cataract, which I called the Falls of St. Anthony of Padua, in gratitude for the favors done me by the Almighty through the intercession of that great saint, whom we had chosen patron and protector of all our enterprises. This cataract is forty or fifty feet high, divided in the middle of its fall by a rocky island of pyramidal form. The high mountains which skirt the river Colbert last only as far as the river *Onisconsin*, about one hundred and twenty leagues; at this place it begins to flow from the west and northwest without our having been able to learn from the Indians, who have ascended it very far, the spot where this river rises. They merely told us that twenty or thirty leagues below [above?] there is a second fall,†† at the foot of which are some villages of the prairie people called *Thinthonka*,‡ who live there a part of the year. Eight leagues above St. Anthony of Padua's Falls, on the right, you find the river of the *Issati*, or *Nadoussion*,‡‡ with a very narrow mouth, which you can ascend to the north for about seventy leagues to lake Buade,§ or of the *Issati*, where it rises. We gave this river the name of St. Francis. This last lake spreads out into great marshes, producing wild rice, like many other places down to the bay of the *Puans*.§§ This kind of grain grows in marshy places, without any one sowing it; it resembles oats, but tastes better, and the stalks are longer as well as the ear. The Indians gather it in due season. The women tie several ears of it together with whitewood bark to prevent its being all devoured by the flocks of ducks and teal found there. The Indians lay in a stock for part of the year and to eat out of the hunting season.

Lake Buade, or lake of the *Issati*, is situated about seventy leagues west of lake Condé; it is impossible to go from one to the other by land on account of the marshy and quaggy nature of the ground; you might go, though with difficulty, on the snow in snowshoes; by water there are many portages, and it is one hundred and fifty leagues, on account of the many turns to be made. From lake Condé, to go conveniently by canoe, you must pass by Tomb river, where we found only the skeleton of the Indian whom I mentioned above, the bears having eaten the flesh and pulled up the poles which the deceased's relatives had planted for a monument. One of our boatmen

* Lake Pepin. ** Bois Brule. † St. Croix. †† Little Falls. ‡ Tintonwan ‡‡ Rum river. § Mille Lacs. Green Bay.

found a war calumet beside the grave, and an earthen pot upset, in which the Indians had left fat buffalo meat, to assist the departed, as they say, in making his journey to the land of souls.

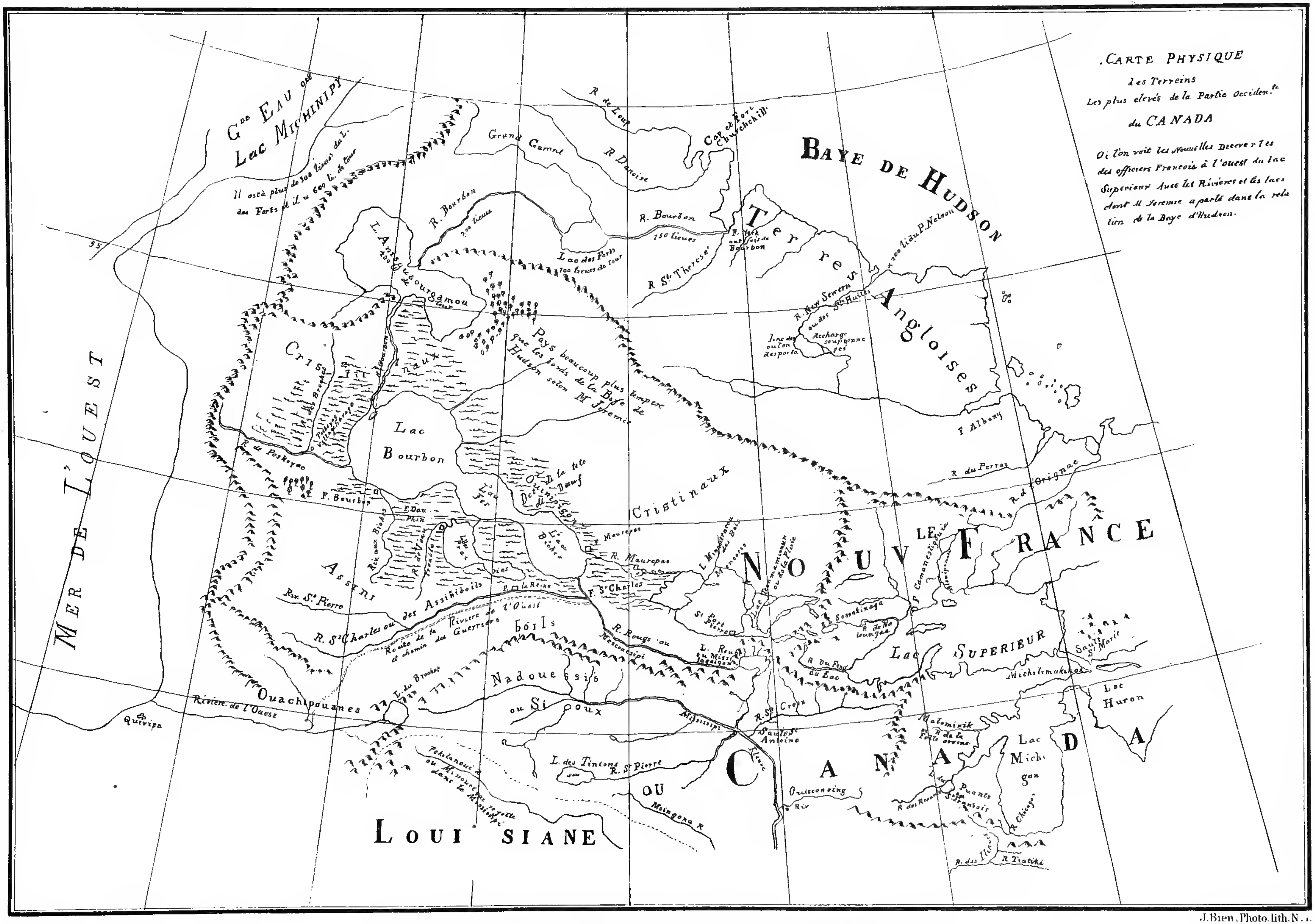
In the neighborhood of lake Buade are many other lakes whence issue several rivers, on the banks of which live the *Issati*, *Nadouessans*. *Tinthona* (which means prairie-men), *Ouadebathon*,* River-people, *Chongaskethon*, Dog or Wolf tribe (for *Chonga* among these nations means dog or wolf), and other tribes, all which we comprise under the name *Nadouessiou*. These Indians number eight or ten thousand warriors, very brave, great runners, and very good bowmen. It was by a part of these tribes that I and our two canoemen were taken in the following way:

The map accompanying Hennepin's work, as published at Paris, is reduced and reproduced in plate-pages 5 and 6. The Mississippi is conjecturally represented by a dotted line as flowing into the gulf of Mexico. The Illinois river is named *Seignelay*; the Wisconsin is called *Oisconsins*; above that is the river *Noire*, or Black river; the next above on the east is *R. des Bœufs;* the St. Croix is styled *R. du Tombeau*, and between it and Rum river, which is denominated the *St. Francois*, is a water connection of lakes and streams. There is one river above the St. Francis, but unnamed. The Mississippi is represented as having no tributaries from the west, and as flowing between two ranges of mountains from the Falls of St. Anthony to some distance below the Wisconsin. These "mountains" are none other than the bluffs of the river valley, made of horizontal strata cut by the river itself. Lake Pepin is named *Lac des Pleurs*; Mille Lacs is *Lac Buade*; lake Superior is *Condé ou Supérieur;* lake Michigan is *L. Dauphin ou Illinois;* lake Huron is *L. D'Orleans ou Huron;* lake Erie is *Conty ou Erie*, and lake Ontario is *L. Frontenac*. The coat of arms of France (probably as established by Du Luth) is represented at the most northwesterly point on the map, surmounted by a figure of the cross, and underneath it are inscribed these words:

Armes du Roy telle
quel[le] sont grauée
sur l' éscorce d' un
Chesne à l' endroit
margué—A.

The unscrupulous Franciscan represents missions of his order established some leagues to the northwest of Mille Lacs, on the lower Mississippi, below the Illinois, as well as on lake Ontario. The gulf of California is named *Mer Vermeille*, and toward the north further are the *Straits of Anian*, supposed to lead to the "Northwest Passage," that phantom of all early explorers of North America.

*Warpetonwan.



Reduced for the Geological and Natural History Survey of Minnesota from a tracing of a Map in the Archives des Marines, in the possession of the Department of American History, of the Minnesota Historical Society

J. Bien, Photo. lith. N. Y.

As Hennepin's account of his visit to the Falls St. Anthony has been much criticised for the exaggeration and the egotism which pervade it, the account of La Salle, who planned and despatched the party, is added. It is very probable that La Salle misrepresents Du Luth, and his travels in the upper Mississippi region. Charlevoix refers to Du Luth as a man of veracity, bravery and honor, and Le Clercq as a man of ability and experience.

LA SALLE ON THE DISCOVERY OF THE FALLS OF ST. ANTHONY.

La Salle's letter from Fort Frontenac, 22nd of August, 1682, is found in Part II. of Margry's *Découvertes et établissements des Francais dans l'ouest et dans le sud de l'Amérique septentrionale.* It contains internal evidence that La Salle derived his information of this expedition from Michel Accault, the real leader of the party. Translated into English as follows :

* * * * * The river *Colbert*, named *Gastacha* by the Iroquois and *Mississipy* by the *Outaouacs*, into which the river of the *Islinois*, called *Téakiki*, empties, comes from the northwest. I have caused it to be explored by two of my men, one of the name of Michel Accault and the other a Picard,* with whom the R. P. Louis Hennepin was associated, in order not to lose the opportunity to proclaim the gospel to those people who inhabit the upper country who had never heard it. They left Fort Creve Cœur in the afternoon of the 28th of February, with the Peace Calumet, which is a protection against the savages of these countries that they seldom violate. The said Michel Accault was somewhat acquainted with their language and their customs. He knew all their habits, and was a friend of several of those tribes to whom I sent him, where he had been acquainted; also, he is prudent, courageous and cool. They had about one thousand pounds of goods, such as are most valued in those regions, which, combined with the Peace Calumet, are never disregarded by those tribes, since they are nearly destitute of everything. They met at first a number of *Islinois*, who were ascending their river on a return to their village, who used every effort to induce them to abandon the journey. Michel Accault, who believed he should lose the honor of accomplishing the undertaking, encouraged by the example of the R. P. Louis Hennepin, who desired also to signify his zeal, and wishing to keep his word which he had given me to perish or to succeed, encouraged his comrade who was dispirited by the statements of the savages, and made him believe that the design of the Indians was to profit themselves with their merchandise, and to seize their provisions, and that they should not change the resolution which they had taken. In fact, they continued their journey down the river *Théakiki* until the 7th of March, 1680, when they fell in with a nation called *Tamaroa*, or *Maroa*, about two leagues from the mouth of the river where it reaches the Colbert. This nation numbers two hundred families or thereabout. They desired to conduct them to their village, situated at that time on the west coast of the Grand river, six or seven leagues above the entrance of the *Théakiki*. They would not follow them, but arrived, the same day, at the confluence of the two rivers, distant about fifty leagues from Fort Creve Cœur and ninety from the village of the *Islinois*. The river *Théakiki* is nearly everywhere of equal size throughout these ninety leagues, approaching the size of the Seine, in front of Paris, where it is confined within its own bed; but at various places, as at *Pimiteoui*,† one league to the east of Creve Cœur, and two or three other times below, it swells out to one or two leagues, over much space, while the two shores which border it below the village of the *Islinois*, are distant from each other about half a league. The land which they enclose between them is swampy, as well as the bed of the

*His real name was Du Gay. †Peoria.

river, and often inundated, especially after rains, which easily cause the streams to leave their channels, and expand them exceedingly, though often but a little in height. That of the *Islinois*, from their village to the Grand river, has a very deep and even bed. There is a border of timber nearly its whole length. The low grounds all sustain very large trees of all kinds, the slopes of the shores being generally covered. But immediately after one has crossed that which the river overflows from time to time, and ascended the banks, he finds only beautiful fields spread before his view, interrupted here and there with clumps of trees, which appear to be there only from necessity. These uninhabited plains extend sometimes even to the brink of the river, particularly about the environs of the village, and at sixty leagues to the east and northeast, where timber can be seen very rarely along the shore of the river; but below it is more generally bordered. The current is hardly perceptible when there has not been a great fall of rain. Although this happens only in the spring, it is perfectly navigable, nevertheless, throughout the year, for large boats as far as to the *Islinois*, and above that only for canoes, partly on account of the rapidity of the stream, and partly on account of the greater descent and the shoals which destroy its depth. Ice which they encountered in the Grand river stopped them at the mouth of the *Islinois* till the 12th of March. It washes on the south shore a steep rock, about forty feet high, suitable for the establishment of a fort, and on the opposite side extends a fine prairie, the limit of which cannot be seen, very good for cultivation. This place seems to me very well adapted for settlement, for many reasons which I have not time here to state, and I shall easily be able here to establish myself on my return. Just at and below *Pimiteoui* the river turns somewhat to the south, so that its *embouchure* is between 46 and 47 degrees of north latitude, and separated from the gulf of Mexico about 120 or 130 leagues. There are between Quebec and Montreal 43 leagues difference east and west; from Montreal to Fort Frontenac, 61 leagues; from the fort to Niagara, 65; from Niagara to the head of Lake Erie, 122; from there to the mouth of the river of the *Miamis*, 117; from there to the *Islinois*, 52; thence to *Pimiteoui*, or Creve Cœur, 27, and from Creve Cœur to the *Mississipi*, 18, which makes, altogether, about 500 leagues, or 24 degrees of longitude. The *Mississipi* appears, in leaving the mouth of the *Téatiki*, to go toward the south and southwest, and above there to come from the north and the northwest. It runs between two ranges of mountains of considerable height—much more than that of Mt. Valerian, which wind about in the same manner as the river, from which presently they fall back a little, leaving between them and its channel a prairie of some width, which is sometimes washed by the water of the river, in such a way that when along one coast it is bordered by the foot of a mountain, on the other is formed a bay, the head of which is terminated by a prairie or by a little patch of woods. The slopes of these shores, which are either of rubbish or of rock, are covered here and there with little oaks, and at other times with very beautiful herbs. The height of these mountains conceals the plains beyond, which are of rather poor land, quite different from that of the *Islinois*, though they sustain the same animals. The channel of the great river, although, for the most part of the width of one or two leagues, is entirely intercepted by a number of islands covered with wild timber, in which are so many vines that one can hardly pass through it. These are subject to inundation by the overflow of the river. They conceal generally the other shore of the river from view, so that it is rarely seen because of these islands. The bottom is very uneven, in ascending the river above the mouth of the *Islinois*. There are often shoals which cross the channel from one side to the other, over which canoes have difficulty in passing. It is true that in the current of the stream there is generally sufficient water to float the largest vessels; but there the stream is extremely rough and difficult to make headway. The *Mississipi* does not receive any considerable rivers from the west side, from the river of the *Islinois* up to the country of the *Nadouessioux*, where it receives that of the *Otoutantas*, *Paoté* and *Maskoutens*, who are the *Nadouessioux* of the East, about one hundred leagues from *Téakiki*.

THE WISCONSIN VALLEY AND THE ROUTE TO GREEN BAY.

Following the course of the *Mississipi*, one finds the river *Ouisconsing*, *Misconsing* or *Meschetz Odeba*, which flows between the bay of the *Puans* and the *Grand* river. It runs at first from the north to the south, to about the 45th degree of north latitude, and from there turns to the west and southwest, and after a course of sixty leagues, falls into the *Mississipi*. It is almost as large as that of the *Islinois*, navigable up to that bend where a canoe portage is made across a divide and a swampy prairie to reach the river *Kakaling*, which falls into the bay of the *Puans*, and perhaps further. The *Misconsing* runs between two hill-ranges, which recede from time to time and leave between them and the river prairies of considerable size, and lands untimbered, which are sandy and sterile. At other times the patch which is between these ridges and the river is, in places, more low and marshy; and then it is covered with timber and is flooded by the overflows of the river. The mountains diminish imperceptibly in size as one ascends the river, and at length, about three leagues from the portage, the land becomes flat and marshy, open on the side from which the portage sets out, and covered with pines on the other side. The place where the canoes are carried is marked by a tree, on which there are two canoes rudely delineated by the savages; whence, after having walked about half a league, the river *Kakaling* [Fox] is found, which is only a rivulet rising from a marsh, and which winds about exceedingly, forming little lakes by enlarging itself, and then often becoming narrow. It is followed about 40 leagues, in the course of the bends it makes, and then is found the village of the *Outagamies*. At one-half league from the river, on the north side, before arriving there, the river falls into a lake which may be eight leagues long and three leagues wide; and after passing the village about two leagues are found the *Kakaling* rapids, which are difficult to descend on account of the swiftness of the water, the frequency of rocks which it encounters. and three waterfalls where it is necessary to carry the canoes and their burden. They continue six leagues. Three leagues below them, at the *debouchure* of this river into the bay of the *Puans*, is a house of the Jesuits, who truly have the key to the country of the beaver, where a brother blacksmith whom they have, and two companions, have changed more iron into beaver than the Fathers have of savages into Christians.

About 23 or 24 leagues to the north, or northwest, from the mouth of the *Ouisconsing* [Wisconsin], which has also a rocky coast on the south side and a beautiful prairie on the north, near to three beautiful basins or bays of quiet water, is the river *Noire* [Black], called *Chabadeba* by the *Nadouesioux*. This is of inconsiderable size, and at its mouth it is bordered on both sides by alders. Ascending about 30 leagues, all the way in nearly the same direction, we have the river *Bœufs* [Chippewa], about as large at its mouth as that of the *Islinois*. It is so called because of the number of these animals which are there found. It was explored ten or twelve leagues, and it remains of the same size and without rapids, bordered by mountains, which are separated farther, occasionally, so as to form prairies. There are several islands at its mouth, and it is lined with woods on both shores.

LA SALLE'S OPINION OF DU LUTH.

Thirty-eight or forty leagues higher is found the river by which Du Luth descended to the *Mississipi*. For three years he had been, contrary to orders, with a band of *coureurs des bois*, in the lake Superior region. He had acted very boldly there, publishing everywhere that at the head of his braves he did not fear the *Grand Prévost*, and that he would forcibly make him grant him amnesty. The *coureurs des bois*, to whom he first had revealed his pretence, have been several times in the settlement, and have returned carrying merchandise and furs, of which they have meantime despoiled lake Superior, from all the approaches to which they have kept out the *Outaouac* during this year, so that they could not descend to Montreal.

During this time and while he was at lake Superior, the *Nadouesioux*, invited by the presents which the late Sieur Randin had made them in behalf of Count Frontenac, and the *Sauteurs*, who are the savages that bring the most peltries to Montreal, and who dwell at lake Superior, wishing to observe the repeated injunctions of said Frontenac, concluded a peace, which was to unite the nation of the *Sauteurs* to the French, and to allow them to go in trade to the country of the *Nadouesioux*, distant about 60 leagues to the west from lake Superior. Du Luth, in order to conceal his desertion, took this occasion to give it some excuse, and causes himself, with two of his fellow-deserters to pass as an envoy of the Count and charged with his orders, for the purpose of negotiating that peace—during which his comrades negotiate for a great number of beaver. He had a number of conferences with the *Nadouesioux*, and as he had no interpreter, he bribed one of mine, named Faffert, till then a soldier at Fort Frontenac. Finally, the *Sauteurs* having been several times back and forth to the *Nadouesioux*, and the *Nadouesioux* to the *Sauteurs*, seeing that there was nothing to fear, and that it was possible to increase the number of their beaver, he sent there this Faffert, by land, with some *Nadouesioux* and *Sauteurs*, who returned in company with him. This young man having made a report on his return of the number of beaver which he might obtain from that direction, he resolved to attempt to go there himself; and under the guidance of a *Sauteur* and a *Nadouesioux*, with four Frenchmen, they ascended the *Nemitsakouat*, whence, by a short portage, he descended into that in which he said he had passed forty leagues of rapids; and having seen that the *Nadouesioux* were further down with my men and the Father,§ having gone down the river from the village of the *Nadouesioux* where they had already been, he comes on to find them. He returned to the village, whence they all together re-descended and by the way of the river *Ouisconsing* reached Montreal. There he was considerably elated at having been one of their party, having even insulted the commissaries, and also the Deputy Procureur, (at présent the Procureur-General), named d'Auteuil. Mons. le Comte de Frontenac had him arrested, and took measures to keep him in prison in the bastile at Quebec, intending to send him to France on the certification of the facts by Mons. l'Intendant, to the end that the amnesty granted to his *coureurs des bois* should not result in his discharge.

To know who this Du Luth is, it is necessary that you be informed by Mons. Dalera. Meantime he pretends to have made a considerable discovery, and to demand this country as if to the advantage of the *Islinois*, a proceeding which is quite agreeable, and which he hopes may compensate for his rebellion. Secondly, there are only three routes by which to go there—one is by lake Superior, the second by the bay of the *Puans*, and the third by the *Islinois* and the territory that is covered by my commission. The first two lie under suspicion, and it will not be necessary to open to him the third to my disadvantage, he not having incurred any expense, and having made great gain without risk, at the same time that I have endured great fatigues, perils and losses. Further, through the *Islinois* is a detour of three hundred leagues for him. For the greater part of the country of the *Nadouesioux* is not that which he has discovered. It has been known for a long time, and the R. P. Hennepin and Michel Accault were there before him. Even that one of his fellow-deserters who was there, was one of my soldiers whom he bribed. Furthermore this country is not habitable, little adapted to cultivation, having only marshes full of wild rice (*folle avoine*) on which the people live; and there can be derived from this discovery no advantage whether it be attributable to my men or to Du Luth, because the streams are not navigable. But the king having granted us the trade in buffalo hides, this would be ruined in going to and coming from the *Nadouesioux* by any other route than by lake Superior by which Count Frontenac has power to send him there in search for beaver, in pursuance of the authority which he has to grant permits. But if they go by way of the *Ouisconsing*, where for the present the chase of the buffalo is carried on, and where I have commenced an establishment, they will ruin the trade of which alone I am laying the foundation on account of the great number of buffaloes which are taken there every year, almost beyond belief.

LA SALLE'S DESCRIPTION OF THE FALLS OF ST. ANTHONY.

Ascending still the *Mississipi*, at twenty leagues above this river, are found the falls which those whom I sent, and who passed there first of all, named from St. Anthony. They have the height of thirty or forty feet, and there the river is also narrow. There is an island in the midst of the fall, and the two shores of the river are no longer bordered by mountains, which diminish insensibly up to there ;* but the land on both sides is covered with light timber, ** as we style it, that is to say, oaks and other hard woods, standing far apart, such as grow only in poor lands. There are also some prairies. Here the canoes are carried about three or four hundred steps, and eight leagues above is the river of the *Nadoesioux*, on the west† side. It is narrow at its entrance and drains a poor country covered with shrubs through about fifty leagues, where it terminates in a lake called lake of the *Issati*, which spreads over a great marsh where grows the wild rice, at the point of its outlet in this river.

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*Hennepin says the mountains extend only to the mouth of the Wisconsin. § Hennepin.

** Perhaps this *bois clairs* means *deciduous trees.*

† This is evidently an error of some copyist, as the river, which is well known as Rum river, is an eastern tributary of the Mississippi.

CAPTURE OF ACCAULT AND HIS PARTY.

The *Mississipi* comes from the west, but it was not followed because of the adventure which happened to R. P. Louis, Michel Accault and their comrade. This affair happened in this way. After having pursued the course of the *Mississipi* till the 11th of April about three o'clock in the afternoon, rowing along the shore on the side of the *Islinois*, a band of a hundred *Nadouesioux* warriors who were going to slaughter some of the *Tchatchakigona*,* were descending the same river in thirty-three canoes made of birch bark. There were with them three women, and one of those slaves who serve the women, although they are men, whom the *Islinois* call *Ikoueta*. They passed along on the other side of some islands, and so several of the canoes had descended below that of the Frenchmen; but descrying it, they all gathered together, and those who had gone below returning with all haste, they easily encompassed it about and closed up the way. There was one party of them on the land, who surrounded them on that side. Michel Accault, who was the leader, presented them the calumet. They accepted it and smoked, after having made a circle on the ground covered with straw where they caused the Frenchmen to sit down. Immediately two of the old men began to weep for the death of those of their kinsmen whom they designed to avenge; and after having taken some tobacco they made our men embark, and cross over first to the other side of the river. They followed on, after having uttered three cries, and pushed their canoes with all haste. On disembarking Michel Accault presented them with twenty knives and a measure and a half of tobacco, which they accepted. They had already stolen a demi-pique and several other small articles. They then traveled together ten days, without giving any sign of discontent or of evil design; but on the 22nd of April, having reached the islands where they had slain some *Maskcutens*, they put the two dead whom they were going to avenge, and whose bones they carried with them, between P. Louis and Michel Accault. This is an ambiguous ceremony which they perform before their friends in order to incite them to compassion, and to cause them to make presents to cover them with, and before their slaves whom they take in war to make them understand that they must expect a treatment like to that which they render to the dead. Michel Accault unfortunately did not understand this nation, and there was not one slave of the other nations whom he did understand, which hardly ever happens, all the tribes in America having a number of those to whom they have granted life in order to replace their dead, after having sacrificed a great number to satisfy their vengeance. This enables them to understand almost all the tribes, since they become acquainted with three or four languages of those tribes who go farthest in war, such as the *Iroquois*, the *Islinois*, the *Akonsa*, the *Nadouesioux* and *Sauteurs*. Accault understood all these except the *Nadouesioux*; yet there are among them a number who have been slaves with the others, or who had come from them and have been taken in war, but by chance he did not find one of them in this company to interpret him to the others. It was necessary to give a full case of merchandise, and the next day twenty-four hatchets. At eight leagues below the falls of St. Anthony they determined to go by land to their village, distant about sixty leagues from the place of disembarking, not being willing to carry the goods of our men, nor to conduct them there by water. They made them then give up the rest of their hatchets, which they shared amongst themselves, promising to repay them well at the village; but two days afterward they divided also among themselves two cases of merchandise, and, falling into a quarrel concerning the division both of the merchandise and of the tobacco, each chief claiming to be the master, they separated in jealousy as they led the Frenchmen toward the village, where they promised to make satisfaction with beaver skins which they said they had in great number.

THE PARTY AT MILLE LACS.

There they were received well, and at once made a banquet for Accault, who was in a different village from that where the R. P. Louis and the Picard were, but who were there also well received except that, several sportive young men having told the Picard to sing, the fear that he experienced made a coward of him, since only slaves sing on arriving at a village. Accault, who was not there, was not able to prevent it; but they were subjected to no other treatment like that

*Hennepin says *Outagamis*, and Parkman says *Miamis*.

which they impose on slaves. They were never tied; and after that, they promised the return of that which their young men had seized, since Accault, who had found some men to whom he could make himself understood, made them comprehend the importance of it, when they immediately danced two calumets, and offered several beaver skins with which to begin the payment; but as these were too little Accault would not be satisfied. Six weeks afterward, all having returned to the *Ouisconsing* with the *Nadoesioux* on a hunt, the R. P. Louis Hennepin and the Picard resolved to go to the mouth of the river where I had promised to send messages, as I had done by six men, whom the Jesuits deceived, telling them that the R. P. Louis and his fellow travelers had been slain. They allowed them to go there alone, to show them they were not regarded as slaves, and that Du Luth is wrong in boasting of having released them from slavery, since on the journey and as long as their food lasted, the Frenchmen had the best, although they suffered great hunger when the savages were without food. Jealousy was the sole cause of the pillage, because, as they were from different villages, and but few from that where the Frenchmen were to go, they did it in order to secure their portion of the merchandise, of which they feared they would receive none if they once entered the village where the Frenchmen were to go; but the old men blamed greatly the young men, and offered and even began to make the restitution that Accault ought to have. They regarded the French so little as slaves that they gave to R. P. Louis and the Picard a canoe to go in search of my messengers. All that Du Luth can say is, that having come to the place where the Father and the two Frenchmen had gone in a hunt from the village, where, along with them he went for the first time when they returned there, he made it easier for them to return sooner than they would have done, because messengers whom I had sent had been dissuaded from going on; but we should have been in search for them the following spring if we had not learned, as we did in the winter, of their return by way of the *Outagamis*. Accault found himself so little a slave that he was intending to remain there until he should receive the payment that had been promised him.

LA SALLE JUSTIFIES THE EXPEDITION.

I do not doubt but several things may be said of this expedition.

(1.) That I ought to have sent a man who understood the language. To this it is easy to reply that I did not send Accault to the *Nadouesioux* but to explore the *Grand* river, that he understood the language of those who were nearest, such as the *Otontanta* the *Aiounouea*, the *Kikapou* and the *Maskoutens Nadouesioux* through whom he was to pass first, and to take an interpreter from there for going further on, it being impossible to send those who understood all the languages.

It will be said also that in the first expeditions it was not necessary to go with so much merchandise, which tempts the young men, already under bad subjection to the elders, and leads them to deeds which they would not do if they saw nothing which tempted them. To this I reply that, sending to those nations with whom we had acquaintance through the *Islinois*, and to whom Accault was a friend, because he had passed two winters and a summer there, during which time he had seen several of the most important of their villages where he was to pass, whom he had won by little presents, there was nothing to fear, at least in all probability—there being no likelihood that they would encounter an army of the *Nadouesioux* three hundred leagues from that country. (2) These voyages being difficult, those who undertake them do it only through the hope of gain, which they could not accomplish without merchandise. (3) Several of those savages having come to the *Islinois* while we were there, and having seen the merchandise which we had there, they would be filled either with anger or jealousy, believing that going into their country with but little would be either from a want of friendship for them or from some evil design. Finally, wishing to attract them to come and buy of our commodities and to make them accustomed to the use of them, it would be necessary to have a somewhat considerable quantity of them.

I have thought it proper to give you this account of the adventures of this canoe, because I do not doubt its being spoken of, and if you wish to confer with Father Louis Hennepin, Recollect, about it, who has returned to France, it is well to know something of it, for *he will not fail to exaggerate everything; it is his character;* and to me even he has written as if he had been nearly burnt up, although he has not been even in danger of it; but he believes it is honorable in him to act in that way, and *he speaks more in accordance with what he wishes than what he knows.*

Hennepin's account of the capture and captivity among the Nadouesioux is more circumstantial than that of La Salle, but in the main similar to his. Hennepin, however, recounts various indignities and deprivations to which they were subjected, regarding himself as a prisoner and a slave while at lake Buade.

"In the beginning of July" the Frenchmen set out with the Indians on a grand buffalo-hunt down the Mississippi. In four days they reached the mouth of the St. Francis, or Rum river,* where they halted for the purpose of making more canoes; while Hennepin and the Picard proceeded down the Mississippi alone in a poor canoe intending to reach the Wisconsin river, where La Salle had agreed to send messages to them. It is probable, therefore, that Hennepin first saw the Falls of St. Anthony on the 5th day of July, 1680,† in company with the Picard alone. On the 11th they were not far from the Wisconsin, after some adventure and delay.

It is plain, also, that Hennepin saw the Falls of St. Anthony before he encountered Du Luth, and may be accredited with the first recorded examination of the Mississippi between the Wisconsin river and the Rum river, and Du Luth with the first visit to the St. Croix river, which he probably descended from the headwaters of the Bois Brulé, known then as the *Nemissakouat.* (Plate-pages 5 and 6.)

LA HONTAN IN MINNESOTA.

Baron La Hontan's work, in which he describes a voyage on the river Long, made by himself in the winter of 1688-89, is largely fictitious. He states that he traveled sixty days in winter on a river 500 miles long, at the mouth of which are many rushes, which entered the Mississippi from the west. Mr. J. N. Nicollet regards the river that La Hontan entered as the Cannon river. It has also been suggested that on ascending this river to its source he passed into the Minnesota river, through some of the canoe routes and lakes which cause the headwaters of the Cannon to interlock with those of the Le Sueur. Keating, the chronicler of Major Long's expedition to the sources of the St. Peter, supposed that the Root river

* On modern maps the name of St. Francis is applied to the next stream above the Rum, and that may have been the river to which Hennepin referred in his journal, since by a portage the route by it to lake Buade is much less than the course of the Rum river, and the Indians may have followed that route.

† The Minnesota Historical Society celebrated July 5, 1880, as the Bi-centennial of the discovery of the Falls of St Anthony.

was the one referred to by La Hontan, while others, with perhaps as good reasons, think he actually entered the Minnesota river. The very general and vague description which he makes of the physical character of the valley of the *Rivière Longe* will apply with equal correctness to either of these valleys, but the direction of the river he says he explored, as represented on his map, can only apply to the Root river. The Root river is less likely to be frozen in winter than either of the others, owing to the fact that it is derived largely from copious springs and subterranean streams that flow from the rocky bluffs between which it runs (see the geology of Fillmore county), and is a larger stream than the Cannon, and further south.*

LE SUEUR IN THE MINNESOTA VALLEY.

Although there is mention made in the treatise of Nicholas Perrot, a trader and interpreter, and later an agent of the government in the upper Mississippi region, *on the habits, customs and religions of the savages of North America,* of the St. Croix and St. Peter's rivers, there seems to have been no further extension of knowledge of the geography of the region till the time of Le Sueur.

The first accredited exploration of the Minnesota valley was made by Le Sueur, who first visited the upper Mississippi in 1683, with Perrot, in the interests of trade. He built a trading-post on Isle Pelée, a few miles below Hastings, in 1695, and in 1699 received a commission from D'Iberville to visit and examine a copper mine which he claimed to have discovered in the country of the Ioways. In April, 1700, with a single shallop and about twenty-five persons, he started from the settlements on the lower Mississippi for the mouth of the Minnesota river, where he arrived on the 19th of September; and on the last day of the same month, being stopped by ice forty-four leagues above its union with the Mississippi, he determined to build his fort. His narrator, Penicaut, who was also his carpenter, states that this place was *a league up the Green river* (now the Blue Earth) *on a point of land a quarter of a league distant from the woods.* This river was so called "because it is of that color by reason of a green earth, which, loosening itself from the copper mines, becomes dissolved in it and makes

* Coxe in French's Hist. Col. of Louisiana, Part II., p. 233, says lake Pepin was *above* the "Long" river of La Hontan.

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Destroit d'Anien
Armes du Roy telle quelle sont grauée sur l'Escorce d'vn Chesne a lendroit marqué A
Lac des Assenipoils
Chongasquabé ou Nation des Forts
Missions des Recollects
Les Hanctons
Nadouessans
Lac de Buade
Oüa de Battons ou gens de Riuiere
Tinthonha ou gens des Prairies
Issati
Lac de Condé ou Superieur
Sault de St. Antoine de Padoüe
Mesilimackinac
Baye des Puans
Portage
Forte de Frontenac
MontReal
Quebec
Tadoussac
ACCADIE
Nlle ANGLE TERRE
HOLANDE
Les Illinois
Fort de Crouecœur
Mission des Recollects
Portage
Fort des Miamis
Lac de Conty ou Erie
R. Colbert
La Louisiane
Virginie
FLORIDE
MER VERMEILLE
MEXIQUE OU NOUVELLE ESPAGNE
Les Mines de Ste Barbe
GOLFE DE MEXIQUE
C. de la Floride
Canal de Bahama
Tropi
I. de Cuba
I. de St Domingue
I. Iamaique
Mexico
OCCIDENT
MER DE AMER
Ligne Equinoctiale
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J. Bien, Photo. lith. N.Y.

it green." Four leagues above the mouth of the St. Croix, at the mouth of a small lake, Le Sueur saw a large mass of copper. "It is on the edge of the water, in a small ridge of sandy earth, on the west of this lake."* The blue, or green, earth, which was mistaken for an ore of copper by Le Sueur, was obtained in a mine three-quarters of a league distant from the fort. The fort was named L'Huillier, from one of the chief collectors of the king, who had assayed the ore in Paris in 1696. Having spent the winter at his fort, in the spring of 1701 he descended the Mississippi with a large quantity of the ore, 4,000 pounds of which were sent to France. He intended to return, but in 1703 the garrison left by him arrived at Mobile, in charge of Derague, having been compelled to abandon the post on account of ill treatment by the Indians, and lack of supplies. This river is further described as being near a range of hills (Keating says *mountains*) ten leagues long that seemed to be composed of the same substance. Charlevoix says: "After removing a burnt, black crust, as hard as a rock, the copper could be scraped with a knife." Penicaut says: "This mine is situated at the beginning of a very long mountain which is upon the bank of the river, so that boats can go right to the mouth of the mine itself. At this place is the green earth, which is a foot and a half in thickness, and above it is a layer of earth as firm and hard as stone, and black and burnt like coal by the exhalation from the mine. The copper is scratched out with a knife. There are no trees upon this mountain. If this mine is good, it will make a great trade, because the mountain contains more than ten leagues running of the same ground. It appears, according to our observations, that in the very finest weather there is continually a fog upon this mountain."†

Mr. W. W. Mather, who accompanied Featherstonhaugh, says that he "found the green earth, but it contained no copper." Mr. Featherstonaugh is very positive in his denial of the existence of any copper in that locality, and pronounces the whole account a fabrication by Le Sueur.

It is more probable that Le Sueur was honest in his conviction, but was mistaken in the value of the *green earth* which he mined. Charlevoix, La Harpe and Penicaut agree in the statement of the main facts, and if

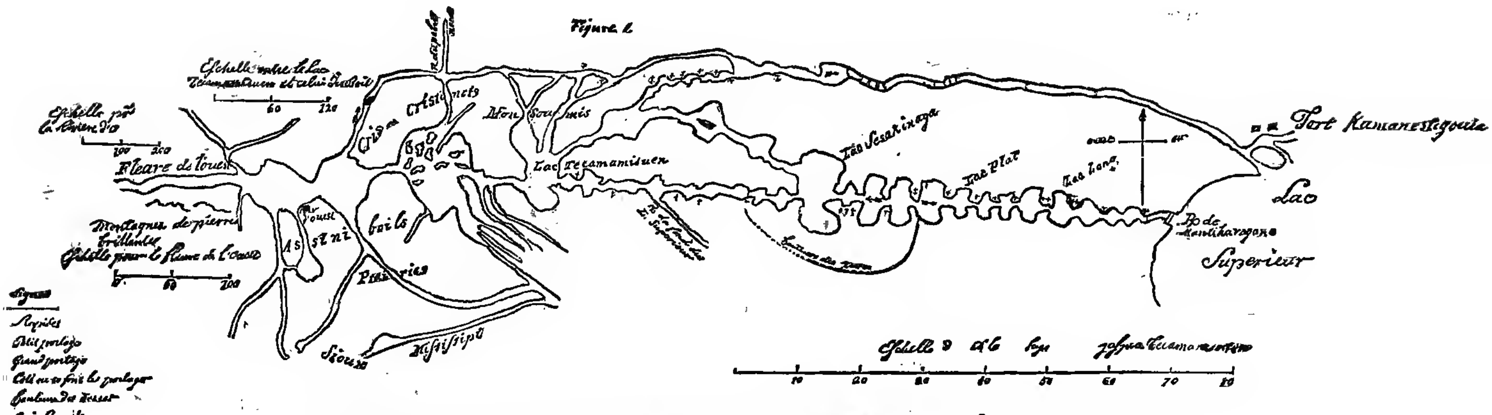
* Neill's *Minnesota*, p 161.
† Translated by A. J Hill, in the Third Volume of the *Minnesota Historical Collections*.

Le Sueur took a quantity to France for assay, it is not likely that he wilfully falsified the facts as to its origin and nature. There can be no question of the existence of both green and blue earth in that vicinity. The shales of the Cretaceous are common in that part of the state, and there is also a clayey deposit, supposed to be of the Cretaceous, found lying unconformably in eroded places in the Cambrian limestones of that valley. The hard, black, burnt crust mentioned, which, on being scraped, exhibited the copper, can be no other than the ironstone incrustation that covers the Cambrian limestones, as seen at Mankato, wherever the Cretaceous clays lie unconformably over them.

OCHAGACH'S MAP.

The oldest map of the region west of lake Superior was traced by a chief of the Assiniboines, named Ochagach, for Verendrye, in 1730, and was taken by Verendrye to the governor of Canada to induce him to equip an exploring expedition in search of a passage to the western ocean. This map was sent to Paris and deposited in the *Archives de la Marine.* A reduced transcript of this map is given below (Fig. 1.), derived from a facsimile tracing in the Department of American History of the Minnesota Historical Society, through the courtesy of Mr. Neill. It was reproduced on the margin of Buache's map of 1754, and its contents are also incorporated in Buache's general *Carte Physique.* (V. Plate 4.) It gave rise to the important and extensive explorations of Sieur Verendrye and his sons and nephew (Jeremaye), which extended through several years and covered the valleys of the Assiniboine and Saskatchawan, as well as those of the upper Missouri and the Yellowstone, to the "shining mountains."

The water-course rudely represented on this chart, extending westward from lake Superior, is that which afterward became the international boundary. The river marked "R. de fond du L. Supérieur" is evidently that which is now known as Vermilion river, north of Vermilion lake, and derived its designation by Ochagach from the fact that it furnished the main route, for east-bound canoes, to the head of lake Superior and the south shore of that lake; and, for a similar reason, that marked "Mississipi" represents the Big Fork river. The "Fleuve de l'ouest" is evidently the present Saskatchawan river, flowing into lake Winnipeg from the west, and rising in the Rocky Mountains. Plate IV however, represents the river of the west as flowing into the Pacific, rising in lake Brochet in the neighborhood of the sources of the Missouri.



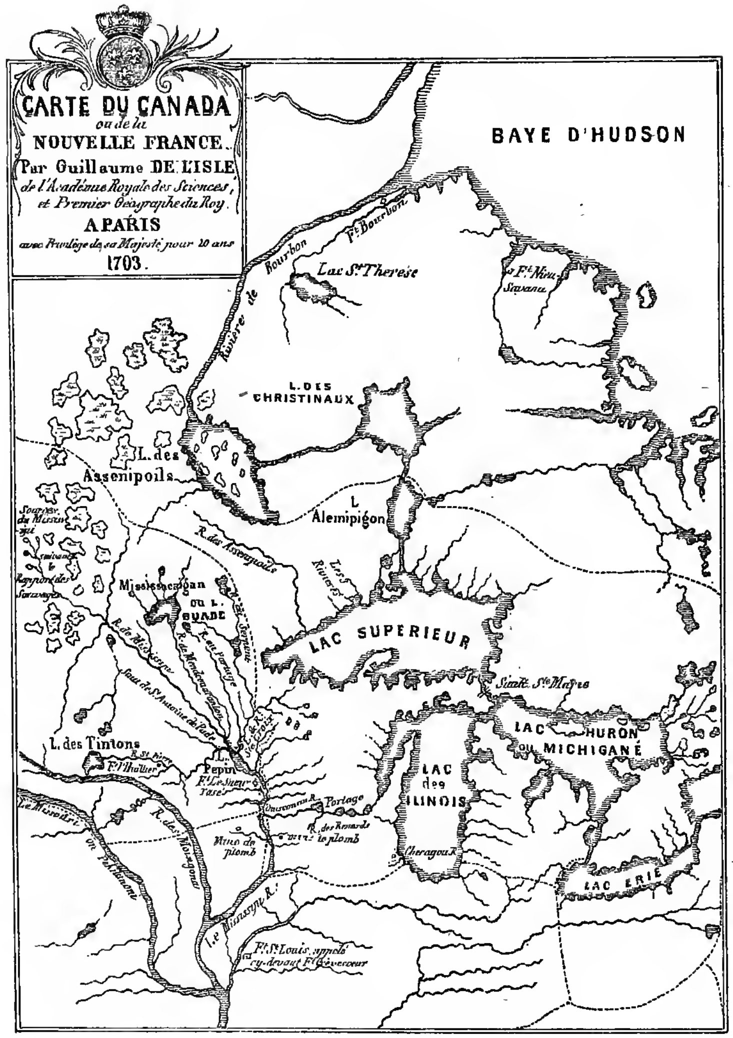
Carte tracée par le Sauvage Ochagach et autres. laquelle a donné lieu aux decouvertes des Officiers Francois representees dans la Carte cy apres

JONATHAN CARVER.

Jonathan Carver in 1766 was the next to contribute to the geography and natural history of Minnesota. By this time the route for canoes along the northwestern boundary had become well known, and was annually traversed by hundreds of *coureurs des bois* and by thousands of Indians conveying furs to the lake shore, where at Fort Charlotte, now Grand Portage, they were exchanged for supplies from Montreal, or were despatched in the light birch canoes to the distant markets of Montreal and Quebec. This route had been mapped by Ochagach in 1730 for Verendrye, and by Jeffrey in 1762.

Carver ascended the Mississippi from the mouth of the Wisconsin to the falls of St. Anthony, of which he gives the fullest description up to that time, and, passing above the falls, reached the St. Francis river. Thence he descended, and made his way up the Minnesota river as far as the mouth of the Waraju, or Cottonwood, where he spent seven months — the winter and spring of 1766-67. Subsequently descending the Mississippi to Prairie du Chien, he passed through Wisconsin to lake

FIGURE 2.



Superior and Grand Portage, returning to Boston by way of the north shore of lake Superior, Michillimackinac and Detroit.

Carver's book* states that he intended at first to pass by way of the lake of the Woods and lake Winnipeg, to the "heads of the river of the West, which, as I have said before, falls into the straits of Annian, the termination of my intended progress," but falling short of supplies for presents to the Indians, and being unable to obtain them of the traders at Grand Portage, he was compelled to abandon his great exploration.

*Travels through the interior parts of North America, in the years 1766, 1767 and 1768. By J. Carver, Esq., Captain of a company of provincial troops during the late war with France, Dublin, 1779.

Passing through lake Pepin, he gives the usual description, adding the following respecting the fauna:

CARVER ON LAKE PEPIN AND THE MISSISSIPPI RIVER.

Great numbers of fowl also frequent this lake and rivers adjacent, such as storks, swans, geese, brants and ducks; and in the groves are found plenty of turkeys and partridges. On the plains are the largest buffaloes of any in America. Here I observed the ruins of a French factory, where it is said Captain St. Pierre resided and carried on a very great trade with the Naudowessies, before the reduction of Canada.

The Mississippi, as far as the entrance of the river St. Croix, thirty miles above lake Pepin, is very full of islands, some of which are of considerable length. On these also grow great numbers of the maple or sugar tree, and around them vines loaded with grapes creeping to their very tops. From the lake upwards few mountains are to be seen, and those but small.

CARVER ON CARVER'S CAVE.

About thirty miles below the falls of St. Anthony, at which I arrived the tenth day after I left lake Pepin, is a remarkable cave of an amazing depth. The Indians term it *Wakon-teebe*, that is the Dwelling of the Great Spirit. The entrance into it is about ten feet wide, the height of it five feet. The arch within is near fifteen feet high and about thirty feet broad. The bottom of it consists of fine, clear sand. About twenty feet from the entrance begins a lake, the water of which is transparent, and extends to an unsearchable distance; for the darkness of the cave prevents all attempts to acquire a knowledge of it. I threw a small pebble toward the interior parts of it with my utmost strength; I could hear that it fell into the water, and notwithstanding it was of so small a size, it caused an astonishing and horrible noise that reverberated through all those gloomy regions. I found in this cave many Indian hieroglyphics, which appeared very ancient, for time had nearly covered them with moss, so that it was with difficulty I could trace them. They were cut in a rude manner upon the inside of the walls, which were composed of a stone so extremely soft that it might be easily penetrated with a knife; a stone everywhere to be found near the Mississippi. The cave is only accessible by ascending a narrow, steep passage that lies near the brink of the river.

At a little distance from this dreary cavern is the burying-place of several bands of the Naudowessie Indians. Though these people have no fixed residence, living in tents, and abiding but a few months on one spot, yet they always bring the bones of their dead to this place, which they take the opportunity of doing when the chiefs meet to hold their councils and to settle all public affairs for the ensuing summer.

Ten miles below the falls of St. Anthony the river St. Pierre, called by the natives Wadapaw Menesotor, falls into the Mississippi from the west. It is not mentioned by Father Hennepin, although a large, fair river; this omission, I conclude, must have proceeded from a small island that is situated exactly at its entrance, by which the sight of it is intercepted. I should not have discovered this river myself had I not taken a view, when I was searching for it, from the high lands opposite, which rise to a great height. Nearly over against this river I was obliged to leave my canoe, on account of the ice, and travel by land to the falls of St. Anthony, where I arrived on the 17th of November. The Mississippi, from the St. Pierre to this place, is rather more rapid than I had hitherto found it, and without islands of any consideration.

CARVER AT THE FALLS OF ST. ANTHONY.

The falls of St. Anthony received their name from Father Louis Hennepin, a French missionary, who traveled into those parts about the year 1680, and was the first European ever seen by the natives. This amazing body of waters, which are about 250 yards over, form a most pleasing cataract; they fall perpendicularly about thirty feet, and the rapids below, in the space of 300 yards more, rendered the descent considerably greater; so that when viewed at a distance they appear to be much higher than they really are. The above-mentioned traveler has laid them down at about sixty feet; but he has made a greater error in calculating the height of the falls of Niagara, which he asserts to be 600 feet, whereas, from later observations accurately made, it is well known that it does not exceed 140 feet. But the good father, I fear, too often had no other foundation for his accounts than report, or, at best, a slight inspection.

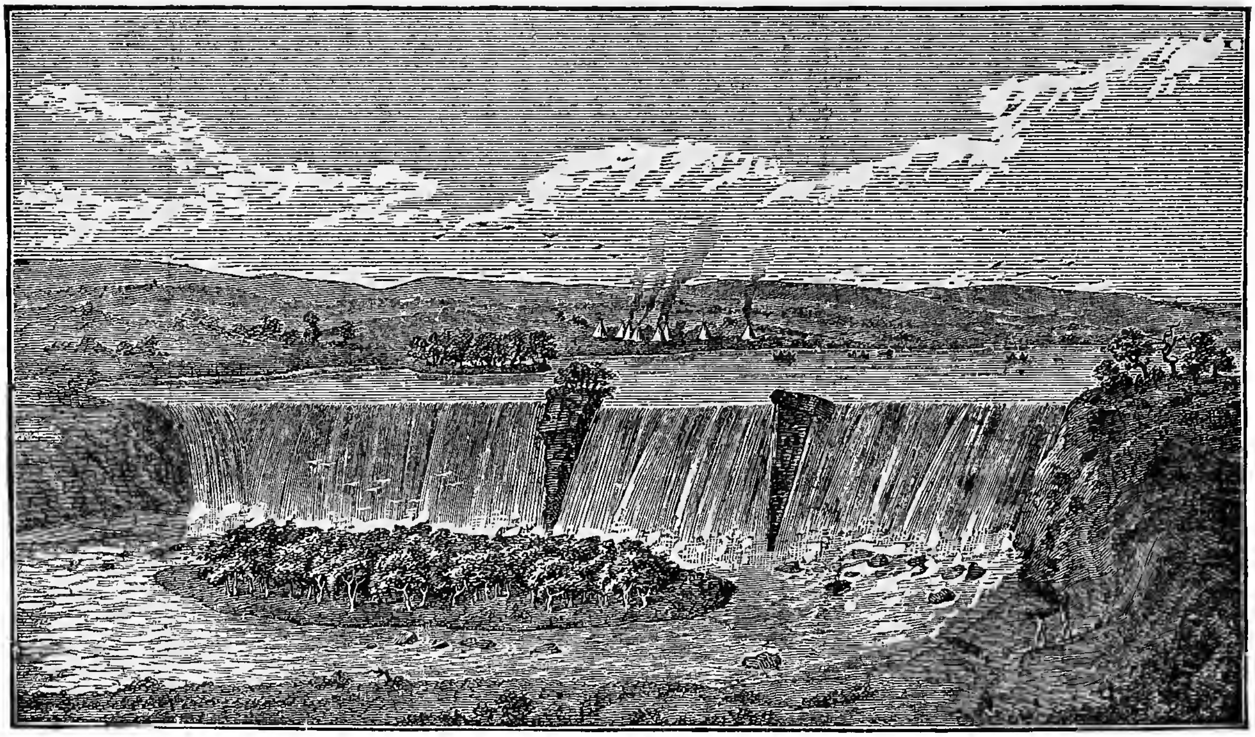


FIG. 3. CARVER'S SKETCH OF THE FALLS OF ST. ANTHONY, 1766.

In the middle of the falls stands a small island about forty feet broad and somewhat longer, on which grow a few cragged hemlock and spruce trees, and about half way between this island and the eastern shore is a rock, lying at the very edge of the fall in an oblique position, that appeared to be about five or six feet broad and thirty or forty feet long. These falls vary much from all the others I have seen, as you may approach close to them without finding the least obstruction from any intervening hill or precipice.

The country around them is extremely beautiful. It is not an uninterrupted plain where the eye finds no relief, but composed of many gentle ascents which, in the summer, are covered with the finest verdure, and interspersed with little groves that give a pleasing variety to the prospect. On the whole, when the falls are included, which may be seen at the distance of four miles, a more pleasing and picturesque view cannot, I believe, be found throughout the universe. I could have wished that I had happened to enjoy this glorious sight at a more seasonable time of the year, whilst the trees and hillocks were clad in Nature's gayest livery, as this must have greatly added to the pleasure I received; however, even then, it exceeded my warmest expectations. I have endeavored to give the reader as just an idea of this enchanting spot as possible in the plan annexed; but all description, whether of the pencil or the pen, must fall infinitely short of the original.

At a little distance below the falls stands a small island, of about an acre and a half, on which grow a great number of oak trees, every branch of which, able to support the weight, was full of eagles' nests. The reason that this kind of birds resort in such numbers to this spot is that they are here secure from the attacks either of man or beast, their retreat being guarded by the rapids, which the Indians never attempt to pass. Another reason is that they find a constant supply of food for themselves and their young, from the animals and fish which are dashed to pieces by the falls and driven on the adjacent shore.

Having satisfied my curiosity, as far as the eye of man can be satisfied, I proceeded on, still accompanied by my young friend,* till I had reached the river St. Francis, near sixty miles above the falls. To this river Father Hennepin gave the name of St. Francis, and this was the extent of his travels, as well as mine, toward the northwest. As the season was so far advanced, and the weather extremely cold, I was not able to make so many observations on these parts as I otherwise should have done.

It might however, perhaps, be necessary to observe that in a little tour I made about the falls, after traveling fourteen miles by the side of the Mississippi, I came to a river nearly twenty yards wide which ran from the northeast, called Rum river. And on the 20th of November came to another termed Goose river, and about twelve yards wide. On the 21st I arrived at the St. Francis which is about thirty yards wide. Here the Mississippi itself grows narrow, being not more than ninety yards over; and appears to be chiefly composed of small branches. The ice prevented me from noticing the depth of any of these rivers.†

The country in some places is hilly, but without large mountains, and the land is tolerably good. I observed here many deer and carraboes, some elk, with abundance of beavers, otters and other furs. A little above this to the northeast, are a number of small lakes, called the Thousand lakes; the parts about which, though but little frequented, are the best within many miles for hunting, as the hunter never fails of returning loaded beyond his expectations.

CARVER ASCENDS THE MINNESOTA.

On the 25th I returned to my canoe which I had left at the mouth of the river St. Pierre; and here I parted with regret from my young friend the prince of the Winnebagoes. This river being clear of ice by reason of its southern situation, I found nothing to obstruct my passage. On the 28th, being advanced about forty miles, I arrived at a small branch that fell into it from the north; to which as it had no name that I could distinguish it by, I gave my own, and the reader will find it in the plan of my travels denominated Carver's river. About forty miles higher up I came to the forks of the Verd and Red Marble rivers, which join at some little distance before they enter the St. Pierre.

The river St. Pierre, at its junction with the Mississippi, is about a hundred yards broad, and continues that breadth nearly all the way I sailed upon it. It has a great depth of water, and and in some places runs very briskly. About fifty miles from its mouth are some rapids, and much higher up there are many others.

I proceeded up this river about two hundred miles, to the country of the Nadowessies of the Plains, which lies a little above the forks formed by the Verd and Red Marble rivers [*i. e.* The Blue Earth and Watonwan rivers.—N. H. W.] just mentioned, where a branch from the south nearly joins the Messorie river.‡ By the accounts I received from the Indians I have reason to believe that the river St. Pierre and the Messorie, though they enter the Mississippi twelve hundred miles from each other, take their rise in the same neighborhood, and this within the space of a mile. The river St. Pierre's northern branch [*i. e.* The main river.—N. H. W.] rises from a number of lakes [Big Stone L.—N. H. W.] near the Shining Mountains, and it is from some of these, also, that a capital branch [Red River of the North.—N. H. W.] of the river Bourbon [Nelson river.—N. H. W.] which runs into Hudson's bay, has its sources. * * * I have learned that the four most capital rivers of North America, viz., the St. Lawrence, the Mississippi, the river Bourbon, and the Oregon, or River of the West, have their sources in the same neighborhood. The waters of the three former, are within thirty miles of each other; the latter, however, is rather farther west.§

*A young "prince" of the Winnebago Indians whom he had encountered a few miles below the Minnesota river.

†The distance to Rum river is approximately correct. The Goose river is now the Crow river, and the Elk, which is now sometimes styled the St. Francis river (though Hennepin applied the name to the outlet of L. Buade) is the only one to which Carver can refer, said to be 30 yards wide.

‡The sources of the Waraju river are near those of the Rock river, the latter being a branch of the Missouri. Carver wintered at the mouth of the Waraju (or Cottonwood) river.

§This idea of the proximity of the source of the Oregon to those of the other rivers mentioned is represented on the map accompanying Du Pratz' *Histoire de la Louisiane.*

This shows that these parts are the highest lands in North America; and it is an instance not to be paralleled on the other three quarters of the globe, that four rivers of such magnitude should take their rise together, and each, after running separate courses, discharge their waters into dfferent oceans at the distance of two thousand miles from their sources.

CARVER'S OPINION OF THE MINNESOTA VALLEY.

The river St. Pierre, which runs through the territories of the Naudowessies, flows through a most delightful country, abounding with all the necessaries of life that grow spontaneously, and with a little cultivation it might be made to produce even the luxuries of life. Wild rice grows here in great abundance; and every part is filled with trees bending under their loads of fruit, such as plums, grapes and apples; the meadows are covered with hops, and many sorts of vegetables; whilst the ground is stored with useful roots, with angelica, spikenard, and ground-nuts as large as hen's eggs. At a little distance from the sides of the river are eminences from which you have views that cannot be exceeded even by the most beautiful of those I have already described; amidst these are delightful groves, and such amazing quantities of maples that they would produce sugar sufficient for any number of inhabitants.

THE ST. PETER SANDSTONE.

A little way from the mouth of this river, on the north side of it, stands a hill, one part of which, that toward the Mississippi, is composed entirely of white stone, of the same soft nature as that I have before described; for such indeed is all the stone in this country. But what appears remarkable is, that the color of it is as white as the driven snow, The outward part of it was crumbled by the wind and weather into heaps of sand, of which a beautiful composition might be made; or, I am of opinion, that when properly treated, the stone itself would grow harder by time, and have a very noble effect in architecture,

Near that branch which is termed the Marble river, is a mountain, from which the Indians get a sort of red stone, out of which they hew the bowls of their pipes. [This, doubtless, is a reference to the *catlinite* of Pipestone county.—N. H. W.]

Carver's work contains a dissertation on the origin, manners, customs, religion and language of the Indians, followed by a chapter on the leading species of animals, particularly the game animals, and on the trees, shrubs, roots, herbs and flowers of the interior parts of North America, but as he assigns none of them to their habitats, they cannot be claimed as indigenous to Minnesota, though doubtless most of them are.

Carver gives a description and location of many of the lakes northwest from Grand Portage, and of some in northern Minnesota, about the headwaters of the Mississippi and the Red river of the North, but as he did not visit them, and his account is based wholly on descriptions derived from the Indians and traders, it is quite incorrect in some particulars. He states that "the most remote source" of the Mississippi river is a lake not far from Red lake, a little to the southwest, called White Bear lake, of about the same size as Red lake.* It is now known as lake Whipple.

*The map accompanying Carver's book (London edition) shows the general inaccuracy of Carver not only in depicting his own observations, but also in reproducing those of earlier writers. "The country of peace" and the Red Marble river, are so named doubtless from the red quartzyte and catlinite (the latter used for making the peace calumet) about the headwaters of the Watonwan and Cottonwood rivers, and should be represented on the west Fork of the Verd river instead of the east. The mountains of "The country of peace" are a poetic exaggeration, like Hiawatha's "Mountains of the Prairie." Compare Keating's strictures upon Carver in Long's Expedition in 1823, Vol. I, p. 336.

Captain Carver did not give up his design of reaching the "straits of Annian" through the headwaters of the great streams flowing east and west from Minnesota, and organized a party to carry out the purpose in which he had failed, on his return to England. This was to be under the auspices of Richard Wentworth, Esq., member of Parliament for Stafford, and was to set out in 1774, when the troubles incident to the Revolutionary war put a stop to the enterprise.

II. PERIOD OF TERRITORIAL EXPLORATION, 1783 TO 1858.

The war of the Revolution which left the east bank of the Mississippi in the possession of the United States and the west bank in the possession of the French, operated not only to terminate English and French exploration, but to retard that of the United States. It was not till after the cession of Louisiana by France that the United States government instituted measures for the exploration of the unknown country west of the Mississippi, when, in 1805, Captains Lewis and Clarke were dispatched to explore the Missouri river, and Lieutenant Z. M. Pike to ascend the Mississippi to its source. Lieut. Pike found the upper Mississippi country occupied by trading posts of the Northwest Fur Company, over which was still flying the English flag, a fact which attests the isolation of that region since the peace concluded in 1783. One of these posts was found at Red Cedar lake, (north of Mille Lacs) one at Sandy lake and two at Leech lake, whose influence extended "from the head of lake Superior to the source of the Mississippi and down Red river." This company had employed Mr. David Thompson as explorer and geographer for many years, and Lieut. Pike refers to his having established the latitude of Red Cedar lake (now Cass L.) supposed to be the source of the Mississippi, in 1798, finding this Post to be in latitude 47° 38'. Mr. Thompson's maps and papers never having been published. Lieut. Pike is to be accredited with the first authenticated examination of the Mississippi valley from the St. Francis river to Red Cedar lake.*

* An account of expeditions to the sources of the Mississippi, and through the western parts of Louisiana. * * * * Performed by order of the Government of the United States during the years 1805, 1806 and 1807, by Major Z. M. Pike. Philadelphia, 1810.

MORRISON DISCOVERS ITASCA LAKE IN 1804.

The country of the upper Mississippi was pretty well known to the *coureurs des bois* of the various fur companies probably, before the advent of Pike, but there is almost nothing preserved of all their explorations. Mr. William Morrison, however, has given in a brief letter to the Minnesota Historical Society* a statement of his own discovery of Elk lake (now called Itasca) in 1804, mentioning also Cross lake, (Pemidji lake), Red Cedar lake and Leech lake for the first time. He also states that he wintered at Rice lake, tributary to Rice river, a branch of the Red river of the North, in 1803–4. In order to reach it he made a portage from the Mississippi, a short distance below Elk lake, westward, known as the Portage of the Height of Land, or the dividing ridge that separates the waters of the Mississippi from those that empty into the Red river of the North.

LIEUT. Z. M. PIKE.

Reaching the falls of St. Anthony Lieut. Pike made a careful survey, and wrote a description of the portage route in his journal, and a brief description of the falls in a letter to General Wilkinson at St. Louis. He added nothing of value to the natural history and geography of the Mississippi valley below the falls of St. Anthony. With twenty soldiers he attempted to reach Leech lake, but by stress of weather and early snow was compelled to erect a winter stockade on the west side of the Mississippi a short distance below Pike rapids. Here having deposited the most of his baggage and supplies, he pushed forward in midwinter, with indefatigable energy and industry, with a foot-party, as far as Sandy lake. Thence he proceeded toward Leech lake (then denominated lake La Sang Sue) by way of the Willow river valley and Pokegama lake, where he arrived February 1st, 1806. A few days later, having visited the N. W. Co.'s station at Red Cedar lake and ascertained its latitude (47° 42′ 40″), where he found a hospitable Canadian named Roy, he set out on his return to his stockade, by a different route, traveling south-eastwardly by way of lakes to Whitefish lake, which he states may be considered the main source of Pine river, reaching the Mississippi at the mouth of a creek about nine miles above the mouth of Pine river. Making

*Minnesota Historical Collections, Volume I. p. 417.

a short visit to Mr. Grant's trading-post on "Red Cedar lake"* he left on the 28th of February on his descent to his stockade, where he stayed till the ice broke up in the spring, when he returned to St. Louis.

LIEUTENANT PIKE ON THE FALLS OF ST. ANTHONY.

In order to complete the history of the falls of St. Anthony from the time of their discovery to the final occupancy of the place by permanent settlements, with a view to ascertaining their rate of recession by means of the islands which have undergone changes from time to time, as noted by different visitors, Lieut. Pike's description is herewith given, as one of the most exact and reliable.

In the appendix to his journal is found a letter addressed to Gen. Wilkinson, dated "26th Sept. above the falls of St. Anthony" containing the following:

The place where the river falls over the rocks appears to be about fifteen feet perpendicular, the sheet being broken by one large island on the east and a small one on the west, the former commencing below the shoot, and extending 500 yards above; the river then falls through a continned bed of rocks, with a descent of at least 50 feet perpendicular in the course of half a mile—from thence to the St. Peters, a distance of eleven miles by water, there is almost one continued rapid, aggravated by the interruption of twelve small islands. The carrying place has two hills, one of 25 feet, the other of 12, with an elevation of 45°, and is about three-fourths of a mile in length. Above the shoot the river is of a considerable width, but below (at this time) I can easily cast a stone over it. The rapids, or suck, comes about a half a mile above the shoot, when the water becomes calm and deep. He adds that this is merely a *coup d' œuil.*

On page 51, of the same appendix, he gives further particulars concerning the falls, viz:

As I ascended the Mississippi the falls of St. Anthony did not strike me with that majestic appearance which I had been taught to expect from the description of former travelers. On an actual survey I find the portage to be 260 poles; but when the river is not very low, boats ascending may be put in 31 poles below, at a large cedar tree, which would reduce it to 229 poles. The hill over which the portage is made is 69 feet ascent, with an elevation at the point of debarkation of 45°. The fall of the water between the place of debarkation and reloading is 58 feet; the perpendicular fall of the shoot is 16½ feet. The width of the river above the shoot is 627 yards; below 209. For the form of the shoot see a rough draught herewith. In high water the appearance is much more sublime, as the great quantity of water *then* forms a spray which in clear weather reflects from some positions the colors of the rainbow, and when the sky is o'ercast, cover the falls in gloom and chaotic majesty.

LIEUT. PIKE ABOVE THE FALLS OF ST. ANTHONY.

From the falls of St. Anthony to Rum river, the Mississippi is almost one continued chain of rapids, with the eddies formed by winding channels. Both sides are prairie, and scarcely any timber but small groves of scrub oak. *Rum* river is about 50 yards wide at its mouth, and takes its source in Le Mille Lac, which is about thirty-five miles south of *Lower Red Cedar* lake. The small Indian canoes ascend this river quite to the lake, which is considered as one of the best

*This Red Cedar lake in other places is styled Lower Red Cedar lake, and is a few miles southwest of Aitkin.

fur-hunting grounds for some hundreds of miles, and has been long a scene of rencounters between the hunting parties of the Sioux and Sauteaux. The last winter a number of the Fols Avoins and Sioux, and some Sauteaux, wintered in that quarter. From *Rum* river to *Leaf* river, (called by Father Hennepin and Carver the river *St. Francis*, and was the extent of their travels) the prairies continue with a few interruptions. The timber, scrub oak, with now and then a lonely pine. Previous to your arrival at *Leaf* river you pass *Crow* river on the west, about 30 yards wide, which bears from the Mississippi S. W. *Leaf* river is only a small stream of not more than 15 yards over and bears N. by W.

The elk begin to be very plentiful; some buffalo, quantities of deer, raccoons, and on the prairie a few of the animals called by the French brelaws.

From thence to *Sac* river [Sauk river] a little above the Grand rapids, both sides of the river are generally prairie, with skirts of scrub oak. The navigation still obstructed with ripples, but with some intermissions of a few miles.

At the *Grand rapids* the river expands itself to about 3-4 mile in width (its general width being not over 3-5 mile) and tumbles over an unequal bed of rocks for about two miles, through which there cannot be said to be any channel; for notwithstanding the rapidity of the current, one of my invalids who was on the W. shore waded to the E. (where we were encamped.) The east bank of the rapids is a very high prairie, the west scrubby woodland. The Sac river is a considerable stream which comes in on the west, and bears S. W., and is 200 yards wide at its mouth.

The quantity of game still increasing from the Sac river to Pine creek, (the place where I built my stockade and left part of my party) the borders are prairie, with groves of pine on the edge of the bank; but there are some exceptions, where you meet with small bottoms of oak, ash, maple and lynn. In this distance there is an intermission of rapids for about 40 miles when they commence again and are full as difficult as ever. There are three small creeks emptying in on the west scarcely worthy of notice, and on the east are two small rivers, called *Lake* and *Clear* rivers.* The former quite a small one bears N. W. and is about 15 yards wide at its mouth; and about three miles from its entrance is a beautiful small lake, around which resort immense herds of elk and buffalo. *Clear* river is a beautiful little stream of about 80 yards in width, and heads in some swamps and small lakes on which the Sauteaux of *Lower Red Cedar* lake, and *Sandy* lake, frquently came to hunt. The soil of the prairies from above the falls is sandy, but would raise small grain in abundance; the bottoms rich and fit for corn or hemp. *Pine* creek† is a small stream which comes in on the west shore and bears nearly west. It is bounded by large groves of *white* and *red* pine. From *Pine* creek to the *Isle De Corbeau*, (or river of that name) two small rivers come in on the west shore. The first is of little consequence; but the second, called *Elk* river is entitled to more consideration from its communication with the river *St. Peters*. They first ascend it to a small lake, cross it, then ascend a small stream, [Long Prairie river] to a large lake, [Carlos lake] from which they make a portage of four miles west and fall into the *Sauteaux* river, [Little Chippewa] which they descend into the river *St. Peters*. On the east side is one small stream, (*Nunkesebe river*) which heads toward *Lower Red Cedar lake*, and is bounded by hills. The whole of this distance is remarkably difficult to navigate, being one continued succession of rapid shoals and falls; but there is one deserves to be more particularly noticed, viz: the place called by the French *Le shute de la Roche Peinture*, which is certainly the third obstacle in point of navigation which I met with in my whole route. The shore where there is not prairie is a continued succession of pine ridges. The entrance of the river *De Corbeau* is partly hid by the island of that name, and discharges its waters into the Mississippi above and below it; the lowest channel bearing from the Mississippi N. 65° W. This (in my opinion) should be termed the forks of the Mississippi, it being nearly of equal magnitude and heading not far from the same source; although taking a much more direct course to their junction. It may be observed on the chart, that from St. Louis to this place, the course of the river had been generally N. to the W. and that from here it bore N. E. This river affords the best and most approved communication with the *Red* river, and the navigation is as follows. You ascend the river *De Corbeau* 180‡ miles to the entrance of the river *Des Feuilles*, which comes from the N. W. This you ascend 180 miles also,

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*Lake river is now called Little Rock creek, and Clear river is the Platte.

†Now called Swan river.

‡Pike's distances are generally too great.

then make a portage of half a mile into *Otter Tail* lake which is a principal source of *Red* river. The other branch of the river *De Corbeau* [Long Prairie R.] bears S. W. and approximates with the St. Peters. The whole of this river is rapid, and by no means affording so much water as the Mississippi. Their confluence is in lat. 45° 49′ 50″ N. In this division the elk, deer and buffalo were probably in greater quantities than in any other part of my whole voyage. From thence to Pine river the Mississippi continues to become narrower and has but few islands. In this distance I discovered but one rapid which the force of the frost had not entirely covered with ice. The shores in general presented a dreary prospect of high barren knobs covered with dead and fallen pine timber. To this there were some exceptions of ridges of yellow and pitch pine, also some small bottoms of lynn, elm, oak and ash. The adjacent country is (at least two-thirds) covered with small lakes, some of which are three miles in circumference. This renders the communication impassable in summer, except with small bark canoes. * * * The *Pine* river bears from the Mississippi north 30° east, although it empties in on that which has hitherto been termed the west shore. It is 80 yards wide at its mouth, and has an island immediately at the entrance. It communicates with the lake *La Sang Sue* by the following course of navigation: In one day's sail from the confluence you arrive at the first part of *Whitefish* lake, which is about six miles long and two wide. From thence you pursue the river about two miles, and come to the *Second Whitefish* lake, which is about three miles long and one wide; then you have the river three miles to the third lake, which is seven miles long and two in width (which I crossed on my return from the head of the Mississippi, on the —— of February, and is in 46° 32′ 32″ N. latitude). From thence you follow the river a quarter of a mile to the fourth lake, which is a circular one of about five miles in circumference. From thence you pursue the river one day's sail to a small lake; from thence two days' sail to a portage, which conveys you to another lake; from whence, by small portages from lake to lake, you make the voyage to *Leech* lake. The whole of this course lays through ridges of pines or swamps of pinenet, sap pine,* hemlock, &c., &c. From the river *De Corbeau* to this place the deer are very plenty, but we found no more buffalo or elk. From this spot to *Red Cedar* lake the pine ridges are interrupted by large bottoms of elm, ash, oak and maple, the soil of which would be very proper for cultivation. From the appearance of the ice (which was firm and equal) I conceive that there can be but one ripple in this distance. *Red Cedar* lake lays on the east side of the Mississippi, at the distance of 6 miles from it, and very near equally distant from the river *De Corbeau* and lake *De Sable.* Its form is an oblong square, and may be ten miles in circumference. From this to lake *De Sable*, on the E. shore, you meet with *Muddy* river,† which discharges itself into the Mississippi by a mouth twenty yards wide, and bears nearly N. E. We then meet with *Pike* river‡ on the west, about 77 [17?] miles below *Sandy* lake, and bears nearly due north, up which you ascend with canoes four days' sail and arrive at a wild-rice lake, which you pass through and enter a small stream, and ascend it two leagues; then cross a portage of two acres into a lake seven leagues in circumference; then two leagues of a river into another small lake. From thence you descend the current N. E. [N. W?] into *Leech* lake. The banks of the Mississippi are still bordered by the pines of the different species, except a few small bottoms of elm, lynn and maple. The game scarce, and the aborigines subsist almost entirely on the beaver, with a few moose and the wild rice or oats.

Sandy lake river (or the discharge of said lake) is large, but is only six miles in length from the lake to its confluence with the Mississippi. Lake *De Sable*§ is about 25 miles in circumference, and has a number of small rivers running into it; one of those is entitled to particular mention, viz., the river *Savanna*, which by portage of three miles and three-quarters, communicates with the river *St. Louis*, which empties into lake Superior at the *Fond du Lac*, and is the channel by which the N. W. Company bring all their goods for the trade of the upper Mississippi. Game is very scarce in this country. In ascending the Mississippi from *Sandy* lake, you first meet with *Swan* river on the east, which bears nearly due E. and is navigable for bark canoes ninety miles to *Swan* lake. You then meet with the *Meadow* river,‖ which falls in on the east, and bears nearly E. by N., and is navigable for canoes 100 miles. You then in ascending meet with a very strong ripple, and an expansion of the river, where it forms a lake. This is three miles below the falls of *Packegamau*, and from which the noise of the shoot might be heard. The course of the river at the falls was N. 70° W., and just below, the river is a quarter of a mile in width, but above the

*Tamarac and balsam fir; but hemlock does not occur. †Rice River. ‡Willow river. §Sandy lake. ‖Prairie river.

shoot not more than 20 yards. The water thus collected, runs down a flat rock which has an elevation of about 30 degrees. Immediately above the fall is a small island of about 50 yards in circumference, covered with sap-pine.* The portage, which is on the E. (or N.) side is no more than 200 yards, and by no means difficult. Those falls, in point of consideration as an impediment to navigation, stand next to the falls of St. Anthony, from the source of the river to the gulf of Mexico. The banks of the river, to the *Meadow* river, have generally either been timbered by pine, pinenett, hemlock, sap-pine, or the aspen tree. From thence it winds through high-grass meadows (or savannas), with the pine swamps at a distance appearing to cast a deeper gloom on the borders. From the falls in ascending you pass the lake Packegamau on the west, celebrated for its great production of wild rice; and next meet with the *Deer* river on the east; the extent of its navigation unknown. You next meet *Riviere Le Cross*, on the east side, which bears nearly north, and has only a portage of one mile to pass from it into the lake *Winipeque*† branch of the Mississippi. We next come to what the people of that quarter call the *Forks of the Mississippi*, the right fork of which bears N. W. and runs eight leagues to lake *Winnipeque*, which is of an oval form of about 36 miles in circumference. From lake *Winnipeque* the river continues 5 leagues to *Upper Red Cedar* lake‡, which may be termed the upper source of the Mississippi. The *Leech* lake branch bears (from the forks) S. W. and runs through a chain of *Meadows*. You pass *Muddy* lake, which is scarcely anything more than an extensive marsh of 15 miles in circumference; the river bears through it nearly N., after which it turns again W. In many places this branch is not more than ten or fifteen yards wide, although 15 or 20 feet deep. From this to *Leech* lake the communication is direct, and without any impediment. This is rather considered as the main source, although the *Winnipeque* branch is navigable the greatest distance. To this place the whole face of the country has the appearance of an impenetrable morass. or boundless savanna. But on the borders of the lake is some oak, and large groves of sugar maple, from which the traders make sufficient sugar for their consumption the whole year. *Leech* lake communicates with the river *De Corbeau* by seven portages, and the river *Des Feuilles* also, with the *Red* river by the *Otter Tail* lake on the one side, and by the *Red Cedar* lake and other small lakes to *Red* lake on the other. Out of these small lakes and ridges rise the upper waters of the *St. Lawrence*, *Mississippi*, and *Red* river,§ the latter of which discharges itself into the ocean by lake *Winipie* and *Hudson's* Bay. All those waters have their upper sources within 100 miles of each other, which I think plainly proves this to be the most elevated part of the N. E. continent of America. But we must cross (what is commonly termed) the *Rocky Mountains*, or a spur of the *Cordeliers*, previous to our finding the waters whose currents run westward and pay tribute to the western ocean.

In this quarter we find moose, a very few deer and bear, but a vast variety of fur animals of all descriptions.

MAJOR S. H. LONG AT THE FALLS OF ST. ANTHONY.

In 1817 Major Stephen H. Long, of the United States Army, made a visit to the falls of St. Anthony,‖ and has made so correct a description of them that, by comparison with that of Pike, in 1805, such changes are seen to have taken place that some idea of their rate of recession can be gained.

The perpendicular fall of the water at the cataract, as stated by Pike in his journal, is 16½ feet, which I found to be true by actual measurement. To this height, however, four or five feet may be added for the rapid descent which immediately succeeds the perpendicular fall within a few yards below. Immediately at the cataract the river is divided into two parts by an island which extends considerably above and below the cataract, and is about 500 yards long.

*Balsam Fir. †Winnibigoshish. ‡Cass Lake.

§Pike has this footnote: Red river discharges itself into Hudson's Bay by lake Winipie and Nelson's river.

‖Minnesota Historical Collections, Vol. II.—Voyage in a six-oared skiff to the falls of St. Anthony in 1817, by Major Stephen H. Long, with an introductory note by Edward D. Neill.

The channel on the right side of the island is about three times the width of that on the left. The quantity of water passing through these is not, however, in the same proportion, as about one-third part of the whole passes through the left channel. In the broadest channel, just below the cataract, is a small island also, about fifty yards in length, and thirty in breadth. Both of these islands contain the same kind of rocky formation as the banks of the river, and are nearly as high. Besides these, there are immediately at the foot of the cataract, two islands of very inconsiderable size, situated in the right channel also. The rapids commence several hundred yards above the cataract, and continue about eight miles below. The fall of the water, beginning at the head of the rapids, and extending two hundred and sixty rods down the river to where the portage road commences, below the cataract, is, according to Pike, fifty-eight feet. If this estimate be correct the whole fall from the head to the foot of the rapids is not probably much less than one hundred feet. But as I had no instrument sufficiently accurate to level, where the view must necessarily be pretty extensive, I took no pains to ascertain the extent of the fall. The mode I adopted to ascertain the height of the cataract was to suspend a line and plummet from the table rock on the south side of the river which at the same time had very little water passing over it, as the river was unusually low. The rocky formations at this place were arranged in the following order from the surface downward: A coarse kind of limestone in thin strata containing considerable silex; a kind of soft friable stone of a greenish color and slaty fracture, probably containing lime, alumina and silex; a very beautiful stratification of shell limestone, in thin plates, extremely regular in its formation and containing a vast number of shells, all apparently of the same kind. This formation constitutes the table rock of the cataract. The next in order is a white or yellowish sandstone so easily crumbled that it deserves the name of sand-bank rather than that of a rock. It is of various depths, from ten to fifty or seventy-five feet, and is of the same character with that found at the caves before mentioned. The next in order is a soft, friable sandstone, of a greenish color, similar to that resting upon the shell limestone.* These stratifications occupy the whole space from the low-water mark nearly to the top of the bluffs. On the east, or rather north side of the river, at the falls are high grounds at the distance of half a mile from the river, considerably more elevated than the bluffs, and of a hilly aspect.

GOVERNOR LEWIS CASS' EXPEDITION TO THE UPPER MISSISSIPPI.

In 1820 Gov. Lewis Cass, of Detroit, conducted an exploring expedition from Detroit to the upper Mississippi region, coasting the shores of lakes Huron and Superior in canoes. From the head of lake Superior he followed the route, then much traveled, for canoes, by portaging, to Sandy lake and the upper Red Cedar lake, the latter of which was denominated Cass lake, by Mr. H. R. Schoolcraft, the chief narrator of the expedition.† This lake was considered by him, as by Lieut. Pike, the chief head of navigation of the Mississippi.

In passing the falls of Pokegama, Mr. Schoolcraft made the observation, that "the Mississippi at this point forces its way through a quartzy rock, during which it sinks its level, as estimated, twenty feet, in a distance of about three hundred yards. There is no perceptible cascade, or abrupt fall,

*Major Long here seems to have made an error similar to that of Keating at Fort Snelling, taking fallen fragments to be *in situ*.

†Summary narrative of an exploratory expedition to the sources of the Mississippi in 1820, resumed and completed by the discovery of its origin in Itasca lake in 1832, with appendixes. By Henry R. Schoolcraft.

but the river rushes with the utmost velocity down a highly inclined rocky bed toward the northeast." * * * * * . "Immediately above the fall is a small rocky island bearing a growth of spruce and cedars."

Schoolcraft states that the Mississippi, instead of having its source in Cass lake, or even in Turtle lake, enters Cass lake from the south at a distance of eight or ten miles from the mouth of Turtle river.*

Mr. Schoolcraft's geological and mineralogical resumé of the expedition is quite full, but embraces much territory beyond the limits of Minnesota. He is the first to give a geological account of the lower valley of the St. Louis river, but his statements about its tributaries being from "the northwest of the Rainy lakes," and Vermilion lake tributary to its volume, while in keeping with a general looseness in his statements, show still a lack of geographical knowledge of that region. He estimates its descent from Knife falls, through the "Cabotian Mountains," at about 418 feet. He says that the red sandstone at Fond du Lac is succeeded, up the river further, by "trap, argillite and grauwacke." * * * "The river is continually in a foam for nine miles, and the wonder is that such a furious and heavy volume of water should not have prostrated everything before it. The sandstone, grauwacke, and the argillite, the latter of which stands on its edges, have opposed but a feeble barrier; but the trap species, resisting with the firmness, as it has the color, of cast-iron, stand in masses which threaten the life and safety of everything that may be hurled against them. I found a loose specimen of sulphuret of lead, and some common quartz, in place in the slate rock, a vein of chlorite slate, and a locality of coarse graphite, to reward my search."

*Resultiog from the expedition of Gov, Cass, were several scientific papers, which at the date of their publication were valuable additions to the natural history of the region, viz:

1. Results of observations for latitbde and longitude during the expediton of 1820. By Capt. David B. Douglass.
2. Report on the copper mines of lake Superior. H. R. Schoolcraft.
3. Observations on the Mineralogy and Geology of the country embracing the sources of the Mississippi river and the Great Lake Basins. By Henry R. Schoolcraft.
4. Report in reply to a resolution of the U. S. Senate on the value and extent of the mineral lands on lake Superior. By Henry R. Schoolcraft.
5. Rapid glances at the Geology of Western New York, beyond the Rome summit, in 1820. By Henry R. Schoolcraft.
6. A memoir on the Geological position of a fossil tree in the secondary rocks of Illinois, 1822. By Henry R. Schoolcraft.
7. List of plants collected by Capt. D. B. Douglass, at the sources of the Mississippi river. From the 4th Volume of Silliman's Journal of Science. By Dr. John Torrey.
8. A letter embracing notices of the Zoology of the Northwest, addressed to Dr. Mitchell, on the return of the expedition. By Henry R. Schoolcraft.
9. Species of Bivalves collected by Mr. Schoolcraft and Capt. Douglass in the Northwest. From the 6th Volume of the American Journal of Science. D. H. Barnes.
10. Fresh water shells collected by Mr. Schoolcraft in the valleys of the Fox and Wisconsin rivers. From the 5th Volume of the American Philosophical Transactions. By Isaac Lea.
11. Summary remarks respecting the Zoological species noticed in the expedition. By Dr. Samuel L. Mitchell.
12. *Mus busarius.* Medical Repository, Vol. 21. By Dr. Samuel L. Mitchell.
13. *Sciurus tridecem-striatus.* Medical Repository, Volume 21. By Dr. Samuel L Mitchell.
14. *Proteus* of the lakes. Am. Jour. Sci., Vol 4. Dr. Samuel L. Mitchell.
15. Memoranda on Climatic Phenomena and the Distribution of Solar Heat, in 1820. By Henry R. Schoolcraft.

SCHOOLCRAFT AT LITTLE FALLS AND SAUK RAPIDS.

In descending the Mississippi below the Pakagama, the first stratum of rock, which rises through the delta of the river, occurs between the mouth of the Nokasippi and Elm rivers below the influx of the Great De Corbeau. This rock, which is greenstone trap, rises conspicuously in the bed of the stream in a rocky isle seated in the rapid called—I know not with what propriety—the BIG FALLS or *Grand Chute*. The precipitous and angular falls of this striking object decide that the bed of the stream is at this point on the igneous, granitical and greenstone series. This formation is seen at a few points above the water, until we pass some bold and striking eminences of shining and highly crystalline hornblendic sienite, which rises in the elevation called by us Peace Rock, on the left bank near the Osaukis rapids. This rock lies directly opposite to the principal encampment on the 27th of July, which was on an elevated prairie on the west bank. To this point a delegation of Sioux had ascended on an embassy of peace from Fort Snelling to the Chippewas, having affixed on a pole what the exploring party called a bark letter, the ideas being represented symbolically by a species of picture writing or hieroglyphics. In allusion to this embassy, this locality was called the *Peace Rock*. This rock is sienite. It is highly crystalline, and extends several miles. Its position must be, from the best accounts, in north latitude 44° 30′. From this point to Rum river, a distance of seventy miles, no other point of the intrusion of this formation above the prairie soil was observed.

The rock at the falls of St. Anthony Mr. Schoolcraft regards as belonging "to the great carboniferous and metalliferous formations, which for so great a length, and in so striking a manner characterize both banks of the Mississippi below St. Anthony falls." The white sandstone at the falls is said to be overlain by the "metalliferous limestone." The grains of sandrock are held together by "the cohesion of aggregation," and embrace, sparingly, "orbicular masses of hornblende." The overlying limestone is the "same in character, which assumes at some points a siliceous, and at others a magnesian character. It is manifestly the same great metalliferous rock which accompanies the lead ore of Missouri and mines of Peosta or Dubuque." Referring to Chimney and Castle rocks, in Dakota county, Mr. Schoolcraft thinks they are the result of degradation and wasting away, on the Huttonian theory, of all but these, probably harder, portions of the strata.

KEATING'S NARRATIVE OF MAJOR LONG'S EXPEDITION IN 1823, TO THE SOURCE OF THE ST. PETER RIVER.

Major S. H. Long, who had, in 1817, visited the falls of St. Anthony, was directed by the United States Secretary of War, in 1823, to conduct a party of exploration to the source of the St. Peter river, and to lake Winnipeg. He was accompanied by a number of scientific gentlemen of Philadelphia, including Prof. William Keating of the University of Pennsylvania, who embodied the notes and manuscripts of the various members of the party, in a work of two volumes, published in 1825, in London. The appendix embraces a general list of animal species observed by Thomas Say, and a list of plants by Lewis D. de Schweinitz, also astronomical and meteorological data by J. Edward Colhoun and Dr. Joseph Lovell, concluding with a vocabulary of Indian words by Mr. Keating.*

This work may be correctly pronounced the first attempt to apply the accurate methods of modern science to the exploration of any portion of Minnesota. Although the progress of the party was much too rapid for geological examinations, yet the collections made, the notes on geographical features recorded, and the few geological facts stated, constitute a good preliminary account of the western portions of the state. The party returned to lake Superior from lake Winnipeg, by way of a route through British territory to the lake of the Woods; thence following the northern boundary line to the west end of Hunter's island, they again turned northward, and reached lake Superior at Fort William, by way of the route of Sir Alexander McKenzie. The map accompanying the report is an embodiment of information from several sources, besides the observations of the party, chiefly the report of Lieut. Pike on the upper Mississippi, Buchett's map of Upper and Lower Canada, statements by officers of the Hudson's Bay Company, and by Dr. J. J. Bigsby, of the English Commission for determining the boundary between the United States and the British possessions. On this map are given for the first time the names and positions of numerous streams in the western part of Minnesota, and in eastern Dakota, and of some flowing north in the northern part of the state.

KEATING'S VISIT TO THE FALLS OF ST. ANTHONY.

On the 6th of July we walked† to the falls of St. Anthony, which are situated nine miles along the course of the river, seven by land) above the fort. The first glimpse which we caught of the fall was productive of disappointment, because it yielded but a partial view; but this was amply redeemed by the prospect which we obtained of it when the whole fall opened itself before us. We then discovered that nothing could be more picturesque than this cascade. We had been told that it appeared like a mere mill-dam, and we were apprehensive lest a fall of sixteen feet would lose all its beauty when extended upon a breadth of several hundred yards, but we soon observed that this was by no means the case. The irregular outline of the fall, by dividing its breadth, gives a more impressive character. An island stretching in the river, both above and below the fall, separates it into two unequal parts, the eastern being two hundred and thirty yards wide, and the western three hundred and ten. The island itself is about one hundred yards wide. From

*Narrative of an Expedition to the Source of the St. Peter's river, lake Winnepeek, lake of the Woods, &c., performed in the year 1823, under command of Stephen H. Long. Compiled by Wm. H. Keating. In two volumes. London, 1825.

†From Fort Snelling.

the nature of the rock, which breaks into angular, and apparently rhomboidal fragments of a huge size, this fall is subdivided into several cascades, which adhere to each other, so as to form a sheet of water, unrent, but composed of an alternation of retiring and salient angles, and presenting a great variety of shapes and shades; each of these forms in itself a perfect cascade; but when taken together in one comprehensive view, they assume a beauty of which we could have scarcely deemed them susceptible. We have seen many falls, but few which present a wilder and more picturesque aspect than those of St. Anthony.*

Prof. Keating gives the following section of the bluff at Fort Snelling, in descending order:

1. Limestone, of a distinct slaty structure; compact, but with a splintery uneven fracture; filled with organic remains (*Producti*); of a light grayish-yellow color; 8 ft.
2. Limestone, of a blue color, destitute of fossils; an excellent stone for building, and good for quicklime. 15—20 ft.
3. Sandstone, constituting the principal mass of the bluff. This is friable, but every fragment, examined with care, seems *to be a regular crystal*. Keating inclines to the opinion that it must have been from a chemical precipitation, and not from mere mechanical deposition. The process of its formation may have been a very rapid one, such as is obtained in the manufacture of fine salt; and to this may be attributed the circumstance of its fine texture. The color is white—sometimes a little grayish, when it resembles the finer varieties of Muscovado sugar. 60 ft.
4. Limestone; slaty, striped with curved zones; very argillaceous, softer than the preceding; structure quite earthy; color light yellow. 10 ft.
5. Limestone; bluish, or yellowish gray, conglomeritic with small black pebbles of quartz; more crystalline than the last; vesicular; rises four feet above the level of the river. 7 ft.
6. Limestone; much finer grained and more earthy than the last. The bed of the river near the fort is excavated in this limestone.† 4 ft.

He remarks that at the falls of St. Anthony the same section may be een, except that the lower limestones are not there visible. The foregoing limestones, stated to lie below the sandstone at Fort Snelling, must have been large fallen fragments from the top of the bluff, since no subsequent observer has ever reported them. Mr. Featherstonhaugh makes the same correction.

KEATING ON THE MINNESOTA RIVER.

At the Indian village of Taoapa, estimated at thirty-seven and one-half miles from Fort Snelling, probably the same place as Shakopee, Major Long observed limestone which appeared to him to be *in situ*.

Keating mentions the rapids at Carver, "caused by two bars of sandstone," the first forming a fall of four feet in twenty yards. Half a mile above this is a second bar. The aggregate fall is estimated to be seven feet. This sandstone is seen in the bank, and "resembles that at Fort Snelling. It

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*Major Long's party forded the river above the falls, walking on the rock from the west to the east side. Prof. Keating, who was debilitated by a fever, succeeded in reaching only the island dividing the fall, and with great difficulty returned to the west bank.

†Compare *Bulletins of the Minnesota Academy of Natural Sciences, Vol. 1, p. 91.*

has a fine crystalline grain and a color varying from white to yellow."* Apparently not observing that this sandstone rises gradually higher in ascending the valley, he refers to several "hills" located near the river, one of which, "composed principally of loose sand," was estimated at about one hundred and fifty feet in hight. At Camp Crescent (old *Travers des Sioux*), Major Long's party abandoned the canoes and followed the trail to Redstone, thus cutting off the great bend where the Blue Earth river enters the Minnesota, and losing the opportunity of examining the copper mine of Le Sueur.

Up to the point of abandoning the canoes the banks of the Minnesota are stated to be composed chiefly if not altogether of sandstone. On the last day of travel in the canoes, a bluff was seen rising sixty to eighty feet, consisting of white sandstone, and called White Rock, probably near Ottawa. He also observed at a distance horizontal ledges of rock that he considered "the limestone that lies on the sandstone." This point was probably at or near Kasota. The only streams that are regarded worthy of mention up to Camp Crescent, are the Elk, entering on the right bank, said to be about twenty miles above the fort, now called Credit river, and "the small rivulet which comes in from the left bank about forty miles above the fort, and which is probably the same as Carver's river." The forest was found to consist chiefly of maple, white walnut, hickory, oak, elm, ash and linden, interspersed with grapevines, &c., and the absence of black walnut was particularly observed.

The party seem not to have passed near enough to the red quartzyte outcrop near New Ulm to have noticed it, since Keating makes no mention of it. The Blue Earth is said to take its rise "in the Coteau des Prairies, a highland that stretches in a northerly direction between the Missouri and the St. Peter." This is the first mention of this natural phenomenon under that name.

BOULDERS OF PRIMITIVE ROCK IN THE MINNESOTA VALLEY.

In reference to the granite and gneiss of the valley Keating makes the following observation:

*The sandstone here mentioned by Keating is the Jordan sandstone lying below the Shakopee limestone.

A feature which struck us was the abundance of fragments of primitive rocks which are strewn in this valley; they were for the most part deeply imbedded in the ground, and bore but few traces of attrition; their bulk was very large. For a while we doubted whether we were not treading upon a crust of a formation of primitive rocks, which pierced through the superincumbent formations; but a close observation evinced such a confusion and diversity in the nature of the primitive blocks, as well as such signs of friction, as satisfied us that these were out of place; still they appeared to warrant the geologist in his prediction, that the party was approaching to a primitive formation, and that certainly the valley of the St. Peter had been one of the channels through which the primitive boulders had been removed from their original site. This assertion was fully substantiated two days afterward by the discovery of the primitive rocks *in situ*. A very considerable swell between the river and the right bank of the valley was supposed to be formed by the primitive rocks rising to a greater level than usual. If it be occasioned by an accumulation of fragments and boulders, as the nature of its surface might lead to believe, it is a very interesting feature in the valley.

In traveling up the valley of the Minnesota river, on the south side, various interesting observations were recorded, respecting the fauna and flora of the prairies, from which is the following extract:

Among the birds observed on the prairie, besides the sand-hill crane, are the red-bird, black-bird, yellow-headed black-bird, the black-breasted tern, the last of which was very abundant. Mr. Say shot the female of the Mergus cucullatus and a blue-winged teal. Among the reptiles, besides the common garter-snake, there was one with lateral red spots. A coluber like the melanoleucus, but spotted, and similar to that found on the Missouri, was killed on these prairies. In several of the marshes the huts of the muskrat were found very abundant. The herbarium was enriched by the addition of a beautiful specimen of the Lilium Philadelphicum, which was still seen flowering, though it had nearly ceased to bloom. Another great ornament of the prairies is the Lilium superbum. The Gerardia was still occasionally seen. This plant is, as we were informed, considered by the Indians to be a specific against the bite of a rattlesnake; the root is scraped and the scrapings applied to the wound; it is said that, if used upon a recent wound, a single application will suffice. The boulders which are so common in the valley of the St. Peter, are but seldom seen on the prairies.

No further geological notes are made till reaching the Redwood river, when he makes the statement that its banks "are formed of a fine white sandstone." It is probable that he mistook at a distance, the white kaolin bluffs which occur at that point, derived from the decomposition of the granite *in situ*, for sandstone. There is a little sand in the Cretaceous at that point, but there are no bluffs of white sand. The red pipestone was said to exist on its banks at three days' journey from its source.

No primitive rock *in situ* was noted, although it occurs at frequent intervals between New Ulm and Big Stone lake, till he reached a point several miles above Patterson's rapids. He notes "a very interesting fragment of rock" at the place where the Redwood joins the Minnesota, said to be forty or fifty feet in circumference, evidently out of place, of an enormous mass, and irregular hemispherical form, cleft by lightning. This mass was said to be granitic, presenting "very distinctly the appearance of a formation of concentric shales." The rock at Patterson's rapids was considered as primitive, but was not carefully examined.

GRANITE IN THE MINNESOTA VALLEY.

On the afternoon of the 18th of July, Major Long's party first met with unmistakable primitive rock *in situ*, at a point a few miles below the mouth of the Yellow Medicine river. Of this Keating remarks:

When descending into the valley from the prairie, with a view to select a suitable spot for our evening's camp, our attention was suddenly called to the new features which it displayed. High rocks of a rugged aspect arose in an insulated manner in the midst of the widened valley through which the St. Peter winds its way. We spent the rest of the afternoon in examining them, and experienced no little satisfaction in finding them to be primitive rocks *in situ*.

The pleasure we experienced sprang not from the mere associations of home, connected with the view of a primitive formation which we had not seen since the first five days of our journey; but it resulted also, in a great measure, from the certainty that we had at last arrived at what we had long been looking for in vain. We had traced those scattered boulders which lay insulated in the prairies from the banks of the Muskingum to this place; we had seen them gradually increasing in size and number, and presenting fewer signs of attrition as we advanced further on our journey. Two days before, their number, size and features had induced the geologist of the party to predict our speedy approach to the primitive formations, and it was a pleasing confirmation of his opinions to find these rocks really *in situ*, within thirty miles, in a straight line, of the place where he had made this assertion. The character of these rocks was examined with care, and found very curious. It seemed as if four simple minerals, quartz, fieldspar, mica and amphibole, had united here to produce almost all the varieties of combination which can arise from the association of two or more of these minerals; and these combinations were in such immediate contact that the same fragment might, as we viewed one or the other end of it, be referred to different rocks; while, in some places, granite was seen perfectly well characterized, varying from the fine to the coarse grained; in others a gneiss, mica slate, greisen (quarts and mica) compact feldspar (weisstein of Werner), sienite, greenstone, and the sienite with the addition of quartz forming the amphibolic granite of D'Aubuisson, were equally well characterized. The only rock composed by the union of two of these principles which we did not observe, but which may perhaps exist there, is the graphic granite (pegmatite, Hauy). These rocks are not very extensive; the circumference of the largest probably does not exceed one-quarter of a mile; they rise to about thirty-five feet above the level of the water. Their form is irregular; their aspect rugged and barren compared with the fertile bottom of the valley; their general color is of a dark gray; they appear to be the summit or crest of primitive rocks which lie beneath this valley, and which protrude at this place through the superior strata. As the adjoining prairies are elevated about fifty feet above the level of the river, these primitive rocks are observable only in the valley; they doubtless constituted at one time a continuous ridge, but have been divided into insulated masses by the corroding action of the stream, whose very circuitous bed winds between them. They extend upon a distance of about six miles in the direction of the valley. After having examined almost every one of these masses, I feel unwilling to decide, with certainty, which of the primitive combinations predominates, for the passage of the one into the other is more constant and more sudden than in any other primitive formation that has ever come under our notice. Indeed we know of none with which to compare it, except it be that which we observed at a subsequent period of the expedition between lake Winnipeek and the lake of the Woods; but even there the features were somewhat different, for they were on a larger scale. The passages which we there observed were sometimes to be traced only upon large masses; whereas on the St. Peter it would have been difficult to break off a fragment of a cubic foot in size presenting an uniform character of composition. It is however probable, as far as our observations extended, that granite is the predominating rock. These masses bear very evident signs of a crystalline origin, but the process must have been a confused one. Tourmaline is found disseminated throughout the rock, yet in no great abundance. In one or two spots where the mass assumed a more slaty appearance than in other places a faint tendency to a stratification, directed from the north-northeast to the south-southwest, with a dip toward the south, was observed. Viewing the insulated masses from the prairie, they appeared to be directed in a transverse line through the valley, and in a northeasterly course, so that this may be the remains of a dike which existed across the valley, but which was finally broken. This observation was, however, a partial one, and it would be improper to attach much weight to it. When calling the attention of our guide to the difference between these rocks and those observed below. he appeared to have been aware of it himself, and stated that rock similar to these extended down the valley to about four miles below Redwood rivulet. It was partly from this circumstance that we inferred that Patterson's rapids were probably formed by a bar of these rocks rising across the bed of the river. This appeared to us to be the more probable from the circumstance that a rapid known by the name of the Little falls, occurs just above the place of our encampment of the 18th, and that it is occasioned by a ledge of granite rocks over which the river passes at this place. In the examination of this spot two points appeared to us chiefly to deserve our attention, in order to avoid all source of error; the first was to ascertain that the rocks were really *in situ*; the second, that they were primitive and crystalline, not conglomerated or regenerated rocks, such as are sometimes observed. But upon these two points we think that not the least doubt can be entertained. The immense mass of these insulated rocks, the uniform hight to which they attain, the uniform direction in which they lie, prove them to be in place; while an attentive inspection of their nature shows them to be really crystalline. There is a gradual, though rapid, passage of the granite into the sienite, which proves them to be of contemporaneous formation, and which precludes the idea that the rock is formed by the union of fragments of granite, sienite, &c., cemented together.

The discovery of this granitic formation here appeared the more interesting, as its small extent might easily have prevented us from observing it, had not chance brought us to the river at this place; for if we had been traveling on the prairie, within half a mile of the edge of the bank, the greater hight of the bluff would have concealed these rocky islands from our view. We feel, therefore, unable to decide whether they do not occur at some other bends of the river which we avoided; yet from the character of the stream itself we doubt it. For we find that as soon as these rocks protrude into the valley, they occasion rapids and falls in the river, while otherwise its course is smooth. Had we not seen the "Little rapids", which we passed on the 11th, we might have been induced to consider them as resulting from the appearance of the primitive rocks at the surface, but having examined with care the sandstone rocks, by which they are produced, and having ascertained that no other rapids are found in the St. Peter, between these and the Patterson falls, we are induced to believe that this is the only place where granite may be seen *in situ*. In attempting to connect this primitive formation with those observed elsewhere, we find that it lies in a direction about W. S. W., at a distance probably not exceeding eighty miles, of the "granitic and hornblendic rocks" which Mr. Schoolcraft states as having seen "occasionally rising in rugged peaks and beds" on the Mississippi.* We feel, however, disposed to consider all this section of our country as reposing on this granite, and we entertain but little doubt of its identity with the sienitic granite observed at a later period of our journey, and which we first struck near fort Alexander at the mouth of the Winnipeek river.

Subsequently Mr. Keating observed that these rocks, which were made out to be in latitude 44° 41′ 26″ N., did not extend far in the valley. The last of them were seen at about four miles above the little falls, and he was assured by the guide that they did not recur for a considerable distance. Still he observed, at a distance, a rocky island in the bed of the river, which had the same kind of rock as that at Patterson's rapids; and again at points further up the valley rocky knolls were observed.

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*Schoolcraft's Narrative, p. 288.

The recurrence of these primitive knobs disturbs the current of the river, and renders the navigation difficult and hazardous. Five miles below the encampment of the 19th there is a place where the boats and their loads are carried for the distance of a mile; from which circumstance the place is called the Grand Portage. By this portage the canoes avoid thirteen rapids; these, with twenty-six other rapids, constitute all the obstructions to the navigation of the river from its source to its mouth. In a good stage of the waters, there are, however, but two portages, of which this is one. Among the tributaries passed that day only one deserves to be mentioned. It is called the Pejehata Zeze Watapan (*yellow medicine*) It is about the same size as the Redwood, and rises, in like manner, at the base of the Coteau des prairies. Nearly opposite to it a small stream falls in; the Indians call it the Chataba (*that hatches sparrow-hawks*); the traders term it *L'Eau de Vie.* On our map we have retained the name Epervier, which being in use among some of the traders, and intelligible both to French and English travelers, appears likely to prevail.

The foregoing exposures were wholly below Lac qui Parle, which is said to be a short day's journey further up, consisting of an expansion of the river, similar to lake Pepin, about seven and a half miles long, and from one-quarter to three-quarters of a mile wide. Mention is made of the Chippewa river, coming in from the north, said to interlock with the headwaters of the Red river, also of "Beaver rivulet" (Lac qui Parle river) which, with steep and high banks consisting of loose, white sand, joins the St. Peter near the foot of Lac qui parle. Of the country about Lac qui parle Keating notes that the elevation evidently became greater as they advanced, but with no hills of any magnitude, the only ascents being the river bluffs, which sometimes reach or exceed one hundred feet. The surrounding undulated plains were destitute of wood, the only trees seen skirting along the water-courses. Above the lake the bluffs are said to diminish in hight, not being more than forty feet, the high prairie sometimes blending gradually with the river valley. Above the lake the St. Peter was found to be only a rivulet from twenty to thirty feet wide, very much obstructed with high grass and wild rice, and stagnant water. Five leagues higher the Spirit Mountain* creek joins the St. Peter from the south, so named from a hill near which it is said to rise. Near the mouth of this stream the primitive rock is again noted scattered here and there across the valley, one exposure in particular being remarkable for the beauty of its feldspar, which is described as "very lamellar, with an easy cleavage, and intermixed with quartz, giving it almost the appearance of graphic granite." Big Stone lake is described as the "last expansion of the river, improperly called a lake."

*Yellow Bank river.

THE COTEAU DES PRAIRIES.

Although the party did not visit the Coteau des Prairies, Prof. Keating makes some interesting notes on its character and direction, which may be summarized briefly thus: Its hight above the St. Peter, at Big Stone lake, is thought to be not short of 1,000 feet. According to the best information he could obtain, "this ridge commences about the 49th parallel of north latitude, and between the 98th and 99th degrees of west longitude from Greenwich. It proceeds in a direction nearly south south-east, passes east of the group of small lakes called Devil's lake, divides the tributaries of the St. Peter from those of the Missouri, and extends southerly as far as the head of the Blue Earth, where it gradually widens and sinks to the level of the surrounding country." He mentions a second ridge or coteau, commencing at the southern bend of Mouse river, running in a direction nearly parallel with that of the other, from near the 48th parallel to beyond the 44th parallel, in a southeasterly course for about eighty miles, when it turns to the west of south and likewise sinks and disappears, the valley of the James river being between the two ridges. Mr. Keating was informed that no rocks can be seen composing the Coteau, but that it presents a uniformly smooth, prairie-like appearance, the ascent being gradual aud easy on both sides. He however was of the opinion that it is formed by an elevation of the granite rocks above their usual level, although, perhaps, covered as with a mantle by the secondary and alluvial rocks, predicting that if its whole course were to be followed "from the Assiniboine to the Blue Earth" the geologist would be rewarded by the discovery of the "granite formations, if not along the whole of its crest, at least in some of the ravines which head near it." Above Big Stone lake the St. Peter is said to divide itself into two branches, coming from the west, heading in the Coteau, one of which comes from west by south for abont twelve miles. The northern, and larger branch, has its source in Polecat lake, about twenty-four miles distant, west by north, from the point where they join Big Stone lake. That lake is one and a half miles long, and half a mile wide, and frequently dry. There are many indications in the narrative that this hasty reconnoissance of the Minnesota valley was not satisfactory to Prof. Keating.

In the Red River valley Keating mentions numerous salt springs, one being situated at the confluence of Red Lake river with the Red river of the North; states that although the soil of the prairies is occasionally sandy, it is generally argillaceous and rather dry, yielding along the river valley and its tributaries a good grass, though at a distance a rather scanty growth, but being extremely fertile wherever trees were seen to be growing; and attributes to the annual fires that run over the prairies the principal agency in keeping the country treeless.

ON THE NORTHERN BOUNDARY.

Respecting the northern boundary of Minnesota, Prof. Keating gives the first geological information, besides naming for the first time several of the principal rivers in that part of the state. Ascending the Winnipeg river from lake Winnipeg he found a great contrast between the adjacent country and that through which he had been traveling hitherto. The country is rocky very soon after leaving lake Winnipeg, with the crystalline rocks common to the northern part of Minnesota, there being between lake Winnipeg and the lake of the Woods several alternations from red granite and gneiss to slate and schists. The timber which sets in with this change in the character of the rocks, consists of a great abundance of evergreens, deciduous trees being rather the exception. The conifers were found to be tamarack, juniper, spruce, white pine, pitch pine &c., interspersed with spots where aspen and birch were found common, and other spots of hazel, willow and cherry. The rocks and the general characters of the country at the lake of the Woods were stated to be similar to those of the Winnipeg river. The lake is filled with islands, all resting on the solid rock which was found to be generally a greenish or micaceous slate. One island, known as Red Rock island,* was of a reddish granite. The direction of the "strata" of the mica slate was stated to vary from N. 60° to N. 80° E. and the angle of inclination to vary from 65° or 70° to perpendicular; but it is quite probable that Keating here refers to the direction and dip of the slaty cleavage. Although no limestone *in situ* is reported by Keating, he refers to the fact that Dr. Bigsby, whom he met on the British Northern Boundary Com-

*Subsequently named Keating Island by Mr. G. M. Dawson.

mission, states that it exists on the shore of the lake.* In Rainy-lake river he mentions two places only, where canoes are lightened and towed up, the current of this river being generally steady and of greater depth. The face of the country also changed very perceptibly, becoming more cheerful, and the grass "of a livelier green." At its mouth the banks of the stream are low and marshy; beyond this eastward they rise somewhat, but do not become hilly; the river having often a pebbly bed, leading to an anticipation of limestone rocks *in situ*. The rocks, however, seldom appeared in place along the river, and when seen consisted of mica slate and syenite; the slate containing, according to Dr. Bigsby, the mineral staurotide.† The fall at Rainy Lake fort is surpassed by two or three only of those on Winnipeg river. "The whole of the waters of the lake discharge themselves into the river by these falls, the hight of which is about twenty-five feet. The beauty of the spot depends much on the wildness of the rocky scenery, occasioning a foaming or dashing of waves that are very striking. The rock is chiefly sienite, in which we thought we could distinguish a tendency to a stratification directed about northeast and inclining about 65° to the southeast. This, however, may have been a local feature. The principal growth about the lake is the pitch pine, white pine and spruce. The soil is rather light, but in the immediate vicinity of the fort it is excellent; potatoes and wheat are cultivated, together with maize, pease, pumpkins, beans, water and musk melons, &c., &c. The wild strawberry seemed to be more abundant there than elsewhere. Our soldiers were kept busy, while encamped at the fort, in fishing for the pike and freshwater salmon, which are found in great abundance and excellence at the falls." Throughout Rainy lake are many small islands, which, according to Keating, are based on a rock which for the most part is a mica-slate, with strata directed north 70° east, and nearly vertical; but in a few places may be seen granite and syenite, the lake thus resembling in most of its characters the physical features of the lake of the Woods. East of Rainy lake the party pursued the boundary line canoe-route as far as the east end of Sturgeon island and there diverged northward, reaching Fort William through a region of successive lakes, and a rocky country, descending what was known as Dog river, but now as Kamanistigoia.

*Dr. J. J. Bigsby reports limestone *in situ* on the shores of the southwest part of the lake, "some miles off in a low country, and buried beneath mounds of quartzose, sand, clay, and immense assemblages of blocks from the north."

† See Bigsby's *List of minerals and organic remains*, in Am. Jour. Sci. (1) VIII, p. 60, and *Jour. Geol. Soc.* London, Vol. VIII, p. 405.

MAJOR LONG'S RESUME OF THE EXPEDITION.

In a general topographical report of the expedition Major Long mentions the chief physical features of the country traversed, repeating many of the facts given by Keating in his journal. The Coteau des Prairies, he says, is a very remarkable feature in the aspect of the country about the headwaters of the Minnesota river. He regards it not only as the dividing ridge between the Mississippi and the Missouri rivers, but as a "grand dike," obstructing the latter in its progress eastward. Its elevation he gives at one thousand feet above the common level of the country. He mentions a second ridge west of the main one, with the James river between them, the two being thirty or forty miles apart. Of the Red river he says it is navigable for canoes, and even for pirogues of two tons burden, from its mouth to its source, as also to the sources of several of its tributaries when swollen by freshets. "On such occasions canoes have been known to pass from lake Travers, its source, into the St. Peter, and back again, without inconvenience." He estimates the descent from lake Traverse to lake Winnipeg at 200 feet, and that from the lake of the Woods at 400 feet. Lake Winnipeg he places at 630 feet above the ocean, Rainy lake 1100 feet, and lake of the Woods at 1040 feet, and the general elevation of the country containing the sources of the streams tributary to lakes Superior and Winnipeg, and to the Mississippi river, at 1200 feet.

BELTRAMI DISCOVERS THE JULIAN SOURCES OF THE MISSISSIPPI.

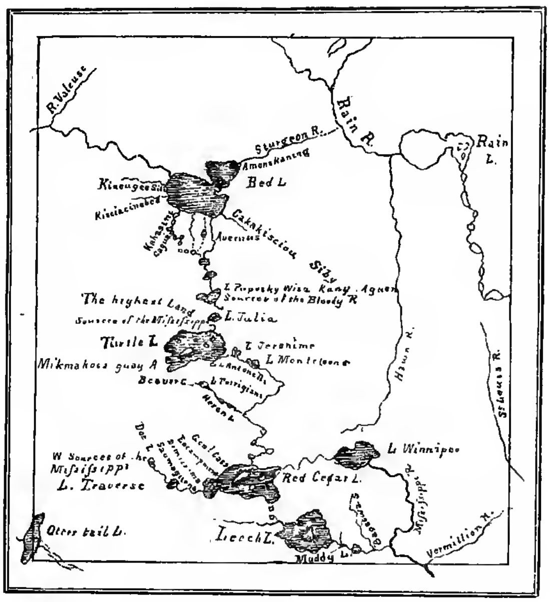
In Major Long's party for the exploration of the St. Peter's river, was an educated Italian gentleman, a political exile, of a romantic and sentimental cast of mind, named J. C. Beltrami, who, having joined the expedition at Fort Snelling, accompanied it as far as "Pembinar," where, considering himself rather discourteously treated by Major Long, and wishing to signalize his visit to the Northwest by some noteworthy discovery on his own account, he parted from Major Long and reached the upper Mississippi at Red Cedar lake, by way of Bloody river,* Red lake, and Turtle lake, and descended it as far as New Orleans, where he published his notes in French,† at a date

*Now the Red Lake river.

† La Decouverte des Sources du Mississippi et de la riviere Sanglante. One volume 8vo. 328 p., New Orleans, 1824

considerably earlier than the appearance of any of the official papers of Major Long, and several years earlier than Keating's "Narrative." It was subsequently enlarged and reprinted in London in English.* Although his "letters," constituting as they do a gossipy and literary curiosity in the field of exploration, may be justly styled a romance in the discovery of the upper Mississippi, and although they are characterized by numerous errors, both historical and geographical, as well as ethnological and zoological, they still give some additional information respecting the geography of the upper Mississippi and Red lake. The Minnesota legislature having set aside a large tract, under the name of Beltrami county, covering the Julian sources of the Mississippi, it is to be hoped that the names applied by Mr. Beltrami to the lakes and streams he visited may be preserved in the future settlement of the region, which, however, is still nearly as wild and uninhabited as when Mr. Beltrami passed through it.

FIGURE 4.



BELTRAMI'S MAP OF THE JULIAN SOURCES.
[Fac-simile.]

The above fac-simile of that portion of Beltrami's map embracing the region of the *Julian sources of the Mississippi*, coincides with his statement

*A Pilgrimage in Europe and America, leading to the discovery of the sources of the Mississippi and Bloody river with a description of the whole course of the former, and of the Ohio, by J. C. Beltrami, Esq., formerly Judge of a royal court in the Ex-Kingdom of Italy, London. 1828, 2 vols., 8vo. pp. 1093.

that he traveled almost due south from Red lake to Red Cedar lake. But in fact Red Cedar lake is considerably to the eastward of Red lake, and his course of travel was necessarily about southeast. The river which he first struck in traveling from "Pembinar" was the Thief river. His map names it Valeuse, and his book Robbers' river. His Indian guides found here their canoe which they had secreted for a murderous foray on the Sioux the previous week. Before reaching Red lake he was attacked by the Sioux, and one of his Chippewas was wounded in the arm. This caused them to desert him and pursue the route by land to Red lake. Then he started alone to drag the canoe containing his baggage to the lake by a cord, being unable to paddle it in the manner of the Indian. Meeting a party of Indians descending the "Bloody" river, he prevailed on one of their number to conduct him to the lake. Employing there a *bois brulé*, he ascended the stream that led him to Turtle lake, first making a long portage, to avoid an extensive wind-fall which had thrown many large forest trees across the stream. To the southwest of Red lake he visited and named a series of eight small lakes, which all communicate with each other, of which Gravel river (Kahasinilague) is the outlet into Red lake. These he named Alexander, Lavinius, Everard, Frederica, Adela, Magdalena, Virginia and Eleonora, names of a family to which he was "united by the most cordial friendship." On the western side the lake receives the river Broachus (Kinongeo) and that of the Great Rock (Kisciacinabed). The next, on the south shore, are the Gravel river and the Gold Fish river (Kiogokague), also the Great Portage (Madaoanakan). On the southeast is the Cormorant river (Cacakiscin). The northern portion of Red lake receives the Sturgeon river (Amenikanions) which communicates by means of two portages, with lake Superior and the waters of Hudson's bay. He regarded the Great Portage river as the real continuation of the Bloody river and cites the opinion of the Indians to that effect. "According to the theory of ancient geographers the sources of a river which are most in a line with its mouth should be considered as its principal sources, and particularly when they issue from a cardinal point and flow to one directly opposite." For the purpose of ascending this river he was compelled to make a portage of twelve miles, beginning on the lake between it and Gold Fish river. A small lake, about half way on this portage, he styled Avernus, and another near the end of the portage he named lake of the Pines, "from the immense number of those trees with which it is surrounded." Its outlet is into the series of eight lakes that are discharged by Gravel river. From this lake he made another portage of four miles and reached the Grand Portage river. Ascending this river he passed two lakes which he denominated *Manomeny-Kany-aguen*, or Wild Rice lakes. These were formed by the enlargement of the waters of the river. The third lake, formed in the same way, the Indians called *Puposky-wiza-Kany-aguen*, or *end of the shaking lands*, nearly all the region traversed from the lake of the Pines, being so low and nearly level as almost to float upon the water. About six miles further south the real source of the Bloody river was found. It "springs out of the ground in the middle of a small prairie, and the little basin into which it bubbles up is surrounded by rushes. We approached the spot within fifty paces in our canoe."

LAKE JULIA.

Making a short portage from this spring, over a hill, Mr. Beltrami approached a wonderful lake. It is situated on a hill, with no higher land about it, in "the whole extent of the clearest and widest horizon." Mr. Beltrami's florid description is in these words: "All places around it are, on the contrary, considerably lower. I have made long excursions in all its environs, and have been unable to perceive any volcanic traces, of which its banks are equally destitute. Yet its waters boil up in the middle; and all my sounding lines have been insufficient to ascertain their depth; which may be considered as indicating that they spring from the bottom of some gulf, the cavities of which extend far into the bowels of the earth; and their limpid character is almost a proof that they become purified by filtrating through long subterraneous sinuosities; so that time may perhaps have effaced the exterior and superficial traces of a volcano, and the basin of the lake have been, nevertheless, its effect and its crater. Whither do these waters go? This I conceive may be more easily answered, although there is no apparent issue for them."

From this lake with no visible outlet he supposes there is a filtration northward so as to supply the water of lake *Puposky*, thus becoming the source of Bloody river, and also southward, where they appear in a little basin at the foot of the hill, about eighty feet in circumference, thus becoming also "the actual sources of the Mississippi." This remarkable lake, which he styled lake Julia, is described as "about three miles around, in the shape of a heart, and it may be truly said to speak to the very soul. Mine was not slightly moved by it. It is but justice to draw it from the silence in which geography, after so many expeditions, still suffered it to remain, and to point it out to the world in all its honorable distinction."

The stream from the small basin that has been noticed, on the south side of the hill, runs directly south, and after three miles reaches Turtle lake. "The majestic river, which embraces a world in its immense course, and speaks in thunder in its cataracts, is at these, its sources, nothing but a timid Naiad, stealing cautiously through the rushes and briars which obstruct its passage. The famous Mississippi, whose course is said to be twelve hundred leagues, and which bears navies on its bosom, and steamboats superior in size to frigates, is at its source merely a petty stream of crystalline water, concealing itself among reeds and wild rice which seem to insult over its humble birth."

TURTLE LAKE.

Turtle lake, including its bays, he estimates at more than one hundred miles in circumference. The first lake below he christened *Jeromine*, from the countess to whom his letters were addressed. Another, seven or eight miles further east-southeast, he named *Monteleone*. A stream coming into the Mississippi from the northwest the Indians styled *Scisaiaguay*, or Heron river. He passed up this tributary, and found it drained a number of small basins, the highest of which he named lake *Torrigiani*, "from the stately and spreading trees which overhang its banks." From this he made a portage northward and came to another lake of an oval form, which he named *Antonelli*, four or five miles across. This discharges into Turtle lake near the point at which the Mississippi leaves it.

Descending below Turtle lake he passed four lakes, which he named *Providence* lakes, on account, as he says, of the fields of wild rice which Providence has formed there, the ears of which resemble those of the land of promise. The river, throughout, to Red Cedar lake, is described as having a deep, steady and uniform channel and current, the land all being low and frequently submerged or shaking.

BELTRAMI'S OPINION OF THE ITASCAN SOURCE.

Mr. Beltrami heard of the Itascan branch of the upper Mississippi, but he regarded it as a subordinate tributary, and did not pursue it. Had he not rested his claim to the discovery of the true source of the Mississippi, confidently on the principle stated, he certainly would have penetrated to its "western sources". He was a man of zeal, adventure, energy and ambition, and never would have left the region without visiting what he styles *Doe lake*, had he supposed there was a possibility of doubting the actuality and correctness of his discovery. This western branch he learned of under the name of the *River of lake Traverse*, and says that above lake Traverse (Pemidji), it issues from a lake "which receives no tributary stream, and seems to draw its waters from the bosom of the earth. It is here, in my opinion, that we shall fix the western sources of the Mississippi."

Respecting the geology of the country, a single extract from Mr. Beltrami's pen will show at once the amount and character of the information he gives us. The following is his comment on the valley of the Redwood river, near its mouth, where the expedition passed.

BELTRAMI AT THE MOUTH OF THE REDWOOD RIVER.

We now reached a valley of the most lovely and interesting character. Never did a more striking illusion transport my imagination back to the classic lands of Latium and Magna Græcia. Rocks scattered, as if by art, over the plain, on *plateau*, and on hills, were, at a little distance, perfect representations of every varied form of the ruins of antiquity. In one place you might think you saw thermal substructures, or those of an amphitheatre, a circus, or a forum; in another the remains of a temple, a cenotaph, a basilicon, or a triumphal arch. I took advantage of the time which chance procured me, to survey this enchanted ground; but I went alone, that the delicious reverie it threw me into might not be broken by cold heartedness or presumption. My eyes continually met new images; at length they rested on a sort of tomb, which for some time held me motionless. A thousand afflicting recollections rushed to my heart; I thought I beheld the tomb of Virtue and of Friendship; I rested my head upon it, and tears filled my eyes. The spot was of a kind to soften and embellish grief, and I should have long given myself up to its sweet influence had I not been with people who had no idea of stopping for any thing but a broken saddle, or some such important incident.

The rocks are granitic, and of so beautiful and varied a quality, that the tricking dealers of the Piazza Navona, at Rome, would sell them to the most enthusiastic, and,—in their own opinion,—the most learned antiquarians, as oriental and Egyptian porphyry or basalt, which are now generally admitted to be merely granite more elaborated by time and water.

BELTRAMI AT THE FALLS OF ST. ANTHONY.

What a new scene presents itself to my eyes, my dear Madam! How shall I bring it before you without the aid of either painting or poetry? I will give you the best outline I can, and your imagination must fill it up. Seated on the top of an elevated promontory, I see, at half a mile distance, two great masses of water unite at the foot of an island which they encircle, and whose majestic trees deck them with the loveliest hues, in which all the magic play of light and shade are reflected on their brilliant surface. From this point they rush down a rapid descent about 200 feet long, and, breaking against the scattered rocks which obstruct their passage, they spray up and dash together in a thousand varied forms. They then fall into a transverse basin, in the form of a cradle, and are urged upwards by the force of gravitation against the side of a precipice, which seems to stop them but a moment, only to increase the violence with which they fling themselves down a depth of twenty feet. The rocks against which these great volumes of water dash, throw them back in white foam and glittering spray; then, plunging into the cavities which this mighty fall has hollowed, they rush forth again in tumultuous waves, and once more break against a great mass of sandstone forming a little island in the midst of their bed, on which two thick maples spread their shady branches.

SCHOOLCRAFT AT ITASCA LAKE IN 1832.

In 1832 Mr. Henry R. Schoolcraft conducted an expedition to the source of the Mississippi river, pursuing nearly the same route from Sault St. Mary, as in 1820. From Upper Red Cedar lake he passed up the Mississippi under the guidance of a Chippewa chief named Ozawindib, accompanied by Dr. Douglass Houghton, afterward state geologist of Michigan, Lieut. James Allen, U. S. A., and Rev. W. T. Boutwell, and a sufficient number of packers and canoe-men. Mr. Schoolcraft regarded himself as the discoverer of the true source of the river, and in the absence of published accounts by other travelers it was a just claim. Still there is no doubt that among the *coureurs des bois* of the fur companies there were several who knew well that the Mississippi could not be followed further than to Itasca lake. Mr. Schoolcraft's claim was generally scouted among the white residents of the northwest who were at all conversant with the country during the previous twenty-five years. The statement of Mr. Morrison of his visit to the lake in 1804 has already been referred to, and to him it is just to accord the discovery of the source of the great river, although first published so late as 1856. Mr. Schoolcraft's expedition, however, enjoyed the zest, as it received the popular acceptance, of a first discovery, and he fully described the route he took, giving several names to lakes before unknown. He named the first lake west of Cass lake, formed by the expansion northward of the Mississippi, lake Andrusia. This is in T. 146, R. 31. The next, which enlarges toward the south, situated in T. 146, R. 32, he styled the *Twin* of lake Andrusia. Its Indian name was Pamitascodiac, preferable to that which he applied. A few miles above this point begin a series of rapids, ten in number, styled Metoswa rapids. The Indian name Pemidjegumaug (now lake Pemidji), which is the Chippewa for *Lac Travers*, Mr. Schoolcraft saw a good reason for rejecting in favor of Queen Anne, whose name he applied to that lake. The little lake immediately south of it he dedicated to Washington Irving. Half a mile above this he reached what he styled the "primary forks of the Mississippi," that from the west, or Itascan fork, bearing the larger volume of water. Under the guidance of Ozawindib, the party took the southern fork, through which, by a series of lakes, they attained a point nearly east from Itasca lake. They then made a *grande portage* over the drift hills intervening, to Itasca lake, descending the other fork to Pemidji lake the following day. He bestowed the name of Marquette on the first of the lakes of the south fork, and on the second that of La Salle. The third lake, of larger dimensions, deemed by Lieut. Allen to be ten miles long, he named Plantagenet. Passing the junction of the Naiwa river and at the same time ascending a rapid by means of a portage trail of about two miles, the stream was again struck at a point a few miles below Assawa or Perch lake. A short distance above this lake the party left the south fork, by portage to Itasca lake,* the elevation passed over being estimated at 1695 feet above the gulf of Mexico.

In descending the other fork of the river, from Itasca lake, Mr. Schoolcraft found the outlet to be "quite a brisk brook, with the mean width of ten feet and the depth of one foot." After passing some severe rapids he mentions a river by the name of Chemaun, entering on the right bank, which nearly doubles the volume of the stream. Further down enters a stream, with a lake near its mouth, which the Indians styled Piniddiwin (or Carnage) river, but which he denominated De Soto river. Both these streams enter the Mississippi in T. 146, R. 35. A small stream below, originating in a lake, in T. 146, R. 34, coming in on the left, he designated Allenoga, "putting the Iroquois local terminal in *oga* to the name of the worthy officer who traced out the first true map of the actual sources of the Mississippi." He also applies names to a series of lakes between Leech lake and the headwaters of the Crow Wing river, but his descriptions cannot be made to agree with any published maps of that country, particularly in respect to distances traveled, and the sizes of the lakes, although they are

*"*Having previously got an inkling of some of their mythological and necromantic notions of the origin and mutations of the country which permitted the use of a female name for it, I denominated it Itasca.*" – Schoolcraft Disc. Sources Miss. Mr. Neill has stated on the authority of Rev. W. T. Boutwell, who accompanied the expedition, that the name *Itasca* was derived by Schoolcraft from the Latin words *veritas* and *caput*, meaning *true source*.

represented on the map accompanying his *Narrative*, published in 1834. Like nearly all pioneer travelers he over-estimates distances. The following names he applies to lakes between Leech lake and the mouth of Shell river, and they should be perpetuated on the settlement of the country, viz.: Warpool, Little Long, lake of the Mountain, lake of the Isle, Longwater lake (the source of this branch of Crow Wing river), Little Vermilion, Birch, Lac Plè, Assowa, Lac Vieux Desert, Long Rice, Allen, Illigan and Douglass. Schoolcraft descended the Crow Wing river to its union with the Mississippi, being the first to explore it, and to render an account of its course.*

LIEUT. JAMES ALLEN'S REPORT OF SCHOOLCRAFT'S EXPEDITION OF 1832 TO THE SOURCE OF THE MISSISSIPPI RIVER.

Lieut. Allen's report† is accompanied by a map of the country from the Red river of the North to the Bois Brulé river of Wisconsin, extending from lake Pepin to Red lake. On this map the Cloquet river is named Rapid river. The principal sources of the St. Louis river are represented to come from Vermilion lake and White Wood lake, the latter probably being intended for what is now known as Basswood lake. The branches of the St. Croix river from the west, in descending order, are Pine river, Nenandag river, Fowle river, Kettle river, Snake river, and three others above St. Croix lake. One also joins St. Croix lake from the west. Ascending the Mississippi river above the falls of St. Anthony, the following are represented as its eastern tributaries, Raccoon river (now Coon creek in Anoka county), Rum river, Leaf or St. Francis river, Elk river, Clear river, Long river (having its source in Long lake situated west of Mille Lacs), Muddy creek, West Savanna river, Swan, Trout, Prairie and Deer rivers; the last being the first stream above Pokegama falls. The western branches above the falls of St. Anthony,

* Resulting from this expedition were the following scientific papers:—

1. Limits of the range of the *Cervus sylvestris*, in the northwestern part of the United States. By Henry R. Schoolcraft. [Northwest Journal.]
2. Description of the *Fringilia vespertina*, discovered by Mr. Schoolcraft in the Northwest, By William Cooper. [An. N. Y. Lyc. Nat. Hist.]
3. List of shells collected by Mr. Schoolcraft in the western and northwestern territory. By William Cooper.
4. List of species and localities of plants collected in the northwestern expeditions of Mr. Schoolcraft, of 1831 and 1832. By Douglass Houghton. M. D.
5. A report on the existence of deposits of copper in the geological basin of lake Superior By Dr. D. Houghton.
6. Remarks on the occurrence of native silver and ores of silver in the stratification of the basins of lakes Huron and Superior. By Henry R Schoolcraft.
7. A general summary of the localities of minerals observed in the Northwest in 1831 and 1832. By Henry R. Schoolcraft.
8. Geological outline of the Taquimenon valley of lake Superior. By Henry R. Schoolcraft.
9 Suggestions respecting the geological epoch of the deposit of sandstone rock at St. Mary's falls. Ry Henry R. Schoolcraft.

Of the above, those not otherwise noted, are in the appendix to Schoolcraft's work, *Discovery of the Sources of the Mississippi*.

†American State Papers Vol. V. Military Affairs p. 312.

so far as named, are Rice (probably Shingle creek in Hennepin county), Crow, Sac, Elk, Swan, Crow Wing, Pine, and Willow. The Crow Wing has a northern tributary near its mouth called Salt river, coming from Gull lake. The Shell river rises in Shell lake, and the Leaf river is not named. Although his journal alludes to Leaf river, giving it a size nearly as large as the Crow Wing where they join, and states its source is in Leaf lake fifty miles above its mouth, yet neither is represented on his map. He has incorrectly named it "Shell river," which really joins the Crow Wing much higher up, as represented by Schoolcraft, and later by Nicollet. A large tributary of the St. Peter's river from the north is Beaver river, undoubtedly the Pomme de Terre (or Tipsinah) river. Big Stone lake is named Big Salt lake, and the Minnesota river above that lake is called Cold creek. The head of the Coteau is styled "Thunder Nest Mountains," and a series of "salt ponds" is represented just to the east. The eastern branches of the Red river of the North are the Chippewa, the Wild Rice, Plum, Sand Hill and Red Lake rivers. The map is characterized by the representation of marked hill-ranges, sometimes called mountains. The great moraine of western Minnesota is shown from a point north of Cass lake southward to near the source of the Crow river, under the name, "Dividing Ridge between the Mississippi and Red rivers." The "Cabotian Mountains" begin between the Cloquet river and lake Superior and extend southwestwardly across the St. Louis river, forming the *Dalles*, and several miles further. A range designated "Pine hills", extends from the upper St. Croix lake westward nearly to the source of Snake river. The Nemadji, or Left Hand river, entering lake Superior near Superior City, is named "La Rivière à Gauche." Red Cedar lake is near the Mississippi northwest of Mille Lacs, and Red lake is between it and Long lake toward the southwest, and empties into the Mississippi by a small stream.

Lieut. Allen further defines the geography of the upper Mississippi in his journal, mentioning various streams and lakes that are not put down on his map. In first making the "grand portage" through the Cabotian mountains, he describes it as running back from the river in some places four or five miles but touching it at "La Roche Galet." The rock in the river at the upper end of the portage is described as "coarse, hard, argillite rock," and the country through which it passes as rich, and timbered with birch, pine and sugar maple. "Three miles" above the grand portage begins the *portage à couteau*, or knife portage, on the west side of the river, beginning at a small island of argillyte which rises abruptly to the hight of 100 feet, in the midst of the river at the foot of a strong rapid. This portage is stated to be a mile and a half long. "Nine and a half miles" above the knife portage he mentions continued rapids through argillyte rock for about four miles. The St. Louis river of the map he styles Fond du Lac river in his journal. The country on the portage to the West Savanna river is described as very swampy, but divided by a ridge of higher land timbered with sugar maple, birch and linn, running southeastwardly, about a mile and a half from the West Savanna river. It is less than half a mile wide, and is succeeded by swamps again on its west or Mississippi side, which extend with some alternating ridges of higher land to the West Savanna river. The highest point on the portage is about 150 feet above the Savanna rivers. Sandy lake overflows with the Mississippi, and the great flood covers the country for many miles around. At "Pacagama falls" the descent of the river is between twenty and thirty feet in the distance of a hundred yards, and is nowhere perpendicular, but the channel is much contracted. In one place the whole water runs down the surface of a smooth, plain rock for a distance of forty feet, with a pitch of about twelve degrees. The river is here said to break through a low ridge that traverses its course perpendicularly in a northeast and southwest direction, the rock being of granular quartz. At a small stream which joins the Mississippi a short distance above the falls, from the west, commence the great swamps and savannas which border the Mississippi on one or both sides for a great distance above. By way of Lac la Crosse (remarkable for the fine whitefish it afforded) and a small river extending three or four miles to another little lake, he left the Mississippi, at last, making a portage of 800 yards to Little Winnipeg lake, through which the Mississippi runs. A few miles further up he reached Big Winnipeg lake, from which he says there is a short portage to a river of Rainy lake, probably the Big Fork river. Red Cedar lake, the former name of Cass lake, derived its name from a little high island called *Red Cedar island.*

LIEUT. ALLEN AT THE SOURCE OF THE MISSISSIPPI, AND ON THE CROW WING RIVER.

In company with Mr. Schoolcraft, Lieut. Allen left Cass lake under the guidance of *Yellow Head*, an Indian of the Cass lake band, for the exploration of the Mississippi river to its source. Passing Lac Travers, now lake Pemidji, which he describes as a beautiful lake about ten miles long from north to south and about half as broad, surrounded by pine woods which rise into high hills on the north and northwest, forming a part of the chain dividing the waters of the Mississippi from those of the Red river, he followed a broad channel, 100 yards long, and reached another small lake. Half a mile above this he reached the forks of the river, the branches being nearly of the same width, but the right hand branch having the most water discharge. He ascended the left branch, and in about twelve miles reached lake Rahbahkanna, or Resting lake, which is four miles in diameter and nearly round. Ascending the river still further, a distance estimated by him between fifty and sixty miles, he reached Usaw-way, or Perch, lake, which is about two miles long and half a mile broad. From this lake he set out overland to *Lac la Biche*, which was supposed to be the source of the larger fork of the Mississippi, making a portage of six miles, and struck the lake near the end of its southeastern bay. The portage passed over a rough country, two or three hundred feet above the lake, with tamarack swamps and Banks' pine, the latter growing in a poor and sandy soil, hung with lichens and without animal life. Mr. Schoolcraft hoisted a flag on a high staff, on the island, and left it flying. Lac la Biche is said to be about seven miles long and from one to three broad, but of irregular shape, conforming to the bases of the pine hills which for a great part of its circumference rise abruptly from its shore. Its shores are formed of boulders of primitive rock but have no rock in place. Schoolcraft island is 150 yards long and 50 yards broad. The Indian who acted as guide declared this lake to be the "true source and fountain of the longest and largest branch of the Mississippi." He had hunted all round it, and said there was a little creek too small for the smallest canoes to ascend, emptying into the south bay of the lake and having its source "at the base of a chain of high hills, which we could see not two miles off." To the west he saw distinctly "a range of almost mountains, covered with pine, which was undoubtedly the chain dividing us from the waters of the Red river." Respecting the "Julian sources" Lieut. Allen says: "There is, however, a little stream, Turtle river, entering Cass lake from the north, in the route of traders to Turtle lake and Red lake, but it is a very small and insignificant stream, and is only forty-five miles in length." On leaving Lac la Biche he found the Mississippi twenty feet broad and two feet deep with a current two miles per hour. It soon ran through a chain of high pine hills, where the channel contracted very much and numerous rapids occurred, of very great fall over boulders of primitive rock, the river running for a distance in a deep ravine.

Lieut. Allen made a series of portages, and traverses of little lakes, from the south end of Leech lake "to Long lake, the source of Crow Wing river. These portages were all short, and over pine ridges, with yellow and pitch pine; the lakes were deep, clear and beautiful, with pine hills coming down to the water. The lakes had neither inlet nor outlet, and from the summits of the hills several could be seen at once. Long lake is only the beginning of a chain of eleven pretty little lakes near together, from two to five miles in length, from which the Crow Wing takes its rise."

In descending the Crow Wing river Lieut. Allen mentions the Leaf and the Shell rivers, but gets their names interchanged; also the Long Prairie river, but he does not name it on his map.

LIEUT. ALLEN ON THE MISSISSIPPI.

At the "little falls" he describes the river as forming a chute, and contracted from 300 yards to fifty yards, the fall amounting to ten feet in sixty, "through a formation of talcous slate rock, the first rock we had seen in place since leaving the falls of Pacagama. A little further down we passed Pike rapids, and the site of Pike's blockhouse, where Lieut. Pike wintered his command in 1805–'6; and a little further a chain of rapids called the 'grand rapids,' where the river runs over an extensive rock formation of granular quartz." He also mentions another rapid at the mouth of Elk river, and the "big falls" at the mouth of Sac river, and a short distance above the latter the mouth of the Little Sac, or Wattah, river; also, the "mouth of the St. Francis, or Parallel, river, a considerable stream running parallel with the Mississippi, and navigable for canoes 150 miles." The Rum river, on the same side, is said to be navigable for canoes 150 miles to "Mil Lac, a lake almost as large as Cass lake."

The whole descent at the falls of St. Anthony, including the rapids, he estimated at eighty feet, the perpendicular fall at eighteen feet.

LIEUT. ALLEN ON THE ST. CROIX RIVER.

The St. Croix enters the Mississippi by a mouth seventy-five yards broad, opposite an island of the latter, and fifty miles below Fort Snelling. Its right bank at the mouth is a perpendicular rock eight or ten feet high (calcareous sandrock) and the left is a low acute point. A few hundred yards from the mouth it opens into a long, narrow lake, lake St. Croix, which seems to fill or lie in a valley, the hills rising to form its banks, on each side, in green gentle slopes. * * * * A few miles above where I encamped, the river is traversed by a primitive rock which for a distance of one or two hundred yards, confines the channel within perpendicular walls fifty feet high, and rises in a high abrupt little island in the middle of the stream, but occasions no rapid. Above this the banks are high and steep, but not rocky, till within a mile of the falls, when the channel becomes suddenly contracted to from fifteen to thirty yards, by rocks forming mural precipices on each side fifty and a hundred feet high, between which the river, though very deep, is urged with great velocity. This rock and the narrow channel continues, with a few interruptions of caves and fissures, one mile up, to the *falls*, where the river is but forty feet broad, and rushes with great force and violence down a fall of fifty feet in three hundred yards. The whole of this rock is greenstone trap, and its surface presented to the river in high cliffs is exceedingly rugged and broken, prismatic fragments being continually detached from it and tumbled down.

In the further ascent of the St. Croix river to the upper St. Croix lake, Lieut. Allen encountered great difficulties, on account of being abandoned by Mr. Schoolcraft and his party, and on account of the almost interminable rapids. His description of this stream above the falls of St. Croix confirms Duluth's assertion as quoted by La Salle, that in descending it he "had passed forty leagues of rapids."

G. W. FEATHERSTONHAUGH, U. S. GEOLOGIST.

In the summers of 1834 and 1835, an English gentleman, under the title of U. S. Geologist, was commissioned by Col. J. J. Abert, of the bureau of topographical engineers, with loose and apparently aimless instructions, to execute rambling explorations in the western country. The first year he visited the Red river of Arkansas, and the second he proceeded to the vicinity of that elevated ridge which separates the Missouri river from the St. Peter's. From the latter expedition resulted two works—one entitled "Report of a geological reconnoissance made in 1835, from the seat of government by the way of Green bay and the Wisconsin territory to the Coteau des Prairies, an elevated ridge dividing the Missouri from the St. Peter's river," printed by order of the Senate in 1836, and the other "A Canoe Voyage up the Minnay Sotar," published in London in 1847.

The latter is taken up largely with personal and journalistic details, and the former with a statement of geological principles, as understood by English geologists of that day. In his geological report proper Mr. Featherstonhaugh ascribes the existence of lake Pepin to the entrance of the Chippewa river, nearly at right angles to the Mississippi, damming up the water above it; mentions Castle rock as an instance of how "the mineral level has been reduced," and gives an illustration of it, in which it appears very much as it does at the present day; visited Fountain cave near St. Paul, and describes it under the impression that it is that visited by Carver; speaks of the "carboniferous limestone" at Fort Snelling, correcting Mr. Keating's error in supposing fallen pieces of limestone from the top of the bluff were *in situ* at the level of the river, and gives the following account of the falls of St. Anthony:

FEATHERSTONHAUGH AT THE FALLS OF ST. ANTHONY.

An island about 450 yards long divides the Mississippi into two parts at the falls of St. Anthony, which have a very irregular outline, owing to the soft sandstone being washed out unequally in places, and the superincumbent strata of limestone falling down in large blocks; these are piled up in large quanities on the bed of the river immediately at the foot of the falls. That part of the river on the north side of the island is about 220 yards wide. There is a very fine, smooth section of the rocks here to the water, about ninety feet high. I should think the fall would not average more than twenty feet. The immense slabs which have fallen from the limestone beds at the top are covered with producta, mixed with spirifers and cardia. On the south side of the river the line of the falls is a very irregular curvature, and measures about 450 yards to the island; the hight of the fall does not appear so great on this side, owing perhaps to the bed of the river being so much choked up with the fallen slabs. It is a wild rocky scene, but deficient in interest as a waterfall on account of its want of hight. To a geologist, however, it is exceedingly interesting, finding here the uninterrupted continuation, for one thousand miles, of the carboniferous limestone with its characteristic fossils. At the south side of the falls I got some exceedingly fine ones, including beautiful specimens of delphinula, bellerophon, nautilus, euomphalus, &c.

FEATHERSTONHAUGH ASCENDS THE MINNESOTA RIVER.

Mr. Featherstonhaugh's geological notes on the Minnesota river may be summarized somewhat as follows. Mentioning Carver's river, he says: "Something short of fifty miles from the fort there is a short rapid with a strong current. Above this is another rapid, with sandstone in place on the right bank, the same as at the fort." This is probably the rapid near Carver.

Further up the Bois Franc district, a stream comes in from the left bank called Wee-tah Wakatah, or Tall island,* and about five miles higher up some ledges of horizontal fawn-colored limestone jut out on the right bank, very cherty and somewhat vesicular; near the surface it takes a reddish salmon-color, resembling very much some beds I had previously seen on the Wisconsin and upper Mississippi. Within a few yards of these ledges, and north of them, a beautiful pellucid stream comes in, containing the purest water I had seen in the country. I could not learn that any name had been given to it, and as it is in the immediate vicinity of the first calcareous rock I had met with in place here, and its purity rendering it a very rare stream in a country where all are turbid, I named it Abert's run, after Col. Abert, of the United States army, and chief of the topographical bureau.†

Eight or nine miles below Traverse des Sioux is Myah Skah, or White Rock,‡ where he mentions an escarpment consisting of forty feet of granular sandstone surmounted by ten feet of fawn-colored limestone, the same as that at Abert's run. This sandstone, he says, is formed of semi-transparent grains loosely adhering, with nodules here and there, where they are cemented by a paste of clear siliceous matter; the whole making a hard flinty mass resembling siliceous oolite. At the junction of the limestone with the sandstone he notes a seam of marly, mineral matter "containing a great deal of silicate of iron," of a bluish-green color. About two miles above Moon creek§ (or camp Crescent, of Keating) he saw the sandstone and limestone again in place; again, at a point three miles higher, a long bluff twenty-five feet in hight. Five miles further the White Earth bluff occurs, where he mentions multitudes of large boulders on the prairie, some of which he estimates at 100 tons' weight. Beyond this point, having passed an island about 400 yards long, the current becoming very strong, with bold bluffs and many boulders, he judged that the river had worked its way through a ridge. Sixteen miles beyond this point he estimated the bluffs at 150 feet in hight, and found the current of the river swift, this being near the mouth of the Makato, or Blue Earth river.

In searching for the supposed copper mines of Le Sueur, under the guidance of his interpeter, Milor, he could ascertain nothing, not even a traditional report, of anything like a copper mine in that region. The

* High Island creek, four miles north of Henderson.

† The inaccuracies of Mr. Featherstonhaugh's description, even with the aid of his small map, render it impossible to state what stream is here meant; but the bluff of rock seems to be that situated at Rocky point, Sec. 30, Blakely.

‡ Near Ottawa.

§ Keating ascribes the name *Crescent* to a bend in the Minnesota river, but Mr. Featherstonhaugh says it is due to a series of half-moon turns in the little creek that enters from the east a short distance below the Traverse des Sioux.

Indians concurred in saying that there were some bluffs a few miles beyond the St. Peter's where they procured a blue earth with which to paint themselves; and this point was so precisely described that he had no difficulty in finding it. In passing up he evidently regarded the Le Sueur as the main stream, and refers to the fork now styled the Blue Earth, as "a fork of the river from the left bank." This he ascended, finding little current, and at a place estimated at two miles from the fork, came to a bluff about 150 feet high on the left bank, containing the blue-earth locality. "On climbing it I found the same horizontal limestone and siliceous sandstone common to the whole country. Toward the top was a broad seam of bluish clay intermixed in places with silicate of iron, being a continuation of the deposit I had seen before at Myakah; and valuable only for the savages to paint themselves with. From this bluff I advanced in a westerly direction about two miles, over a part of the country grown up with small poplars, hazels, wild roses and grass, in the hope of seeing the Coteau des Prairies, and of making arrangements to proceed to it from this quarter; but I saw nothing of the kind from any eminence which I could gain, and having in my hand, and reading on the spot, what had been said by M. Le Sueur, his mountains and his copper mines, I found myself obliged to come to the conclusion that these discoveries were fables invented to give himself influence at the court of France. Before I left the northwest country, and after I had visited the Coteau des Prairies, I found it was distant at least sixty miles from this spot, which leaves only the bluffs of the river to represent the mountains spoken of in the manuscript of La Harpe."*

Twenty miles above the mouth of the Blue Earth, he states that the Minnesota "has made a recent cut-off and abandoned its old bed; not far from this place a large mass of sandstone is in place in the middle of the river." Swan lake lies nearly five miles north of this place.

FEATHERSTONHAUGH DESCRIBES THE QUARTZYTE AT REDSTONE.

"About twenty-five miles above Makato some red earth bluffs occur on the left bank, with numerous boulders. From this point the general appearance of the soil and country begins to vary, and announces a change

*The deposit containing the pigment he places in that seam "which divides the limestone from the sandstone," when describing this locality in the "Canoe Voyage."

in the formations, and five miles further some rocky bluffs come in on the left bank, the lower beds of which are a brick red color and of a fine grain. On landing and leaving the bank I found the country covered with beds of red gritstone of a very hard quality, inclined about fifteen degrees. These rocks are full of potholes, some of them a foot in diameter and eight inches deep, and are as smooth as metal. The carboniferous limestone formation seems to terminate here, and to be stopped by a conglomerate resembling in its mineralogical characters the upper beds of the Old Red sandstone. The river has in old times passed over these rocks, worn the pot-holes, and made them so glassy smooth."

He mentions the first granite met, known as "little rock," and says that no other kind of rock was seen in place during his further progress toward the northwest.

THE COTEAU DES PRAIRIES.

He estimated the Coteau to rise 450 feet above the level of the general prairie; the ascent being so gentle that one is hardly aware of going up hill. The ascent perhaps continues two and a half miles, and is not more than at the rate of 160 feet to the mile. "The Coteau itself is only another upland prairie, somewhat more diversified than that I had left behind, having numerous small wooded lakes on its surface, which have a very picturesque appearance. From the plateau here there is an extensive view of the prairies below, with the lakes. The prairies in every direction are bounded only by the horizon; a few occasional trees indicate stagnant water. It is two good days' march from here to the Shyan, and eight further to Pembina, on Red river of lake Winnipeg, the whole of it over a prairie country with many small lakes and occasional wood. The Nid de Tonnère, or Nest of Thunder, a name derived from some Indian tradition, comprehends a small tract of country with a very irregular surface, where knolls, depressions and small wooded lakes prevail. The sand-hills I have before spoken of as lying in front of the Coteau des Prairies, extend into this vicinity and still further to the northwest. Farther to the northwest are several saline lakes, one of which, named Saline lake on the map, is about ten miles long. On the shores of these lakes crystallized salt is found in dry seasons, when the surface has been much evaporated; muriate of lime appears to be mixed with it. As there is no rock in place around here, conjectures only can be formed upon the nature of the subjacent beds. * * * * * * * The Coteau des Prairies, about which very little has been known, is a very broad ridge of land dividing the waters tributary to the Missouri from those which discharge themselves into the St. Peter's and into the Red river of lake Winnipeg. Its general direction is about north-northwest and south-southeast, though in places in appears to be irregular. To the south it comes down to the sources of the Makato, whilst to the north it terminates for a while near the sources of the Psee, where a flat country comes in, intersected by the Shyan and the Goose rivers. *Lac du Diable* is in this area with Turtle river. Here the Coteau rises again, to the north, but it is called the 'Pembina hills' by the traders; these extend beyond the Assinaboin river and die away about Flat lake, near seventy miles from lake Winnipeg. East of the Pembina hills there are salt springs, and from the somewhat vague accounts I received from the Indians, there is coal in their vicinity. A very respectable trader informed me he had once picked up some bituminous coal on the shore of lake Traverse."

GEORGE CATLIN AT THE RED PIPESTONE QUARRY.

Although Mr. Catlin is best known as an Indian delineator, he has also left a brief geological description of the pipestone country.* He was the first to carry a sample of the red pipestone away with him, and take measures to have it subjected to chemical examination. Such examination was made by Dr. C. T. Jackson, of Boston, who gave the substance the mineralogical name of *catlinite*.†

Mr. Catlin had plans laid for visiting the pipestone quarry in 1835, when at Fort Snelling, but hearing of the expedition of Mr. Featherstonhaugh, under government directon to explore the Coteau des Prairies, he abandoned his project. Subsequently hearing that that gentleman did not

*American Journal of Science, First Series, Vol. 38, p. 138.

† In the journal of the council of the first legislative assembly of the territory of Minnesota, September 11, 1849, is a letter of H. H. Sibley, presenting a sample of this stone to the territory for use in the Washington monument at the city of Washington. Its size was stated to be "about two and a half feet in length, and a little over one and a half in breadth, and two inches in thickness" Mr. Sibley objects to the use of the designation *catlinite* since it seems to have been given on the assumption that Mr. Catlin was the first white man who had visited that region. "whereas it is notorious that many whites had been there and examined the quarry long before he came to the country. This designation therefore is clearly improper and unjust The Sioux term for the stone is *E-yan-shah* by which I conceive it should be known and classified."

Mr. Schoolcraft, in 1854, published for the first time a report on the Geology and Mineralogy of the expeditions made by him to the Mississippi region. This appears in the appendix to his "Summary Narrative." It purports to have been written in 1822, and addressed to John C. Calhoun, Secretary of War. In this report the red pipestone of Minnesota is named with the true mineral name *opwagonite*, which he says is the Algonquin word for calumet stone. If this word had been applied to this mineral as early as 1822, and had been published even as early as 1832, it would antedate Jackson's name of *catlinite*. But there is no evidence that it was published—indeed the references of Mr. Schoolcraft to his own early descriptions of the substance do not bear out his implication of such use of the name.

visit the quarry, he carried out his design, starting from New York, "a distance of 2,400 miles, for which purpose I devoted eight months, traveling at a considerable expense, and for a great part of the way with much fatigue and exhaustion."

Starting on horseback from the falls of St. Anthony, in company with "a young gentleman from England of fine taste and education," and under the guidance of a faithful Indian, he followed the usual route along the south side of the Minnesota river to the Traverse des Sioux, where he crossed the river; he recrossed it at a point about thirty miles above the mouth of the "Terre Bleue," near the mouth of the Waraju, and thence, leaving the Minnesota, pursued a course "a little north of west," steering for the Coteau des Prairies. He represents the vast prairie that he passed over as one of the most beautiful countries in the world, for a distance of one hundred and twenty or one hundred and thirty miles. It everywhere showed the richest soil, and an abundance of good water which flowed from a thousand living springs.

For many miles in the distance before us we had the Coteau in view, which looked like a blue cloud settling down in the horizon; and when we had arrived at its base, we were scarcely sensible of the fact, from the graceful and almost imperceptible swells with which it commences its elevation above the country about it. Over these swells, or terraces, gently rising one above the other, we traveled for a distance of forty or fifty miles, when we at length reached the summit, and also the pipestone quarry, the object of our campaign. From the base of this majestic mound to its top, a distance of forty or fifty miles, there was not a tree or a bush to be seen in any direction. The ground was ever, where covered with a green turf of grass, about five or six inches high; and we were assured by our Indian guide that it descended to the west, toward the Missouri, with a similar inclination, and for an equal distance, divested of everything save the grass that grows and the animals that walk upon it.

On the very top of this mound or ridge, we found the far-famed quarry, or fountain, of the Red Pipe, which is truly an anomaly in nature. The principal and most striking feature of this place is a perpendicular wall of close-grained, compact quartz, of twenty-five or thirty feet in elevation, running nearly north and south, with its face to the west, exhibiting a front of nearly two miles in length, when it disappears at both ends by running under the prairie, which becomes there a little more elevated, and probably covers it for many miles, both to the north and south. The depression of the brow of the ridge at this place has been caused by the wash of a little stream, produced by several springs on the top of the ridge, a little back from the wall, which has gradually carried away the superincumbent earth, and having bared the wall for a distance of two miles, is now left to glide for some distance over a perfectly level surface of quartz rock, and then to leap from the top of the wall into a deep basin below, and from thence to seek its course to the Missouri, forming the extreme source of a noted and powerful tributary called the Big Sioux.

This beautiful wall is perfectly stratified in several distinct horizontal layers, of light, gray and rose, or flesh-colored, quartz; and through the greater part of the way, both on the front of the wall, and over acres of its horizontal surface, it is highly polished, or glazed, as if by ignition.

At the base of this wall, and running parallel to it, there is a level prairie of half a mile in width, in any and all parts of which the Indians procure the red stone for their pipes by digging through the soil and several slaty layers of the red stone to the depth of four or five feet. From the very numerous marks of ancient and modern digging, or excavations, it would appear that this place has been, for many centuries, resorted to for the red stone, and from the great number of graves and remains of ancient fortifications in the vicinity (as well as from their actual traditions) it would seem that the Indian tribes have long held this place in high superstitious estimation, and also that it has been the resort of different tribes, who have made their regular pilgrimages here to renew their pipes.

It is evident that these people set an extraordinary value on the red stone, independently of the fact that it is more easily carved and makes better pipes than any other stone ; but whenever an Indian presents a pipe made of it, he gives it as something from the Great Spirit ; and some of the tribes have a tradition that the red men were all created from the red stone, and that it thereby is "a part of their flesh." Such was the superstition of the Sioux on this subject, that we had great difficulty in approaching it, being stopped by several hundred of them, who ordered us back and threatened us very hard, saying that no white man had ever been to it, and that none should ever go. * * * * * * * * * *

The red pipe-stone will, I suppose, take its place, amongst interesting minerals; and the "Coteau des Prairies," will become hereafter an important theme for geologists, not merely from the fact that it is the only known locality of that mineral, but from other phenomena relating to it. The single fact of such a table of quartz resting in perfectly horizontal strata on this elevated plateau is of itself, as I conceive, a very interesting subject for investigation, and one which calls upon the scientific world for a correct theory with regard to the time when, and the manner in which, this formation was produced. That it is a secondary and sedimentary deposit, seems evident; and that it has withstood the force of the diluvial current, while the great valley of the Missouri, from this very wall of rocks to the Rocky mountains, has been excavated and its debris carried to the ocean, I confidently infer from the following remarkable fact.

At the base of the wall, and within a few rods of it, and on the very ground where the Indians dig for the red stone, rests a group of five stupendous boulders of gneiss leaning against each other, the smallest of which is twelve or fifteen feet, and the largest twenty-five feet in diameter, weighing, unquestionably, several hundred tons. These blocks are composed chiefly of feldspar and mica, of an exceedingly coarse grain (the feldspar often occurring in crystals of an inch in diameter). The surface of these boulders is in every part covered with a gray moss, which gives them an extremely ancient and venerable appearance, while their sides and angles are rounded by attrition to the shape and character of most other erratic stones which are found throughout the country.

That these five immense blocks, of precisely the same character, and differing materially from all other specimens of boulders which I have seen in the great valleys of the Mississippi and Missouri, should have been hurled some hundreds of miles from their native bed, and lodged in so singular a group on this elevated ridge, is truly matter of surprise for the scientific world, as well as for the poor Indian, whose superstitous veneration for them is such that not a spear of grass is broken or bent by his feet within three or four rods of the group ; where he stops, and in humble supplication, by throwing plugs of tobacco to them, solicits their permission (as the guardian spirit of the place) to dig and carry away the red stone for his pipes. The surface of the boulders I found in every part entire and unscratched by anything, and even the moss was everywhere unbroken, which undoubtedly remains so at this time, except where I applied the hammer to obtain some small specimens, which I brought away with me.*

The fact alone that these blocks differ in character from all other specimens which I have seen in my travels, amongst the thousands of boulders which are strewed over the great valley of the Missouri and Mississippi, from the Yellowstone almost to the gulf of Mexico, raises in my mind an unanswerable question as regards the location of their native bed, and the means by which they have reached their isolated position like five brothers, leaning against and supporting each other, without the existence of another boulder of any description within fifty miles of them. There are thousands and tens of thousands of boulders scattered over the prairies, at the base of the Coteau on either side, and so throughout the valley of the St. Peter's and Mississippi, which are also subjects of very great interest and importance to science, inasmuch as they present to the world a vast variety of characters, and each one, although strayed from its original position, bears incontestible proof of the character of its native bed. The tract of country lying between the

* In a specimen with which we are favored by Mr. Catlin, the feldspar is in distinct crystals, is tinted red, and greatly abounds; the quartz is gray and white, and the mica black, while the moss covers nearly half the mass.—*Eds.*

St. Peter's river and the Coteau, over which we passed, presents innumerable specimens of the kind, and near the base of the Coteau, they are strewed over the prairie in countless numbers, presenting almost an incredible variety of rich and beautiful colors, and undoubtedly traceable (if they *can* be traced,) to separate and distinct beds. Amongst these beautiful groups it was sometimes a very easy matter to sit on my horse and count within my sight some twenty or thirty different varieties of quartz and granite in rounded boulders, of every hue and color, from snow white to intense red and yellow and blue, and almost to a jet black, each one well characterized and evidently from a distinct quarry. With the beautiful hues and almost endless characters of these blocks, I became completely surprised and charmed, and I resolved to procure specimens of every variety, which I did with success by dismounting from my horse and breaking small bits from them with my hammer, until I had something like a hundred different varieties containing all the tints and colors of the painter's pallet. These I at length threw away, as I had on several former occasions other minerals and fossils, which I had collected and lugged along from day to day, and sometimes from week to week.

Whether these varieties of quartz and granite can all be traced to their native beds, or whether they all have originals at this time exposed above the earth's surface, are generally matters of much doubt in my mind. I believe that the geologist may take the varieties which he may gather at the base of the Coteau in one hour, and travel the continent of North America all over without being able to put them all in place; coming at last to the unavoidable conclusion that numerous chains or beds of primitive rocks have reared their heads on this continent, the summits of which have been swept away by the force of the diluvial currents; and their fragments jostled together and strewed about, like foreigners in a strange land, over the great valleys of the Mississippi and Missouri, where they will ever remain and be gazed upon by the traveler as the only remaining evidence of their native ledges, which have again been submerged or covered with diluvial deposits.

There seems not to be, either on the Coteau, or in the great valleys on either side, so far as I have traveled, any slaty or other formation exposed above the surface, on which grooves or scratches can be seen, to establish the direction of the diluvial currents in those regions; yet I think the fact is pretty clearly established by the general shapes of the valleys, and the courses of the mountain ridges which wall them in on their sides.

The Coteau des Prairies is the dividing ridge between the St. Peter's and the Missouri rivers; its southern termination or slope is about in the latitude of the falls of St. Anthony, and it stands equi-distant between the two rivers, its general course bearing two or three degrees west of north, for the distance of two or three hundred miles, when it gradually slopes again to the north, throwing out from its base the headwaters and tributaries of the St. Peter's on the east; the Red river and other streams which empty into the Hudson's bay on the north; "La Riviere Jacques" and several tributaries to the Missouri on the west; and the Red Cedar, the Ioway and the Des Moines on the south.

This wonderful anomaly in nature, which is several hundred miles in length, and varying from fifty to an hundred in width, is undoubtedly the noblest mound of its kind in the world. It gradually and gracefully rises on each side, by swell after swell, without tree, or bush, or rocks (save what are to be seen at the pipestone quarry), and is everywhere covered with green grass, affording the traveler, from its highest elevations, the most unbounded and sublime views of—nothing at all, save the blue and boundless ocean of prairies that lie beneath and all around him, vanishing into azure in the distance, without a speck or spot to break their softness.

The direction of this ridge clearly establishes the course of the diluvial current in this region, and the erratic stones which are distributed along the base I attribute to an origin several hundred miles northwest from the Coteau. I have not myself traced the Coteau to its highest points, nor to its northern extremity, but on this subject I have closely questioned a number of travelers who have traversed every mile of it with their carts, and from thence to lake Winnipec on the north, who uniformly tell me that there is no range of primitive rocks to be crossed in traveling the whole distance, which is one connected and continuous prairie.

The surface of the sides and the top of the Coteau is everywhere strewed over with granitic sand and pebbles, which, together with the fact of five boulders resting at the pipestone quarry, shows clearly that every part of the ridge has been subject to the action of these currents, which could not have run counter to it without having disfigured or deranged its beautiful symmetry.

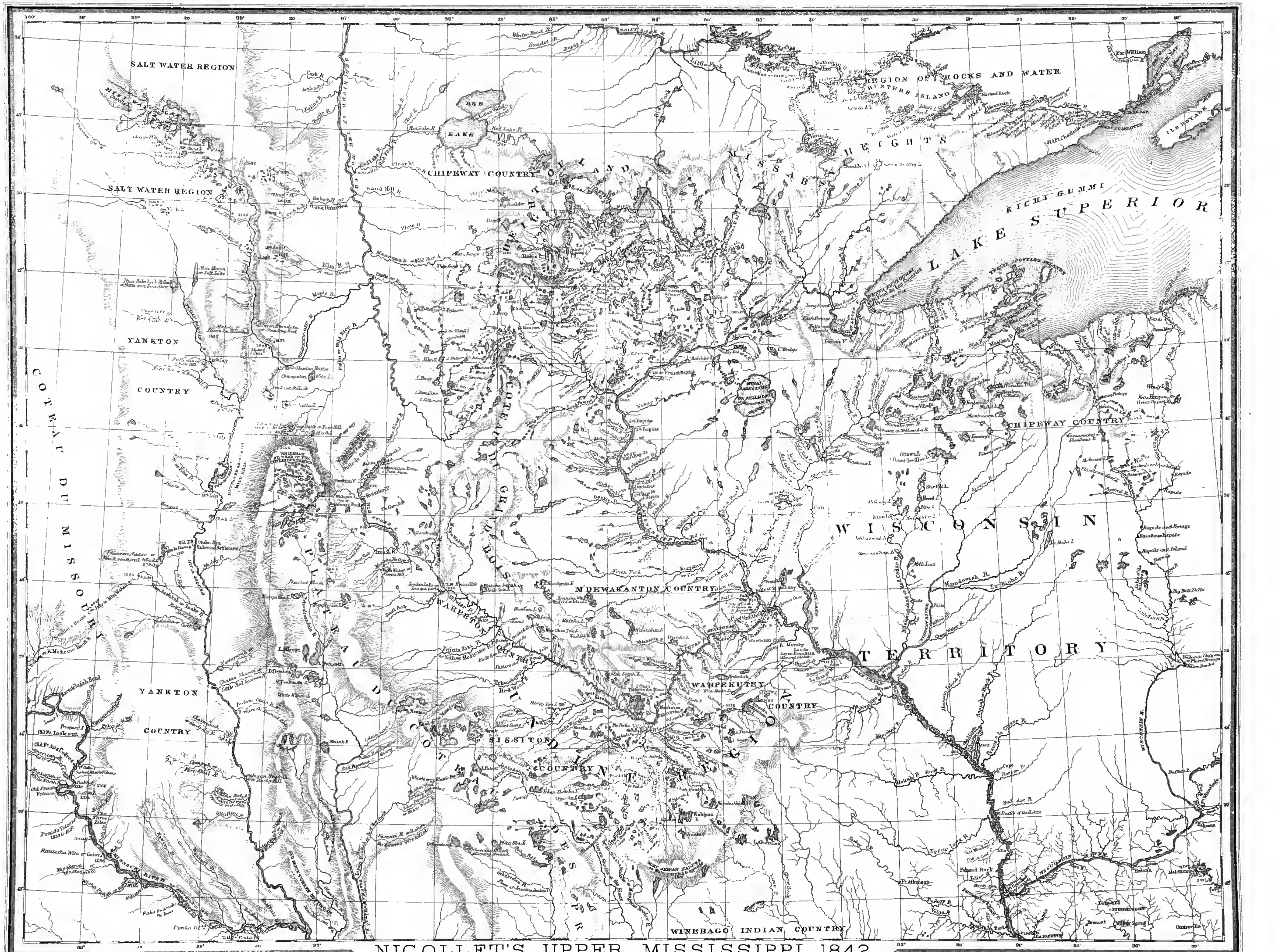
The glazed or polished surface of the quartz rocks at the pipestone quarry, I consider a very interesting subject, and one which will hereafter produce a variety of theories as to the manner in which it has been formed and the causes which have led to such singular results. The quartz is of a close grain and exceedingly hard, eliciting the most brilliant sparks from steel, and in most places where it is exposed to the sun and air, its surface has a high polish, entirely beyond any result which could have been produced by diluvial action, being perfectly glazed as if by ignition. I was not sufficiently particular in my examination to ascertain whether any parts of the surface of these rocks under the ground, and not exposed to the action of the air, were thus affected, which would afford an important argument in forming a correct theory with regard to it; and it may also be a fact of similar importance that the polish does not extend over the whole wall or area, but is distributed over it in sections, often disappearing suddenly and reappearing again, even where the character and exposure of the rock are the same and unbroken. In general, the points and parts most projecting and exposed, bear the highest polish; which would naturally be the case, whether it was produced by ignition or by the action of the air and sun. It would seem almost an impossibility that the air in passing these projections for centuries, could have produced so high a polish on so hard a substance, and, in the total absence of all igneous matter, it seems equally unaccountable that this effect could have been produced by fire. I have broken off specimens and brought them home, which have as high a polish and luster on the surface as a piece of melted glass; and then as these rocks have certainly been formed where they now lie, it must be admitted that this strange effect has been produced either by the action of the air or by igneous influence, and if by the latter cause, we can come to no other conclusion than that these results are volcanic;* that this wall has once formed the side of an extinguished crater, and that the pipestone, lying in horizontal strata, was formed by the lava which issued from it. I am strongly inclined to believe, however, that the former supposition is the correct one, and that the pipestone, which differs from all known specimens of lava and steatite, will prove to be a subject of great interest, and worthy of careful analysis.

The first plate-page is designed to show at a glance the history of geographical exploration in Minnesota, from the time of the earliest French exploration to the date of Catlin's visit to the pipestone quarry. Plate-page No. 2 is a reduced copy of Franquelin's map of 1688, being the oldest known map of the region west of lake Superior.

LIEUT. ALBERT M. LEA ON THE BLACK HAWK PURCHASE.

Lieut. A. M. Lea's map, accompanying his report on the "Black Hawk purchase," entitled "Notes on the Iowa District of Wisconsin Territory," 1836, shows the southern and southeastern counties of Minnesota, and the tributaries of the Mississippi river as far north as the foot of lake Pepin. The Whitewater river, by this map, joins the Embarras river just before the latter reaches the Mississippi. A tributary of the Whitewater from the south is named Swallow creek. Lake Albert Lea is there styled Fox lake. Fountain lake he styled Chapeau lake. A branch of the Blue Earth river is represented, and Council lake as one of its tributaries. This is probably Walnut lake, of Faribault county. The head of Lime creek is

*These smoothed surfaces are due to the polishing effect of sand and dust driven by the high winds.—N. H. W.



NICOLLET'S UPPER MISSISSIPPI_1842.

Reduced for the Geological and Natural History Survey of Minnesota

Julius Bien & Co. lith.

Trail lake, with a smaller one flowing into it from the northwest. Northwest from Chapeau lake, and between its two affluents from the northwest is "Paradise Prairie." A "trading house" is represented at Red Wing's village, at the foot of lake Pepin. Lieut. Lea's brief general notes pertain wholly to the region south of Minnesota, though his return trail passes through our southern counties.

JEAN N. NICOLLET.

From 1836 to 1843, Mr. Jean N. Nicollet prosecuted the geographical exploration of the upper Mississippi. He died while his report, intended to show the result of his labors, was undergoing print and revision.* It is accompanied by a map, which, up to that time, was the most complete and correct of the upper Mississippi region. It covered not only the whole of Minnesota but also Iowa, about one-half of Missouri and much of Dakota, Wisconsin and Illinois. It has been pronounced by high authority† "one of the greatest contributions ever made to American geography." That part of his map covering Minnesota, where the greater part of his time was spent, and where he brought out the most interesting and matured results, is reproduced in plate-page No. 7. He not only expresses the names of streams and lakes, but gives the first representation of the striking topographical features of the western and northern portions of the state. Without any just idea of the origin of the immense "erratic deposite" which characterizes the western and northern part of the state, he has, with tolerable correctness, delineated the course of a series of knolls and hills, made up of drift, under the names, *Plateau du Coteau des Prairies, Coteau du Grand Bois, Hight of Land, Missabay Hights,* which extend through Minnesota and mark the continuous limit of the ice-sheet at the time of the last glacial epoch. He aims to locate correctly, by astronomical observations, the numerous streams and lakes, and the main geographical features of the state, filling in by eye-sketching, and by pacing, the intermediate objects. His methods, allowing for the imperfection of his appliances, and the meagerness of his outfit and supplies, were established on the same principles as the most approved geodetic surveys of the present day. It would, perhaps, have been

***Report intended to illustrate a Map of the Hydrographical Basin of the Upper Mississippi river*, made by J. N. Nicollet, while in employ under the Bureau of the Corps of Topographical Engineers. Feb. 16, 1841, Washington. Senate document No. 237. 26th Congress, 2d Session.

†Gen. G. K. Warren, Pac. R. R. Reports. Vol. XI., p. 41.

well if the methods of Nicollet could have been adhered to in the further surveying and mapping of the western territories. Their geography would have been less rapidly developed, but it would have been done more correctly. Nicollet's map embraces a multitude of names, including many new ones, which he applied to lakes and streams. These are not represented on the general historical map, but may be seen on referring to Nicollet's map as reproduced.

Mr. Nicollet makes but few references to the geology and natural history of the region he surveyed, his main purpose being geographical information. Lieut. J. C. Fremont was his principal aid. He also employed Mr. Charles Geyer as a practical botanist, whose collections were named by Prof. John Torrey. His fossils were named by himself, or by the assistance of Vanuxem and Conrad of the New York Geological Survey, then lately instituted.

MR. NICOLLET ON THE COTEAU DES PRAIRIES.

The basin of the upper Mississippi is separated in a great part of its extent from that of the Missouri, by an elevated plain, the appearance of which, seen from the plain of the St. Peter's, or that of the river Jacques, *looming as it were a distant shore*, has suggested for it the name of *Coteau des Prairies*. Its more appropriate designation would be that of *plateau*, which means something more than is conveyed to the mind by the expression, *a plain*.

Its northern extremity is in latitude 46°, extending to 43°; after which it loses its distinctive elevation above the surrounding plains, and passes into rolling prairies. Its length is about two hundred miles, and its general direction N. N. W. and S. S. E. Its northern termination, (called *Tete du Coteau*, in consequence of its peculiar configuration,) is not more than fifteen to twenty miles across; its elevation above the level of the Big Stone lake is 890 feet, and above the ocean 1916 feet. Starting from this extremity (that is, the head of the Coteau,) the surface of the plateau is undulating, forming many dividing ridges which separate the waters flowing into the St. Peter's and the Mississippi from those of the Missouri.

Under the forty-fourth degree of latitude, the breadth of the Coteau is about forty miles, and its mean elevation is here reduced to 1450 feet above the sea. Within this space its two slopes are rather abrupt, crowned with verdure and scolloped by deep ravines thickly shaded with bushes, forming the beds of rivulets that water the subjacent plains.

The Coteau itself is isolated, in the midst of boundless and fertile prairies, extending to the west, to the north, and into the valley of the St. Peter's.

The plain at its northern extremity is a most beautiful tract of land, diversified by hills, dales, woodlands and lakes, the last abounding in fish. This region of country is probably the most elevated between the gulf of Mexico and Hudson's bay. From its summit, proceeding from its western to its eastern limits, grand views are afforded. At its eastern border, particularly, the prospect is magnificent beyond description, extending over the immense green turf that forms the basin of the Red river of the North, the forest-capped summits of the *hauteurs des terres* that surround the sources of the Mississippi, the granitic valley of the upper St. Peter's, and the depressions in which are lake Traverse and the Big Stone lake. There can be no doubt that in future times this region will be the summer resort of the wealthy of the land. * * *

The other portions of the Coteau, ascending from the lower latitudes, present pretty much the same characters. This difference, however, is remarkable: that the woodlands become scarcer, whilst the open prairies increase in extent. It is very rarely only that groves are met with, to which the *Ndakotahs*, or Sioux, have given the name of *Tchan Witah*, or Wood islands. When these groves are surrounded by water they assume some resemblance to oases, and hence I have assigned this name to some of them on my map.

These oases, possessed of a good soil, well wooded, offering an abundance of game, and waters teeming with fish, offer inducements for permanent settlements. In this region there are frequent instances of a marsh, or lake, furnishing waters to different hydrographical basins—a fact observed by the Sioux, and which they express, in the compound word of their dialect, *mini akipan kaduza;* from *mini*, water, *akipan*, division, share, and *kaduza*, to flow, to run out.

There are, besides, other fine lakes, that would furnish, on their borders, eligible sites for such villages as were formerly occupied by some of the *Ndakotah* tribes, previous to the war of extermination waged against them by the Sac and Fox Indians. Among them may be numbered the series of lakes designated as the Shetek, Benton, Titan-kahi, Poinsett, Abert, Spirit, and Tizaptonan lakes.

Whatever people may fix their abode in this region must, necessarily, become agriculturists and shepherds, drawing all their resources from the soil. They must not only raise the usual agricultural products for feeding, as is now but too generally done in some parts of the west, but they will have to turn their attention to other rural occupations, such as tending sheep for their wool; which would greatly add to their resources, as well as finally bring about a more extended application of the industrial arts among them. * * * * * The plateau of the Coteau des Prairies is composed in a great measure, of the materials belonging to what I have named the *erratic deposite*, as is evidenced by the nature of the soils, the physiognomy of the ridges and hillocks that diversify its surface, the deep ravines by which it is flanked, and the innumerable erratic blocks strewed over the borders of its lakes.

We have no data by which to determine the inferior limits of this deposite; still there is reason to think that it rests upon such primary rocks as show themselves along the line of rapids of the upper St. Peter's, consisting of granite, sienite and other metamorphic rocks. Nevertheless, over the vast extent of this plateau, there is, apparently, but one spot where the subjacent rock makes its appearance, and this is at the Indian red pipestone quarry, so-called.

NICOLLET AT THE RED PIPESTONE QUARRY.

The Indians of all the surrounding nations make a regular annual pilgrimage to it unless prevented by their wars or dissensions. The quarry is on the lands of the Sissiton tribe of Sioux.

The idea of the young Indians, who are very fond of the marvellous, is, that it has been opened by the Great Spirit, and that whenever it is visited by them, they are saluted by lightning and thunder. We may cite as a coincidence, our own experience in confirmation of this tradition. Short of half a mile from the valley, we were met by a severe thunder-storm, during which the wind blew with so much force as to threaten the overthrowing of Mr. Renville's wagon; and we were obliged to stop for a few minutes during the short descent into the valley.

If this mode of reception was at first to be interpreted as an indication of anger on the part of the Great Spirit for our intrusion, we may add that he was soon reconciled to our presence; for the sun soon after made his appearance, drying both the valley and our baggage. The rest of the day was spent in pitching our tent on the supposed consecrated ground, and in admiring the beautiful effects of lights and shadows produced by the western sun as it illumined the several parts of the bluff, composed of red rock of different shades, extending a league in length, and presenting the appearance of the ruins of some ancient city built of marble and porphyry. The night was calm and temperate, of which we took advantage to make astronomical observations.

* * * * * * * * * *

The valley of the "Red Pipestone" extends from N. N. W. to S. S. E. in the form of an ellipsis, being about three miles in length, with a breadth at its smaller axis of half a mile. It is cradle-shaped, and its slope to the east is a smooth sward, without trees and without rocks. Its slope to the west is rugged, presenting a surface of rocks throughout its whole length, that form a very picturesque appearance, and would deserve a special description if this were the place to do so. But I am now more particularly interested in defining its geological features.

The principal rock that strikes the attention of the observer in this remarkable inland bluff, is an indurated (metamorphic) sandrock, or quartzyte, the red color of which diminishes in intensity from the base to the summit. It is distinctly stratified; the upper beds being very much weather-worn and disintegrated into large and small cubic fragments.

The whole thickness of this quartzyte, which immediately overlies the bed of the red pipestone is 26½ feet. Its strata appear to have a small dip to the N. E. The floor of the valley, which is higher than the red pipestone, is formed by the inferior strata of the quartzyte, and in the spring of the year is most generally under water; the action of which upon the rock is apparent in the great quantity of fragments strewed over the valley, so as to render it uncomfortable to walk over them. The creek by which the valley is drained, feeds in its course three distinct small basins at different elevations, that penetrate down as far as the red pipestone.

This red pipestone, not more interesting to the Indian than it is to the man of science, by its unique character, deserves a particular description. In the quarry of it which I had opened, the thickness of the bed is one foot and a half; the upper portion of which separates in thin slabs, whilst the lower ones are more compact. As a mineralogical species it may be described as follows: compact; structure slaty; receiving a dull polish; having a red streak; color blood-red, with dots of a fainter shade of the same color; fracture rough; sectile; feel somewhat greasy; hardness not yielding to the nail; not scratched by selenite, but easily by calcareous spar; specific gravity 2.90. The acids have no action upon it; before the blowpipe it is infusible *per se*, but with borax gives a green glass.

According to Prof. Jackson, of Boston, who has analyzed and applied to it the name of catlinite, after Mr. Catlin, it is composed of—

Water	8.4
Silica	48.2
Alumina	28.2
Magnesia	6.0
Peroxide of iron	5.0
Oxide of Manganese	0.6
Carbonate of lime	2.6
Loss (probably magnesia)	1.0
Total	100.0

But Prof. Jackson assimilates it to the agalmatolite, from which it differs, however, very materially by its general aspect, its conduct before the blowpipe, and its total insolubility in sulphuric acid.*

Another feature of the Red Pipestone valley is the occurrence of granitic boulders of larger size than any I had previously met. One of these measured about sixty feet in circumference, and was from ten to twelve feet thick. They are strewed over the valley, in which it is remarkable that there are no pebbles.

The name of Mr. Nicollet, and the initials of his companions, are handsomely cut in the hard quartzyte at the top of the ledge near the Leaping Rock, a little north of where the creek passes over the brow of the escarpment, as here represented and arranged, viz:

J. N. Nicollet.
C. F.
C. A. G.
J. L.
J. E. F.
J. R.
Expedition
July, 38.

*The red pipestone is also found on the upper part of the Mishkwagokag, or Red Cedar river, which falls into the Chippeway river that empties itself into the Mississippi river below lake Pepin.

THE UNDINE REGION.

I shall now proceed to give a short account of some of the regions of country adjoining the Coteau des Prairies, omitting those which have already found a place in the geography of the United States, so as to be more particular concerning such as are but little or not at all known. Among these, that which appeared to me the most favorable, is the one watered by the bold Mankato or Blue Earth river, and to which I have given the name of *Undine region.*

The great number of the navigable tributaries of the Mankato, spreading themselves out in the shape of a fan; the group of lakes surrounded by well-wooded hills; some wide-spreading prairies with fertile soil; others apparently less favored, but open to improvement;—the whole together bestow upon this region a most picturesque appearance. It was while on a visit to lakes *Okamanpidan* and *Tchanhassan* (Little Heron and Maplewood lakes), that it occurred to me to give it the name that I have adopted, derived from that of an interesting and romantic German tale, the heroine of which belonged to the extensive race of water-spirits living in the brooks and rivers and lakes, whose father was a mighty prince. She was, moreover, the niece of a great brook (the Mankato) who lived in the midst of forests, and was beloved by all the many great streams of the surrounding country, etc., etc.

I do not know why I fancied an analogy between the ideal country described in the tale, and that of the one before me; but I involuntarily, as it were, adopted the name.*

The limit of this region is the N. E. prong of the Coteau des Prairies, which takes in the sources of the Mankato and of the La Hontan rivers, subdividing itself into undulations whence proceed the waters of the *Wazioju*, or Pine river, *Miniska*, or White Water river, *Okah*, or Heron run, &c., &c., all emptying into the Mississippi.

The Mankato becomes navigable with boats within a few miles of its sources. It is deep, with a moderate current along a great portion of its course, but becomes very rapid on its approach to the St. Peter's. Its bed is narrowly walled up by banks rising to an elevation of from sixty to eighty feet, and reaching up to the uplands through which the river flows. These banks are frequently cliffs, or vertical escarpments, such as the one called by the Sioux *Manya kichaksa*, or cleft elevation. The breadth of the river is pretty uniformly from 80 to 120 feet wide; and the average breadth of the valley through which it flows scarcely a quarter of a mile. The latter, as well as the high grounds, are well-wooded; the timber beginning to spread out on both shores, especially since they have become less frequented by the Sioux hunters, and are not so often fired. But the crossings of the river are hard to find, requiring to be pointed out by an experienced guide. I have laid down on the map my route over the Undine region, and the geographical positions of the crossing places will be fonnd in the table at the end of the report.

On the left bank of the Mankato, six miles from its mouth, in a rocky bluff composed of sandstone and limestone, are found cavitives in which the famed blue or green earth, used by the Sioux as their principal pigment, is obtained. This material is nearly exhausted, and it is not likely that this is the spot where a Mr. Le Sueur (who is mentioned in the narrative of Major Long's Second Expedition, as also by Mr. Featherstonhaugh) could, in his third voyage during the year 1700, have collected his four thousand pounds of copper earth sent by him to France. I have reason to believe that Le Sueur's location is on the river to which I have affixed his name, and which empties into the Mankato three quarters of a league above Fort L'Huillier, built by him, and where he spent a winter.

This location corresponds precisely with that given by Charlevoix, while it is totally inapplicable to the former. Here the blue earth is abundant in the steep and elevated hills at the mouth of this river, which hills form a broken country on the right side of the Mankato. Mr. Fremont and myself have verified this fact—he during his visit to Le Sueur river; and I upon the locality designated by Mr. Featherstonhaugh, where the Ndakotahs formerly assembled in

* The beautiful poetic conceit of Nicollet in applying the name of Undine to this region should be perpetuated. Undine was a water-sprite, that had control of the waters so as to accomplish her designs. Her uncle, Kuhleborn, who possessed a great stream, was influential over many, and caused sudden floods to stop travel, and to intercept fugitives. His passage from province to province was often subterranean, and brought him into numerous lakes, He made his realm obedient to Undine, and aided her ambitious design to captivate a rich and noble knight. The story is one of the eighteenth century, written by Fouque. The multiplicity of streams, springs, and lakes in this region, with occasional subterranean channels (see *Geology of Blue Earth County*,) greatly in contrast with the monotonous, treeless prairies on either side, make it an image of the domain of Kuhleborn, and suggest that it is the habitation of Undine, and her associate water-nymphs. The valleys, and some of the uplands, in this region, are wooded and the streams sometimes run in deep, rock-bound gorgea.

great numbers to collect it, but to which they now seldom resort, as it is now comparatively scarce—at least so I was told by *Sleepy Eye*, the chief of the *Sissitons*, who accompanied me during this excursion.

As I did in the case of the red pipestone described above, I will state the mineralogical character of the Indian blue earth or clay. It is massive, somewhat plastic, emits an argillaceous odor when breathed upon; color bluish green; easily scratched with the nail, when formed into hardened balls. The acids have no action upon it; it is infusible before the blowpipe, but loses its color and becomes brown. This color is due to the peroxide of iron which it contains in the proportion of ten per cent. at least. It contains no potash and but a small proportion of lime. It is a very different mineral from that described by Dr. Thompson under the name of pipe-clay.

Next comes the region of country between the St. Peter's and the upper portions of La Hontan and Le Sueur rivers, above referred to. This is an extensive district, thickly set in forests amidst which there are reported to be many large lakes. The French give to the forests the name of *Bois-francs*, or *Bois-forts*, whenever they are not composed principally of trees belonging to the family of the *Coniferæ*.

To complete an account of the physical geography of the country, including the Undine region with the last mentioned, I will now enumerate some of the most important trees, shrubs and plants that characterize its *sylva* and *flora*.

The whole country embraced by the lower St. Peter's and the Undine region exceeds any land of the Mississippi above Wisconsin river, as well in the quality and quantity of its timber as the fertility of its soil. The forests of the valley on the right bank are connected by groves and small wooded streams of the adjoining prairies with the forest called *Bois francs*, and they extend so far southwest as to include the lands of the upper waters of the Mankato river.

The forest trees, as reported to me by Mr. Geyer, are chiefly soft maple, American and red elm, black walnut, the nettle tree, basswood, red and white ash; the undergrowth, the common hawthorn, prickly ash, high cranberry, red root, gray dogwood, fox grapes, horse-briar and moonseed. Among the herbs are the wild and bristly sarsaparilla, Indian turnip, the gay orchis and others; rushes and the flowering ferns are abundant along the low banks of the rivers. The valley prairies are rich in pasture grasses and leguminous and orchideous plants, such as the yellow lady's slipper, American and tufted vetch, and others. The lowest parts near the borders of the woods, and those subject to inundations, are filled with the high weeds common to such places—as the ragged cup, tall thistle, great bitterweed, the tuberous sunflower, and others.

Swamps are frequent, and some of them contain extensive tracts of tamarack pines. Cedars grow, intermixed with red birch, on the rocky declivities of the lower Mankato river. Red and bur oak, with hazel, red-root, peter's-wort, and the wild rose, are the trees and shrubs of the uplands. There are, besides, thickets of the poplar birch that are frequent in the elevated prairies near the river. The prairies are very luxuriant, and generally somewhat level and depressed; the gum-plant and button snake-root are their most abundant and conspicuous herbs.

To give animation to the Undine region, and to the valley of the St. Peter's, as well as to develop trade between the British possessions, the territory of Iowa and the state of Missouri, it would be necessary for government to open routes of communication between St. Peter's and the Travese des Sioux, through the *Bois francs* mentioned above; between St. Peter's and the Prairie du Chien; between Dubuque and the Lac-qui-parle; through the Undine region, with a fork in the direction of the Traverse des Sioux, passing by Fremont* and *Okoman*† lakes, (which latter is at the headwaters of La Hontan river,) and in other directions that would naturally suggest themselves.

The geological formation that characterizes the Undine region as well as the St. Peter's, as far nearly as the mouth of the *Waraju*, is the same as that of Fort Snelling which I shall describe further on. It consists mainly in a thick stratum of friable sandstone as the basis, succeeded by a deposite of limestone, which is sometimes magnesian, and occasionally contains fossils; the whole covered by what I have called the erratic deposite.

The sandstone forms the Little rapids of the St. Peter's, and, reappearing at the Traverse des Sioux, determines other rapids that are observed in a beautiful stream‡ two miles northeast of

* Probably Clear Lake, near Waseca.
† Lake Elysian.
‡ Moon creek, now called Cherry creek, at Ottawa.

the trading-post in this place. At other intermediate localities the sandstone and limestone both appear; but further on the limestone disappears altogether; because it goes thinning out as the western limits of the formation are approached. This may be observed near the Waraju, and toward the upper parts of the Mankato, where the limestone, and indeed the sandstone, are replaced by beds of clay or of calcareous marl.

In the argillaceous deposits last referred to there are red ochre, other ferruginous minerals, and lignites. Between the sandstone and the limestone there is a bed of whitish clay, enclosing nodules of the blue earth; and sometimes, between the strata of limestone, bands of argillaceous iron ore, intermixed with siliceous and calcareous incrustions.

The account given above applies equally to the rocky cliffs on the upper part of the La Hontan river, and especially to the interesting locality* at the entrance of its south fork, which is four miles to the east of lake *Ti-tanka-tanninan*.†

LA HONTAN'S RIVIERE LONGUE.

Those who have read the travels of Baron La Hontan, in which he mentions his discovery of a certain long river coming from the west, and falling into the Mississippi, may, perhaps, think that, by giving his name to a river upon my map, I meant to clear up the doubt which has existed, for more than 150 years, as regards the veracity of this officer.

Such was not originally my intention; but I am forced into it after terminating my exploration of the Undine region. Having afterward procured a copy of La Hontan's book, in which there is a roughly made map of his Long river, I was struck with the resemblance of its course, as laid down, with that of Cannon river; which I had previously sketched in my own field-book. I soon convinced myself that the principal statements of the Baron, in reference to the country, and the few details he gives of the physical character of the river, coincided remarkably with what I had laid down as belonging to the Cannon river.

Thus the lakes and swamps corresponded; traces of Indian villages mentioned by him might be found in the growth of a certain grass that propagates itself around all old Indian settlements. Some of the names which he assigns to them may be referred to dialects of the Sioux tongue; and even his account of the feasting of his men on the large number of the American hare which he found there, is substantiated by the voyageurs.

His account, too, of the mouth of the river, is particularly accurate. The most scrupulous geographer, describing it at this time, would have but little to alter. As this locality is in the way of travelers going to St. Peter's, I will quote from the text of La Hontan, so that they may judge of the truth of my assertion. "We entered," he says, "the mouth of this long river, which is a sort of large lake filled with canebrakes (*joncs*); in the midst of which we discovered a narrow channel, which we followed up," &c.

I do not pretend, however, to justify his gross exaggeration of the length of the river; of the numerous population on its banks; and his pretended information respecting the nations inhabiting the more remote regions. This sort of exaggeration seems to have belonged to the period; but there is apparently a more serious objection to be made to his narrative—namely, that it appears, from his text, he traveled during the months of November and December; at which period of the year the rivers in these parts are mostly frozen over, and the voyage therefore impracticable. But the received opinion, on the other hand, is, that it is one of the last to freeze, and is the last resort of the wild fowl. The Sioux are said to congregate, in consequence upon its banks in large numbers; relying on this resource, whilst they are otherwise collecting their peltries, insomuch that the American Fur Department at St. Peter's has always kept up this post for the purpose of securing the advantages of this trade. Besides, this river is fed by a great number of springs; and the upper portion of its course is in a remarkable manner protected from sudden changes of temperature by high rocky banks and thick forests that cover them.

Under all these circumstances I have thought proper to notice these facts, that seem to possess sufficient interest in the history of the geography of the west; I have stated what appeared to me the true facts in the case; and I may add, in conclusion, that if La Hontan's claims to discoveries are mere fables, he has had the good fortune or the sagacity to have come near the truth.

* The vicinity of Faribault.

† Cannon lake, in Rice county.

Further, in reference to La Hontan river: when the French were in possession of the country it was known by the name *Riviere aux Canots* or Canoe river, as it was there that the traders were in the habit of concealing their canoes. Its present name of Cannon river is evidently a corruption of the French one. The one which it bore among the Sioux in 1700, when Le Sueur ascended the Mississippi (and which it still bears) was *Inyan-bosndata*, or Standing Rock.

CASTLE ROCK, LONE ROCK AND CHIMNEY ROCK.

This Indian name (*Inyan-bosndata*) is that of a natural obelisk which occurs on a low and sandy plain four miles to the north of the crossing place, on the "north fork of La Hontan river."* This heap of disintegrated sandstone rock is thirty-six feet high. It is a curious specimen of the weathering of the sandstone of the west, that may be compared to the earth pillars left behind by workmen to mark the extent of their excavations, and is possibly a relic of the thickness of the formation previous to the devastating agency of the elements, that has altered the original level of the surface of the country. My friend, the Viscomte de Montmort (then an attaché to the French legation at Washington, who accompanied me in this excursion), has furnished me with an admirable drawing of it, as well as of the natural monument next to be mentioned.

Twelve miles north of the natural obelisk which I have just described, near the crossing place of the Vermilion river, there are other evidences† of the great denudation of the surface that has taken place in this region. One of them is also remarkable by its symmetrical outlines, bearing the appearance of a dilapidated castle of feudal times, such as are seen in the Alps and other places; hence its name. I have thought it of sufficient importance to indicate their situations on my map. These natural monuments are mentioned by Mr. Featherstonhaugh upon information received from others, but he did not visit them.

THE DES MOINES CONNECTED WITH THE MINNESOTA.

Mr. Nicollet called attention to the hydrographical relations of the Des Moines river with the Blue Earth, the Minnesota and the Mississippi rivers. The point of geographical interest is found in latitude 43° 45′, longitude 95° 12′, where there is a lake very near the Des Moines, called *Tchan shetcha* or Dry Wood lake. The Blue Earth river, by means of its tributary, the Watonwan, has one of its sources in this lake, and the land separating it from the Des Moines is not more than a mile or a mile and a half in width. Thus a short canal would bring the Des Moines into communication with the Minnesota. This interesting fact was formerly taken advantage of by the Indian fur traders, who, after spending the winter on the headwaters of the Des Moines, found it convenient to bring their peltries by water communication through the Watonwan valley and the Blue Earth to the mouth of the Minnesota river.

* Chub creek, in Dakota county.
† Lone rock and Chimney rock.

NICOLLET ASCENDS THE MISSISSIPPI.

In July, 1836, Mr. Nicollet ascended the Mississippi to its source in Itasca lake. He says that above the falls of St. Anthony the rocky formations assume another type, "being the several varieties of greenstone, and finally passing into talcose slate." as seen at the falls of the *Wabezi*, or Swan river, and the *Omoshkos*, or Elk river. Along with Schoolcraft, he mentions, among other trees, the walnut, as one of those native to the Mississippi valley above the falls of St. Anthony. He mentions, as a prominent geological feature of the country, the outcrop of syenitic rock on the east side of the river, a little below the *Pikwabik*, with a flesh-colored feldspar, extending a mile in length, with a breadth of half a mile, and an elevation of eighty feet, known as *little rock*.* At the foot of Knife rapids,† higher up, on the same side of the river, "there are sources that transport a very fine, brilliant and bluish sand, accompanied by a soft and unctuous matter. This appears to be the result of a decomposition of a steaschist, probably interposed between the sienitic rocks previously mentioned. The same thing is observed at the mouths of *Wabezi* and *Omoshkos*." From Crow Wing river Mr. Nicollet pursued a new route to Itasca lake. At a distance of three miles from its mouth he ascended *Gayashk*, or Gull river, and the lake having the same name. Then portaging northeast, he reached Pine river and visited Whitefish lake. Ascending the east fork of Pine river, he reached *Kwiwisens*, or Little Boy river. This he descended through a succession of lakes and over small rapids, as far as Leech lake, where he spent a week, and was befriended from the Indians in an emergency, by Rev. Mr. Boutwell, who had accompanied Mr. Schoolcraft in 1832. From Leech lake he passed westward, through lake *Kabekonang* and *Kabekonang* river, and made a portage of five miles to the La Place river, which is the same that Mr. Schoolcraft called the *East Fork of the Mississippi*, in 1832. He ascended this to lake Assawa, where he found an old camp of Mr. Schoolcraft. The last portage, one of six miles, to Itasca lake, was found to be very arduous, being across numerous sloughs, with low intervening ridges. The soil was found to be sandy and gravelly, overspread with erratic blocks, with a great variety of evergreens. The last of the series of ridges, being also the highest, is 120 feet above the waters of lake Itasca.

* The same as Schoolcraft's *peace rock*, situated in Sec 27, Watab, Benton county.
† Pike Rapids.

NICOLLET AT THE SOURCE OF THE MISSISSIPPI.

The Mississippi holds its own from its very origin; for it is not necessary to suppose, as has been done, that lake Itasca may be supplied with invisible sources, to justify the character of a remarkable stream, which it assumes at its issue from this lake. There are five creeks that fall into it, formed by innumerable streamlets oozing from the clay-beds at the bases of the hills, that consist of an accumulation of sand, gravel and clay, intermixed with erratic fragments; being a more prominent portion of the erratic deposite previously described, and which here is known by the name of *Hauteurs des Terres*, hights of land.

These elevations are commonly flat at top, varying in hight from eighty-five to one hundred feet above the level of the surrounding waters. They are covered with thick forests in which the coniferous plants predominate. South of Itasca lake they form a semi-circular region, with a boggy bottom, extending to the southwest a distance of several miles; thence these *Hauteurs des Terres* ascend to the northwest and north, and then stretching to the northeast and east, through the zone between 47° and 48° of latitude, make the dividing ridge between the waters that empty into Hudson bay and those which discharge themselves into the gulf of Mexico. The principal group of these *Hauteurs des Terres* is subdivided into several ramifications, varying in extent, elevation and course, so as to determine the hydrographical basins of all the innumerable lakes and rivers that so peculiarly characterize this region of country.

One of these ramificationa extends in a southerly direction under the name *Coteau du Grand Bois;* and it is this which separates the Mississippi streams from those of the Red river of the North.

The waters supplied by the north flank of these hights of land, still on the south side of lake Itasca, give origin to the five creeks of which I have spoken above. These are the waters which I consider to be the utmost sources of the Mississippi. Those that flow from the southern side of the same hights, and empty themselves into Elbow lake, are the utmost sources of the Red river of the North; so that the most remote feeders of Hudson bay and the gulf of Mexico are closely approximated to each other.

Now, of the five creeks that empty into Itasca lake (the *Omoshkos Sagaigon*, of the Chippeways, or the *Lac a la Biche*, of the French, or the Elk lake of the British) one empties into the east bay of the lake; the four others into the west bay. I visited the whole of them; and among the latter there is one remarkable above the others, inasmuch as its course is longer and its waters more abundant; so that, in obedience to the geographical rule "that the sources of a river are those which are most distant from its mouth," this creek is truly the infant Mississippi; all others below, its feeders and tributaries.

The day on which I explored this principal creek, (Aug. 29, 1836) I judged that, at its entrance into Itasca lake, its bed was from fifteen to twenty feet wide, and the depth of water from two to three feet. I stemmed its pretty brisk current during ten or twenty minutes; but the obstructions occasioned by the fall of trees compelled us to abandon the canoe, and seek its springs on foot, along the hills. After a walk of three miles, during which we took care not to lose sight of the Mississippi, my guides informed me that it was better to descend into the trough of the valley; when, accordingly, we found numerous streamlets oozing from the bases of the hills. The temperature obtained at a great number of places, by plunging the thermometer in the mud whence these springs arose, was always between 43° 5′ and 44° 2′ Fah.; that of the air being between 63° and 70°. Having taken great pains in determining the temperature, I have a right to believe that it represents pretty accurately the mean annual temperature of the country under examination.

As a further description of these headwaters, I may add that they unite at a small distance from the hills whence they originate, and form a small lake, from which the Mississippi flows with a breadth of a foot and a half, and a depth of one foot. At no great distance, however, this rivulet, uniting itself with other streamlets, coming from other directions, supplies a second minor lake, the waters of which have already acquired a temperature of 48°. From this lake issues a rivulet, necessarily of increased importance—a cradled Hercules, giving promise of the strength of his maturity; for its velocity has increased; it transports the smaller branches of trees; it begins to form sand-bars; its bends are more decided, until it subsides again into the basin of a third lake somewhat larger than the two preceding. Having here acquired renewed vigor, and tried its consequence upon an additional length of two or three miles, it finally empties itself into Itasca lake, which is the principal reservoir of all the sources, to which it owes all its subsequent majesty.

The stream which Messrs. Schoolcraft and Allen have designated as the East Fork of the Mississippi, and which I have named after the illustrious La Place (on which there is a lake that I have called after the celebrated translator of the *Mechanique Celeste*, Mr. Bowditch), has its source, perhaps, as distant as that to which I have exclusively perserved the name of Mississippi; but as it is less important, from having less water, I have considered it only a tributary to that to which it unites itself.

The honor of having first explored the sources of the Mississippi, and introduced a knowledge of them in physical geography, belongs to Mr. Schoolcraft and Lieut. Allen. I come only after these gentlemen; but I may be permitted to claim some merit for having completed what was wanting for a full geographical account of these sources. Moreover, I am, I believe, the first traveler, who has carried with him astronomical instruments and put them to profitable account along the whole course of the Mississippi, from its mouth to its sources.

Mr. Nicollet returned from lake Itasca by way of lake Pemidji, the Metoswa rapids, and Cass and Leech lakes, stopping again with Rev. Mr. Boutwell. Of this last lake he says that its name, both in English and Chippeway, implies that "its waters contain a remarkable number of leeches." The Pokegama falls ("rapids") are said to have a fall of nine feet in the distance of eighty yards. The rock over which the water passes is styled a gray quartzyte, seen in the banks and bed of the river. He parallelizes it with the rocks on the St. Louis river, "where are found calciferous and argillaceous steachists, conglomerates formed of quartz pebbles, and bound together by steachist, containing sulphuret of iron, and a sandstone which may be possibly referred to the 'old red sandstone.'"

THE UPPER MISSISSIPPI COUNTRY.

Over the whole route which I traversed after leaving Crow Wing river, the country has a different aspect from that which the banks of the Mississippi above the falls of St. Anthony present. The forests are denser and more varied; the soil, which is alternately sandy, gravelly, clayey and loamy, is, generally speaking, lighter, excepting on the shores of some of the larger lakes. The uplands are covered with white and yellow pines, spruce and birch, and the wet low lands by the American larch and the willow. On the slopes of sandy hills, the American aspen, the canoe birch, with a species of birch of dwarfish growth, the alder and wild rose, extend to the very margin of the river. On the borders of the larger lakes, where the soil is generally, better, we find the sugar maple, the black and bur oaks (also named over-cup white oak, but differing from the white oak), the elm, ash, lime tree, &c. Generally speaking, however, this woodland does not extend back farther than a mile from the lakes. The white cedar, the hemlock,* spruce pine, and fir, are occasionally found; but the red cedar is scarce throughout this region, and none, perhaps, is to be seen, except on islands of those lakes called by the Indians *Red Cedar lakes*. The shrubbery consists principally of the wild rose, hawthorn, and wild plum; and raspberries, blackberries, strawberries and cranberries are abundant.

The aspect of the country is greatly varied by hills, dales, copses, small prairies, and a great number of lakes; the whole of which I do not pretend to have laid down on my map. The

*The hemlock, *Abies Canadensis*. does not grow in the state of Minnesota.—N. H. W.

natural beauties of the country are, however, impressed with a character of sternness and melancholy; the silence and solitude of which are interrupted or revived only by the water-fowl that congregate about its waters to nestle amidst and fatten upon the wild rice. The naturalist, however, has still an endless field of observations, in the insect world; for everywhere life manifests itself in some form or other. It is, indeed, remarkable that the more we advance to the north (to within a certain extent, nevertheless), the more the mosquito appears to be abundant, as every voyageur knows by sad experience.

The lakes to which I have just alluded are distributed in separate groups, or are arranged in prolonged chains along the rivers, and not unfrequently attached to each other by gentle rapids. It has seemed to me that they diminish in extent, on both sides of the Mississippi, as we proceed southwardly, as far as 43° of north latitude; and this observation extends to the arctic region, commencing at Bear's lake, or Slave lake, Winnipeg lake, &c. It may be further remarked that the basins of these lakes have a sufficient depth to leave no doubt that they will remain characteristic features of the country for a long time to come. Several species of fish abound in them. The white-fish (*Corregonus albus*) is found in all the deep lakes west of the Mississippi, and indeed from lake Erie to the Polar sea. That which is taken in Leech lake is said by amateurs to be more highly flavored than even that of lake Superior, and weighs from three to ten pounds. There is another species of this white-fish, called by the Indians *tuliby* or *ottuniby* (the *Corregonus artedi*) which resembles it, but is much less esteemed. Both species furnish a wholesome and palatable food. Among the other species of fish that inhabit these waters, are the *mashkinonge*, or *mashkilonge;* the pike or jack-fish; the pickerel or gilt carp; the sucker or true carp; the perch; a species of trout called by the Chippeways *namogus*, &c., &c. These lakes, which are somewhat deep, swarm with leeches; and among the amphibious reptiles there are several species of terrapin and turtle, of which Mr. Say has described three of each kind in the appendix to the second expedition of Major Long.

FOSSILS COLLECTED BY MR. NICOLLET.

Appendix C of Mr. Nicollet's report contains names of fossils collected at different points in Iowa, Missouri, Dakota, and the following at the falls of St. Anthony in Minnesota:

Strophomena, allied to *S. alternata.*

Strophomena, new species.

Orthis testudinaria? (Murch. Sil. Syst. pl. 20, fig. 10).

Orthis polygramma? (Murch. Sil. Syst. pl. 21, fig. 4[a]).

Orthis (three new species).

Steriocisma (resembling *Terebratula schlothrimi*, Dal.)

Atrypa (new species).

Pleurotomaria (new species—numerous).

Euomphalus, allied to *Maclurites magna* (Des.)

Euomphalus, resembling *E. sculptus* (Sowerby).

Phragmolites, same as in the Trenton limestone in N. Y.

Phragmolites, new species.

Bellerophon bilobatus.

Orthoceras (two species, undetermined).

Crinoidal remains of peculiar forms, one resembling *Lipocrinites*.
Turbinolopsis bina? (Sil. Syst. pl. 16 bis, fig. 5.)
Favosites lycoperdon (Say). Trenton limestone fossil.
Favosites (two new species).
Fucoides (obscure).
Cyathophyllum ceratites?
Turritella.

Of the list of plants determined by Dr. Torrey for Mr. Nicollet, the greater part were collected in Dakota or in Missouri, out fifty-six species being assigned to Minnesota.

CAPT. J. ALLEN'S EXPEDITION TO THE SOURCE OF THE DES MOINES IN 1844.

This expedition reached a lake which was found by observations of the sun with a small sextant to be in lat. 43° 57′ 32″. This was probably what is now known as lake Shetek, which is somewhat above 44° of latitude.* This lake he named lake of the Oaks. He described it as remarkable for a singular arrangement of the peninsulas running into it from all sides, and for a heavy growth of timber that covers these peninsulas and the borders of the lake. He explored the country north from this lake thirty-seven miles, and thence eastward to the St. Peter's river. Returning to lake Shetek he traveled westward to the Big Sioux river which he followed to its mouth.

ELK AND BUFFALO ON THE DES MOINES IN 1845.

"From Lizard creek of the Des Moines to the source of the Des Moines, and thence east to the St. Peter's, is a range for elk and common deer, but principally elk. We saw a great many of the elk on our route and killed many of them; they were sometimes seen in droves of hundreds, but were always difficult to approach, and very difficult to overtake in chase, except with a fleet horse and over good ground. No dependence could be placed upon this game in this country for the subsistence of troops marching through it.

"Twenty-five miles west of the source of the Des Moines we struck the range of the buffalo and continued in it to the Big Sioux river, and down

* Ex. Docs., First Session, 29th Congress, 1845-'6, Vol. VI. No. 168.

that river about eighty-six miles. Below that we could not see any recent signs of them. We found antelope in the same range with the buffalo, but no elk, and very seldom a common deer. While among the buffalo we killed as many as we wanted, and without trouble."

THE UPPER DES MOINES RIVER.

Upon approaching the region of the boundary line between Iowa and Minnesota he became penned among numerous lakes, and was compelled to cross a narrow strait by swimming 200 yards. This was probably across a narrow spot in Swan lake, in Emmett county, Iowa. From there he sent a party to examine the country toward the east. This party reached Iowa lake (on the boundary line) and explored its outlet toward the east and into the East Chain of lakes, reaching the conclusion that the water was tributary to the Blue Earth, "or of an unknown tributary of the Big Cedar." He passed by Eagle lake, and Independence lake, camping at each, and arrived in the vicinity of Windom where he describes the country as a "wonderfully broken surface, rising and falling in high knobs and deep ravines, with numerous little lakes in the deep valleys, some of them clear and pretty and others grassy." A party which visited the Blue mounds, near Windom, found an artificial mound of stone on the highest peak. He visited Talcott lake, where he rested his men in camp, and himself visited lake Shetek, which he pronounced the highest source of the Des Moines worth noticing as such, though he also mentions an inlet from the northward, "but of no size or character." He crossed the Cottonwood nearly north from lake Shetek, also the Redwood river still further north, and the latter again near Redwood falls. From the mouth of the Redwood he explored the south shore of the Minnesota several miles up and down, and returned to lake Shetek. He crossed the *Coteau des Prairies* in Cottonwood county, styling it the "Big Prairie." He reached the Big Sioux river without finding any such stream as that which had been shown on the maps as "Floyd's river."

CAPT. E. V. SUMNER'S EXPEDITION IN 1845.

The expedition of Capt. E. V. Sumner* seems to have been made more

*Executive Documents, 1st Sess., 29th Congress, 1845-46. No. 2, p. 217.

for the purpose of impressing the Indians with the power of the government and the necessity of committing no depredations on the settlers, than for the purpose of learning the nature of the country. He left Fort Atkinson, June 3d, and arrived at "Traverse des Sioux" June 22d, having met Lieut. Allen June 13th, about midway between Fort Atkinson and the St. Peter's river. The companies continued together from that time. From Traverse des Sioux they marched to Lac qui Parle, where Capt. Sumner had an important conference with the *Warpeton Sioux*, whom he distinguishes as the "upper Sioux." He reached Big Stone lake on the 5th of July, where he met in council a large band of *Sissitons*. He reached "Devil's lake" on the forty-eighth degree of north latitude, on July 18th, where he had a conference with a party of the Winnipeg half-breeds, numbering about one hundred and eighty. He reached Traverse des Sioux on his return, the 7th of August; whence he repaired to Fort Atkinson on the 11th, Capt. Allen returning to Fort Des Moines.

THE SURVEY OF D. D. OWEN, 1847–1850.

The fine quarto volume which resulted from Dr. Owen's survey of Wisconsin, Iowa and Minnesota, was a report made in pursuance of instructions from the Treasury Department, Washington, addressed to Hon. J. Butterfield, Commissioner of the General Land Office, and was published by Lipcott, Grambo & Co., Philadelphia, in 1852. While it was not the first of the scientific reports published by the U. S. government relating to the geology of the territories, it was the first of note conducted and published by other than the Department ot War. It has proved to be the worthy sire of a numerous progeny, the initiation and exemplar of a series of scientific publications by the U. S. government, partly under the War Department and partly by the Department of the Interior, which have caused American science to illumine the whole world. The work of Owen was continued by Foster and Whitney, and revived and extended by Hayden. Dr. Owen's field extended from St. Louis to the British line, and from the west shore ot lake Michigan to the Missouri river. Its primary object was to derive information for the removal of such lands as were valuable for their mineral resources from sale, in the land office at Washington. Such an inquiry necessarily embraced many geological and chemical questions, and required at least a preliminary geological survey. The earlier reconnoissances of Majors Long and Pike, and Mr. Schoolcraft, embraced many isolated important facts bearing on the geology and natural history of Minnesota, made incidentally along the routes they took, but Dr. Owen's survey was more comprehensive and more detailed. Its primary object being an examination of the country and not a military reconnoissance, it did not contend with the difficulties incident to rapid marching, complained of by Keating and Beltrami. His report throws the first real light, derived from the systematized science of modern times, on the geology and the present fauna and flora of Minnesota. The work was sufficiently prolonged to enable the naturalists who co-operated with him to gather reliable facts enough to lay down correctly the ground-work of a vast extent of scientific research. His report not only corrected prevalent errors, but established on correct paleontological evidence the age of most of the bedded rocks of Minnesota, and disseminated information concerning its topography and soil.*

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*Dr. Owen's corps consisted of the following gentlemen: J. G. NORWOOD, Assistant Geologist; J. EVANS, B. F. SHUMARD, B. C. MACY, C. WHITTLESEY, A. LITTON, R. OWEN, heads of sub-corps; G. WARREN, H. PEATTEN, F. B. MEEK, J. BEAL, sub-assistants.

Dr. Owen's own report, covering the first 206 pages of the volume, is divided into six chapters. He gives a brief history of the explorations of the various corps, sketches the difficulties and adventures that befell them, and names the salient points of interest in the progress, and the results of the survey, in the Introduction. The chapters are as follows:

1. Formations of the upper Mississippi and its tributaries, belonging to the Silurian Period.
2. Formations of the Cedar, and part of the lower Iowa river, belonging to the Devonian Period.
3. Carboniferous rocks of southern and western Iowa.
4. Formations of the interior of Wisconsin and Minnesota.
5. Formations of lake Superior.
6. Incidental observations on the Missouri river, and on the Mauvaises Terres (Bad Lands).

Dr. Norwood's report on some portions of the country adjacent to lake Superior consists of—

1. Boundaries and topographical notices.
2. Descriptive catalogue of the rocks referred to in his report.
3. Narrative of the explorations made in 1847, between La Pointe and St. Louis river, and between Fond du Lac and the falls of St. Anthony, and on the St Croix river.
4. Physical structure and geology of the northwestern and western portions of the valley of lake Superior.

Col. Chas. Whittlesey's report pertains to that portion of Wisconsin bordering on the south shore of lake Superior, with the following chapters:

1. General description and geology of the Bad river country, and of that between the Bad river and the Brule; with descriptions and detailed sections of rocks like those which in Michigan are copper-bearing; and accounts of the magnetic-iron beds of the Penokie Iron range, and of "Iron Ridge", in Dodge county, Wisconsin.
2. Description of the country between the Wisconsin and Menomonie rivers; with a discussion of the general geology, and its relations to other parts of the Northwest.
3. Red clay and drift of Green bay and Wisconsin.
4. Barometrical and thermometrical observations.
5. Lumbering on the waters of Green bay.

Dr. B. F Shumard's report pertains to local and detailed observations in the valleys of the Minnesota, Mississippi and Wisconsin rivers, as follows:

1. Detailed observations of the St. Peter's and its tributaries
2. Local sections on the upper Mississippi.
3. Local sections on the Wisconsin and Baraboo rivers.
4. Observations on Snake, Kettle, and Rush rivers.

Dr. J. Leidy furnished for the volume a memoir on the remains of extinct *Mammalia* and *Chelonia*, from Nebraska territory.

The Appendix embraces—

1. Descriptions of new and imperfectly known genera and species of organic remains collected during the geological surveys of Wisconsin, Iowa and Minnesota. By D. D. Owen.
2. Descriptions of one new genus and twenty-two new species of *Crinoidea* from the Subcarboniferous limestone of Iowa. By D. D. Owen and B. F. Shumard.
3. Summary of the distribution of orders, genera and species in the Northwest. By D. D. Owen and B. F. Shumard.
4. Additional chemical examinations. By D. D. Owen.
5. Systematic catalogue of plants of Wisconsin and Minnesota. By C. C. Parry.
6. Table of stratigraphical and geological distribution of genera and species in the Northwest.

The volume is illustrated with twenty-six plates of fossils, twenty maps and large plates of geological sections, and a general geological map of the whole country reported on; the whole constituting at that time one of the largest and most expensive scientific publications of the United States government, and a monument at once to the learning, the zeal and wise management of Dr. Owen.

The survey of Owen, so far as it threw light on the state of Minnesota, served for a reconnoissance, and indicated within certain broad limits the general topography and geology. It first established the Lower Silurian age of the rocks outcropping along the upper Mississippi valley, and especially of that forming the brink of the falls of St. Anthony which had generally been regarded as Carboniferous. Under the general term "protozoic rocks," he describes the "lower sandstone of the upper Mississippi," which he says may be seen in the lower portions of the bluffs of the river, and in the sandstones of the Minnesota valley above Shakopee. In the upper portions of this great formation he brought to light an interesting and very important series of organic remains, and in its lower portions he found beds charged with *Lingulæ* and *Orbiculæ*. He enumerates six horizons that hold trilobites, the uppermost separated from the lowest by an interval of about 500 feet, though it is highly probable that some of these trilobite beds are contemporary, and that the actual thickness of this formation is somewhat less than 500 feet, as developed on the upper Mississippi. Nowhere in his report does Dr. Owen parallelize these beds with the Potsdam sandstone of New York, but seems to believe that the "palæozoic base" of the Mississippi as seen on the St. Croix river, is from seventy-five to one hundred feet lower than the parallel of the "Lingula beds" of the New York Potsdam, which, up to that time, had been regarded as the lowest fossiliferous base in the United States (page 50). But in the appendix (p. 634) are tables of the equivalency of the geological formations, and of the stratigraphical distribution of genera of fossils, in which, presumably constructed by Dr. Owen, this formation is parallelized with the Potsdam of New York state.* Under the term "protozoic rocks" he not only includes the lowest sandstones but also the rest of the Lower and Upper Silurian. He separates the limestones of the Northwest into Lower and Upper Magnesian, the former being that which still retains that name, though by him and his corps always confounded with the Shakopee limestone of Minnesota, in the same manner as he confounds the outcrops of the Jordan sandstone with the "lowest sandstone". In the latter he has included the Galena of the Lower Silurian and the Niagara of the Upper Silurian, having failed to

*See also *Proc. Acad. Nat. Sci. Phil.* 1852, p. 190.

observe any thing that represented the Maquoketa shales, which separate them in Iowa. The Galena he makes the equivalent of the Utica slate and Hudson River group, which latter also seems to include the Maquoketa shales. He recognized the Devonian formation near the southern boundary of the state along the Cedar river, but he made no note of the Cretaceous within the state. Its exposures are referred by his assistant, Dr. B. F. Shumard, either to the Lower Silurian or to the epoch of the drift. Fragments of lignite found in the valley of the "Mankato" river were supposed by him not to have come from the rock *in situ* within Minnesota, but to have been transported with the drift from the north, perhaps from the beds reported by Dr. Richardson to contain coal on the shore of Great Bear lake, "or from the Cretaceous or super-Cretaceous lignite formations which were observed by Nicollet and others, off toward the Missouri and Rocky mountains."

That part of the report which is most valuable to Minnesota was written by Dr. J. G. Norwood. It is also the most voluminous.* The rock specimens collected by him, numbered up to 680, are described with care and discrimination, and were probably deposited in the Smithsonian Institution at Washington. They were obtained in the northern and eastern portions of the state, and illustrate specially the northwest shore of lake Superior. The report on the north shore of lake Superior is remarkable for the minuteness of the description of the topography of numerous valleys, and for the correctness of the general views of its geology. Its numerous illustrations are graphic, and, although sometimes aided by idealization, are essentially correct. They show vividly the interstratification of the igneous and sedimentary rocks, and depict numerous remarkably picturesque spots at which both the artist and the geologist willingly linger. His views of the metamorphism of the sedimentary beds by the action of the igneous, were in accord with the current interpretation of crystalline rocks of his day, and were in confirmation of the views of Mr. Mather of the New York state survey, in opposition to those of Mr. Emmons, on the Taconic controversy, although the bearing of his report on that controversy was not mentioned by Dr. Norwood. The frequency and importance of the action of the igne-

*This valuable report is not mentioned by Dr, T. S. Hunt in his resume of the literature of the crystalline rocks of America for the second Pennsylvania Survey (Rep. E.)

†In the ninth annual report of the Smithsonian Institution, where the collections of Dr. Owen are catalogued, together with those of Jackson, Locke, Foster and Whitney, no mention is made of those of Norwood.

ous rocks on the sedimentary is prominently brought out in the report. This complicates the geology and renders the identification of the rocks both difficult and sometimes erroneous. In conclusion he remarks "that there is perhaps no extinct volcanic region in the world where trap and other igneous intrusions can be studied to better advantage than in the country bordering on the northwest shore of lake Superior. Not only are the vertical dykes numerous and conspicuous, but there are abundant examples of overflows, as well as interlaminated insinuations producing all degrees of metamorphosis on the adjacent strata, graduating from mere induration of the beds to complete obliteration of stratification and sedimentary origin, so that the beds of deposition become confounded with the igneous masses that have invaded them and produced such extraordinary changes."

Dr. B. F. Shumard made the only examination of the valley of the Minnesota; which he ascended as far as the mouth of the Redwood river. At that point he was attacked with pleurisy, and was compelled to return hastily to Traverse des Sioux and Fort Snelling. His report exhibits the first attempt ever made to parallelize the rocks of the valley with those of the rest of the state, or to determine their age by reference to a known standard of nomenclature. He recognized Dr. Owen's Nos. 2C and 3A, at the mouth of the river in the Fort Snelling bluff, i. e. the Trenton and Black River limestones, and the St. Peter sandstone. At Shakopee, and thence to Little rapids (near Carver) he notes the Lower Magnesian. The sandstone at the last place he regards as belonging to a formation several hundred feet below the white sandstone of the Fort Snelling bluff,* and probably to the sandstones of Formation 1. The limestone and sandstone exposed at intervals from Shakopee to Mankato, forming the immediate bluffs of the river, and constituting several islands, he refers to the Lower Magnesian and the sandstones of Formation 1. Ascending the Blue Earth river six or eight miles, and observing the same geological horizon as far as he went, he notes subsequently two or three exposures of Formation 1, before reaching the mouth of the Waraju (Cottonwood) river, one being two miles below the mouth of that stream. The red quartzyte opposite the mouth of the Waraju he regards as the lower beds

*It is the *Jordan Sandstone*, and lies about seventy-five feet below the sandstone of the Fort Snelling bluff, the Shakopee limestone separating them.

of Formation 1, more or less altered by metamorphism "where they abut upon the igneous rocks." He also notes conglomerate and granite outcrops about a mile in a straight line above the mouth of the Waraju. He mentions granite at La Petite Roche, and at frequent other points before reaching the Redwood river. He describes an interesting exposure two or three miles below the mouth of this river, probably the same as that described by Keating and by Beltrami.

Mr. Shumard also gives the details of local sections on the upper Mississippi in Minnesota and Wisconsin, beginning with the falls of St. Anthony, and on the Wisconsin and Baraboo rivers, as well as observations on the sandstones, conglomerates and trap-rocks of Snake and Kettle rivers. On the Snake and Kettle rivers he made collections of a peculiar green mineral from the amygdaloids, which at first was soft as tallow but on exposure became brittle. It was analyzed by Dr. Owen and regarded as new,* but resembling phillipsite from Iceland, being really a "magnesian harmotome."

MAJOR WOODS' EXPEDITION TO PEMBINA.

In the summer of 1849, Major S. Woods was despatched by the Secretary of War to the Pembina settlement for the purpose of selecting a site for a military post. His report† is not accompanied by any map, although Capt. John Pope states he prepared a map of the route. He proceeded from Fort Snelling to Sauk Rapids, along the east side of the Mississippi, a route well known and traveled at that time every summer by large "trains" of carts from the Red River settlements. Passing up the Sauk valley, on the north side of the river, the expedition crossed it at the great bend, and reached lake David, which is described as having a length north and south and draining into a branch of Crow river, twelve miles west of the great bend of the Sauk river. Seven or eight miles from lake David is lake Henrie, of about the same size. Lightning lake, is about seven miles from the point at which the trail crossed the branch of Crow river, so named from the incident of a terriffic thunder-storm in which Lieut. Nelson's life was nearly lost by lightning striking his tent-pole. Fourteen miles further

Jour. Phil. Acad. Science, (2), II. 183.

†House Ex. Doc. No. 51, 1st Sess. 31st Cong.

was White Bear lake, with an average width of two miles, and a length of perhaps eight or ten miles east and west, seventy-five miles from Sauk Rapids. "The heavily timbered highlands that range parallel with the Mississippi and back some distance from it, edge upon this lake. * * * On the north of the lake the prairie is broken and irregular, but the east, west and south borders lie handsomely for cultivation." The lakes are all described as having abundance of excellent fish. Fourteen miles from White Bear lake he reached Pike lake, and twelve miles further crossed the main branch of the Chippewa river. After passing Elk and Elbow lakes he came to Rabbit river, then Otter-tail Lake river flowing south of west. At the ford of the latter stream he states the bottom of the river is "rocky", the banks are good, water two to three feet deep and some fifty yards wide. Twenty-two miles further he crossed the Red river again, ten or fifteen miles below the mouth of the Bois des Sioux river. The rest of his journey was in Dakota, and he returned by the same route. Respecting the country west of the Red river he says it is "a level, marshy region back about thirty miles to Pembina mountain, which rises into a high peak near the forty-ninth parallel and ranges off nearly south, forming the western border of the valley of the Red river, and connects with the highlands extending out from lake Traverse near the headwaters of the St. Peter's river."

CAPT. POPE'S REPORT OF THE PEMBINA EXPEDITION.

Capt. Pope's report of the same expedition was addressed to Col. J. J. Abert, of the corps of topographical engineers, and was dated February 5, 1850, transmitted from St. Louis, Missouri, and printed by order of the Senate, Ex. Doc. No. 42, 31st Congress, first session. Instead of returning to Fort Snelling by the route by which the expedition went out, Capt. Pope organized a party which ascended the Red river of the North from Pembina to Otter-tail lake in canoes, and thence reached the Mississippi by Leaf and Crow Wing rivers, for the purpose of further exploration of the country. He places the head of navigation at a point in the vicinity of the mouth of the Sioux Wood river, distant forty miles from the St. Peter's. The Pomme de Terre river he mentions under the name Tipsenah, or Potato river.

"The valley of the Red river is entirely alluvial in its formation, no rocks in place being found in its entire length within the territories of the United States. It abounds with boulders or erratic blocks of granite, which in all cases are very much rounded by the action of water. They are most abundant upon the highest ridges of the prairies, and cause all the rapids in the small streams tributary to the Red river, the St. Peter's and Mississippi. About seventy miles north of our frontier (at Pembina) a secondary limestone appears at the falls of the Red river, which is unquestionably the basis of the whole valley, but at what depth below the surface at different points it is impossible to say. There are no rocks in place found west of the Mississippi along the route pursued by the expedition to the Red river of the North, and the geological features of the banks of the Mississippi have been given in the report of Mr. Nicollet, published in the year 1842."

Capt. Pope states that there were three routes by which to reach the valley of the Red river of the North, used by the traders and trappers in their annual pilgrimages to the Mississippi with their peltries. The most southern follows the valley of the St. Peter's, and descends into the plains of the Red river near lake Traverse. The middle route leaves the Mississippi at Sauk Rapids, seventy-six miles above the mouth of the St. Peter's, and intersects the Red river near its most southern point. This is the route pursued by the expedition. The northern route follows for some distance the valley of Crow Wing river, and turning the northern extremity of Otter Tail lake, descends into the valley of the Red river near the mouth of Buffalo river. These routes were mere trails, and followed as far as possible the open prairie.

The further geographical facts which his report contains can be summarized as follows: Between Pembina and the mouth of the Red Lake river he passed successively the Two rivers, Park river, "Rivière au Marais No. 1," from the east; Big Salt river and "Rivière au Marais No. 2," from the west; Turtle river, and "Rivière au Marais No. 3" from the east, and a small stream called "Coulée* de l'Anglais." The largest of these were the "Rivière au Marais No. 1," and the Park, Big Salt and Turtle rivers, which were about eighteen yards wide and six feet deep, the Red Lake river itself being about fifty yards wide near its mouth and fourteen feet deep, and with a

*Coulee is often anglicized to *couley* or *coulie*. It signifies a deep ravine, and was in common use among the ch voyageurs.

more rapid current than the Red river of the North. Above the mouth of the Sioux Wood river the Red river takes the name of Otter-tail Lake river, and, with a constant depth of water of four feet, becomes much more tortuous in its course.

GEN. POPE'S DESCRIPTION OF THE PARK REGION.

As we approached the western and northwestern slope of the Leaf mountain at the point where the river debouches from it into the level plains to the north, the current becomes sensibly more rapid, and the water clearer, until at about fifteen miles east of the crossing of the land route we found it necessary to use the cordelle. The banks become also much higher, with a tract of level, swampy land three-fourths of a mile in width between them, the river running from side to side through the swamp in the most serpentine manner. Small islands begin to be numerous, and the steep banks are perforated, in a thousand places, with clear cold springs. The woods along the banks also become much larger and more dense, oak being the more common tree. At about thirty miles above the mouth of the Sioux Wood river the rapids commence, and are almost continuous to Otter-tail lake. There are two and a half and three feet of water over them, and in the intervening pools of still water about three and a half feet. The bed of the river is filled with loose boulders of all sizes, and the deep water assumes an exceedingly crooked channel among them. Every hour of our advance toward the east increased the amount of heavy timber on the banks, and we began also to perceive, at various distances on each side, large groves of heavy timber upon the borders of numerous lakes, which I have described as forming so peculiar a feature of the country between the Mississippi and St. Peter's.

We had thus again entered the second general division of country I have made in a previous part of this report, and as we progressed toward the east the lakes became much more numerous, and the timber much heavier and more abundant. From Otter-tail lake to its entrance into Leaf mountain, the river passes through a number of beautiful lakes surrounded by rolling country, heavily timbered, with a depth of water from nine to twenty feet, and filled with the most luxuriant growth of wild rice. The largest and most beautiful of these is lake Gardiner, which is within eight miles of Otter-tail lake. On the 14th of September we reached the mouth of Little Pelican river, which, at its confluence with Otter-tail river, is about twenty yards wide, and about three feet deep.

On the morning of the 17th we arrived at Otter-tail lake, and encamped near its northeastern extremity, at the remains of several small trading houses. Upon entering this lake from the southwest, the woods to the northeast, although very large, are not visible, and it is by far the largest sheet of water we had yet seen. It is about ten miles in length from southwest to northeast, and four or five miles in width, filled with fish, with clear pure water, with a depth of twenty feet, and no islands. The fish are white, and said to be the same known as the white-fish of the lakes, so celebrated for their flavor.

To the west, northwest and northeast, the whole country is heavily timbered with oak, elm, ash, maple, birch, bass, &c., &c. Of these the sugar maple is probably the most valuable, and in the vicinity of Otter-tail lake large quantities of maple sugar are manufactured by the Indians. The wild rice, which exists in these lakes in the most lavish profusion, constitutes a most necessary article of food with the Indians, and is gathered in large quantities in the months of September and October. To the east the banks of the lake are fringed with heavy oak and elm timber to the width of one mile. The whole region of country for fifty miles in all directions around this lake, is among the most beautiful and fertile in the world.

The fine scenery of lakes and open groves of oak timber, of winding streams connecting them, and beautifully rolling country on all sides, renders this portion of Minnesota the garden spot of the Northwest. It is impossible in a report of this character to describe the feelings of admiration and astonishment with which we first beheld the charming country in the vicinity of this lake, and were I to give expression to my own feelings and opinions in reference to it, I fear they would be considered the ravings of a visionary or an enthusiast. * * * * *

On the 19th of September we made a portage of one mile toward the east, to a small round lake about one and a half mile in diameter. This lake is completely isolated, having no apparent outlet or inlet. From the dip of the land, and the evident marks of an artificial obstruction (said to be a beaver dam) I am quite satisfied that this lake at one time discharged its waters into Otter-tail lake. The evidences of this kind of obstruction are numerous throughout this region of country, and, whatever may be the theory as to the original extent of the waters, it is quite certain that the largest of the lakes has been divided into several smaller ones by the occurrence of these artificial dams.

The small lake on which we again embarked in our canoe is about ten feet deep, the water very clear, and no doubt containing abundance of fish.

A second portage of about twenty yards, over a dam of the same character, brought us to another lake of about the same size; a third portage of about half a mile through dwarf oak, brought us at the western extremity of Leaf lake, the source of Leaf river, which is a tributary of the Crow Wing. We had thus, in two hours, passed with our boat and baggage from the waters of the Red river of the North, which flow into the Hudson's bay, to the waters pouring into the gulf of Mexico.

The tributaries of the Red river of the North, and those of the Mississippi overlap each other to such an extent that I suppose there are a thousand places where a portage even shorter would have enabled us to pass from the waters of one into those of the other.

CAPT. RENO'S ROAD FROM THE BIG SIOUX RIVER TO MENDOTA.

In 1853 Capt. J. L. Reno executed a survey for a military road from the mouth of the Big Sioux river to Mendota. The carefully prepared and very full map transmitted with his report, seems not to have been published. After crossing the Des Moines river and traveling ten miles further, he entered Minnesota. This was in the vicinity of lakes which he names Spirit, Okamanpidan, and Omanhu, being, as he supposed, in the Undine region of Nicollet. He crossed the Chaniushkah and Perch rivers, the former a branch of the Blue Earth and the latter of the Watonwan. The route chosen lay along the west side of the Blue Earth to its union with the Minnesota, thence to Mankato, and thence on the Shakopee stony terrace to Babcock's mill near Kasota. Here the road left the river and ascended to the table-land, nearly 300 feet above the Minnesota, and entered the "Big Woods," owing to the discontinuance of the "second bottom." Opposite Traverse des Sioux Capt. Reno encountered Capt. Dodd of Minnesota, who had anticipated the government and had recently constructed a road from St. Paul to Rockbend (a short distance above Traverse des Sioux), thus much aiding Capt. Reno in getting through the unexplored labyrinth of lakes and marshes which there characterize the Big Woods. Passing by way of Eagle lake, Lakeville and the western border of the Vermilion prairie to the Mendota and Cannon river road, he followed it for six miles into Mendota.

GOVERNMENT ROADS IN MINNESOTA.

According to the report of Capt. J. H. Simpson,* dated September 20th, 1855, the following territorial roads were in course of construction at that time by the general government, viz., from Point Douglas to the mouth of the St. Louis river; from Point Douglas to Fort Ripley; from Wabasha to Mendota; from Mendota to the mouth of the Big Sioux river; from the mouth of Swan river to Long Prairie; from Fort Ripley to Pembina, and from St. Anthony falls to Fort Ridgely.†

PACIFIC RAILROAD SURVEY.

The reports of explorations and surveys to ascertain the most practicable and economical route for a railroad from the Mississippi river to the Pacific ocean, made in 1853, 1854 and 1855, contain a few articles relating to the natural features of Minnesota. Such are found in Vol. I., pp. 39–55, on the *Route near the 47th and 49th parallels of north latitude;* Vol. II., p. 45, on a *Railroad from Puget sound via Smith pass to the Mississippi river*, by Fred. W. Lander; Vol. XII., Parts I. and II., wholly devoted to the Northern Pacific route, containing a *Final Report and Narrative*, by Gov. J. J. Stevens; and reports on *Botany* and *Zoology*, by Drs. Cooper, Gray, Suckley, and others. The Botanical Report embraces pp. 7–76, and six plates; the Zoological Report has 1–399 pages, and seventy-six plates. These Natural History papers, however, refer almost exclusively to the western portion of the route.†

PERIOD OF STATE EXPLORATION AND SURVEY, 1858–1881.

The first legislature that met after the admission of the State into the Union, gave due consideration to the subject of a geological survey. Although burdened with the legislation incident to the organization of the various institutions of a new state, the evident importance of some scheme for ascertaining the natural resources of the state, as the first step toward

*Ex. Docs. 1855-6. First Sess. 34th Congress. Vol. I. Part II., p. 468.

†The report and map of Capt. Sully, of a reconnoissance from Fort Ridgely to Fort Pierre in 1856, have not been published. Capt. Sully determined the source of the Big Sioux river to be in lake Kampeska (Warren.)

their full development, was felt; and although no general survey was instituted, a law was passed ordering at once a reprint of portions of the geological report of Wisconsin,* by Prof. Daniels, for the years 1854 and 1858. This was printed in 1860, and contained Dr. D. F. Weinland's "sketch of the lead region," with notes on the evidences of iron ore, which closed with a statement of the "objects of a geological and natural history survey," embracing thirty-four pages, dated Cambridge, Mass., Oct. 27, 1857. It also embraced a paper read before the American Geographical and Statistical Society, in 1856, by Mr. A. S. Hewitt, on the "statistics and history of the production of iron."

JOSEPH A. WHEELOCK.

[First Annual Report of the Commissioner of Statistics, or the year ending January 1st, 1860.]

The second legislature enacted, in February, 1860, a law establishing a bureau of statistics, and creating a Commissioner of statistics. Mr. Wheelock was appointed; and such was his indefatigable industry and his knowledge of the state, that on July 1st of the same year he rendered a voluminous report "for the year ending January 1st, 1860." This was the first official presentatiou of her natural capabilities on the part of the new state of Minnesota; and it is not saying too much to assert that it has been one of the most powerful instruments in recommending the state to eastern capitalists and farmers, and in hastening, as well as directing, the almost unprecedented growth that she has maintained from that time. This document deals not with the discovery of new facts, or the description of new regions, or the establishment ot new principles, but it is a forcible presentation, in easy grouping, of those known natural features and resources of the state, in a harmonious and terse yet comprehensive review, which give the state a commanding pre-eminence in the Union in point of agriculture, and promise for it a corresponding position in respect of population, manufactures, wealth and general intelligence. The statistics proper, presented by the Commissioner, are preceded by an able essay on the geographical position, physical geography, agricultural capabilities and climatology of the state. Chapters are also added on the condition and progress of agriculture, commerce, railroads, manufactures and public lands.

*Minnesota was formely embraced in the territory of Wisconsin.

Mr. Wheelock's second report as Commissioner of statistics, rendered December 1st, 1861, is very similar in scope and character to that of 1860, with the added value of the U. S. census returns for 1860.

ANDERSON AND CLARK.

The second legislature also passed, March 10th, 1860, a concurrent resolution providing for "Commissioners" to report on the geology of the state, and to submit a plan for a thorough geological survey of the state. The commissioners appointed were Charles L. Anderson and Thomas Clark. These gentlemen submitted separate reports under the date of January 25th, 1861, making an octavo pamphlet of twenty-six pages. It embraces a chapter on the general geological features of Minnesota, and one on a plan for a geological survey, by Mr. Anderson; also one by Mr. Clark on some general climatic, topographical and geological features of the north-eastern portion of the state. Governor Ramsey discouraged the inauguration of a geological survey at that time, knowing that the cost is not only always great, but always greater than was expected, and believing that the actual material advantages to a state from such surveys are commonly overrated.* He considered that the new state had a sufficient burden in the establishment and support of its charitable and educational institutions, but hoped that when the state had reached that point when she "could expend fifty or a hundred thousand dollars in this one department of science," such a survey would be undertaken. He also recommended the commencement of a collection of state minerals at the seat of government, as an index to the extent of its mineral wealth and resources, which would thus become a matter for investigation.

Mr. Anderson's report summarizes briefly some of the chapters of Dr. Owen's report on Wisconsin, Iowa and Minnesota, and closes with some very pertinent remarks regarding the plan, object and cost of a geological survey.

The *objects* of a geological survey may be stated very briefly, as follows: It consists in placing before the people of the state, in the most available and intelligible form, all the information that can be obtained in regard to the rocks, minerals and soils. Also to this might be added information, especially of a practical character, in regard to the vegetables and animals peculiar to the state.

*Message communicating to the House of Representatives the reports of Anderson and Clark.

Whatever part of the survey is undertaken and reported on, should be of the most *substantial* kind. All that is possible for human knowledge to accomplish should be accomplished. There should be no slighting of the work—no necessity for tearing down and building up again.

There is a vast accumulation of *experience* before us. We have the history of surveys in other states. If we are wise we can profit by what has been in many instances their loss. We can see where they have made gross mistakes in the management of their affairs. It would be useless to enumerate their errors. One, however, that I would not be doing my duty to pass in silence, is that of allowing *party prejudices* to interfere in any manner with a survey of this kind. I might mention some of our neighboring states, that have had sad experience in this respect. But that would be personal and might give offence. I may be permitted to say, however, that rewarding a political leader with the office of state geologist, and a liberal yearly salary, when he is totally incompetent for the task, is a thing that *has been*, but I trust *will not* be *again*.

As to the cost of such a survey, the strictest economy, consistent with the attainment of the object sought, should be rigidly pursued. If such were the course adopted, after the first year the survey, instead of being an expense, would be remunerative, at least indirectly so. Attention would be called to our mineral resources, and the erection of manufactories,—it may be of iron, copper or lead.—would soon engage the attention of capitalists, and an inflow of population would be the result, more than enough to repay the state the small appropriation made each year for the survey. But let us look at the subject in a more general way.

When we reflect on the amount of money that goes out of our state each year for articles that, with a little encouragement, might just as well be manufactured at home, it is no wonder that we hear so continuously the cry of "hard times." With as good iron ore as the world can produce, the United States still imports three million dollars worth of that article; Minnesota receiving her share. Copper is sent from lake Superior to England, there to be manufactnred, and returned to us at a cost of more than two hundred per cent. With a deposit of coal in North America twenty times the area of all the known deposits of the eastern continent, and almost thirty-five times as large an area in the United States as Great Britain's coal area, yet the Atlantic cities import annually 285,869 tons; and all these things because our home resources are not opened up, and because there is not sufficient encouragement to our own enterprise. What might be said of the United States, or any one of the states, in this respect, might also be said of Minnesota.

So much in regard to "counting the cost." Instead of the survey, if properly conducted, running the state in debt, it will be a means most potent in relieving her of financial embarrassment, and causing a feeling of independence, in being able to exist by her own internal richness.

HANCHETT AND CLARK.

Nothing seems to have been done, after the publication of the report of Anderson and Clark, respecting a geological survey of the state, till the meeting of the sixth legislature (1864), when the subject was revived, and resulted in the passage of a resolution authorizing the Governor to appoint and direct a state geologist. Dr. Aug. H. Hanchett was appointed, and Thomas Clark was his assistant. The report of Dr. Hanchett, dated New York, November 13th, 1864, covers eight pages, and embraces little of value to the state. He seems to have visited the shore of lake Superior, and coasted as far as Pigeon river, but to little purpose.

Mr. Clark, who accompanied him, was much more industrious in gathering facts and making observations. His report is valuable; it contains seventy pages, with chapters on—

The Physical Geography of the district embraced in that portion of the state bordering on lake Superior. A large share of the geological report of Dr. Owen is devoted to this district; the maps accompanying that report were constructed previous to the linear surveys; Mr. Clark locates many of the points of interest, giving their section, township and range, especially the entrance of rivers, and prominent points or bays of the coast.

Meteorology of the district, embracing the carefully reduced results of one full year's observations, and of several concurrent and parallel months.

A list of plants and trees of the district, observed mainly between St. Paul and lake Superior, on the meridian 16° west from Washington; the northern and southern limits of species being noted.

H. H. EAMES.

The following year, under direction of Governor Miller, Mr. H. H. Eames continued the prosecution of the geological survey of the state, and his first report, without date, was printed in 1866. Mr. Eames' labor was essentially "prospecting." All other objects but a vigorous hunt for "mineral," were ignored. His first report is a pamphlet of twenty-three pages, and throughout it bears evidence that the writer was convinced, *a priori*, that the state of Minnesota was one of the richest mineral countries in the world. He discovered gold and silver, but could not yet state the "angle" at which veins containing them occur, but had the "impression that it would be found to be about 85°." These "discoveries" led to a gold-mining fever, centering on Vermilion lake, in the northern part of the state, in which many hundreds of thousands of dollars were squandered in the next two years. Several companies began mining, hauling their machinery and supplies from Duluth at great expense. Unscrupulous "assayers," "prospectors" and "geologists" fostered the excitement. A town of mushroom growth sprang up near the south side of the lake. A would-be geologist and "spiritualist," who subsequently aspired to the position of "peat-commissioner" to the state of Minnesota, located the precious lodes at Vermilion lake by the necromancy of spiritualistic mediums. The fever spread. The state geologist himself was chief owner and operator of one of the mines. The whole thing very soon collapsed, and in a few years thereafter but one white man, a government officer, could be found in the whole region. Respecting the lignites of southwestern Minnesota, Mr. Eames says that he has no hesitation in recording his conviction that large deposits of good coal will be found there, "the stratum having a course southeast of the Big Cottonwood river, thence northwest to the Redwood river, crossing the Minnesota river at or near that point, also west of the Cottonwood, and having a bearing west of north. The outcrop of the formation can only be seen at a few points, as it has many local upheavals, and corresponding depressions."

Mr. Eames mentioned the iron ore at Vermilion lake, in the vicinity of the stream known as Two rivers. He describes it as lying in two ridges, nearly parallel, one being of hæmatite with jasperoid, quartzose and serpentine rocks, and the other of magetite of very good quality, the latter being north of the former. The iron is said to be exposed at two or three points, between fifty and sixty feet in thickness, presenting quite a mural face.

Passing down the lake Superior shore as far as Temperance river, he has a few words concerning the metalliferous character of the rocks at numerous places.

Mr. Eames' second report purports to give "reconnoissance in detail, of the northern, middle and other counties in Minnesota," comprising fifty-eight octavo pages. After presenting a brief outline of the different formations or systems of rocks that form the crust of the earth, he adds remarks on the igneous, the coal-bearing and the sandstone and limestone rocks of the state; also on peat; on mineral and fissure veins; on agricultural chemistry; on a geological reconnoissance "in detail", of the counties of St. Louis, Lake, Itasca, Cass, Todd, Otter Tail, Douglas, Stearns, Morrison, Benton, Sherburne, Redwood, Cottonwood, Ramsey and Washington, together with results of assays and thermometrical and barometrical observations in the months of June, July and August. He describes Pokegama falls as formed by an exposure of Potsdam sandstone (quartzyte), or the lowest of the Lower Silurian rocks. It presents a mural exposure of twenty feet above the level of the stream, and one-eighth of a mile in length, having a course 15° south of west. A similar fall is described on Prairie river, six or seven miles above its point of union with the Mississippi, where he notes an uplift of igneous and metamorphosed rocks, consisting of granite, coarse and fine, "quartzyte or Potsdam sandstone," and iron ore, the water falling from twelve to fifteen feet. This iron ore occurs also on the west side of the river. At several places above these falls the same rocks are noted in place, particularly at the second falls and in a ridge near the head of the lake about a sixth of a mile from the south shore. The iron ores here seen, he found to afford from fifty to sixty per cent. metallic iron. He reports the same kind of drift limestone fragments on the upper Mississippi, about Pokegama falls, and on the St. Louis river, as in Otter Tail county and the Red river valley.

Mr. Richard M. Eames, his assistant, makes further statements concerning the quartz veins at Vermilion lake and their ramifications through the talcose slates, concluding with the statement that he belives that the "hidden sources of wealth, lying buried in the strata, would justify the investment of capital."

Mr. Eames' survey soon fell into disrepute, and further appropriations were not made by the legislature.

JAMES HALL IN MINNESOTA.

In 1865 the state legislature appropriated two thousand dollars to Mr. N. C. D. Taylor for the exploration of the mineral lands in the valley of the St. Croix river, lying in the state of Minnesota. A report of this work was rendered to the governor January 27th, 1866. It consists of about one page octavo, and states that he had found indications of copper on what is known as the "Kettle river trap range," having expended a considerable sum in examinations sufficient to show it to be "very promising for a rich paying vein." He also mentions a copper vein crossing the St. Croix river below the mouth of Kettle river, and one on Snake river; also one at Taylor's Falls, on which he had sunk a shaft, about forty feet in depth, and a second one three or four hundred feet from the first about twenty-two feet in depth. The most of the rock of the St. Croix valley above Taylor's Falls, he found to consist of different kinds of trap rocks, with belts of conglomerate running through them from northeast to southwest, the conglomerate being particularly abundant on the Kettle river range.

As corroborative of his own opinions, Mr. Taylor incorporates the views of Prof. James Hall who was, presumably, employed to make a reconnoissance of the region in 1865. Prof. Hall is reported as saying that the Taylor's Falls vein is a very distinct vein, quite equal, in what it shows, to many of the best paying veins of lake Superior; and of the Kettle river vein, that so far as can be seen of it, it is even more promising than the one at Taylor's Falls, or the most promising that has been found in the country. He regarded the whole St. Croix region as worthy of further exploration for this metal.*

In the same year Prof. Hall visited the southwestern part of the state, his object being to ascertain the age of the coal that was then being explored on the Waraju river. The next year an interesting paper was published by him "On the geology of some portions of Minnesota from St. Paul to the western part of the state." It is to be found in the Transactions of the Philosophical Society of Philadelphia. The following points are made in this paper:

1. The Lower Magnesian and the Potsdam are seen in the bluffs of the river to Mankato.

2. A small portion of the St. Peter sandstone was seen at St. Peter, still preserved above the Lower Magnesian.

3. The rock at Pipestone he regards as Huronian.

4. At Redwood falls, and at other places, he mentions the "steatitic or glauconitic" beds resulting from the decomposition of the granite under the Cretaceous.

5. The limestone and green marls at New Ulm he regards Cretaceous.

6. The red marls and sandstone underlying, he thinks "are not older than the Triassic."

7. He suggests the former probable continuity of the western and eastern Cretaceous areas with the southern prolongation of the same rocks up the Mississippi valley.

8. Suggests the parallelism of the red marls and ferruginous sandstones

*A hasty statement has been made by Prof. R. D Irving in the Transactions of the American Institute of Mining Engineers, Vol VIII, that this copper region had not been recognized by the Minnesota geologists, but was first brought to light by himself. Dr. Shumard describes the same rocks, and Chas. Whittlesey says they are the "dying out in that direction of the great Kewenaw range."

at Winkelmann's, near New Ulm, with the gypsiferous deposits in the valley of the Des Moines.

9. Regards the Coteau des Prairies as made by a broad synclinal in the quartzyte outcropping at Redstone, and illustrates it by a diagram.*

CHARLES WHITTLESEY IN NORTHERN MINNESOTA.

Mr. Whittlesey, who had been employed on the survey of Dr. Owen, made further examinations in the state for private parties in 1859 and 1864, and his geological notes, with illustrations, were printed at Cleveland, Ohio, in 1866, by order of the legislature of Minnesota. This little pamphlet contains much information concerning the northern part of the state, not to be found in any earlier publication. His ascent of the Big Fork river was made in company with Dr. Norwood, when engaged on the survey of Dr. Owen, in September, 1848, and his description of that stream has but little that is not found in the report of Norwood.

Mr. Whittlesey was the first to make observations on the drift-deposits under the guide of any adequate conception or theory of their origin. Dr. Owen's survey ignored this subject entirely, or incidentally grouped the phenomena under the head of "agricultural capabilities",† while Mr. Eames was too much engaged in a mineral hunt to give them any consideration, except as impediments to "prospecting." Whittlesey's grouping of "glacial etchings" proves the direction of the glacial movement in the northern part of the state to have been from the northeast, and he unhesitatingly ascribes all the phenomena in North America to the agency of glaciers, placing the southern limit of the movement in New Jersey, northern Pennsylvania, Ohio, Indiana, Illinois, Wisconsin and Iowa.‡ The correctness of this early prognostication has been strikingly verified by late explorations in several of the states named. He could see no reason to suppose that any changes of level of the country have taken place since the era of the drift.

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*It is singular that this theoretical explanation of the Coteau should have been incorporated on the late geological map of the United States, by Profs. Hitchcock and Blake, accompanying the ninth United States census report, rather than the positive statements of all other observers who have crossed it, to the effect that no rocky outcrops are to be found If the Huronian rocks underlie the Coteau, they would certainly appear at the surface at a great many places. Prof. Hind visited this ridge near the 49th parallel; so did Dr. Owen; Mr. Featherstonhaugh had described it; Keating had given us information concerning it; Nicollet's opinions were on record. These all testify that it is made up of drift. Probably the basis rock is Cretaceous, as that formation appears on both sides in the adjoining streams. The examinations of the survey have established the "erratic" nature of the whole range. Compare *Bulletins of the Minnesota Academy, Vol. I. p.* 100.

†Compare Owen's description of the "southern confines of the Coteau." Introduction, pp. xxxv. and xxxvi.

‡Compare *Fresh-water glacial drift of the Northwestern states.* Smithsonian *Contributions*, May, 1864.

The lake Superior trap rocks, carrying native copper, he assigned to the age of the Potsdam.* Those carrying the sulphurets of copper, he placed in a different, and older system, the Huronian, after the generalization of Bigsby and Logan. The quartzyte at Pokegama falls, he styled Potsdam.

With the exception of occasional misapprehensions of minerals, Mr. Whittlesey's brief notes, with the accompanying rough illustrations, constitute a valuable and correct geological epitome of the northern part of Minnesota, from Encampment river on the east to the Grande Fourche, or Big Fork river, on the west. It embraces also short chapters on the general geology, the phenomena of the drift period, general elevations in Minnesota, fluctuations in the level of the lakes, the climate, and the cost of mining copper.

GENERAL G. K. WARREN ON THE MINNESOTA VALLEY.

The United States government detailed General Warren in 1866, for the survey of the upper Mississippi, Minnesota and Wisconsin rivers with a view to the improvement of navigation and the construction of bridges which should afford the least possible obstruction to navigation. The work on the Minnesota was continued in 1867 and 1868. In the annual report of the Chief of Engineers for 1868, is found General Warren's first published general expression of his views concerning the physical features of the Minnesota valley, although they were in part presented in Sen. Ex. Doc. No. 58, 39th Congress, 2nd Session, dated January 21, 1867. His final report, *in extenso,* was not rendered till 1874; owing to the intervention of other duties, and is to be found in the appendix to the report of the Chief of Engineers for that year.† Part II of this report is an *essay concerning important physical features exhibited in the valley of the Minnesota river, and upon their signification.* This is illustrated by several maps, plates and diagrams, and accompanied by a detailed description of the valley by his assistant, Mr. C. E. Davis.

The main points brought out in this essay are ; 1st, that the Minnesota valley was formerly the course of a great river ; 2nd, that this river

*On page 7 Mr. Whittlesey makes the following remark concerning the rocks of the Mesabi : "In many cases the syenite and granite appear to be more recent than the metamorphic slates, having all the appearance of intrusive rocks."

†See also the *American Naturalist*, November 1868, for a summary of a paper read by Gen. Warren before the *American Association for the Advancement of Science.*

drained the valley of lake Winnipeg; 3rd, that lake Winnipeg formerly had a great extension southward, according to the opinion of Prof. Henry Youle Hind;* and 4th, that the most plausible hypothesis to account for the former drainage of the Winnipeg basin along the valley of the Mississippi, and for the change to the present outlet by Nelson river, is a subsidence of the northern part of the valley and an elevation of the southern part, extending through a vast period of time, and probably still going on. He refers to the hypothesis that as the glacial epoch tempered off gradually into the present epoch, there might have been a long time when the glaciers had sufficient extension southward to close the outlet to Hudson's bay, which on the further recession of the ice, would be opened and the lake drained off toward the north. This hypothesis he regards as "unsupported, and barren of any fruit." He thinks it does not explain any phenomena presented by other lake-basins and water-courses in North America, nor enable us to predict what probable results we should find in other regions, and thus intelligently direct further investigation. He then mentions topographic features reported at numerous points in the United States and in the British possessions in America which seem to confirm the former hypothesis; and closes with a map showing a restoration of the ancient basin of the Mississippi. In this the source is shown to be a stream joining lake Winnipeg from the northwest. Lake Winnipeg is enlarged to exceed the area of lake Superior, extending to Big Stone lake, having its outlet by way of the Minnesota into the Mississippi; while at the same time an arm of the gulf of Mexico brings salt water up the great valley as far as the parallel on which Chicago lies, and farther still up the Missouri valley, the Ohio itself being an eastward extension from this arm nearly to Pittsburg.

In the proper place this subject will be fully discussed. It is only necessary to say here that the investigations of the survey, while sustaining all Gen. Warren's observations respecting the extension of a lake formerly occupying the Winnipeg and Red river valley, and the large size of the ancient Minnesota, warrant the hypothesis which he rejects, rather than the one which he adopts.

*Narrative of the Canadian Red river exploring expedition of 1857, and of the Assiniboine and Saskatchewan exploring expedition of 1858. By Henry Youle Hind. Two volumes.

HURLBUT ON THE GEOLOGY OF SOUTHERN MINNESOTA.

In 1871 Mr. W. D. Hurlbut, of Rochester, Minnesota, contributed a series of papers to the *Minnesota Teacher* on the geology of southern Minnesota, which were subsequently issued together as a pamphlet. These papers supply a lack, which was a conspicuous and remarkable one, in the geological literature of the state—considering the general accuracy and fullness of Owen's report—since no geologist had before penetrated this part of Minnesota, and nobody had called attention to its marked topography or to its geology. Owen's parties passed around it. They ascended the Mississippi, the Minnesota and the Des Moines, but the valleys of the Root and the Zumbro were not examined. It is in these valleys, and particularly on the upper tributaries, that the upper parts of the Silurian and the Devonian are found exposed.

Taking the Mississippi river, and the measurements and descriptions of Dr. Owen, as initial points, Mr. Hurlbut follows up the streams coming from the west, across the strike of the formations, noting the changes as they occur in the strata, and stating their main characteristics and thicknesses. He thus makes out the Potsdam, the Lower Magnesian, St. Peter sandstone, Trenton limestone flags, Hudson River shales, argillaceous shales which he regards of the age of the Clinton, and the Devonian. He also outlines their geographical extent, and states some of their topographic features. His identifications, being the first recorded attempt to parallelize those strata with any recognized base of nomenclature in the state of Minnesota, and dependent for the greater part on lithological features, were subject to such changes as a study of the fossils might require. His Hudson River shales were restricted to the very base of the rocks of that formation, and designated "Hudson River oil shales," having a maximum thickness of fifteen feet. They are the "Green shales" of the early reports of progress of the survey, and probably belong to the Hudson River group. His shaly limestone (Clinton) is the upper part of the Hudson River, becoming in some places a very calcareous member almost without shales. His Devonian, in which the arenaceous parts were supposed to be Schoharie sandstone, is the buff magnesian limestone of the Galena. The elevated land, further southwest from the strike of the last, in Mower and Fillmore counties, he suggests may contain higher formations, such as the Iowa Subcarboniferous formation, but in the absence of exposures of the rock nothing could be ascertained without artificial excavations.

The discussion of the "Tertiary phenomena" by Mr. Hurlbut embraces Prof. J. D. Whitney's view of the origin of the driftless area in Iowa, and the opinions of Gen. G. K. Warren concerning the former direction of drainage of the Minnesota and upper Mississippi "westward into the Cretaceous ocean," in which he groups in a new and interesting manner many topographic and hypsometric facts, going to show that the interior of the state is a basin whose greatest depression is along the valley of the Minnesota, from its source to the head of lake Pepin. "The supposed surface and shore line of this lake basin is very well indicated, in many places, at about one thousand feet elevation above the sea, by clay terraces and bluffs, containing trunks and branches of trees, lignite clay and other lacustrine formations."

KLOOS' GEOLOGICAL OBSERVATIONS IN MINNESOTA.

In the same journal, in 1871. Mr. J. H. Kloos of St. Paul, records sundry geological observations made in the northern part of the state. He sketches the country briefly along the line of the new railroad from lake Superior to the Mississippi river at St. Paul, noting most closely the region of the slates on the St. Louis river, which he assigns to the Huronian formation; the conglomerates and red sandstones he assigns to the Potsdam, the latter being unconformable on the former, with a dip six or seven degrees toward the south; and suggests that beds of iron ore underlie the slates of the St. Louis river, as they do the slates of the Marquette iron range in Michigan; the hæmatitic and magnetic iron ore at Vermilion lake being perhaps in that horizon, and thus the lowest member of the Huronian formation.

In respect to the rocks at Duluth he describes, in general terms, the "Duluth granite," as a coarse crystalline rock consisting principally of a grayish-white feldspar showing three distinct cleavage planes, two of them being nearly at right angles; one plane has a glassy lustre, and the other a brilliant pearly lustre, with striæ which he regards as an indication of labradorite. Another constituent he named diallage, or hypersthene; and another magnetic iron. The rock he pronounces hyperyte, provisionally. He mentions the first rocks forming the immediate shore at Duluth, styling them feldspar-porphyry, with magnetite and epidote, and also calcite and laumontite, some of the rock being amygdaloidal. Between the hyperyte and the porphyryte he notes another unstratified homogeneous black rock, of igneous origin; but he essays not to trace the relations which these igneous rocks bear to each other, though he states that they seem to be interstratified with the Potsdam sandstone at points farther down the coast.

The "trap rock" at Taylor's Falls he styles porphyryte, places it in the Huronian, and dissents from Dr. Owen, who regards the sandstone overlying as older than the trap. Mr. Kloos, on the other hand, demonstrates, by various diagrams and by his observations, that the sandstone was deposited, and still remains undisturbed, in horizontal stratification, unconformably, over the crystalline rock, and must be of later date.*

In respect to the copper discoveries at Taylor's Falls, he says that there are a great many small feldspathic veins, and that in one of these, where Mr. Taylor had sunk a shaft to the depth of twenty feet, copper was disseminated through the substance of the vein-rock (principally feldspathic and decomposed) in exceedingly thin foliæ, mixed sometimes with a sulphuret of copper, or copper-glance. The Kettle river discoveries he regards more favorably. They are forty miles above Taylor's Falls, and warrant the expectation that in other places on the Kettle river copper-bearing veins will be found at some future time.†

Mr. Kloos was the first to announce the Cretaceous rocks at any point so far north in the state as the Sauk valley. In the *American Journal of Science and Arts*, 1872, he gives the particulars of such a discovery, authenticated by paleontological determinations of Mr. F. B. Meek.

A. WINCHELL EXAMINES THE SALT WELL AT BELLE PLAINE.

The legislature of 1870 passed a law entitled "An act to aid in the development of the salt springs at Belle Plaine," which donated six sections of the state salt lands to a company organized for that purpose, on certain conditions. These conditions, which required the sinking of a drilled well at

*In the third volume of the report of the geological survey of Wisconsin, Mr. Sweet seems to have come to the same opinion independently, at a later date than Mr. Kloos.

†Subsequently Mr. Kloos and Prof. Streng made a careful examination of the crystalline rocks collected in Minnesota. Mr. Kloos' geological observations were published in *Zeitschrift d. d. geol. Gesellschaft*, 1871, S. 428; and the mineralogical papers of Streng and Kloos are to be found in the *Neues Jahrbuch fur Min. Geol. u. Pal.* 1877. *Vide*, also, the translations of these in the tenth and eleventh annual reports of the Geological and Natural History survey of Minnesota.

Belle Plaine, where indications of brine were said to exist, to the depth of several hundred feet, were complied with by the company, and the six sections of land were conveyed to the company. The following year, on the passage of another law to further aid in the development of the same salt springs, the conveyance was conditioned on a favorable report, after a geological survey of the vicinity of Belle Plaine by a competent geologist. Prof. A. Winchell of Ann Arbor, Michigan, having been designated by governor Austin, made the necessary examination, and reported in June, 1871. His report was transmitted to the senate in January, 1872, and was ordered printed. It is an octavo pamphlet of sixteen pages.* After stating the general facts and principles which guided the geologist in coming to a conclusion, the report gives some local geological observations in which the section of the exposed sand-rock along Sand creek, at Jordan, is for the first time carefully made out. It is regarded as of the Potsdam age, and placed beneath the Lower Magnesian limestone of Owen. No distinction is made between the stratigraphical horizon of the limestone at Kasota and that at St. Lawrence, and the sand-rock at Jordan is supposed to lie beneath both; the strata at Kasota being supposed to dip down the river so as to bring them at St. Lawrence about sixty feet nearer the water than at Kasota. From all the facts considered, the conclusion was reached that the prospect of obtaining brine at Belle Plaine was not encouraging; that the horizon of the rocks penetrated is below all known saliferous formations, and that even if the shales of the Trenton group should prove to be saliferous, the product is likely to accumulate under a region far to the south.

Notwithstanding the unfavorable report of the geologist, which rendered the appropriation of 1871 inoperative, the legislature of 1872 appropriated six sections more of the salt spring lands to the same company for the same purpose. Not only has no brine in workable quantities ever been obtained from this well, but the analyses of the present survey have failed to establish the alleged briny character of the water of the spring at Belle Plaine on which the expenditure was at first undertaken.

The same legislature (1872) enacted the law which initiated the present survey.

*Report of a geological survey of the vicinity of Belle Plaine, Scott county, Minnesota. By A. Winchell.

HISTORY OF THE PRESENT SURVEY.

The law under which this survey has been carried on was drafted by president W. W. Folwell, and was introduced in the legislature by senator J. S. Pillsbury, then a regent of the University. It passed both houses, and was approved by governor Horace Austin, March 1, 1872. It reads as follows:

Be it enacted by the Legislature of the State of Minnesota:

SECTION 1. It shall be the duty of the board of regents of the University of Minnesota to cause to be begun as soon as may be practicable, and to carry on a thorough geological and natural history survey of the state.

SEC. 2. The geological survey shall be carried on with a view to a complete account of the mineral kingdom, as represented in the state, including the number, order, dip, and magnitude of the several geological strata, their richness in ores, coals, clays, peats, salines, and mineral waters, marls, cements, building stones and other useful materials, the value of said substances for economical purposes, and their accessibility; also an accurate chemical analysis of the various rocks, soils, ores, clays, peats, marls and other mineral substances; of which complete and exact record shall be made.

SEC. 3. The natural history survey shall include, first, an examination of the vegetable productions of the state, embracing all trees, shrubs, herbs, and grasses, native or naturalized in the state; second, a complete and scientific account of the animal kingdom, as properly represented in the state, including all mammalia, fishes. reptiles, birds and insects.

SEC. 4. The said surveys and examinations shall be made in the manner and order following: First, the geological survey proper together with the necessary and implied mineralogical investigations; all of which shall be undertaken as soon as may be practicable, and be carried forward with such expedition as may be consistent with economy and thoroughness; second, the botanical examinations; third, the zoological investigations. Provided, however, that whenever the said board of regents may find it most economical to prosecute different portions of the surveys in conjunction, or that the public interest demands it, they may, in their discretion, depart from the above prescribed order. And in the employment of assistants in the said surveys, the board of regents shall at all times give the preference to the students and graduates of the University of Minnesota, provided the same be well qualified for the duties.

SEC. 5. The said board of regents shall also cause to be collected and tabulated such meteorological statistics as may be needed to account for the varieties of climate in the various parts of the state; also to cause to be ascertained [by] barometrical observations or other appropriate means, the relative elevations and depressions of the different parts of the state; and also, on or before the completion of the said surveys, to cause to be compiled from such actual surveys and measurements as may be necessary, an accurate map of the state; which map, when approved by the governor, shall be the official map of the state.

SEC. 6. It shall be the duty of said board of regents to cause proper specimens, skillfully prepared, secured and labeled, of all rocks, soils, ores, coals, fossils, cements, building stones, plants, woods, skins and skeletons of animals, birds, insects and fishes, and other mineral, vegetable and animal substances and organisms discovered or examined in the course of said surveys, to be preserved for public inspection free of cost, in the University of Minnesota, in rooms convenient of access and properly warmed, lighted, ventilated and furnished, and in charge of a proper scientific curator; and they shall also, whenever the same may be practicable, cause duplicates in reasonable numbers and quantities of the above named specimens, to be collected and preserved for the purpose of exchanges with other state universities and scientific institutions, of which latter the Smithsonian Institution at Washington shall have the preference.

SEC. 7. The said board of regents shall cause a geological map of the state to be made as soon as may be practicable, upon which, by colors and other appropriate means and devices, the various geological formations shall be represented.

SEC. 8. It shall be the duty of the said board of regents, through their president, to make, on or before the second Tuesday in December of each and every year, a report showing the progress of the said surveys, accompanied by such maps, drawings and specifications as may be necessary and proper to exemplify the same to the governor, who shall lay the same before the legislature; and the said board of regents, upon the completion of any separate portion of the said surveys, shall cause to be prepared a memoir or final report, which shall embody in a convenient manner all useful and important information accumulated in the course of the investigation of the particular department or portion; which report or memoir shall likewise be communicated through the governor to the legislature.

SEC. 9. To carry out the provisions of this act the sum of one thousand dollars per annum is hereby appropriated, to be drawn and expended by the [said] board of regents of the University of Minnesota.

SEC. 10. This act shall take effect and be in force from and after its approval.

The present writer was appointed to conduct this survey in July, 1872, but, having work to complete in the state of Ohio, did not begin service till September. The field-work the first year occupied about a month and was closed by the first heavy fall of snow, November 12th. The means placed at the disposal of the state geologist not warranting the employment of assistants he was only able to make a general reconnoissance of the southern and central portions of the state accessible by railroad, and on this as a basis he was enabled to give a nearly complete section of the strata from the trap and granitic rocks to the Galena limestone in the Lower Silurian, including also about forty feet of the latter. Various out-crops of the Cretaceous were described also in the first annual report.

On the basis of the field-work done in the fall of 1872, and of reports already published, the first annual report of the survey gives a general *sketch of the geology of Minnesota*, as then known, accompanied by a small colored geological map of the state, and also a chart of geological nomenclature intended to express the relation of Minnesota to the great geological series of the earth, and the probable equivalency of some of the names the formations have received in the various states and in Europe.

In the account of the "Potsdam sandstone" of the northwest, as defined by the Iowa and Wisconsin geologists, and of the red quartzytes of the same region, the first step was taken toward the investigation of that stratigraphical problem which seeks to determine the western equivalent of the Potsdam sandstone of New York; and inasmuch as the same name had by good authorities been applied to two different and quite distinct western formations, the name *St. Croix* was suggested for the light-colored sandstone of the upper Mississippi and St. Croix valleys, it being more probable that the Potsdam of New York was represented in Minnesota by the red quartzytes and shales underlying.

The state geologist, under the head of "plans and recommendations," makes the following statement in the first report.

The law under which the present survey is being prosecuted appropriates the sum of one thousand dollars per annum. This is too small for various reasons, the chief of which are, (1) It will not pay for the services of a single employé on the survey capable of working under the law. Hence it well-nigh renders the law inoperative. (2) It does not command the respect and confidence of the citizens of the state and others, and serves as an excuse for refusing aid and co-operation. The survey should be independent of favors for which it now has to beg, sometimes to be scornfully refused. (3) In the survey of those portions of the state inaccessible by public roads, or by railroads, it will be necessary to employ laborers, and incur other expense, for which the sum of one thousand dollars is not sufficient. (4) In order to conduct the survey on one thousand dollars per annum, the state geologist must find some other employment a portion of the year.* (5) The magnitude of the interests involved demands that ample means be allowed for doing the work of the survey thoroughly and without embarrassment. These considerations ought to induce the legislature to increase the amount now appropriated to a sum sufficient at least to keep one man constantly employed, and to pay all expense of field-work and chemical examinations. In connection with the subject of increasing the means provided for a geological survey, it is suggested that the state lands known as *salt spring lands* may be so sold or appropriated under the management of the board of regents of the university, as to be available for that purpose. It would be in perfect consonance with the original design, in the reservation of these lands from sale, if they were placed in the custody of the board of regents, conditioned on their use in the prosecutation of the geological and natural history survey of the state, with a view to the early and economical development of the brines of the state.

This recommendation respecting the use of salt spring lands for the prosecution of the survey, was based on representations made to the writer by Mr. W. D. Hurlbut of Rochester, and Hon. H. B. Wilson, superintendent of public instruction, and on conversations with Hon. O. P. Whitcomb, state auditor, and subsequently with senator J. S. Pillsbury and president Folwell; but it was only through the indefatigable and persistent efforts of senator Pillsbury, that the following law was passed by the legislature of 1873.† It is verbatim as drafted by the present writer, and by its action the survey has been supplied with funds needed for its prosecution.

Be it enacted by the Legislature of the State of Minnesota:

SECTION 1. The state lands known as *state salt lands*, donated by the general government to aid in the development of the brines in the state of Minnesota, shall be transferred to the custody and control of the board of regents of the university of Minnesota. By said board of regents these lands smay be sold in such manner, or in such amounts, consistent with the laws of the state of Minnesota, as they may see fit; the proceeds thereof being held in trust by them, and only disbursed in accordance with the law ordering a geological and natural history survey of the state.

SEC. 2. It shall be the duty of the said board of regents, as soon as practicable, to cause a full and scientific investigation and report on the salt springs of the state, with a view to the early development of such brine deposits as may exist within the state.

SEC. 3. The board of regents of the university shall cause the immediate survey and investigation of the peat deposits of the state of Minnesota, accompanied by such tests and chemical examinations as may be necessary to show their economical value, and their usefulness for the purpose of common fuel; a full report thereon to be presented to the legislature as soon as practicable.

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*He was employed as instructor in the University of Minnesota during six months of each year from 1872 to 1878.

†It was introduced by senator Edmund Rice.

SEC. 4. The sum of two thousand dollars is hereby appropriated annually (in lieu of one thousand dollars) for the purpose of the geological and natural history survey until such time as the proceeds of the sales of the salt lands shall equal that amount, when such annual appropriation shall cease.

SEC. 5. The sum of five hundred dollars is hereby appropriated for the purchase of apparatus and chemicals for the use of the geological and natural history survey, the same to be expended by the order of the board of regents of the university of Minnesota.

SEC. 6. It shall be the duty of the board of regents of the university of Minnesota to cause duplicate geological specimens to be collected, and to furnish to each of the three Normal schools suites of such specimens after the university collection has become complete.

SEC. 7. When the geological and natural history survey of the state shall have been completed, the final report on the same by the said board of regents shall give a full statement of the sales of the salt lands hereby given into the custody and control of the board of regents of the university of Minnesota, together with the amount of moneys received therefrom, and of the balance, if any, left in the hands of said board of regents.

SEC. 8. This act shall take effect and be in force from and after its passage.

Approved March 10, 1873.

In compliance with the above law the state geologist made an examination of the peats in the southern portion of the state and rendered a report on them in 1873. On examining the condition of the United States grant of land for salt springs, which the same law devotes to the prosecution of the survey, it was found that a large part of these lands had never been certified to the state, not through any fault of the governor* or other state officers, but through the tardiness of the officers of the general government. The original grant covered 46,080 acres. Of this sum only 18,771 acres were then available for the prosecution of the survey. The uncertified lands aggregated 19,872 acres. A memorial of the state legislature was presented to congress, asking the privilege to make re-selections, and through the efforts of governor J. S. Pillsbury and senator S. J. R. McMillan, such permission was granted, and the certified amount of the salt spring lands, designed for the prosecution of the survey, was more than doubled.

The survey has continued without interruption since its beginning in 1872. The principal events, and its results from year to year have been recorded in the annual reports, and it is not necessary to enter upon the internal and personal history involved in its management and prosecution.

MINNEAPOLIS, JANUARY, 1881.

[NOTE.—Since this historical sketch was written Mr. Neill has published some new facts concerning Mr. David Thompson, who is mentioned on page 25 as a geographer employed by the Northwest Fur Company,† derived from the records of the company in the Parliament library at Ottawa. From this it appears that Mr. Thompson crossed the state of Minnesota in 1798, from

*Gov. H. H. Sibley had all these lands located according to the terms of the grant. See Report concerning the salt spring lands due the state of Minnesota. By N. H. Winchell, 1874.

†Neill's History of Minnesota, 4th edition, 1882.

the Red river of the North to lake Superior. He ascended the Red Lake river to the Clearwater river, which he followed to the mouth of a tributary from the north, known as Wild Rice river. From the last he made a portage of four miles and again reached Red Lake river. From Red lake he proceeded southward by the usual route to Turtle lake, the same as the Julian Source the Mississippi described by Mr. Beltrami in 1823, thence down the Mississippi to Sandy lake and by way of the Savannah rivers to the mouth of the St. Louis at Fond du Lac.

Mr. Neill has also called attention to the existence of other maps of the region south and west of lake Superior older than that of Franquelin of 1688, represented on plate-page No. 2. One of these is by the engineer Randin, another is by Joliet and Franquelin, and a third is by Joliet. These maps give the name *Buade* to the Mississippi river, and apply the term *Frontenacie* to the whole country north and west of the mouth of the Wisconsin river. Only the third, that of Joliet, of 1764, has been published.

On the historical plate (No. 1), Du Luth's fort (Kamanistigouia) is placed at the mouth of the St. Louis river on the authority of Perrot, who says (*Collections of the Minnesota Historical Society* for 1867, p. 26), *son poste estoit au fond du lac Supérieur*, though many other authorities concur in placing it at Three Rivers, at the head of Thunder bay.]

CHAPTER II.

THE

GENERAL PHYSICAL FEATURES

OF MINNESOTA.

BY N. H. WINCHELL.

It is intended in this chapter to give only such general statements as will serve to make intelligible the more special descriptions of following chapters. The physical features of the state may be considered from different points of view, viz:

1. Position, boundaries and area of the state.
2. The distribution and character of the drift.
3. The surface configuration of different parts of the state.
4. The relative elevations of different parts of the state.
5. The kinds and distribution of the soils and subsoils.
6. The lakes and rivers, and the qualities of water of different portions.
7. The nature and distribution of the native forests and their relation to the prairies.
8. The commanding geographical and commercial position of the state.

I. POSITION, BOUNDARIES AND AREA.

Boundaries. The northern boundary of the state of Minnesota, as far as the lake of the Woods, was defined by the terms of the treaty of peace between the United States and Great Britain, concluded at Paris, September 3d, 1783. The boundary line of the United States was declared to run along the middle of the Ontario, Erie, Huron, Superior, and Long lakes,* and their water

*Carver's map, published in 1779, in London, shows Long lake as an enlargement of the lower part of Pigeon river.

connections "to the most northwestern point of the lake of the Woods, and thence on a due west course to the river Mississippi;" thence down the middle of that river to the thirty-first parallel of latitude. It was defined more carefully by the Webster-Ashburton treaty of Washington, August 9th, 1842, in the following words:

"To the mouth of Pigeon river, and up the said stream to and through the North and South Fowl lakes to the lakes of the hight of land between lake Superior and the lake of the Woods; thence along the water communication to lake Saisaginaga and through that lake; thence to and through Cypress lake, Lac du Bois Blanc, Lac la Croix, Little Vermilion lake and lake Mamecan, and through the several smaller lakes, straits or streams connecting the lakes here mentioned, to that point in Lac la Pluie, or Rainy lake, at the Chaudière falls, from which the commissioners traced the line to the most northwestern point of the lake of the Woods; thence along the said line to the said most northwestern point, being in latitude forty-nine degrees twenty-three minutes fifty-three seconds north, and in longitude ninety-five degrees fourteen minutes thirty-eight seconds west from the observatory at Greenwich; thence, according to existing treaties. due south to its intersection with the forty-ninth parallel of north latitude, and along that parallel to the Rocky mountains; it being understood that all the water communications and all the usual portages along the line from lake Superior to the lake of the Woods, and also Grand Portage from the shore of lake Superior to Pigeon river, as now actually used, shall be free and open to the use of citizens and subjects of both countries."

The "most northwestern point of the lake of the Woods" was found by the joint "survey of the northern boundary of the United States," by commissioners on the part of the United States and Great Britain, in 1872, to be in latitude 49° 23′ 50″.28, and in longitude west from Greenwich 95° 08′56″.7, or about twenty-eight miles north of the forty-ninth parallel. This is the most northern portion of the United States,* and the land area belonging to the state of Minnesota, lying north of the forty-ninth parallel is stated by Major Twining to be about 150 square miles. This irregularity in the northern boundary was occasioned by a lack of geographical knowledge on the part of those forming the treaty of October 20th, 1818, which specifies

*Excepting Alaska.

that the continuation of the boundary from the "northwest angle" should be by a line either north or south as the case might be, to the forty-ninth parallel of north latitude, and thence westerly on said parallel. Subsequently it was found that the "northwest angle" was north of the forty-ninth parallel, and it was so agreed upon and defined by the Webster-Ashburton treaty of 1842.

The southern boundary of the state is the parallel of north latitude 43° 30′, and was established by the act of Congress which defined the present boundaries of the state of Iowa.* It was continued by congress as the southern boundary of the territory of Minnesota, from the main channel of the Mississippi river as far west as the northwest corner of the state of Iowa, by the act of March 3d, 1849, and was finally declared the southern boundary of the state of Minnesota as far west as to the intersection of the north and south line constituting its western boundary south of Big Stone lake.

The eastern boundary of the state was defined by congress in the "enabling act" of Wisconsin, approved August 6th, 1846, in substance as follows: from the waters of lake Superior "to the mouth of the St. Louis river; thence up the main channel of said river to the first rapids in the same above the Indian village, according to Nicollet's map; thence due south to the main branch of the river St. Croix; thence down the main channel of said river to the Mississippi; thence down the centre of the main channel of that river to the northwest corner of the state of Illinois."

The boundary separating Minnesota from Dakota territory is defined as follows by the "enabling act" of Minnesota of 1857: "beginning at the point in the centre of the main channel of the Red river of the North where the boundary line between the United States and the British possessions crosses the same; thence up the main channel of said river to that of the Bois des Sioux river; thence up the main channel of said river to lake Traverse; thence up the center of said lake to the southern extremity thereof; thence in a direct line to the head of Big Stone lake; thence through its center to its outlet; thence by a due south line to the north line of the state of Iowa."

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*Iowa when first admitted embraced that part of Minnesota lying south of the parallel of latitude passing through the confluence of the Blue Earth and Minnesota rivers and east of the meridian 17° 30′ Subsequently this portion of the present state of Minnesota was added to the territory of Minnesota and the state of Iowa was extended westward to the Big Sioux and Missouri rivers.

The Area of the State, by counties, has been given by Henry Gannett, geographer of the tenth United States census, in round numbers, and its aggregate area at 83,365 square miles, of which 4,160 square miles are considered water surface and 79,205 land surface. This, however, does not include any portion of the lake of the Woods, nor Rainy lake, and the areas of the northern unorganized counties are estimated in "thousands" of square miles, viz: Beltrami, 5,000; Cass, 4,000; Itasca, 5,000; Lake, 3,000; Polk, 4,000; St. Louis, 6,000, and Cook, 460. Lac qui Parle, Yellow Medicine and Lincoln counties are reduced for the proposed formation oı Canby county, which, however, not having been approved by the vote of the inhabitants, was not constituted and is not listed. Swift county is given at 580 instead of 757 square miles, and Renville at 900 instead of 981.

For the purpose of getting a more exact statement of the area of the state, the whole has been re-computed from the records of the state auditor's office in St. Paul, with the results shown in the following table.*

AREAS OF THE COUNTIES OF MINNESOTA IN SQUARE MILES AND ACRES.

COUNTIES.	LAND.		WATER.		TOTAL.	
	SQ. MILES.	ACRES.	SQ. MILES.	ACRES.	SQ. MILES.	ACRES.
Aitkin...... ..	1,821.39	1,165,691.90	173.58	111,090.48	1,994.97	1,276,782.38
Anoka....	424.88	271,925.66	20.10	12,860.82	444.98	284,786.48
Becker..........	1,307.79	836,987.09	137.62	88,073.66	1,445.41	925,060.75
Beltrami.........	4,969.44	3,180,445.27	1,037.68	664,109.46	6,007.12	3,844,554.73
Benton	402.81	257,798.90	3.55	2,275.41	406.36	260,074.31
Big Stone..... ..	494.53	316,497.42	41.78	26,737.33	536.31	343,234.75
Blue Earth......	743 09	475,582.34	33.79	21,619.39	776.88	497,201.73
Brown..........	605.91	387,783.30	10.84	6,937.52	616.75	394,720.82
Carlton..........	857.72	548,942.09	9.47	6,057.91	867.19	555,000.00
Carver	354.15	226,652.28	22.35	14,307.30	376.50	240,959.58
Cass............	2,667.78	1,707,382.00	629.76	403,041.25	3,297.54	2,110,423.25
Chippewa.......	578.54	370,269.93	15.67	10,027.23	594.21	380,297.10
Chisago.........	421.02	269,451.12	30.64	19,611.38	451.66	289,062.56
Clay............	1,043.95	668,124.66	23.41	14,984.16	1,067.36	683,108.82
Cook............	1,406.84	900,378.49	273.56	175,076.51	1,680.40	1,075,455.00
Cottonwood.....	636.87	407,594.35	13.52	8,655.65	650.39	416,250.00
Crow Wing.....	824.04	527,387.51	127.46	81 570.49	951.50	608,958.00
Dakota......	605.87	387,753.96	5.45	3,488.61	611.32	391,242.57
Dodge..........	437.43	279,956.47	1.22	782.43	438.65	280,738.90
Douglas	626.58	401,014.74	96.08	61,485.88	722.66	462 500.62
Faribault.......	709 43	454,033.32	14.29	9,151.21	723.72	463,184.53
Fillmore........	864.22	553,101.90	2.99	1,912.54	867.21	555,014.44
Freeborn	701.94	449,242.53	20.74	13,271.87	722.68	462,514.40

*This work was done for the survey by Hon. H. H. Young, secretary of the Board of Immigration. The total land and water area of the state proves to be somewhat more than the commonly accepted figures. The unsurveyed portions and the Indian reservations, have been carefully estimated. Part of the lake of the Woods, and the tract of land west of this lake and north of the 49th parallel, embraced within the boundary of Minnesota, belong to Beltrami county, and are included in the areas given for that county. The water area embraces the interior lakes and larger streams, and half of all boundary waters excepting lake Superior, no part of which is included.

AREAS OF THE COUNTIES OF MINNESOTA.—*Continued.*

COUNTIES.	LAND.		WATER.		TOTAL.	
	SQ. MILES.	ACRES.	SQ. MILES.	ACRES.	SQ. MILES.	ACRES.
Goodhue	764.58	489,329.56	20.21	12,936.06	784.79	502,265.62
Grant	544.15	348,256.21	34.13	21,843.03	578.28	370.099.24
Hennepin	551.44	352,918.68	70.03	44,821.20	621.47	397,739.88
Houston	568.75	363,998.07	11.10	7,104.17	579.85	371,102.24
Hubbard	522.83	334,611.87	62.57	40,045.25	585.40	374,657.12
Isanti	416.61	266,629.79	41.24	26,395.86	457.85	293,025.65
Itasca	5,662.57	3,624,044.12	216.31	138,438.89	5,878.88	3,762,483.01
Jackson	696.98	446,066.45	25.68	16,[illegible]34.75	722.66	462,501.20
Kanabec	527.40	337,535.89	14.59	9,336.41	541.99	346,872.30
Kandiyohi	776.72	497,101.35	90.42	57,867.69	867.14	554,969.04
Kittson	2,148.80	1,375,233.27	15.95	10,206.73	2,164.75	1,385,440.00
Lac qui Parle	770.02	492,809.83	1.91	1,227.57	771.93	494,037.40
Lake	2,076.42	1,328,905.43	322.52	206,420.00	2,398.94	1,535,325.43
Le Sueur	444.52	284,496.41	27.96	17,891.77	472.48	302,388.18
Lincoln	522.43	334,355.00	19.56	12,517.30	541.99	346,872.30
Lyon	709.50	454,072.72	11.16	7,150.08	720.66	461,222.80
McLeod	485.14	310,488.63	22.31	14,283.23	507.45	324,771.86
Marshall	1,673.64	1,071,129.11	1.40	895.01	1,675.04	1,072,024.12
Martin	704.73	451,021.05	19.16	12,267.35	723.89	463,288.40
Meeker	596.00	381,443.02	37.62	24,075.56	633.62	405,518.58
Mille Lacs	571.09	365,497.65	117.10	74,945.53	688.19	440,443.18
Morrison	1,083.52	693,454.07	5.57	3,564.78	1,089.09	697,018.85
Mower	709.07	453 803.10	2.11	1,352.65	711.18	455,155.75
Murray	695.14	444,891.27	26.42	16,909.93	721.56	461,801.20
Nicollet	435.75	278,882.41	28.86	18,469.37	464.61	297,351.78
Nobles	710.75	454,877.12	16.91	10,827.04	727.66	465,704.16
Norman	1,435.11	918,472.60	23.21	14,853.55	1,458.32	933,326.15
Olmsted	658.42	421,391.08	3.94	2,520.20	662.36	423,911.28
Otter Tail	1,985.90	1,270,977.77	254.30	162,748.67	2,240.20	1,433,726.44
Pine	1,419.74	908,632.83	24.76	15,844.68	1,444.50	924,477.51
Pipestone	462.32	295,881.75	0.95	611.76	463.27	296,493.51
Polk	3,117.27	1,995,054.58	41.91	26,818.67	3,159.18	2,021,873.25
Pope	667.61	427,269.27	55.08	35,251.93	722.69	462,521.20
Ramsey	173.70	111,168.71	13.45	8,605.34	187.15	119,774.05
Redwood	870.50	557,122.74	23.33	14,930.13	893.83	572 052.87
Renville	971.33	621,650.89	9.98	6,385.69	981.31	628,036.58
Rice	486.73	311,505.87	17.27	11,054.83	504.00	322,560.70
Rock	480.83	307,736.11	1.84	1,174.04	482.67	308,910.15
St. Louis	5,837.26	3,735,846.26	774.49	495,674.68	6,611.75	4,231,520.94
Scott	342.73	219,344.22	15.87	10,157.58	358.60	229,501.80
Sherburne	448.72	287,180.40	20.16	12.905.72	468.88	300,086.12
Sibley	566.89	362,808.14	30.84	19,737.61	597.73	382,545.75
Stearns	1,272.22	814,220.09	57.85	37,021.27	1,330.07	851,241.36
Steele	426.19	272,761.47	4.40	2,817.69	430.59	275,579.16
Stevens	555.21	355,336.19	16.27	10,411.81	571.48	365,748.00
Swift	743.05	475,553.36	14.68	9,392.08	757.73	484,945.44
Todd	965.98	618,225.14	42.36	27,111.58	1,008.34	645,336.72
Traverse	567.91	363.463.46	13.92	8,906.00	581.83	372,369.46
Wabasha	555.54	355,544.17	39.09	25,018.07	594.63	380,562.24
Wadena	707.43	452,751.16	15.35	9,828.84	722.78	462,580.00
Waseca	419,00	268,161.75	18.01	11,524.16	437.01	279,685.91
Washington	408.87	261,675.02	21.14	13,530.33	430.01	275,205.35
Watonwan	432.89	277,051.92	2.56	1,638.00	435.45	278,689.92
Wilkin	744.35	476,387.76	6.69	4,277.12	751.04	480,664.88
Winona	634.88	406,325.09	4.04	2.584.81	638.92	408,909.90
Wright	663.05	424.353.82	50.92	32,585.50	713.97	456,939.32
Yellow Medicine	752.60	481,664.26	10.52	6,734.01	763.12	488,398.27
Total	78,649.00	50,335,367.19	5.637.53	3,608,012.05	84.286.53	53,943.379.24

II. THE DISTRIBUTION AND CHARACTERS OF THE DRIFT.

Nearly the whole state may be said to be drift-covered; the only exceptions being the extreme southeastern and the extreme northeastern portions. At any point on the northwestern boundary, as far east as the lake of the Woods, one may start out southward and travel to the Iowa boundary line without seeing any rock *in situ* except what he might happen to encounter in crossing the valley of the Minnesota river, and except the rare exposures of red quartzyte in Rock, Pipestone and Cottonwood counties. East of this meridian he would encounter occasional exposures of rock along Rainy river, but southward from the northern boundary he would still have almost an equal scarcity of rock exposure, were he to set out again to the Iowa boundary line. In the flat country south of Rainy river, extending as far as the divide between Red lake and lake Pemidji, there are a few outcrops of crystalline rock in the valleys of the Big Fork river and perhaps of the upper tributaries of Red lake. But that district is in general deeply buried under a sheet of drift similar in composition to that of the Red river valley, but less perfectly drained. The drift then is so thick in the region of lakes Pemidji and Winnibigoshish, and generally throughout the central portion of the state, that it does not afford another rock-exposure until reaching the vicinity of Motley. Rock is seen in scattered patches in Todd, Morrison Mille Lacs, Kanabec, Stearns, Benton and Sherburne counties, as well as at Pokegama falls on the upper Mississippi. But toward the south farther, except in the valleys of the Minnesota and Blue Earth rivers, the drift everywhere conceals the rock with an unbroken mantle from 100 to 200 and sometimes 300 feet thick.

East of the meridian passing through the west end of Rainy lake, the rock is more and more frequently seen projecting above the drift, both along the Iowa boundary and in the central and northern portions of the state, especially in the valleys of streams that flow eastward. There is a tract of the state heavily covered by drift east of Pokegama falls, including the St. Louis valley and its upper tributaries, in which many of the streams that enter lake Superior in the state of Minnesota take their rise; but for the most part in the eastern half of the state the streams expose the rock more and more frequently, indicating an attenuation of the drift sheet toward the east, so that at last they become continuously rock-bound. The drift fades out, on the north, toward the rock-bound shore of lake Superior, as remarkably evinced along the international boundary, and on the south toward the ancient equally rocky valley formed by the St. Croix and the Mississippi.

The diversified nature of the drift cannot be so briefly described. It may be divided under three general distinctions, viz., *till*, *stratified sand and gravel*, and *stratified clay*.

Till. In general the entire drift-sheet might be said to consist of till, that confused mixture of sand, gravel and clay which is believed to be the product of glaciers, or land ice, since the other parts are insignificant in amount and area compared to it, and since they have been derived from it by the assorting and distributing action of water. When two or more of these parts exist at the same place the till always lies at the bottom. Where the drift prevails the most of the surface is till, but it fades out in the southeastern corner of Minnesota, and in its place is found a water-deposited fine clay or loam. This covers Houston, Winona and Wabasha counties, and the eastern portions of Goodhue, Olmsted and Fillmore. Its western area is underlain by till which increases in amount toward the west and finally rises to and forms the surface. This belt, occupied by the vanishing western edge of the loam, crosses Fillmore, Olmsted, western Goodhue, western Dakota and Washington counties. In a similar manner, but from a different cause, the till is found wanting in the northeastern corner of the state, but here no loam takes its place. This driftless region is found to the north and east of Vermilion lake and Net lake. The rocks in this part of the state are bare, and as they consist of the crystalline terranes, the depressions hold numerous lakes which are connected with each other by streams that plunge from one rock shelf to another in their descent to Rainy lake or to lake Superior. Another variation and exception to the almost uniform till surface in Minnesota is found in the northwestern corner of the state. This differs from the northeastern and the southeastern in having an unusually thick and uniform mantle consisting of both till and loam, the latter overlying and separated from the till by a sudden and distinct line of demarcation. This area of loam-covered till not only occupies the valley of the Red river of the North, from lake Traverse to St. Vincent but spreads eastward, covering much of the country to Red lake, the Big Fork river and Rainy river. Toward the south it tapers to very narrow limits and ceases at Brown's Valley. In the southwestern corner of the state is found still another modification of the till. While in the northwest it passes vertically from till to loam, though by a marked line of separation, in Rock and Pipestone counties it changes horizontally into loam, by a gradual and imperceptible transition from the characters of one deposit to those of the other. This change begins in central Pipestone county, and is completed before reaching the southern boundary of Rock county. At first the loam is confined to the surface, but it increases in depth toward the south, and the till gradually becomes converted to a pebbly clay and finally to a loam that shows the action of water in its deposition. Thus the four corners of the state, drained each in its own direction from the central portion of the state, exhibit four remarkable variations from the typical sheet of till that covers the rest of Minnesota in common with much of adjoining states, and each presents an interesting problem of glacial geology. The greater part of the till is blue or gray, but throughout the northeastern and much of the east-central portions of the state it is red, or has the color of non-hydrated iron-peroxide.

Gravel and Sand. Along the valley of the Mississippi river, and also of most of the larger valleys of the state which drain southerly, are found deposits of stratified gravel and sand. These are not everywhere present along these valleys, but instead of them the surface consists of clay or of till; and in many large tracts they are not found at all. Below St. Paul this gravel-and-sand is confined to the river gorge, and constitutes a high-terrace flat. Such a terrace also skirts the St. Croix valley as far north as Taylor's Falls, the Root river and Zumbro valleys, and that of the lower Minnesota. Above St. Paul such stratified gravel-and-sand deposits are found more generally, and sometimes are spread over extensive plains, though still occupying restricted areas. Such plains are found along the St. Louis river and its upper tributaries; along the Mississippi and its tributaries in Cass, Wadena, Benton, Sherburne and Stearns counties; also along the Pomme de Terre and Chippewa, and the Otter Tail and Crow rivers. These are not always immediately tributary to any present drainage valley, but frequently exist as isolated plains, particularly in Cass, Wadena, Meeker, Kandiyohi and Stearns counties. They are, however, in that case so grouped as to suggest a former direction of drainage of the local water-courses different from that of the present. In most cases this gravel-and-sand deposit lies on the till, and in numerous instances it is covered by a finer sand into which it sometimes graduates by imperceptible changes, which sand in the same manner also graduates into fine clay.

Besides these plains of superficial gravel and sand there are extensive beds of the same material embraced lenticularly within the till. These are specially frequent, and constitute a large portion of the drift in the rolling or broken tracts which cross the state, including the *Leaf hills*, the *Mesabi hights* and the *Coteau des Prairies*. They are the open mouths of water-reservoirs which penetrate within the drift-sheet and below it, and give rise to the artesian wells that occur on the lower till-covered portions, and from which issue the springs that feed the highest sources of the great rivers of the state.

Stratified clay. If the loam which covers the southeastern portions of the state, including the counties of Houston, Winona, Wabasha, with portions of Goodhue, Olmsted and Fillmore, be included under such designation, the most important and extensive tracts of stratified clay are found to occur in the most widely separated corners of the state, viz: the northwestern and the southeastern. These clays, however, which have been deposited by the Red river of the North and by the Mississippi, respectively, at some former higher stage, exhibit very different chemical and physical characters. That of the Red river valley is gray, or blue, when unweathered, is compact and impervious without noteworthy exceptions, and lies on a great thickness of blue till, from which, however, it is sometimes separated by an ancient soil-surface or by a bed of vegetable remains. While its largest constituents are alumina and silica, its differential characters are due to the presence of a considerable percentage of the alkaline earths and alkalies, which give a peculiar nature not only to the soils, but also to the waters that are associated with it. That of the Mississippi valley below St. Paul, and especially below Red Wing, is of a yellowish, or yellowish-red color, or like powdered impure limonite, is not conspicuously laminated, though it is so quite distinctly in some places, and frequently becomes so sandy as hardly to justify the name of *clay*. It lies generally upon the rocky surface, only a few angular fragments of the rock of the country, and of weathered chert being embraced in its lowest parts; but toward the west it overlaps the till, and its distinctive features gradually fade out as those of the till increase. The waters that drain it are chalybeate and calcareous, never alkaline, and the soils it forms vary from a fine, stoneless clay to a sandy loam. It makes red brick and pottery, while those made from the clay of the Red river valley are cream-colored. Besides these large areas covered by stratified clay, which may be taken as types, there are numerous smaller areas scattered through the interior of the state, evidently dependent upon the former or present operation of a large stream or lake, which belong to one or the other kind, but also sometimes exhibit a union of the chemical and physical characters of both. Such occur in Carver, Hennepin, Anoka, Meeker, Wright, Blue Earth and Crow Wing counties, and in several others. There is also about the west end of lake Superior a bright red stratified clay, seen at Duluth, and rising to the hight of about 450 feet above the lake. This seems to have been spread by the waters of lake Superior when they stood about 500 feet higher, though probably carried into the lake by the St. Louis and other streams from the red till which characterizes the drift of that district.

III. THE SURFACE CONFIGURATION OF DIFFERENT PARTS OF THE STATE.

The only part of Minnesota that may be styled mountainous is in the northeastern triangle included between the international boundary line, lake Superior and Vermilion lake; and much of this is heavily drift-covered, with a moderately rolling or undulating surface. But there are mountain peaks along the shore of lake Superior, and in the northern part of Cook and Lake counties that rise from 1600 to 1800 feet above the level of the ocean. There are also hill ranges or mountains, particularly those known as the *Sawteeth*, the *Mesabi* and the *Giant's* ranges, which maintain a broken outline, consisting of crystalline rock, and rising from 1200 to 1500 feet above lake Superior, or about 2000 feet above the sea. Westward from this mountainous tract the state shows moderate undulations of level, which primarily are due probably to the general contour of the rocky surface; but as the immediate surface is composed of drift, the configuration is dependent on the manner of deposition and accumulation of the surface materials.

Throughout northern Minnesota west of Vermilion lake, extending as far south as the sources of the Big Fork and of Red Lake river, and along the western boundary to Yellow Medicine county, the country is generally flat, like that which is known as the Red river valley; this is terminated by the Coteau des Prairies, which introduces a change of level amounting to 400–500 feet within a few miles, though the surface contour becomes nearly as uniform again after passing the hights of the Coteau.

East of the Coteau, after a rather abrupt descent of 300–400 feet, the flats of the Minnesota valley are reached. These flats are about one hundred miles wide, and include the counties of Lac qui Parle, Yellow Medicine, Redwood, Brown, Watonwan, Martin, Blue Earth and Faribault on the south side; and Nicollet, Sibley, Carver, McLeod, Renville, Kandiyohi, Chippewa, Swift, Big Stone, Traverse, Stevens and Grant, on the north side of the Minnesota river. Several other counties adjoining these are nearly equally flat, but they are on the drainage slopes to the Mississippi or the Red river of the North. The counties of Mower, Dodge, Steele and Waseca, with much of Freeborn and Le Sueur, are also flat.

The region of the upper Mississippi, above the mouth of the Minnesota river, has in general a much more diversified surface than the valley of the Minnesota. It is marked by numerous low, hill-ranges, and isolated or clustered knobs, consisting of drift, usually till, which give rise to numerous lakes and springs. A conspicuous range, known as the Leaf mountains, rises in Otter Tail and Douglas counties, and extending southeasterly, sinks away in northern Kandiyohi and Meeker counties; but is re-enforced by a branch coming from the north through Todd, Stearns, and Wright counties. It extends through Hennepin, western Dakota, western Rice, Steele and Freeborn counties into the state of Iowa, where it is believed to swing round to the west, returning thence northward upon the *Coteau des Prairies*, which crosses Nobles, Murray, Pipestone and Lincoln counties. Toward the north from Otter Tail county it produces a belt of rolling land through Becker and southern Beltrami and Itasca counties, where it embraces the ultimate sources of the great rivers of the state and of the continent; and in the central portion of St. Louis county blends with the *Mesabi range*, which, partly as a drift moraine and partly as a range of rock-formed hills, extends to the eastern extremity of the state near Pigeon point.

In the midst of this broken tract of the upper Mississippi are flat and sandy areas in the central part of the state, characterized by an abundance of *Pinus Banksiana*, which include much of the region from Leech lake to the Crow Wing and Leaf rivers and Otter Tail lake, and on the east of the Mississippi embrace much of Crow Wing and eastern Morrison counties. Similar flat and sandy tracts are found in Carlton and Pine counties, though not so uniformly characterized by the same species of pine.

In the southeastern portion of the state the surface is broken and hilly, the contour depending immediately on the form of the rocky surface overspread with a sheet of fine loam. This configuration is due to the erosion of deep valleys in the horizontal strata in former ages, without the supplementary planing and filling process of the glacial epoch. Hence the changes of level are abrupt, as bench after bench of the rocky substructure is brought to form the surface. The benches are often separated from each other by wide plains of fertile soil, but along the river-courses they are brought into juxtaposition, and furnish instructive opportunities for making out the stratigraphic geology of the Cambrian and Lower Silurian rocks. This topography is most perfectly illustrated in those counties that border on the Mississippi river below St. Paul. It gradually becomes less conspicuous toward the west, on account of the feebler erosive action of drainage at points removed from the main valley, and also because the drift materials begin to be insinuated within and beneath the loam of that region, preventing the rocky substructure from expressing itself in the topography.

IV. THE RELATIVE ELEVATION OF DIFFERENT PARTS OF THE STATE.

Lake Superior is 602 feet above the sea; and a narrow tract bordering the shore of that lake, including the valley of the St. Louis river as far as Fond du Lac, is the lowest land in the state. The Mississippi river where it leaves Minnesota is 620 feet above the sea. The valleys of the streams in Houston, Winona, Wabasha and Goodhue counties are but little elevated above that river, and probably should be classed, as a group, next higher. But these valleys are narrow, and the adjoining surface rises rapidly to the hight of about 1000 feet above the sea, sometimes reaching 1200 feet. The Red river of the North leaves the state with an elevation of 767 feet above the sea, and the adjoining land is flat, with but a slightly greater elevation. The thousand foot contour-line in the southeastern and northeastern corners of the state runs very near the Mississippi river and lake Superior respectively, but in the northwestern corner it is separated from the valley of the Red river of the North by an intervening tract of flat land thirty or forty miles wide, and above it the same plain extends a great distance further east. In the southwestern corner of the state the Rock river, and the tributaries of the Big Sioux river, pass the state line with an elevation of about 1300 feet above the sea. The surrounding country is about 200 feet higher, and a few miles further northeast, on the Coteau des Prairies, the general level is from 1800 to 1900 feet above the sea. The lowest portion of the state is in close proximity to the highest, which latter is in the Mesabi range north of lake Superior and attains an altitude of a little more than 2200 feet above the sea.

The general surface of the state slopes from the north-central portion in all four directions towards its distant and opposite corners, although there are greater elevations in the northeastern and in the southwestern corners. The region west of Itasca lake rises somewhat more than 1600 feet above the sea, and the Leaf hills in Otter Tail county about 1700 feet.

The great trough which crosses the state from northwest to southeast formed by the Red river of the North, the Minnesota and the Mississippi rivers, has its greatest elevation at Brown's Valley, which is 975 feet above tide. The thousand foot contour-line which bounds the valley on the northeast enters Minnesota from Manitoba about forty-five miles east of the Red river of the North. Its general course is nearly south to lake Traverse. It passes along the immediate bluffs of that lake and Big Stone lake, and thence follows the bluffs of the Minnesota nearly to New Ulm, where it begins to turn northward through northern Nicollet county. Thence it crosses the counties of Sibley, McLeod, Wright, and the eastern part of Stearns. It crosses the Mississippi about six miles above Sauk Rapids. It thence passes tortuously through Sherburne, Isanti, Kanabec and Pine counties, leaving the state where the St. Croix river begins to form its eastern boundary. On the south side the same contour line begins at the foot of Big Stone lake and, following the bluffs of the Minnesota nearly to New Ulm, it thence winds its way over the prairies of Brown and Watonwan counties, under the influence of the Cottonwood and Watonwan rivers; enters Blue Earth county where it is in the same way modified by the Blue Earth river and its tributaries, and barely enters the north side of Faribault county. It passes through Le Sueur and Scott counties east of their centers, and nearly reaches St. Paul, but in the elevated parts of Dakota county it is suddenly deflected southward, and maintains a very crooked course among the bluffs of Goodhue and the southeastern counties, leaving the state near the summits of the bluffs of the Mississippi in Houston county. In the northeastern part of the state this contour-line includes a small part of the St. Louis valley and a narrow strip along the shore of lake Superior as far as the hills of Grand Portage.

ELEVATION OF LAKES ABOVE TIDE-WATER.

	Feet.
Lake of the Woods,	1025
Lake Saganaga,	1518
Vermilion lake,	1511
Rainy lake,	1150
Red lake,	1140
Itasca lake,	1500
Cass lake,	1300
Winnibigoshish lake,	1290
Leech lake,	1292
Mille Lacs,	1246
Otter Tail lake,	1325
Lake Whipple,	1134
Lake Traverse,	970
Big Stone lake,	962
Lake Minnetonka,	922
Swan lake, (Nicollet Co.)	970
Heron lake, (Jackson Co.)	1403
Lake Benton, (Lincoln Co.)	1754
Lake Shetek,	1475
Lake Pepin,	664

Lake St. Croix,	672
White Bear lake,	910

ELEVATION OF HILLS, VALLEYS AND PLATEAUS.

Red river flats at Moorhead,	913
Red river flats at St. Vincent,	800
Coteau des Prairies,	1800–1900
Prairies of the Minnesota valley,	1000–1200
Prairies of Waseca and Steele counties,	1100–1200
Prairies of Freeborn and Mower counties,	1200–1400
The valley lands of the Mississippi and its tributaries in the counties of Houston, Fillmore, Winona, Wabasha and Goodhue,	650– 900
The upland prairies of the same counties,	1000–1200
The wooded region of the upper Mississippi,	1200–1500.
The wooded flats between Cass lake and lake of the Woods,	1100–1400
The summits of the Giant's range,	2100–2200
The summits of the Mesabi range,	2100–2200
The summits of the Sawteeth range,	1800–2000
Rolling plateau surrounding Itasca lake,	1500–1700
Leaf hills, in Otter Tail county,	1500–1750

V. THE KINDS AND DISTRIBUTION OF THE SOILS AND SUB-SOILS.

There is an element in the arable soils of Minnesota which gives them a general uniform similarity whatever be their origin or chemical qualities. *They are seldom stony.* The materials are almost everywhere finely comminuted, constituting a clay, or a loam, or a sandy loam, or a pebbly clay. Even where the till rises to the surface and constitutes the soil, the chief ingredient is clay, and the stones that naturally belong to the till are so few that none are found to interfere with agriculture. The areas of stony soils are restricted to the broken tracts associated with the great moraines that cross the state, and to the slopes or tops of hills where drainage has so denuded the till-surfaces that the stones it contained have been concentrated.

The character and composition of the soils of the state are dependent on two general causes; (1) the nature of the subsoil, (2) the local modifying circumstances, the chief of which is in the nature of the local drainage.

(1) *The nature of the subsoil.* As an element in the production and modification of soil, the subsoil is most potential. Into it vegetation sends its principal roots, and from it rise, by osmose the salts that renew the surface soil when impoverished by cropping or by unfavorable drainage, or by drouth. The soil may be said to be the comminuted and modified upper surface of the subsoil. The subsoils may be grouped under four divisions:

Subsoils of blue till.
Subsoils of red till.
Subsoils of gravel or of sand.
Subsoils of clay or of clay-loam.

Whether the subsoil consist of blue till or of red, its physical characters are nearly the same, except that the blue till is generally closer and more impervious than the red, and is less stony; but its chemical characteristics will differ considerably according as it is blue or red. There is nothing of importance in the difference of color. The color simply indicates the origin of the till, and its accompanying qualities. The *blue till*, in general, is derived from the disintegration of the *Cretaceous*, and the red from *Cambrian*, though there are exceptions, and a blue till is also produced by the other formations. It so happens, however, that in Minnesota a large proportion of the clayey parts of the blue till can be referred to the *Cretaceous*, with as much certainty as the red to the *Cambrian*. The Cretaceous being a marine deposit, of an age when the ocean's waters in the interior of North America were charged with the salts of the alkalies and of the alkaline earths, the till resulting from its disintegration and distribution necessarily exhibits the same qualities: and as the soil is dependent largely on the subsoil for its characteristic chemical qualities, it follows that soils based primarily on the blue till in Minnesota will exhibit the same alkaline characters. Such is the case. Soils based directly on the Cretaceous rocks, without the intervention of any sheet of drift, as in western Dakota and in Montana, exhibit these chemical qualities still more strongly. Such soils are naturally supplied with abundance of soda, lime, magnesia and potash, and they constitute by far the largest part of the immediate surface of the state. With the exception of the soils based on the lacustrine clays of the Red river of the North, and those in the southeastern part of the state based on the löess-loam, the entire prairie part of the state is characterized by such soils. In addition to this, the same blue till underlies much of the timbered area of the state, in most places extending to the east of the Mississippi river, and including Scott and Le Sueur counties east of the lower Minnesota. Still the characteristic qualities of the blue till of the prairie regions become less and less marked toward the east, and in the timbered areas generally the soils would not correctly be denominated alkaline.

Subsoils of *red till* differ from those of blue till in containing a high percentage of iron-oxide, and little or none of the salts of the alkalies. They are generally calcareous, but less calcareous than those of the blue till. They are found distributed from Pigeon river, on the international boundary, southwestward, coincident with the strike of the Cupriferous or Potsdam formation. They form the surface as far as St. Paul, and eastern Hennepin county; and further southwest they are covered by the blue till. Toward the south and southeast from St. Paul they gradually blend with the eastern outrunning limit of the blue-till subsoils on the west and with the clay-loam subsoils of the "driftless area" on the east. Thus it will be seen that the blue and red tills give the dominant characters to the soils of the largest part of the state, and that of these the blue till is the most important.

Subsoils of *gravel, or of sand.* result from the superficial modification of the till of the region. They are always underlain, at a less or greater depth, by a till sheet, and if wells penetrate them they obtain the characteristic water. These subsoils give little effect to the chemical nature of the soils based on them, but on their successful cultivation they have a powerful influence, since they are quickly susceptible to the changes of climate, and the variations of local drainage. In certain seasons they are more productive than the soils based on a clay subsoil, and in others they are nearly sterile. Such subsoils prevail in the higher areas of modified drift along the principal water-courses, accompanied, in the proper latitude, by the black pine *(Pinus Banksiana)*, and in the plains of modified drift isolated from the rivers, as well as in the rolling gravelly (and stony) parts of the Leaf hills moraine. The same subsoils, but more fine, may be said to exist where the löess-loam of the southeastern part of the state becomes so sandy as to show very little clay, as in the upper part of the high terrace below St. Paul, and the terrace flat on which Minneapolis is situated. This is also seen in much of eastern Dakota county, in northern Ramsey and in Anoka counties.

Subsoils of *clay or clay-loam* are found, especially, in the lacustrine areas of the Red river of the North, and of the Mississippi below Red Wing, also in some of the flats of the lower St. Louis and upper Mississippi. In southern and western Rock county, also, the subsoil passes from a blue till to pebbly and finely stratified clays, and these constitute a subsoil of this class. The soils based on these subsoils, possess the characteristics of the till upon which the clays lie, and from which they may be derived, but in a modified and much lessened degree. The alkaline till of the Red river region is due to the immediate disintegration of the marine Cretaceous, but the clays forming these subsoils are a fresh-water deposit; and in the act of deposition a considerable part of the soluble alkaline ingredients of the country till were carried by drainage to the ocean. The pebbly clay subsoil, however, of Rock county, is not so markedly different from the till subsoils of the region, in these chemical qualities. In the northwestern part of the state these subsoils spread eastwardly to the lake of the Woods, and along Rainy river to Rainy lake, including very much of the *Red lake and Pembina Indian reservations;* but toward the south the distinctive characters of the clay subsoil are confined to a narrow belt on the east side of the Red river of of the North, and disappear entirely at Traverse lake. The clay subsoils can easily be distinguished from the blue till subsoils of the same valley, since where they prevail no stones or boulders appear on the surface. These are seen scatteringly in passing eastwardly upon the subsoils of till. Subsoils of this class in the northeastern part of the state are found in the St. Louis valley, below Fond du Lac, and above Knife falls. The flats of the East Savannah river, and of Leech Lake river are based on a clay subsoil. In the southeastern part of the state the soils of the löess-loam are based on a clay subsoil, though sometimes this is too sandy to be styled clay. Such are found throughout Houston, Winona, Wabasha and most of Goodhue counties, and the eastern portions of Washington, Dakota, Rice, Olmsted and Fillmore. Such soils are remarkable for their mellowness and their diversified capabilities.

(2) *The local modifying circumstances.* The local circumstances, due mainly to difference of drainage, sometimes so modify the primary drift soils dependent on the nature of the original drift, as to completely mask their essential and characteristic qualities. If the natural drainage has been imperfect for a long period of time the original soil will become blackened by accumulated carbonaceous matter, or whitened by the evaporation of calcareous waters, or reddened by iron from chalybeate waters. If these processes be carried on to excess, the resultant material is a peat, a marl, or a bog-ore. There are all shades of gradations between these substances and the original soils which they modify, and though they occupy but a comparatively small portion of the area of the state, they are distributed from north to south throughout its whole extent. The peaty, or mucky, soils are more extensive than the others, and are found both in the rolling timbered parts, and in the prairies. The accumulated vegetation sometimes blackens the loams and the subsoils to the depth of six, or even ten, feet. This is due not alone to the growth and decay of vegetation on the spot, but also to the inflow of carbon by surface washing from the surrounding areas. Calcareous or marly soils, are frequently found in the region of the upper Mississippi, and in regions where the drift contains much limestone gravel and stones. Strongly alkaline soils are found in low grounds in the region of the unmodified blue till, and reddened or ferruginous soils occur in the eastern part of the state where waters draining from non-calcareous gravels and sands, evaporate in lower grounds.

In addition to the influence of natural drainage on the original soils, another important cause has operated to blacken and enrich the soils of the entire prairie region of the state. The fires which have destroyed the grass of the prairies for many successive years, have annually deposited on the surface a residuum of charred unconsumed matter, which has entered within the soils and blackened them to varying depths, so that nearly everywhere the surface soil of Minnesota is a rich black loam, the same fires having operated to calcine and disintegrate the few stones of the till which happened to be within their reach.

VI. THE LAKES AND RIVERS, AND THE QUALITIES OF THE WATERS OF THE DIFFERENT PORTIONS.

Lakes. The number of lakes in Minnesota is about ten thousand. These can be divided into three classes based on their origin and topographical surroundings; but the classes fade into each other along the boundaries of the areas containing them, in proportion as the elements that go to make up their characteristics become less powerful and are replaced by others. Sometimes a large lake partakes of the characters of two or of all these classes, like Mille Lacs, and like lake of the Woods.

1. Lakes of the morainic till areas.
2. Lakes of the modified drift areas.
3. Lakes of the areas of bare rock.

Lakes of the morainic till areas. This is by far the most numerous and important class, embracing more than three-fourths of all the lakes in the state. The most remarkable and characteristic of these areas is that known as the *Leaf hills* or *park region* in Becker and Otter Tail counties, where the lakes are so numerous that to the observer one-half of the surface seems to be covered by water. This area, however, extends northward and southward, and in some other parts of its development it shows almost an equal profusion of small, deep lakes. This is true in some parts of Douglas, Carver, Hennepin and Le Sueur counties. This belt of lakes crosses the state to the Iowa line, including much of Scott, Le Sueur, and Freeborn counties, and the western portions of Dakota and Rice counties. It does not show so many lakes in Waseca and eastern Blue Earth. Toward the north and east this series of lakes, though less remarkable, includes the region of Itasca lake, Turtle lake and the "Julian sources" of Beltrami, the lakes that feed the Big Fork river, flowing northward, as well as those that are drained southward by the Mississippi, the Prairie and Swan rivers. Toward the east further it accompanies the *Mesabi range*, and supplies the numerous streams that enter lake Superior, terminating in the Indian reservation near Pigeon point, where some of its lakes exhibit also some of the characters of Class No. 3. This belt of lakes varies in width from ten to fifty miles, and embraces Leech and Winnibigoshish lakes, two of the largest lakes of the state, though they do not perfectly illustrate the lakes of the first class. Lake Minnetonka, in Hennepin county, is most perfectly typical of the lakes of this class.

The lakes of the Coteau des Prairies which crosses the southwestern corner of the state from Lincoln county to Jackson county, belong to the first class, but they are not so thickly spread over the country as those of the central part of the state. Another important area of till-based lakes stretches southeastward from Leech lake to Mille Lacs, and another from Ramsey county northward to southern Pine county. The lakes of the last area, however, are not characteristically based on rolling till, but frequently involve the features of the second class.

Lakes of the modified drift areas. These are found in the level or undulating portions of the state where the till, which is usually the material which confines their waters, is superficially covered with stratified clay or sand and gravel. They are comparatively rare, and usually shallow, but they constitute the largest lakes of the state. Red lake belongs to this class, being the largest in Minnesota, containing about 340 square miles. The northern shores of Leech lake, and the southwestern of the lake of the Woods exhibit the characters of this class. Such lakes are scattered sparsely over the central portions of the state in Cass and Wadena and in southern St. Louis counties. Some of those in northern Ramsey are lakes of this character.

Lakes of the areas of bare rock. These have rocky basins, and are due to the immediate contour of the rocky surface. The lakes of the northern boundary of the state, from the west end of Rainy lake to lake Superior, and the numerous clear lakes that lie on either side of the boundary, illustrate this class. The surface has been subjected to severe glaciation, but for some reason the drift is almost wholly wanting. The lakes take the shapes of the depressions of the rocky contour. They are very numerous, with tortuous and bold shores. They are connected by lively streams that have frequent rapids and cascades. There are here no deep rock-gorges cut by drainage courses, but the surface is that left by the glacier, and the water simply gets from one basin to another by filling them up and overrunning their rims. Lake Superior itself is a stupendous example of the same class, though its rock-rim was formerly covered by drift throughout much of its extent. This has largely been washed off in Minnesota to the hight of about 500 feet above its present level, by the former action of its own waves which have left terraces and other water-marks up to that hight. The lakes of this class extend southward to Vermilion lake, and there they begin to blend with those of the first class. Southwest of Rainy lake they blend with those of the second class. The northern portions of Rainy lake, and of lake of the Woods, exemplify the characters of this class, but the southern portions belong to the second class.

Lakes Traverse and Big Stone, on the western boundary of the state, and St. Croix and Pepin on the eastern, do not belong to either of these classes. They are simply expansions in old river-valleys, not yet filled with sediment; the former excavated in the drift sheet,* and the latter in the Cambrian rocks.

Rivers. The waters of the state all find their way to the Atlantic ocean, but they reach that level through three of the cardinal points of the compass—north, east and south. The French and English geographers of the last century also located in Minnesota the source of another great river which reached the Pacific ocean toward the west. This river, which was designated as the "river of the west" was sometimes thought to be the Oregon, sometimes the Rio Colorado, and sometimes was confounded with the Saskatchewan river that enters the north end of lake Winnipeg from the west. Without this great western river, however, Minnesota occupies in a pre-eminent degree the summit divide of the waters of North America, at least so far as they exist within the United States. The hight of the main divide in the state, in the region west and southwest of Itasca lake, rises between 1600 and 1700 feet above the sea, and the average elevation of the entire state is probably not far from 1275 feet above the sea, the border of lake Superior, the lowest land within the state, being 602 feet. Hence, the streams which drain the surface area amounting to about 84,286.53 square miles, are not characterized by water-falls and rapids, but by their crooked courses and gentle, generally navigable, currents.

The water area of the state is greater than that of any state or terri-

*And partly in the Cretaceous.

tory in the Union, being 5,637.53 square miles, without including any part of lake Superior.* This averages one square mile of water to every fifteen of land for the entire state. This unprecedented water supply leaves the state by the valleys of seven different rivers, viz: the Mississippi, the St. Louis and lake Superior, the Red river of the North, the Rainy river, the Des Moines river, the Rock river, and the Cedar river.

The Mississippi river system. By far the largest and most important of these drainage systems is that of the Mississippi. It is the only one that crosses the entire state. It includes the most of the area of the great water-shed formed by the morainic deposits in the central portions of the state, its whole area being approximately 45,566 square miles. The upper Mississippi drains the timbered regions, and the Minnesota the southern prairie portions of Minnesota. It runs almost exclusively on the surface of the drift to the falls of St. Anthony, and from there till it leaves the state, and even till it enters the gulf of Mexico, it runs in an old, rocky valley excavated in pre-glacial times. All its tributaries, also, below the falls of St. Anthony enter it through similar, deep-cut gorges. The other tributaries of this river, however, are post-glacial, and have excavated their valleys but little within the drift sheet. They rarely reveal the bed-rock. As the area drained by the upper Mississippi, as well indeed as that of the whole state, may be taken all together, as a great, but slightly roughened, or undulating plain, the valleys exhibit great monotony in their topography and other features.

The system of the Red river of the North. The Red river of the North rises in the same rolling region as the Mississippi, at a point about twelve miles west of Itasca lake, at an elevation of 1600 feet above the ocean, and leaves the state, after a circuitous route by the south, with an elevation of 767 feet. The entire area is heavily covered with northern drift, and after leaving the rolling morainic regions of Becker and Otter Tail counties, the river passes through the fertile "Red river valley," which in its flatness and monotony, no less than its area, resembles the northern steppes of Russia and Siberia, to which also it seems to have had an analogous origin. The aggregate area of the state drained by this river is 15,107 square miles, and

*Mr. Gannett, in the Census Report for 1880, gives Minnesota 4160 sq. ms. of water area, but does not include any part of the lake of the Woods, nor of Rainy lake. Minnesota extends 28 miles north of the 49th parallel, and one half the square of that is taken for her share of the lake of the Woods. A similar estimate is made for her portion of Rainy lake, including Namekan bay in that lake.

the river is navigated by steamboats as far south as Moorhead. When the river is high its waters are connected with those of the Mississippi through the valley of lakes Traverse and Big Stone, and boats can pass from the Mississippi to lake Winnipeg in Canada, without unlading.* Indeed there is every evidence of the former existence of a river passing through this valley and draining the waters of the Red river of the North, and lake Winnipeg, by way of the Minnesota to the Mississippi. The flat portion of this drainage area is generally one of prairie, but it extends in its northern part far to the east, embracing Red lake and its tributaries, and includes a large area that is timbered, the prairie-belt at St. Vincent being not more than fifteen miles wide, east of the river.

The Rainy river drainage system has an approximate area, in Minnesota, of 10,330 square miles. It extends along the international boundary from the water-divide between North and South lakes to the "north-west point" of the lake of the Woods. Its waters are derived from the lakes of the "region of bare rock," as far as to the west end of Rainy lake. To the west of that there are several tributaries from the south which rise in the northern sweep of the belt of morainic hills, and in the flat marshy tract south of Rainy river, which flow entirely upon the surface of the drift-sheet, and very rarely come in contact with the underlying rock. Its area in the state is smaller than that of the Red river of the North, but the annual discharge of water is apparently about double that from the Red river valley. It receives waters from land more than two thousand feet above the ocean, and where it leaves the state it has an altitude, in the lake of the Woods, of 1025 feet.† This area also was formerly drained wholly or in part, by the Mississippi. There is a continuous river valley between the southern end of Bow String lake and lake Winnibigoshish, in which in time of freshet there is a continuous water-course from the Mississippi to Hudson's bay. In the same manner, but among the rocks of the northeastern part of the state, the North and South lakes, which are tributary, respectively, to the Rainy river system and the St. Lawrence system, on

*This was attempted in 1859 by Capt. John B. Davis, with a small, flat-bottomed, square-bowed boat, named the *Freighter*, owned and run by himself; but he was compelled to abandon his boat about ten miles below Big Stone lake, on account of the subsidence of the water and the desertion of his crew. The boat was pillaged and nearly destroyed by the Indians, but the timbers of its bottom were still visible in 1879. Capt. Davis stated that if he had started twenty or thirty days sooner, he would have got through with little trouble.

†The elevation of the lake of the Woods here given is that determined by the the U. S. northern boundary commission, Maj. W. J. Twining, chief astronomer, based on Fort Pembina at 760 ft., all determined by a series of barometric observations. Daily means for one year were reduced with this result. The geological report of Canada for 1874 gives the elevation of the lake of the Woods, hy the Canada Pacific R. R. survey, at 1042, which is the same figure as that of the astronomical station of the northern boundary commission at the "northwest angle."

opposite sides of the water divide, have the same level, and probably constitute one connected body of water, although they have no visible over-land connection. A short, low portage trail unites them, and constitutes the international boundary line.

The St. Louis and lake Superior drainage system includes 8,552 square miles, not counting any portion of lake Superior itself. Taken altogether this is the most elevated and most hilly portion of the state. Its waters descend, with frequent cascades, from over 2200 feet above the sea to 602 feet, the level of lake Superior, the most rapid fall being within five or ten miles of that lake, and sometimes within two. The upland is a high rock-plateau marked by three mountain ranges, a large part of the northernmost, or Giant's range, however, being tributary to the Rainy river system. The waters of this system have at present no visible over-land communication with those of the Mississippi; but in glacial times, when the volumes of all the streams and lakes were many times greater than now, and lake Superior stood five hundred feet above its present level, or 1100 feet above the ocean, it had a continuous water-channel through the Moose and Kettle rivers to the St. Croix and thus to the Mississippi.* It appears, therefore, that anciently the whole drainage of the interior of North America may have been carried to the ocean through its main water-way, the Mississippi.

The Des Moines river runs along the northeast side of the Coteau des Prairies from which it receives numerous small tributaries, and carries off the surface waters from an area of prairie, in Minnesota, equal to about 1940 square miles. As this water finally reaches the Mississippi, it might perhaps with propriety be embraced in the drainage system of that river.

The Rock river system, which is tributary to the Missouri river through the Big Sioux, includes about 1702 square miles, and embraces Nobles, Rock and Pipestone counties in the southwestern corner of the state. This system is confined to the southwesterly slopes of the Coteau des Prairies, and the surface is smooth and treeless.

The Cedar river system, which is also connected with the Mississippi through the state of Iowa, is the smallest of the seven drainage areas of the

*See the *American Journal of Science and Arts* (3), II. 15, for an account of another ancient outlet of lake Superior into lake Michigan. Lake Michigan was tributary to the Mississippi through the Illinois, and lake Erie to the Mississippi through the Wabash river in Indiana.

state, embracing but 1089 square miles of prairie situated mostly in Freeborn and Mower counties.

Qualities of the natural surface waters in Minnesota. The natural waters of the lakes and streams of the state may be classed in two main divisions, viz., *the alkaline and hard waters*, and the *chalybeate and soft waters.* These qualities mix in many streams and lakes, indeed in most of them. The natural waters of the Red river valley may be taken as a type of the former class, and those of the Pigeon river, or of any of the streams that enter lake Superior below Duluth, as types of the second class. What has been said respecting the nature and distribution of the drift and the subsoils of the state, should be borne in mind in considering the nature of the impurities of surface waters in different parts of the state, since the cause of one is the cause of the other. They both depend on the nature of the underlying till, or, in the absence of till, of the bedded rocks. The chemical peculiarities of the blue, or gray northwestern till are impressed on, and even are made manifest by, the surface waters. Hence we find *the alkaline and hard waters* occupying the most of the state, but having their characters less and less marked in the eastern portion; we find the *irony and soft waters* draining the surfaces of red till, or, in its absence, of bare rock in the northern part of the state.

VII. THE NATURE AND DISTRIBUTION OF THE NATIVE FOREST AND ITS RELATION TO THE PRAIRIES.

The state has about 31,800 square miles of prairie, and about 52,200 square miles of forest, including in each the water-areas adjacent or embraced within them. In this area of prairie, however, is included a belt of thinly forested country which is interspersed both with prairie and timbered patches, the forest being reckoned to extend only to the limit of large trees and having a continuous margin. Some parts of the prairie portion also embrace isolated patches of heavy timber, as in Fillmore, Houston and Blue Earth counties, as well Olmsted, Winona, Dodge and Wabasha, and along most of the river valleys. At the same time, even within the heavily timbered portions of the state, there are isolated small areas of prairie, or meadow land, but these are in low ground, and their exemption from trees cannot be attributed generally to the same cause or causes as those that have produced the great prairies of the west. Such areas are found along the lower portion of the Minnesota valley, and along the Mississippi in Benton, Sherburne and Anoka counties, and about the shallow lakes of the modified drift areas wherever they occur. There are also large areas within the timbered portions that have been desolated by fire, and although a young growth of trees is rapidly restocking them with forest, they are not now properly regarded as timbered. Of these no account is made in the foregoing statement of the amount ot prairie in Minnesota. Such burnt tracts are most numerous north and east of a line passing nortwestwardly through Mille Lacs, and still more frequent north and east of a parallel line passing through Duluth. These burnt areas are generally flat or moderately undulating, and have a light soil.

In general the line separating the prairie from the forest may be defined as follows: It enters the state from Manitoba, about sixteen miles east of of the Red river of the North, gradually diverging from the river. It crosses Red Lake river eighteen miles east of Crookston, though a large spur of timber follows the Red Lake river westward to within ten miles of Crookston. It crosses the Sand Hill river about the center of town **147.44**, where it rapidly swings east to town **144.38**, except that another important spur accompanies the north side of Wild Rice river as far west as town **144.44**. At Rice lake in town **144.38** it turns south and then west to the center of town **143.41**. Thence it again turns south to White Earth lake, and leaving the sources of Pelican river on the east, it reaches Fergus Falls, which is situated on the very margin of the timbered area. From there it swings eastward, and then southeastward, with a very crooked course to Alexandria, which is also on the margin of the native forest. Sauk Center is similarly situated. The Sauk river forms the limit of timber through Stearns county to its great bend in town **123.30**. Then the line passes southwestwardly, by the shortest distance, to the north branch of Crow river, which in a similar manner defines it to near the east line of Meeker county, where it forms another right angle and reaches the south branch of Crow river. Crossing it, however, north of Glencoe, it dodges again southwestward from Glencoe, about ten miles, when it is turned southeast along the south side of a tributary of the Minnesota, and reaches the vicinity of Henderson. It continues thence southward, to the west of St. Peter, but with considerable interruption by prairie, and crosses the Minnesota a little west of Mankato. Southward from Mankato it sends fingers of timbered land along the streams through the Undine region to the Iowa state line, and turns eastward along the Le Sueur river in Waseca county, and, with a tortuous course, reaches Faribault. It ascends the Cannon valley to Owatonna, with a width of timber on the east side of about three miles, returning abruptly from Owatonna nearly due north through Rice and Dakota counties. At fifteen miles south of St. Paul it turns east and southeast, crossing the Mississippi about five miles above Hastings. This includes the whole of Washington and Ramsey counties within the timber belt, but they are timbered in about the same manner as several of the southeastern border counties, with generally small trees and numerous openings of prairie.

As to the nature of the forests of Minnesota, the northern portion of the timbered tract is largely coniferous. The most southern area of merchantable pine was in Chisago county south of Taylor's Falls, in the valley of Lawrence creek.* Yet pine trees are scatteringly found along the bluffs of the Mississippi as far as the Iowa state line, and on some of its tributaries in Fillmore and Olmsted counties. This species is known as the white pine *(Pinus Strobus)*. It is the most broadly extended, and the most valuable of all the coniferous trees of the state. The Norway pine *(P. resinosa)* does not reach so far south, but constitutes a large and important part of the pine-supply in the central and northeastern portions of the state. The southern limit of the characteristically pine forest, or of merchantable pine, passes north and northwestward from Lawrence creek, in Chisago county, to the southwestern corner of Pine county, where it turns southwestwardly, running a few miles north of Cambridge, and along the north side of Rum river above Cambridge to Princeton, and thence nearly in a right line till it strikes the Mississippi about ten miles below the mouth of the Crow Wing river. On the immediate west bank of the Mississippi pine is found further south. The same line starts from the Mississippi about two miles south of the mouth of Swan river, and with a bend northward where it crosses the western boundary of Morrison county, it enters Todd county northeast of Long Prairie village, but passes north of Long Prairie about six miles; and thence continues northwestward to Rush lake

*This creek was named from Mr. Sam. Lawrence, who had a winter's lumber-camp in its valley and cut most of the pine then standing.

in Otter Tail county, and northward along the west side of Otter Tail river and the associated lakes, to the Rice lakes in the White Earth Indian reservation, leaving the state about twenty-five miles east of the Red river of the North. That portion of the state north and east of this line is not wholly a pine-producing area, but various species of deciduous trees constitute a large part of the forest throughout the most of it, and in some large tracts other members of the cone-bearing family make up nearly the whole. In the northern part of the state. between Red lake and the lake of the Woods, and also very generally eastward to Vermilion lake, the country is flat and poorly drained, the trees consisting largely of tamarack and spruce, with only scattering slight elevations where the white pine flourishes. The Banksian pine is found abundantly on the plains of modified drift on the upper St. Croix, and its affluents from the west, also in a similar situation on the upper waters of the St. Louis, as well as throughout the region of bare rock in the northeastern part of the state. The other coniferous species are tamarack *(Larix Americana)*, spruce *(Picea nigra* and *alba)*, white cedar *(Thuja occidentalis)*, each of which covers large tracts; balsam fir (*Abies balsamea*), which is abundantly mingled with the deciduous forests of the northern part of the state, and occurs locally as far south as the forests of northwestern Fillmore county, near the Iowa state boundary; red cedar (*Juniperus Virginiana*), which grows about the bluffs of lakes in the central part of the state, and also extends southward along the Mississippi river and other streams, to the southern boundary of the state; the American yew (*Taxus baccata*, var. *Canadensis*), which is a shrub forming dense undergrowth in the rolling forest-covered tracts in the northeastern part of the state, particularly northwest of lake Superior; juniper (*Juniperus communis*), which is mostly found in the central part, and another prostrate juniper which probably is *J. Sabina*, var. *procumbens*, found mainly in the northern part of the state. Besides these, *Tsuga Canadensis*, or hemlock, has been reported, as well as *Pinus mitis*, yellow pine, but these identifications are considered doubtful.

The deciduous forest consists principally of various species of oak, elm, bass, poplar, maple, and ash, of which the detailed distribution will be given in another chapter. Beech does not occur native, nor chestnut, but the black walnut (*Juglans nigra*) and the Kentucky coffee-tree (*Gymno-*

cladus Canadensis) are found native as far north as the valleys of the Minnesota and Cannon rivers.*

VIII. THE COMMANDING GEOGRAPHICAL AND COMMERCIAL POSITION OF THE STATE.

The geographical position and natural resources of the state of Minnesota are destined to make her one of the leading states of the Union. In agriculture, and in the manufacture of flour, she already has an advanced rank. Her facilities for diversified manufactures and for commerce, and her resources of timber and iron, not to mention copper and silver, though as yet mainly undeveloped, will in time make her the center of important and far-reaching industries, and these will lead to a corresponding position in political influence and civil institutions.

No state in the Union presents greater contrasts of natural surface than Minnesota, nor a wider range of natural resources. From the flat or undulating prairies of the southern and western counties, where for scores of miles a furrow can be turned from the primeval turf without deviating or stopping for a stone or a snag, one may pass in a few hours' travel to as rough and impassable hill ranges as can be found in America, or to as dense and majestic a "forest primeval." The first decades of a new state are given up to the easiest means of subsistence and income. It is only when the exigencies of growth and civilization begin to reach out for new fields that the more comprehensive industries of commerce and manufactures, or of mining, are brought into activity. Minnesota is at present known as a great wheat-raising state. That is natural. Her prairie soil, requiring only the plow and the seed, was the easiest of her natural resources to bring into quick development; but it should be remembered that she has within her limits equal advantages for other kinds of wealth and influence. The commanding commercial position of Minnesota, and the effect it must have on her future history, have been thus summarized by Wm. H. Seward in a public speech at St. Paul, in 1860.

WILLIAM H. SEWARD'S OPINION OF MINNESOTA.

I find myself now, for the first time upon the highlands in the center of the continent of North America, equidistant from the waters of Hudson's bay and the gulf of Mexico—from the Atlantic ocean and the ocean in which the sun sets. Here, upon the spot where spring up almost side by side so that they kiss each other, the two great rivers, the one of which, pursuing

*A few trees of black walnut once grew in the Mississippi bottoms near Nininger in Dakota county, its strange, capricious, majestic, vivacious career through lake, cascade and river-rapid, and lake after lake, and river after river, cataract and bay, and lake and rapids finally, after a course of two thousand miles, brings your commerce half way to Europe; the other, after passing through highlands and prairie a distance of two thousand miles, taking tributary after tributary, from the east to the west, bringing together waters from the western declivities of the Alleghanies, and from those which trickle down the eastern sides of the Rocky mountains, finds its way into the gulf of Mexico.

Here is the place, the central place, where the agriculture of the richest region of North America must pour out its tributes to the whole world. On the east, all along the shore of lake Superior, and west stretching in one broad plain, in a belt quite across the continent, is a country where state after state is yet to arise, and where the productions for the support of human society in other, old, crowded states, must be brought forth.

This is a commanding field; but it is commanding in regard to the destinies of this country and of this continent, as it is in regard to their commercial future; for power is not permanently to reside on the eastern slope of the Alleghany mountains, nor in the seaports. Seaports have always been overrun and controlled by the people of the interior; and the power that shall communicate and express the will of men on this continent is to be located in the Mississippi valley, and at the sources of the Mississippi and St. Lawrence.

In our day, studying perhaps what might have seemed to others trifling or visionary, I had cast about for the future and ultimate central seat of the power of the North American people. I had looked at Quebec, New Orleans, at Washington and San Francisco, and Cincinnati and St. Louis, and it had been the result of my conjecture that the seat of power for North America would yet be found in the valley of Mexico, and the glories of the Aztec capital would be surrendered, in its becoming ultimately, and at last, the capital of the United States of America. But I have corrected that view. I now believe that *the ultimate, last seat of government on this great continent will be found somewhere within a circle or radius not very far from the spot on which I stand, at the head of navigation on the Mississippi river.*

CHAPTER III.

THE BUILDING STONES

OF MINNESOTA.

BY N. H. WINCHELL.

(A.) THEIR QUALITIES AND DISTRIBUTION.

I. CRYSTALLINE ROCKS.

The first quarry in the crystalline rocks in Minnesota, was that now owned by Breen and Young at East St. Cloud, in Sherburne county. It was opened in 1868, and the stone taken out first was used in the corners, steps and trimmings of the United States custom house and post office, in St. Paul. Three kinds of stone were quarried and used indiscriminately, and all of them may be seen in the building first erected. These are Nos. 1, 6 and 7 of the following *table of the qualities of the building-stones of Minnesota.* Owing to the large content of free quartz in Nos. 6 and 7, rendering them more difficult to dress under the hammer, the use of these stones has been abandoned, and only No. 1 is now used. The stone quarried at Sauk Rapids by Searles, Collins and Mitchell, and by G. S. Reeder, is very nearly the same in all respects as No. 1 from East St. Cloud, and there is no doubt that many other localities both in Sherburne and Benton counties would afford the same. The red and gray syenite of East St. Cloud (Nos. 6 and 7), particularly the red, are also found throughout a considerable part of Benton and Sherburne counties, and also in much of Stearns county, under very favorable conditions for profitable working.

The East St. Cloud stone, now generally used, is of a gray color and uniform texture. The crystalline grains are rather fine, so that the texture is close. The color, however, is disturbed sometimes by the sudden appearance of greenish spots of the size of butternuts, or even as large as six inches in diameter, caused by the abundance of a greenish, rather softer, mineral; which seems to imply that the whole rock was originally a conglomerate containing rounded pebbles and stones of different composition, and that, on metamorphic crystallization, some of the pebbles refused to become wholly obliterated or absorbed into the homogeneous mass. Some of these may be seen in the water-table of the union depot building at St. Paul. In the most of the rock, however, these spots are not seen; and this is particularly true of the quarries at Sauk Rapids (No. 4).

The fine-grained gray granite (Nos. 1 and 4) consists largely of quartz, embraced in a matrix of orthoclase, with but a small proportion of mica or chlorite. The dark mica is biotite, and there is but occasionally a grain of hornblende. This last sometimes prevails largely over all the other minerals in small areas or veins, making a very dark-colored, and also generally a coarser-grained, rock. There is also occasionally a grain of a triclinic feldspar and of magnetite and some minute crystals of pyrite. These minerals have a relative hardness, when expressed on a scale of ten, as follows, seven being the hardness of an ordinary knife-blade, and one the hardness of soapstone.

Quartz,	7
Triclinic Feldspar,	6–7
Orthoclase,	6-6½
Hornblende	5–6
Biotite,	2½–3
Muscovite,	2–2½
Chlorite,	1–2

About one-third of the whole rock is made up of quartz and two-thirds of the remainder of orthoclase. About one-half of the rest is hornblende, and the residue is divided between the other minerals, chlorite predominating. The minerals biotite, muscovite and chlorite, which make the crystalline rock easier to cut, are, in this rock, arranged sometimes with their cleavage surfaces prevailingly in one direction, or lie in belts, giving a faintly striped aspect, constituting gneiss, and much facilitating the operations of the quarry by giving the stone a "rift" so-called, the beds being from eight inches to five feet thick. These minerals, however, in much of this variety of the East St. Cloud rocks, are evenly scattered through the whole rock, rendering it as a mass slightly softer, but requiring the guidance of the plug-and-feather in reducing the large blocks to sizable and desired dimensions.

The composition of the red syenite from East St. Cloud (No 6) is not very different from the foregoing, but the feldspar is mainly flesh-red, and all the grains are coarser. It also has a higher percentage of silica, a fact that has been discovered practically by the owners who have given up the general use of it because of its being more costly to work. In some of the outcrops west of St. Cloud, in Stearns county, it becomes coarser-grained, somewhat resembling the red Scotch granites imported to the United States. In the winter of 1874-5 a block weighing ten tons was taken out of the red granite quarry about three miles west of St. Cloud for a monument base. It was polished at St. Cloud and was delivered to its purchaser at Chicago. This was very fine and greatly resembled the Scotch granite in color, grain and polish. At the point where this was taken out the granite rises about twenty feet above the general surface, and spreads over more than an acre. A similar red granite, found at Watab (No. 10), has furnished several handsome monuments, some of which were put on exhibition at the Centennial Exposition of 1876, at Philadelphia, by Mr. Gurney, the owner.

The other gray granite (No. 7) which is found at the East St. Cloud quarries has been noticed at several other places, and it is probably largely distributed wherever the red granites are found. In some places it passes by a gradual change into the red, in such a way as to suggest that the whole was originally gray, and that the red color has been superinduced since its formation by some difference of exposure to the elements. It is No. 835 of the geological survey series.* The true composition of this rock is not readily ascertained by simple ocular inspection, since the quartz and the feldspar are very similar in color and luster. When freshly quarried they both appear glassy; the cleavage of the feldspar is not evident, though that mineral exhibits an irregular parting or stepstone fracture, and when in compact mass it seems to be translucent. Hence the general aspect is very much like that of the gabbro of Duluth when freshly quarried. It has a clear, bluish-gray, uniform color, and is feebly translucent. The whole content of silica in this rock is 74.72 per cent., being a

*Tenth annual report, p. 121.

little more than that in the red syenite, and for the same reason it has ceased to be wrought at East St. Cloud.

Microscopic characters of No. 1. The intimate structure of the fine-grained gray syenite from East St. Cloud can be seen more minutely by examining the colored illustration, plate A, fig. 1, which shows a magnified thin-section of the rock in ordinary light increased forty diameters. The dark brown grain is biotite, the light brown and the brownish-green grains are hornblende, and the green grains are chlorite. The most of the figure contains minerals that are not individualized in common light. They simply show a general cloudiness due to such included impurities as ochreous limonite. The same field is shown in the same position, as it appears in polarized light between crossed Nicols, in plate A, fig, 2, where that portion which was unindividualized in common light is seen to consist of numerous different grains, the larger part of them being quartz.

Microscopic characters of No. 4. In plate A, figures 3 and 4, are seen the characters of this rock magnified forty diameters, the former in ordinary light and the latter in polarized light between crossed Nicols, the same field being represented in each. The green mineral is derived from a change in the hornblende, and is as near chlorite as any established mineral; but it shows all stages of change from pure hornblende to a green, granular, confusedly polarizing substance. When this green substance accumulates abundantly, it acquires a minutely foliated structure which indicates chlorite. The large striated grain in the center (fig. 4) is plagioclase, and probably albite.

Microscopic characters of Nos. 6 *and* 10. This rock has very evident grains of quartz, orthoclase and hornblende, but they are all more or less affected by included impurities. The quartz shows clouds and linear groups of bubbles and cavities, polarizing brilliantly. The orthoclase is filled with impurities so as to be sometimes nearly opaque, and at other times has alternating but nearly parallel, undulating and interrupted lines of light and light gray; while the hornblende is in about the same condition as described in the last. The figure (No. 5, plate A) represents a microscopic field containing these three minerals magnified forty diameters, some of the hornblende evidently being darkened by emery derived from the polishing lap. With an objective magnifying two or three hundred diameters these minerals, particularly the quartz and feldspar, are seen to contain minute crystallites, some of them being acicular like apatite, or tremolite.

Microscopic characters of No. 7. This rock is composed mainly of quartz and gray orthoclase, which are about equally abundant. The quartz is pierced by numerous irregular fissures, and has lines of pores, and in the pores are undetermined microlites. The feldspar shows no twinning striation, but has the generally clouded appearance of orthoclase when somewhat changed.

At lake Saganaga are other granitic rocks. They extend over very large areas, and are favorably exposed for quarrying. Some of them are quite light-colored, or very similar to the "white granite" of Watab. They change to a bedded light-colored syenitic gneiss.

There is also a red syenite, which is seen back of Duluth in the hill-ranges, and probably extends from there northwestwardly, in an interrupted manner nearly to the international boundary line. It is associated with gabbro (No. 2) intimately, and they interchange in areas so quickly that they seem to have been once both molten at nearly the same time. This rock has not attracted much attention, and has not been quarried except at Beaver Bay, where Messrs. Wieland Brothers have used it in the filling of the cribs of their dock. The analysis of this red syenite from Beaver Bay is given in the general table (No. 5) showing a content of silica amounting to 71.81 per cent. Another analysis of a sample from Duluth gave the following results.*

Silica,	75.78
Alumina,	11.09
Sesquioxide of iron,	2.09
Calcium oxide,	.86
Magnesium oxide,	.65
Potassium oxide,	1.06
Sodium oxide,	6.43
Water,	1.82
	99.78

At the two points mentioned this red syenite is fine-grained; but from the occurrence of occasional boulders of very coarse grain, evidently from the same formation in its northeastern extension, along the shore of lake Superior, it is believed that this rock affords a very beautiful and coarsely crystalline building stone.† Besides quartz this rock contains red orthoclase, hornblende (often changed to chlorite), magnetite, apatite and ferrite.

In the Minnesota valley, extending from near New Ulm to Big Stone lake, are numerous exposures of crystalline rocks. Sometimes these rocks present favorable opportunities for the prosecution of this industry, but they differ considerably from those of Stearns, Benton and Sherburne counties. They are generally gneissic, instead of massive. They are more frequently true granite. They are always red. While their laminated structure renders them more easily wrought. and thus gives them an advantage over the firm gray syenites, of the Mississippi valley, it also renders them softer and more destructible under the action of the weather. They seem to have less quartz, and more of the cleavable minerals orthoclase and mica. Still there are exceptions to the gneissoid structure of the Minnesota valley granites, as may be seen in some of the exposures at Big Stone lake, and in the railroad-cuts near Montevideo.

At East St. Cloud and Watab there is still another variety of syenite (No. 9), which, however, is probably only a coarser crystalline condition of the fine-grained gray syenite (Nos. 1 and 4),‡ since on analysis it has about the same content of silica, alumina and iron. It contains more lime and magnesia, but less potash and soda. It consists essentially of the minerals quartz, orthoclase, plagioclase, hornblende and biotite. At East St. Cloud

*Tenth annual report, p. 204.
†Compare Nos. 667, 668 and 673; also 685 and 686, tenth report.
‡Nos. 801 and 805, p. 106, Tenth annual report.

PLATE A.

EXPLANATION.

Figure 1. Fine-grained gray syenite from East St. Cloud........................p. 145
Magnified forty diameters. No. 1 of the systematic table.

Figure 2. The same between crossed Nicols.

Figure 3. Fine-grained gray syenite from Sauk Rapids..........................p. 145
Magnified forty diameters. No. 4 of the systematic table.

Figure 4. The same between crossed Nicols.

Figure 5. Red quartzose syenite from East St. Cloud............................p. 145
Magnified forty diameters. No. 6 of the systematic table.

Figure 6. Gabbro from Rice Point, Duluth.......................................p. 147
Magnified forty diameters. No. 2 of the systematic table.

this rock was opened by Messrs. Saulpaugh Brothers in 1881, for use in the Northern Pacific railroad bridge at Bismarck over the Missouri river.

Microscopic characters of No. 9. The feldspar of this rock shows the twinning striation of plagioclase in some of its grains, but it is wanting in a large portion of them. Magnetite accompanies the biotite, and slender cylindrical colorless microlites cut through the feldspar. Pyrite in small quantity is associated with hornblende.

The so-called "granite" of Duluth (No. 2), quarried at Rice's Point, belongs to a very different class of rocks, and is now generally designated *gabbro* by lithologists. This term, derived from Italy, is applied to an igneous rock consisting of the triclinic feldspar labradorite, augite and magnetite. These minerals are all softer than quartz, which is wholly absent from the Duluth rock, but which makes up so large a part of the foregoing syenites. The rock, however, is more difficult to quarry on account of its toughness and homogeneity. It has no gneissoid structure, and the cleavable labradorite has but little effect in producing an easier fracture in one direction than in another. While, therefore, taken in mass, this rock is softer than the St. Cloud syenites, it is more difficult and expensive to quarry and to reduce to convenient blocks.

This gabbro makes the chief rock of an important range of hills in Minnesota. The "Mesabi" in much of its extent consists of the same rock. It is found to vary somewhat in its color and composition, yet always within narrow limits, constituting on the one hand the "felspar rock" of Norwood,* where the feldspathic ingredient predominates largely over the other minerals, and is of a clear, almost glassy transparency, and of a gray color, weathering nearly white, and on the other hand the "trap-rock" so-called, as it is displayed at many interesting points along the shore of lake Superior, where it has frequently been described as "greenstone." The green color in the latter case results from the change of the augite to delessite, or to some chlorite-like mineral under the influence of the weather, and from the absorption of iron. The former variation from the typical gabbro is No. 8 of the general table, and the latter is No. 11 or No. 3; the last being from Taylor's Falls.

Microscopic characters of Nos. 2 *and* 8. The labradorite which composes the largest part of this rock exhibits beautiful polarization colors, and generally an evident twinning striation in some of its grains. Sometimes it shows a banding of different colors between crossed Nicols. It is cut by innumerable irregular cracks, by which finally impurities enter and change its average composition. The augite is apt to be somewhat fibrous from incipient decay, but when fresh its play of

*Owen's geological report of Wisconsin, Iowa and Minnesota, p. 360.

colors in polarized light is nearly as brilliant as that of the labradorite. Plate A, fig. 6 is so drawn as to show a fibrous grain of augite, surrounded by labradorite containing scattered impurities. In some parts of this rock the magnetite, which is titaniferons, is very rare, and then it becomes the rock No. 8, and in some places it is so abundant as to compose the greater part of the mass. making an iron ore.* Figures 1 and 2, plate B, represent a section of the labradorite of Beaver Bay (No. 8) magnified forty diameters, the former in common light and the latter between crossed Nicols.

The "granites" of Minnesota are adaptable to a wide range of architecture. That which is most used from St. Cloud (No. 1), is of a neutral gray color, of rather fine, inconspicuously granular texture, and has a resisting strength of over twenty-five thousand pounds per square inch. It resists fire and the sudden cooling produced by cold water thrown upon it, better than the more quartzose, and more coarsely granular rocks quarried at East St. Cloud and Watab. The other varieties, however, are more showy in construction, on account of their lighter color as well as their more close crystalline texture. Some of them will take and preserve a better polish, particularly Nos. 6 and 7, and are to be preferred for that reason for fine work, such as monuments or tablets, and for all inside trimmings. The syenite from Beaver Bay has a uniformly brownish red color and fine grain, and when polished is very beautiful.

These crystalline rocks have been used in some of the principal buildings in St. Paul and Minneapolis for trimmings, and have been sent for the same purpose to several other cities, particularly to Milwaukee, Chicago and Des Moines. At Sauk Rapids the fine-grained gray syenite (No. 1) is made into monuments. Stone from the Sauk Rapids quarries was used in the trimmings of the state capitol at Des Moines, and constitutes the entire front wall of the block of Nicols and Dean, at St. Paul. It is that used for paving at Minneapolis and St. Paul. The trimmings of the U. S. custom house and post office at St. Paul were taken from the East St. Cloud quarries, and embrace all the principal varieties there found, i.e. Nos. 1, 6 and 7. Much of the stone put into the bridge over the Missouri river at Bismarck for the Northern Pacific railroad, came from East St. Cloud, but at a point further southeast than the quarries of Breen & Young, and consists of another variety (No. 9) of syenite. This rock seems to have stood the physical tests that have been made by the survey, on Minnesota building stones, less successfully than the other crystalline rocks. This,

*Tenth annual report, p. 80—Rock sample No. 695.

however, may be due in some measure to the fact that in reducing a block for a test to the required dimensions with a hammer and chisel, it is more likely to be checked and weakened if coarsely crystalline, as this rock is, than if it be fine-grained; and some of the tests may have been influenced by such imperfection in the samples. Still, the greatest care possible was taken to avoid any unfavorable results from such a cause.

The gabbro of Rice's Point, Duluth, has been employed in a few buildings at Duluth, both as cut trimmings and for rough walls. It has also been used for monuments and for bases, to which it is specially adapted, being cut under the chisel and polished more easily than any of the crystalline rocks that contain quartz. The same kind of rock at Taylor's Falls has been but little employed for any purpose, though the rock there is favorably situated both for working and for transportation.

The labradorite rock (No. 8) has a lavender-blue or bluish-gray color, and is vitreous and subtranslucent in thin sheets. It does not have the opalescence which distinguishes the labradorite from the typical locality and from Lewis county, New York, but it has a compact, perfectly crystalline texture, with crystals as large as $\frac{1}{2}$ or $\frac{3}{4}$ inch across. In some of the "greenstone" at Beaver Bay are perfect crystals over two inches in diameter, distributed porphyritically in the mass, but this structure is very rare. This beautiful rock, when suitably handled, will constitute a valuable material for ornamental slabs and columns, and probably also for china ware. Titanic acid, which sometimes is found in this rock, even in large quantities, is found in nearly all porcelain clays,* at least in those of New Jersey, and suggests not only the possible origin of the kaolinic clays used for earthen-ware, but also the adaptability of the undecayed rock to the same uses.

2. QUARTZYTES.

The red quartzyte at Redstone, in Nicollet county, which also is seen in Cottonwood, Watonwan, Rock and Pipestone counties, is sparingly used for building stone at points contiguous; and one or two car-loads are known to have been shipped to Minneapolis. It is the hardest stone in the state, or in the United States, probably, that can be stated to have been used for purposes of building. It consists almost wholly of quartz (84.52 per cent.), the red

*Report on the clay deposits of New Jersey. Cook, 1878, p. 274.

color being due to iron oxide which is disseminated among the grains and throughout their cement. As a layer embraced in this rock, the material known as "red pipestone", or catlinite, is found in Pipestone county and other places in southwestern Minnesota. This rock is very difficult and costly to dress into dimension blocks, but it is indestructible when once placed in a wall.

The quarry at Redstone, near New Ulm, was opened in 1859 by Nicholas Thinnes, but since then several other parties have done most of the quarrying, none of it, however, in a systematic manner. The quarries are contiguous and exhibit the same kind of rock. Much of that which is used now is thin-bedded, from one-half inch to two inches thick, but the stone could be got of any size and thickness desired. The layers dip about 15 degrees toward the N. N. W. As compared with the rock at Sioux Falls, the opportunities here for quarrying are greater, and the stone is much more easily wrought. Its bedding is thinner and softer, though it is likely that by excavating deeply these beds would be found to be firm and purplish within. Some of the stone is wholly disintegrated, or loosened so as to be a sandrock, losing its color to the depth of 2—8 feet, and some beds are loose-grained. Some of the lower beds are syenitic.*

Samples of the Redstone rock in construction can be seen in Sommers' block and Frank Erd's residence, both at New Ulm, and also in the basement of the Catholic church at the same place.

In Cottonwood county an extensive ridge of this rock, mainly covered by the glacial drift, runs east and west through Storden, Amboy, Delton and Selma townships, and enters Adrian in Watonwan county. Along the branches of Mound creek in Amboy and in Germantown, are frequent and favorable exposures. On the Little Cottonwood river are excellent opportunities for quarrying flagging; some pieces loosened by the action of the water being five or six feet long by three to five feet wide, and three or four inches thick. Many pieces much thinner are also found. Outcrops of the quartzyte occur frequently along the summit and on both slopes of this ridge, even where there is no water-course. The rock here has mostly a reddish gray color. Its stratification is in some places nearly horizontal, but more commonly it dips several degrees, often toward

*See the first annual report, p. 75.

the south. This range of quartzyte, being the only rock found accessible throughout a wide extent in that part of the state, will be more largely quarried as the country becomes settled more thickly, and as buildings of more substantial character come to be required in the larger towns.

In Rock county are numerous exposures of the same red quartzyte,* the principal one, known as *The Mound*, being west of the Rock river, near Luverne. This mound is caused by the breaking off, nearly perpendicularly, of the strata of an extensive high plateau running northwest from there, consisting of this rock. The elevation is 175 feet above the river. The perpendicular bluff of rock rises from forty to sixty feet in its highest part, but owing to a dip of about twenty degrees from the horizon toward the west, or partly northwest, and to the breaking off of the upper layers, causing a gradual ascent from the brow of the hill backward through several rods, the actual thickness of beds visible may be 150 feet. The rock here appears to be almost entirely a reddish, or pink, heavy-bedded quartzyte. If wrought there might be some softer and thinner layers discovered, and such probably exist in the lower parts of the bluff, now hid by the copious talus of refractory and large blocks fallen from the hard layers above. The main bluff curves westwardly at both ends, and by reason of the dip and ravines that enter the valley from the west, its exposed layers gradually disappear under the soil in that direction, but evidently are the cause of the range of elevated land running northwestwardly, since they are seen in numerous other places.

The principal locality in Pipestone county is at the famous quarry of the Indians near Pipestone City, which, however, was worked by them for the layer of metamorphosed red clay which is embraced between the quartzyte strata. There has been but little quarrying done at this place, the greater part of it having been executed by the Indians. There is a ledge of rock which runs north and south nearly three miles, consisting of layers of red quartzyte with a gentle dip toward the east, forming a perpendicular escarpment toward the west, and rising at its highest point not more than twenty-five feet above the level of the prairie on the west. The rock here in general is exceedingly hard, in heavy layers one to three feet thick, separated by jointage planes into huge blocks of angular shapes, that

*Compare the sixth annnal report.

lie often somewhat displaced. The color is sometimes pinkish, but in the massive portions it is also purplish. When it is brick-red the strata are apt to be thin and also more aluminous.

At Sioux Falls, in Dakota, this rock has one of its characteristic outcrops, not only being the cause of the water-fall but presenting perpendicular walls between which the river flows for some distance before it reaches the falls. The rock here dips six or eight degrees toward the south. The beds are purple within, especially the thick ones, but toward the outside and along the joints they are changed in color to a rose-red, or to a pinkish red. None of the brick-red, heavily iron-stained color can be seen. The effect produced by weathering not only changes the color but also the hardness, so that the rock goes into a loose sandrock again and crumbles in the hand. This occurs to so large an extent that in suitable places it is gathered and used for mortar. There are also some beds that are now wholly (so far as can be seen) in this friable condition. The sand that results is a pure silica, nearly white, and translucent, though it is apt to show at first a slight pinkish tint, arising from the remains of the cement among the grains. There is visible here, of the bedding, a thickness of about fifty feet, and the river goes over the beds from south to north, producing a fine water-power. At the quarries the regular strata are from six to eighteen inches thick. Some of the beds are purple, but that color seems to fade out gradually, passing through the "fawn color" of the Kasota stone of this state, to a light pink sandrock. The county jail at Sioux Falls is built of this rock, also the *Queen Bee* flouring mill, and it is being employed exclusively in the territorial penitentiary at the same place. It is used at Omaha, Nebraska, for street paving, under the name of "Sioux Falls granite."

For ornamental purposes this rock has not been much employed. It will take a perfect polish, owing to its large content of free quartz, and will retain it longer than any granite. Small ornaments have been made of some of the richly colored strata, and sold under the name of "jasper", and some monumental bases have been constructed of it. The strata are very regular and firm, but at the same time are broken with a heavy sledge at the quarry. They break at random, and those blocks which happen to present a face suitable are used for range-work in the wall, the remainder being needed for filling and for the back-side.

This stone is destined to be extensively used in the southwestern part of the state, and in the states still further southwest, notwithstanding its refractory nature, because of its accessibility, and the absence of all other kinds of building-stone, and at the same time it seems to be one of the most promising formations for flagstone in the state, though it has not been employed for that purpose. Similar quartzytes are found in the northern part of the state.

There is another silicious rock, perhaps deserving the name of quartzyte, of a very different color and belonging in a very much later geological period, which is seen at several points in the banks of the Minnesota river between New Ulm and Mankato. It has supplied some very good building material, and will also furnish flagstone. The layers are about four inches in thickness as they appear after long weathering and are tough and firm. They are associated with alternating layers of friable sandstone which aid in their extraction. These beds are sometimes so coarse as to warrant their being designated a conglomerate. The whole rock is light colored, or sometimes rusty, and horizontally stratified. As a building material it is very desirable, but the toughness and hardness of the texture, and the thinness of the beds, make it more suitable for flagging than for building. These beds are exposed on the N.E. ¼ Sec. 16, Courtland, Nicollet county, rising 35 or 40 feet above the river, favorably situated for working. Some of the layers reach a thickness of six feet when they are wrought, this effect arising from the union and cementation of several of the thin layers at some depth within the quarry, a phenomenon which is common to all formations.

Microscopic characters of No. 12. The quartz is in rounded grains from one-tenth$^{mm.}$ to one$^{mm.}$ in diameter. They all have the optical characters of crystallization. They are generally not in immediate contact, but are separated by the cementing substance. They contain many impurities which seldom have an evident crystalline form. There are also other large grains which are now nearly or quite opaque from decay. These seem to have been originally some other mineral, perhaps feldspar. Some of these are red in reflected light, and they give the color to the rock, but when reduced in size they seem to be scatteringly disseminated even through the quartz grains, where they do not appear red, but somewhat yellowish, and semi-transparent. The cementing substance is composed partly of this red amorphous altered mineral. Figures 3 and 4 on plate B, show this rock magnified forty diameters, the latter in polarized light.

3. DOLOMITES.

Under the term dolomite are embraced here only those magnesian limestones that show, on analysis, at least as much as forty per cent. of carbonate of magnesia.* It will be seen by the table that, so far as they

*Dolomite is a compound of carbonate of magnesia and carbonate of lime, the lime being 54.4 per cent. and the magnesia 45.6.

are employed as material for construction, the dolomites are confined to the St. Lawrence formation, and at the same time that none of them reach the percentage of magnesia required for pure dolomite. Besides the analyses that have been made by the survey, Dr. Norwood's may be referred to, exhibiting the same fact, viz:

	Carb. lime.	Carb. mag.
From the shore of lake Pepin,	52.	42.2
From lake St. Croix below Stillwater,	48.3	36.8
From Gray Cloud island, a short distance above Hastings,	51.4	40.7
From thirty miles below lake Pepin,	29.7	9.7

It seems not only that the formation varies slightly from place to place, in respect to the per cent. of magnesia, but also from layer to layer within itself, since from the same quarry (as at Stillwater) the compact, even-grained beds which are most highly prized for building, containing over forty per cent. of carbonate of magnesia, alternate successively with vesicular and irregular strata which contain somewhat over thirty-seven per cent. The texture, however, does not always vary with the per cent. of carbonate of magnesia in the same direction ; at Lanesboro the even-bedded and compact rock contains between twenty-eight and twenty-nine per cent. carbonate of magnesia, while the vesicular beds show forty-two per cent. The vesicular texture of the Lanesboro rock, however, is not like that of the rock from Stillwater with which it is here compared, but more like the finely vesicular texture of the rock from Frontenac. The vesicular rock at Stillwater is irregularly porous, or cavernous, and has a darker color.

The St. Lawrence formation is the limestone which is conspicuously exposed in the bluffs of the St. Croix and Mississippi rivers from Stillwater to the Iowa state boundary. It generally forms the tops of the bluffs, and causes the precipitous portions, the lower portions being made up of fallen debris, hiding the underlying sandstones. It is not only seen abundantly along these streams, but also along the bluffs of all the streams that flow into the Mississippi from the west between Hastings and Brownsville. Of the limestones of the state it affords more exposure, and is more generally employed for construction, than any other. Throughout its whole extent in Minnesota it furnishes a very excellent material for building—indeed one of the best, considered in all respects, to be found in the United States. Not only does it furnish the dolomites (Nos. 13, 14, 15 and 16), but also many of

PLATE B.

EXPLANATION.

Figure 1. Labradorite feldspar, from Beaver Bay ....p. 147
Magnified forty diameters. No. 8 of the systematic table.

Figure 2. The same between crossed Nicols.

Figure 3. Red quartzyte from Pipestone county.... ....p. 153
Magnified forty diameters. No. 12 of the systematic table.

Figure 4. The same between crossed Nicols.

Figure 5. Dolomite from Frontenac..p. 155
Magnified forty diameters. No. 13 of the systematic table.

Figure 6. Dolomite from Stillwater........ ....p. 155
Magnified forty diameters. No. 14 of the systematic table.

those here classed as dolomitic limestones, which rank (some of them) higher on the comparative scale than some of the dolomites. It shows also sometimes a percentage of insoluble matter as high as ten or eleven, which seems to replace carbonate of magnesia rather than carbonate of lime. When, however, the insoluble matter is largely aluminous it seems to replace also carbonate of lime, and the comparative rank of the stone as a building material is injured.

An analysis of a sample from Sugar Loaf, Winona, largely used in the State Normal School at that place, gave the following result.

Insoluble (mainly quartz),	24.21
Ferric and aluminic oxides,	3.32
Calcium sulphate,	4.32
Calcium carbonate,	47.11
Magnesium carbonate,	20.67
Total,	99.72

In this case the high rate of the per cent. of silica was due partly to the existence of silicious aggregations isolated from the mass of the rock, and partly to the geodic cavities lined with fine quartz crystals. The bulk of the rock probably would not show any higher rate than ten or eleven per cent.

Microscopic character of the dolomites, Nos. 13, 14, *and* 16. No. 13 is seen in plate B, fig. 5, No. 14 in plate B, fig. 6, and No. 16 in plate C, fig. 1. They are all magnified forty diameters. The first (No. 13) is interspersed with natural cavities which the rock shows to the naked eye. These seldom exceed a millimeter in diameter. In some places there are similar spots in the thin section, which are now filled with a very fine-grained substance which has the same general color as the rock itself, but which appars isotropic between crossed Nicols, and if highly magnified does not exhibit any crystalline forms of microliths. Sometimes these isotropic spots have a dim concentric banding of light and dark, as if they were due to successive accretions from the surrounding rock. Sometimes between crossed Nicols they show a black cross which becomes dissipated on rotation and returns again. The whole rock is somewhat stained with ochre, and shows very rarely a small grain of quartz. The individual grains of dolomite are small, and do not often show the two cleavage systems.

No. 14 is a much more dense rock. Its individual grains are from one-fiftieth$^{mm.}$ to four-fiftieths$^{mm.}$ in diameter. They are angular, but show no cleavage lines. They are flecked with numerous impurities. When seen with a low magnifying power they polarize between crossed Nicols in colors of blue and yellow. This rock also contains an occasional grain of quartz.

No. 16 is very similar in all respects to No. 14, but is somewhat coarser, some of the larger grains sometimes having a trace of the natural cleavage remaining, as well as the rhombic form of the crystals.

The dolomites here spoken of, and the dolomitic limestones from the same formation (Nos. 17, 18 and 21), are of a buff color, varying to a light drab, the latter appearing in the coarsely vesicular beds, as No. 18, from Stillwater, and they have therefore a lively and cheerful expression in any building. The rock is but slightly changed after many years of exposure to atmospheric influences; indeed it has not been in use long enough yet in the state to show any change whatever by lapse of time, although it is in some of the oldest buildings of the state. The homogeneity of its texture and composition, and the regularity and thickness of its bedding, are qualities that enable it to supply slabs and blocks of any desired dimensions. At Frontenac it is cut into ornamental forms with comparative ease, and the same kind of beds as those at Frontenac are found throughout the southeastern part of Goodhue county, and the northern portion of Wabasha. Its resistance to pressure, amounting sometimes to 25,000 pounds per square inch, is more than that of most granites,* and is sufficient to warrant its use in all structures, while for door moldings and caps, for sills and water-tables, and for all trimmings to brick structures it is unsurpassed.

As a material for building, dolomites and dolomitic limestones rank very high. Numerous remains of Roman architecture in England, and particularly at York, the seat of the commercial and military power of the Roman empire in Britain, have been found executed in dolomitic limestone, and many of them are in a better state of preservation than the generality of structures of later date.† Conisburgh castle, as old as the time of the Normans, situated between Doncaster and Rotherdam, is built of a coarse-grained, semi-crystalline and partially oölitic magnesian limestone, and some of the blocks still show the marks of the chisel. The old Southwell church is constructed of magnesian limestone from Bolsover Moor. The new houses of parliament at Westminster are constructed of dolomite or dolomitic limestone, quarried at Norfal near North Anston, England. This stone was chosen after an exhaustive search throughout the British islands by a government commission, as the most suitable, all things considered, for the important structures that were contemplated, notwithstanding the gratuitous offer of granites from Scotland. This stone from North Anston is nearly a pure dolomite, containing from forty-four to forty-five per cent. of carbonate of magnesia, and about two per cent. of silica, iron and alumina. The report of the commission, consisting of Sir Henry T. De la Beche and Dr. William Smith, geologists, Charles Barry, architect, and Charles H.

*Of ninety-nine tests of granites, reported by general Gillmore in the report of the chief of engineers, 1875, part II. p. 846, not one reached 25,000 pounds per square inch.

†Lithology, or observations on stone used for building. C. H. Smith.

Smith, "a practical man well acquainted with the working of stone", concludes with the following recommendation:

"Having weighed, to the best of our judgment, the evidence in favor of the various building stones which have been brought under our consideration, and freely admitting that many sandstones as well as limestones possess very great advantages as building materials, we feel bound to state that for durability, as instanced in Southwell church, &c., and the results of experiments as detailed in the tables; for crystalline character, combined with a close approach to the equivalent proportions of carbonate of lime and carbonate of magnesia; for uniformity in structure, facility and economy in conversion, and for advantage of color; the magnesian limestone, or dolomite, of Bolsover Moor and its neighborhood, is, in our opinion, the most fit and proper material to be employed in the proposed new Houses of Parliament."

This preference for magnesian limestones is confirmed by the physical and chemical tests that have been conducted by the survey on the building stones of Minnesota, and by observations made in numerous places on the practical capacity of such stones to resist the action of the weather, as may be witnessed by any one in the bold and precipitous escarpments of the St. Lawrence limestone, as they appear in the bluffs of the Mississippi river between Hastings and the Iowa boundary line.

If the inquiry be pushed further, and some cause for the remarkable durability of dolomites and dolomitic limestones be sought, it will doubtless be found in the chemical nature of magnesia as compared with lime, or of carbonate of magnesia with carbonate of lime, or at least of dolomite as compared with calcite.

Magnesia as compared with lime. Magnesia, which is represented by the chemical symbol MgO, is a compound of the metal magnesium and oxygen; and lime, represented by CaO, is formed by uniting calcium and oxygen. Either one may be obtained by the calcination of their carbonates, which is performed in any ordinary lime-kiln. In the case of the production of quicklime from a magnesian limestone the magnesia and lime are intimately connected. In the burning of pure limestone a pure quicklime is obtained. In the former case the magnesia may be separated from the lime by dissolving them first in hydrochloric acid, and then adding a solution of soda or potassa, when the magnesia is precipitated in the form of a hydrate. Magnesia and lime differ in solubility in water. The former is almost insoluble in water, while the latter unites with it with great avidity, the heat evolved, as in slaking lime, being sufficient, sometimes for the ignition of wood. The hydrate thus produced is soluble in 530 times its weight of cold water.

Lime has a much stronger attraction for carbonic acid than magnesia, and in calcination of their carbonates the magnesia parts with it sooner than the lime. Non-air-slaked magnesian quicklime (i. e. a lime produced by the calcination of a magnesian limestone) remains in a caustic state much longer than pure quicklime, when freely exposed to the air, and hence is injurious to vegetation when mixed with soils, for several months. This is owing to the slowness with which the magnesia extracts carbonic acid from the air. But pure quicklime very soon becomes neutralized or "sets" by the absorption of carbonic acid from the air. It is for the slowness of setting, and the gentler evolution of heat in slaking, that the magnesian quicklime is preferred by masons; at the same time the cement is more permanent. These distinctions all show the greater immobility and permanence of magnesia as compared with lime.

Carbonate of magnesia as compared with carbonate of lime. Magnesium carbonate, or magnesite, which occurs in nature as a mineral, is infusible in the blowpipe flame, and is nearly insoluble in cold dilute hydrochloric acid. It is insoluble in water. On the other hand the carbonate of lime, which constitutes the bulk of all limestones and marbles, is not only soluble in cold acid with rapid effervescence, but also in water, making what is known as "hard water."

Dolomite compared with calcite. If a grain of pure dolomite be placed in hydrochloric acid it will effervesce very feebly, if at all. On applying heat the solution is more evident. Calcite effervesces rapidly in hydrochloric or nitric acid. Dolomite has a hardness of 3½ to 4, and calcite has a hardness of 3. Water containing a small amount of carbonic acid derived from the soil, passing into the earth dissolves carbonate of lime from the rocks and becomes hard. When it evaporates again, as in caverns, it leaves a small sediment which by long accretion forms stalactites. In regions of magnesian limestones the incrustations and stalactites that are formed in caverns consist almost wholly of carbonate of lime, containing only a mere trace of magnesia. When it is remembered that atmospheric air contains carbonic acid, and that rain-water contains nitric acid, the greater destructibility of limestone as compared with magnesian limestone, not only in the weather but also when subjected to artificial physical tests, is fully explained by the foregoing comparisons.

The oldest quarry in this formation, in the state of Minnesota, is that of Dr. C. Carli, at Stillwater, now operated by Mr. Conkling, opened in 1847. It is near the northern limits of the city, at the top of the bluff of St. Croix lake. Since then several other quarries more favorably situated, have been opened, and have furnished considerably more stone than that of Dr. Carli, viz. those of Hersey, Staples and Hall, and of Fayette Marsh. These were begun in 1854. The stone from all these quarries is of about the same quality, and the stratification is very similar. There is, at least at the quarries of Mr. Marsh and of Hersey, Staples and Hall, an alternation of horizontal strata, from three to six feet each, of differently textured rock, the whole thickness amounting to about seventy feet. One kind is coarse and vesicular, of a dark color, and is used only for heavy masonry. The blocks taken out are from eighteen to thirty inches thick. This is No. 18 of the general table. Another kind (No. 14) is useful for all work, owing to its homogeneous and granular but compact texture. It yields a good surface under the hammer, so much so that it is also employed for bases for marble tombstones. It is also used for ashlers, pilasters and copings, and for all common trimmings. It is in every way a valuable stone, and should compete in Minneapolis and St. Paul successfully with the argillaceous stone imported at considerably greater cost from Iowa (No. 40). The ridiculous infatuation for *an imported stone* is exhibited in numerous buildings in Stillwater, particularly in the school-houses and churches, where can be seen the blue, disintegrating shaly limestone of St. Paul used as trimmings in walls made of much more durable stone quarried at Stillwater. In some places the blue stone is already splitting apart in thin laminæ, and will wholly disintegrate long before the walls themselves show any damage from the weather. Sometimes this compact and fine-grained rock is more coarsely granular, or consists of little crystals of dolomite, in certain strata, in which condition the quarrymen distinguish it as "sandrock."

Some of the principal buildings that contain the Stillwater rock are the following, located at Stillwater, viz., the Irish Catholic church and the State Prison (both with trimmings of Kasota stone, No. 23), the public schools, the Holcombe block, the store of Isaac Staples, the Universalist church, and others; the Marsh block, the Phalen and the Torinus blocks.

At Red Wing this formation is more used for quicklime than for building stone. The principal quarries are owned by Dr. W. W. Sweeney in Barn bluff, R. L. Berglund and G. A. Carlson. The quarry of Dr. Sweeney was opened in 1865, and has been in constant use from that time to the present. That of Mr. Berglund was opened in 1868, and Mr. Carlson's somewhat later.

The stone obtained at Red Wing from the quarries exhibits the same kind of alternation of strata as that which has been described at Stillwater, except that the vesicular beds are somewhat more siliceous, and at the same time not so coarsely porous, which renders the whole product of the quarries somewhat better adapted for construction than that of the quarries at Stillwater. At Red Wing the aggregate thickness of the St. Lawrence formation is about 120 feet, in which there is much excellent building-stone, some layers being five feet thick. Pieces of any size, limited only by convenience of handling, can be got out, and some of it is very conveniently quarried in the form of flagging. The quarry of R. L. Berglund, situated in a bluff near Oakwood cemetery, furnished stone which has been cut into rounded columns for the fronting in a block on Bush street, between third and fourth. They are ten feet long tapering from about a foot to about nine inches in diameter. The porousness of the rock makes only a bush-hammer dressing suitable, but these columns show that the rock is adapted to a great range of architectural uses. The stone in the Catholic church at Red Wing came from the quarry of Mr. Berglund, and the stone in the Episcopal church from Mr. Carlson's in Sorin bluff. The Red Wing and the Diamond flouring mills are built of the Red Wing stone; also the piers of the railroad bridge at Hastings.

The rock obtained at Frontenac (No. 13), known as the *Frontenac stone* is light buff, and evenly and finely vesicular, in heavy beds of five feet and less. It was formerly obtained in the N. W. ¼ Sec. 21, T. 112, R. 13, Florence. But now it is quarried near lake Pepin, at Frontenac, from near the bottom of the St. Lawrence formation, 110 feet below the top of the bluff. The perpendicular exposure of the beds in the bluff amounts to sixty-six feet. This stone is largely shipped to St. Paul, Minneapolis and other cities of the state. Machinery (steam) is employed at Frontenac for sawing and rubbing the stone. It has been put into the Lindeke & Shurmeier block in St. Paul as trimmings, also in the state capitol, and composes the entire wall of the Barney block. In Minneapolis the Wood block is built of it. According to the tests of general Gillmore (see the general table)* this stone has greater strength to resist crushing when set "on edge" than when "on bed", which is an unusual peculiarity, and one which adds considerable to its desirability for use in columns that are to be subjected to great weight. The future supply of this stone is practically unlimited. The same vesicular texture which pervades it at Frontenac, and the same ease of quarrying, extends over many square miles in southeastern Goodhue and northern Wabasha counties, in some cases passing into an oölyte. The quarries at Florence were opened in 1855.

At Winona the first quarrying was done in 1854, at the quarry now owned by John O'Dae. That of C. H. Porter was begun in 1870. E. O. Wallace also has a quarry in the same bluff. Generally throughout Winona county the uppermost 75-90 feet of the St. Lawrence formation are cherty and concretionary, and wholly worthless for building purposes, and nearly so for lime-burning. There are hardened masses, or tors, projecting from the face of the bluffs in numerous instances, some of which may be seen in the valley followed by the Winona and St. Peter railroad, and others near Homer, which are due to the concentration of this siliceous and concretionary structure, rendering the rock more capable of resisting the attacks of the weather. The lower layers are the most valuable for construction, and they are wrought at Winona and at Dresbach. The rock is fine-grained, homogeneous and compact, of a light-buff color, some of it also being stained like the Kasota rock, but in stripes horizontal with the beds. See the general table, No. 15.

At Winona, blocks eight by nine by seven feet have been taken out by Mr. O'Dae. Indeed there is no trouble at any of the quarries in obtaining as large blocks as may be needed for any purpose. Yet the most of the product of the Winona quarries is used for quicklime. As a building stone, it has been sent to Minneapolis, St. Paul, and to Deadwood, in Dakota

*The same result was reported in 1875, by general Gillmore. *Report of the chief of engineers*, 1875, Part II. p. 851.

territory, and has formerly been considerably used for bridges and other construction on the line of the Winona and St. Peter railroad. It is seen in the Congregational and Episcopal churches at Winona, and in the county jail. The Congregational church at Winona is represented on plate E.

The most extensive quarry in this formation in the state is that of the Chicago and Northwestern railway, near Stockton. This quarry was first opened in 1876, in a systematic manner, though some stone had been taken out at intervals before. The rock lies here, as in other quarries mentioned, in regular horizontal strata, from nine inches to twenty-five inches in thickness, with rather more frequent and irregular joints than in the quarries along the Mississippi. The texture, so far as the stone is used, is homogeneous and fine, though somewhat vesicular. The beds, however, are disturbed by porous and cherty masses which obliterate the stratification, and are much more difficult to reduce to blocks suitable for transportation. This is only fit for rip-rap and filling, and is so employed largely. The largest block ever shipped from this quarry contained sixty-eight cubic feet. Some 300 men have employment about these quarries, and nearly fifty more are engaged in dressing the stone for various bridges and buildings along the line of the railroad. The formation has a thickness of 162 feet, as measured, back of Stockton, on the road to Winona, but at the quarries the thickness visible is only 145 feet.

This formation is quarried about a mile east of Caledonia, in Houston county, whence it has furnished the stone seen in several large buildings at Caledonia, notably the German Catholic church and the county jail. The latter is a fine building, the courses being about ten inches thick, rubble-dressed, with trimmings of the same. At La Crescent the public schoolhouse was built of stone from the St. Lawrence, quarried in the bluff north of the village. At Brownsville is a quarry in the same rock, which supplied heavy stone for the railroad, and for other uses.

The quarries at Lanesboro, in Fillmore county (Nos. 16 and 21), have been used in the construction of several large buildings at Lanesboro. The most of the rock is vesicular, often coarsely so, in which case it is used in heavy blocks for the coarse masonry of bridge piers and foundations. When finer-grained it can be cut into delicate forms. When dressed for window-

PLATE E.

EXPLANATION.

Congregational Church, Winona . . . . p. 162

Erected in 1880-82.

Built of dolomitic limestone quarried at Winona. Has trimmings of Fond du Lac sandstone, except the carved capitals at the door-corners, which are from Frontenac. The front steps are from Kasota.

CONGREGATIONAL CHURCH

WINONA

Julius Bien & Co. Lith. N.Y.

PLATE D.

EXPLANATION.

The state Capitol, St. Paul........... ....p. 163

Erected in 1882.

The walls are of red pressed-brick made at Red Wing.

The trimmings are of the dolomite quarried at Frontenac.

At the grade line is one course of ten inches of the brown sandrock from Fond du Lac.

The foundation, and the range-work below the water-table are from the limestone quarried at St. Paul.

STATE CAPITOL

Julius Bien & Co Lith

caps and sills the cut surfaces appear nearly white. The bedding varies in thickness from two or three inches to two or three feet. Similar beds are quarried at Whalen, in Fillmore county, and at Rushford. At Lanesboro the Lanesboro hotel, the large flouring mill, the Presbyterian and the Catholic churches and the public school, as well as a number of business blocks, are constructed of this stone.

The state capitol at St. Paul, erected in 1882, is built wholly of Minnesota materials (plate D). The walls are made of red pressed-brick from Red Wing. The trimmings of the windows and doors, the cornice and the water-table, are of the dolomite of Frontenac (No. 13). At the grade line is one course of ten inches of the brown sandrock from Fond du Lac (No. 34). The foundation and all below the grade line, is of the blue dolomitic limestone of the upper part of the Trenton quarried at St. Paul (see No. 22), and from the grade-line to the water-table the walls are of the regular blue limestone of the Trenton in broken ashler work (No. 28).

4. DOLOMITIC LIMESTONES.

As already remarked, the same formation which furnishes the dolomites just described, also furnishes the most of those here grouped as dolomitic limestones, and very often the two are found in the same quarry in regularly alternating strata. The characters of these rocks, and their manner of occurrence, have been described therefore, in some instances, in giving the particulars concerning the dolomites. The two sorts do not present such unlike physical characters, in some instances, as to require their separation in construction, and they are then used undistinguishably in the same building. This is particularly true of the quarries at Stillwater, Red Wing, Frontenac, Winona, Stockton and Lanesboro, which are all in the St. Lawrence formation. But the quarries at Shakopee, Kasota and Mankato, situated in the lower portion of the Minnesota valley, are from another and a higher formation (the Shakopee), though still embraced, in general, in the same series of alternating sandstones and limestones, which with some misapprehension of the stratigraphy, were placed by Dr. Owen partly in the "Lower Magnesian," and partly in the Potsdam, and partly denominated St. Peter.

The rock of these last mentioned localities, however, is very similar to that from the St. Lawrence, in outward characters, a circumstance which explains the reference of its outcrops to the same horizon as the St. Lawrence, by Dr. Owen and others. In chemical constitution, however, it is found to be rather more silicious, having more frequent cherty beds or nodules, and distinctly arenaceous portions. Toward the Mississippi valley, however, this limestone becomes thinner, and its line of outcrop is found inconspicuously running along the valleys at same distance back from the tops of the bluffs, and often invisible over many square miles. It is very seldom wrought for building stone in the counties bordering on the Mississippi river, though its integrity even to the eastern portions of Winona county, distinct from the St. Lawrence, has been fully established by careful field examinations. The most eastern point where it is worked is at Troy, in Winona county, where the Troy mills have been built from it. It is seen there twenty-five feet thick, underlain by the Jordan sandstone, whereas, at points in the Minnnesota valley it exhibits a thickness of about seventy feet.

At Shakopee and Louisville, in Scott county, this rock is principally employed for lime-burning. The same is true at Ottawa, in Le Sueur county. At Kasota, in Le Sueur county, it is quarried extensively, and is shipped to distant markets under the name *Kasota stone.* Several large quarries were opened in this stone at St. Peter, and the stone from them was largely used in the construction of the older portions of the insane asylum at that place. Very extensive working of the same beds is carried on at Mankato.

The rock is sub-crystalline, homogeneous, and rather compact than vesicular.

Microscopic characters of the dolomitic limestones. The dolomitic limestones of the St. Lawrence formation (Nos. 17, 18 and 21) do not differ from the dolomites in microscopic characters. In chemical composition the principal difference is the lower percentage of carbonate of magnesia in the aggregate. But this does not seem to express itself in any perceptible manner in the forms of the crytalline grains. Indeed, the percentage of carbonate of magnesia sometimes runs very low in the double carbonate of lime and magnesia, and the change cannot be distinguished under the microscope, because the crystals of dolomite and calcite have the same forms. Still, as the mineral becomes pure calcite, very evident colored bands, due to a twinning on the face $-\frac{1}{2}$ R are developed when the analyzer alone is used. This, however, has not been seen in any of the sedimentary limestones of Minnesota. Figure 2, plate C, shows the manner in which the impurities resulting from decay pervade the central portion of the individual crystalline grains in the rock No. 17. The same change is perceptible in the rhombohedra of Nos. 18, 19 and 23. In the last, however, the colored area is enlarged, and sometimes embraces uniformly the whole grain Some of the grains also in No. 23 are evidently irregular detached parts of larger rhombodedra showing traces of cleavage in one direction. In general, the dolomites and dolomitic limestones are nearly free from quartz granules; the principal acquired impurity is ocher. The granules of

PLATE C.

EXPLANATION.

Figure 1. Dolomite from Lanesboro..p. 155
Magnified forty diameters. No. 16 of the systematic table.

Figure 2. Dolomitic limestone from Red Wing................................p. 164
Magnified forty diameters. No. 17 of the systematic table.

Figure 3. Dolomitic limestone from Minneapolis, from the upper beds of the Trenton..p. 165
Magnified forty diameters. No. 22 of the systematic table.

Figure 4. Argillaceous limestone, St. Paul....................................p. 172
Magnified forty diameters. No. 28 of the systematic table.

Figure 5. Pinkish-yellow sandrock, from Hinckley...........................p. 177
Magnified 40 diameters. No. 30 of the systematic table.

Figure 6. The same between crossed Nicols.

the Mantorville dolomite (No. 20) are very fine, and not distinctly angular. In Nos. 22 and 24, are occasional crystals of pyrite, and traces of organic forms. The grains also of Nos. 22 and 24, are less defined, the mass appearing more like a hardened calcareous pulp. In No. 25 there is a sprinkling of fine quartz particles, and the section has a yellowish, serpentinous aspect. No. 22 is illustrated in fig. 3, plate C. When rotated with only one Nicol in use, very distinct cleavage-lines are made visible in the large central grain ($\times$ 250). The grain itself consists of numerous crystalline parts, each with its own cleavage lines.

The quarries at Kasota, opened in 1868, are owned by Brackenridge, Stewart and Buttars, and by J. W. Babcock. The former is operated by Messrs. Breen and Young. From the quarry of Brackenridge, Stewart and Buttars has been taken the greater portion of the pinkish stone which is characteristically known as the *Kasota stone*, and which was described as fawn-colored by G. W. Featherstonhaugh.

> Further up the Bois Franc district, a stream comes in from the left bank called Wee-tah Wakatah, or Tall island, and about five miles higher up some ledges of horizontal fawn-colored limestone jut out on the right bank, very cherty and somewhat vesicular; near the surface it takes a reddish salmon-color, resembling very much some beds I had previously seen on the Wisconsin and upper Mississippi. Within a few yards of these ledges and north of them, a beautiful pellucid stream comes in, containing the purest water I had seen in the country. I could not learn that any name had been given to it, and as it is in the immediate vicinity of the first calcareous rock I had met with in place here, and its purity rendering it a very rare stream in a country where all are turbid, I named it Abert's run, after Col. Abert, of the United States army, and chief of the topographical bureau.*

The quarry of Mr. Babcock, however, furnishes the same stone, but in less abundance, the staining of the natural beds having been carried on at different points with different degrees of color. Indeed the same beds, as they extend north and south from Kasota are generally not so colored, but rather have the usual buff color of a magnesian limestone, similar to the St. Lawrence. The greater change of color at Kasota is probably due to some local conformation of the country at the time the Minnesota river constantly flooded the terrace in which it is quarried, by which the rock abstracted from the water there more of the coloring ingredients (probably iron and perhaps some manganese) than elsewhere. A sandstone which seems to be the St. Peter is stained in the same way a short distance above Fort Snelling, in the Minnesota valley, giving it a rusty pink color, and at the same time greater tenacity and endurance under pressure. The bedding varies from a few inches to two and a half feet in thickness. Toward the bottom of the quarry the regularity of the strata is disturbed by dish-shaped contortions upward and downward.

***Report of a geological reconnoissance made in 1835, from the seat of government by the way of Green bay and the Wisconsin territory to the Coteau des Prairies*, p. 39. It has already been stated (p. 59.) that the description of Mr. Featherstonhaugh may have been applied to the outcrop at Rocky point, though Abert's run cannot there be identified.

The Kasota stone is shipped to nearly all parts of Minnesota, to Sioux City and Le Mars in Iowa, to various places in Wisconsin and Dakota, as well as to Chicago and Winnipeg. It may be seen in the trimmings of the market house in St. Paul, and of the dry goods house of Auerbach, Finch & Co. At the same place the Baptist church is constructed of it (plate F). Much of the state lunatic asylum at St. Peter was built of it. The trimmings of Christ church, Minneapolis, and of the Plymouth church, are of the Kasota stone; also of the Drake and the Odd Fellows' blocks at St. Paul, and of Williams hall, one of the buildings of Carleton college.

The colored rock which is faintly stained with iron (No. 23) is that which is most highly prized at these quarries, on account of its peculiar color, but it appears from the tests of these stones made by the survey, that the unstained stone (No. 19) from the same quarry, though not varying much in chemical composition from the other, ranks higher in the scale than the fawn-colored stone. It resists a greater crushing weight, but withstands the action of frost and water and of corroding vapors, and of a moist atmosphere, less successfully than the fawn-colored stone.

At Mankato the principal quarries are owned by Geo. Maxfield, J. R. Beatty, the Winona and St. Peter railroad company and by J. R. Beatty and Co. That of Maxfield was begun in 1853; that of Mr. Beatty in 1854. The product of these quarries is quite extensive, most of the stone being used along the line of the Winona and St. Peter railroad. The texture of the stone here is about the same as that at Kasota, but less of it has the peculiar color of the Kasota stone. It is in horizontal heavy strata varying from a few inches to over two feet in thickness. Near the bottom of the quarry most wrought there is a change of color to a light blue. This appears first in the center of the strata, but gradually increases so as to involve the whole rock. This seems to indicate that the original color of the whole formation was blue, and that it has lost it to a great depth (generally below the depth of all quarries) by exposure to the air, assuming the prevalent buff color. The stone here is used for all purposes of construction, and for flagging. Some ornamental cutting has been done (as at Kasota also) for building and for tombstones. It is sent to the western and southern parts of the state and to some points in Wisconsin and Iowa. It may be seen in the trimmings of the public school-houses at Sioux Falls, Dakota,

PLATE F.

EXPLANATION.

First Baptist Church, St. Paul .... p. 166

Erected in 1873-74.

Built wholly of the fawn-colored dolomitic limestone from Kasota.

FIRST BAPTIST CHURCH

ST PAUL

Julius Bien & Co. lith. N.Y.

and Albert Lea, also in the jail at Blue Earth City, and in the state normal school and the city schools at Mankato.

Besides the analyses given in the general table, of the Shakopee limestone, which show a high per cent. of insoluble matter, the following may be added from the same formation taken five miles below Mankato from layers burned for quicklime by Mr. Geo. C. Clapp. These layers are in the very top of the Shakopee, and are slightly fossiliferous and gray with remains of organic matter.

Insoluble,	2.82
Ferric and aluminic oxides,	1.39
Calcium sulphate,	6.74
Calcium carbonate,	52.22
Magnesium carbonate,	36.04
Total,	99.21

The dolomitic limestone quarried at Mantorville, in Dodge county (No. 20), is from the Galena formation, which lies near the top of the Lower Silurian, separated from the Mankato and Kasota quarries by a thickness of over 300 feet of strata. This formation has quite an extensive area in the south-central part of the state, and is also quarried at several other places in Dodge, Olmsted, Mower and Fillmore counties. While this stone is not so strong under pressure as the dolomites and dolomitic limestones already mentioned, it possesses such an average of other good qualities, having no especially weak point in its character, that it ranks well with them, and at the same time its resistance is sufficient to warrant its use in all ordinary construction. Its usual color is buff, although on deep and fresh quarrying it also shows that its normal color, like most other limestones, is blue. Its texture is open, even porous, with minute cavities. In some of its beds, which, however, are not wrought except for the heaviest and roughest masonry, it exhibits large cavernous patches with a rough and forbidding aspect. These, however, are not common, the sedimentation having been generally so undisturbed by chemical or mechanical agencies that the layers are regular and continuous, and the texture uniform throughout large tracts. Minute crystals of brown spar often line the cavities. It also sometimes embraces iron pyrite, which, weathering out, stains the face of the rock with rust of iron. The grain is crystalline, and sometimes granular. This granular texture, which is also frequently seen in other magnesian limestones, has sometimes made it pass for a sandstone. It has a light and lively color, and in that respect it has the advantage of the darker-colored stones. As a material for building it is a little surprising that this formation has not been more employed. It occurs in fine exposure in the western part of Goodhue county, abundantly in Dodge county, as well as in Olmsted and Fillmore, along the streams, and can be wrought extensively. It not only furnishes a building material that is suitable for all ordinary uses in foundations and abutments for bridges, but it also cuts easily to a regular and smooth surface. Its bedding is sometimes heavy, reaching two or three feet in thickness, and the stone is strong enough to endure both pressure and long weathering.

At Mantorville the quarries are owned by Mr. H. Hook, P. Mantor, A. Doig, and others. Mr. Mantor's was opened in 1856, and Mr. Hook's in 1866; Mr. Doig's in 1870. This is one of the oldest quarrying localities in the state, and much stone from here had been hauled over the country, before the construction of railroads, to Rochester and other towns. It has been employed at Mantorville in the construction of Wright's hotel, the county court house, and a couple of churches. At Rochester, Cook's block, the court house, the public school house, and the state insane asylum, are all faced or trimmed with the Galena from Mantorville.

It will be seen by the general table that dolomitic limestones are also found in the Trenton formation, underlying the Galena, and that they are quarried at Minneapolis. They are Nos. 22 and 24. It is probable that this character pervades certain beds of the Trenton on about the same horizon at points further south, but they have not been detected, although there is, even in the blue and argillaceous beds of the Trenton generally, a small percentage of magnesia. These magnesian strata are not those usually employed and desired for construction, but they are for the most part avoided in building, or are put in the interior and protected portions of the walls—at least the stone represented by No. 22 is so treated, while No. 24 is used indiscriminately with No. 27 at the same place. The position of these magnesian strata in the Minneapolis quarries may be seen by examining the following—

General descending section of the Trenton at Minneapolis.

1. Dolomitic limestone (No. 22 of the general table) with considerable argillaceous matter, crystalline, rough to the touch, hard but splitting lenticularly under the weather. This has a

blue color within. but is faded to a drab to a considerable depth depending on the exposure, while the immediate surface is generally a dirty buff. The grain is close, except for cavities resulting from absorbed fossils. The pieces into which the stone weathers are brittle and somewhat sonorous. Contains abundant specimens of *Orthis tricenaria*, and *Strophomena Minnesotensis*, as well as occasionally *Murchisonia*, *Leperditia* and *Edmondia*. The fossils, however, are apt to be in the form of casts and impressions. Thickness about eight feet.

2. Similar to the last, but gradually becoming more impure with shale, the fossils being gathered more into sheets or layers, making mere calcareous belts. Two feet.

3. Green shale, calcareous, weathering blue, with but few fossils. Occasionally is found a large specimen of *Endoceras magniventrum*, H. in this shale, the form only being preserved, surrounded by a thin black film of bituminous matter. Four feet, eight inches.

4. The last passes gradually into a calcareous shale resembling the well known building rock of this place, in which still there are few distinguishable fossils. This stone is sometimes used, like No. 1 above, for rough walls, or in protected positions. It is markedly set off from the rock below by a projecting shoulder formed by the upper portion of No. 5. Two feet, four inches.

5. Blue building-stone layers (No. 27 of the general table), used extensively at Minneapolis and St. Paul. This stone is rather too argillaceous to be a reliable building material, yet it is extensively used. The shale is intimately disseminated through the calcareous layers, without showing regular lamination, yet causes a mottled, or blotched color over the surfaces when cut or broken. The darker spots are shaly; the lighter ones, which constitute the most of the rock, are more purely calcareous. The color of the whole is bluish gray, which gives it the appearance of strength and durability, when placed in a structure. The fossil remains in this number are apt to be comminuted so as to be wholly undistinguishable, yet sometimes large pieces of *Endoceras magniventrum*, H. are found in the layers. Rarely also on separating the layers in quarrying, a rock surface is disclosed that is eminently fossiliferous with forms of *Rhynchonella*, *Orthis*, and other genera of brachiopods and incrusting corals. This is the principal and most constant member of the Lower Trenton. Thickness thirteen feet.

6. Dolomitic limestone (No. 24 of the general table), somewhat vesicular, and of a dirty drab color, less affected by shaly interlaminations than the last, in heavy beds that furnish a good building material. This stone is used indiscriminately with the last in all places, but is evidently a more valuable stone. Two feet.

7. Blue shale, parting chonchoidally under the weather, lying on the St. Peter sandstone. Three feet. Total, thirty-five feet.

These dolomitic layers from the Trenton (No. 22) are more durable than the regular building-stone. The upper dolomitic layers do not appear in the quarries near the falls, but they are seen in the quarries near the university, and in those on the west side of the river at some distance below the falls. The dip of the formation, and the erosions of the past, have destroyed them at and above the falls of St. Anthony. This rock generally is rejected by builders, and is confounded with the worthless shale (Nos. 3 and 4 of the section above) that separates it from the regular building stone layers. The older portion of the state university contains a large amount of this stone, and its greater durability than that of the regular building-stone can there be seen. The lower dolomitic stone from the Trenton (No. 6 of the above section) is found in all the quarries. It is generally not distinguished from the other building-stone layers, though sometimes the quarrymen have noted it under some fanciful description.* It is represented by No. 24 in the general table.

The other stone which in the general table is placed with the dolomitic limestones (No. 25) is hardly worthy of being ranked with the building stones of the state, both because it is a poor material for construction and because it is not much employed. It contains 39 per cent. of insoluble matter, mainly silica or silicate of alumina hydrated. The strata constitute an earthy, or "argillo-magnesian" limerock, which contains much silica, and vary in composition considerably from layer to layer. The layers are usually thin, not exceeding five or six inches. It is fit for rough walls, if the limy layers are carefully selected and the shaly ones rejected. This stone is exclusively used at Lake City in Wabasha county, and at Hokah in Houston county, although at each place the dolomites of the St. Lawrence formation exist in the same bluffs in immediate superposition. At Lake City, however, some importation has been made of the Berea sandstone from Ohio (No. 41). Stone of the same kind is found, wherever, in the state, that geological horizon is seen in outcrop, and hence in most of the bluffs in Winona, Houston and Wabasha counties, and the eastern portions of Goodhue and Fillmore counties. It is near the top of the St. Croix sandstone, where it begins to fade into the St. Lawrence limestone.

5. LIMESTONES.

The limestones that are used for building-stone in the state, are confined to the Lower Silurian. None of them are strictly pure carbonate of lime. The purest that has been observed is the rock formerly quarried near Fountain in Fillmore county (No. 26), containing over eighty-six per cent. of carbonate of lime, the most of the rest being insoluble matter, and less than a half of one per cent. carbonate of magnesia. The rocks of this group also vary to one containing nearly sixteen per cent. of carbonate of magnesia, the same also having over twenty-five per cent. of insoluble matter. The last is from Clinton Falls in Steele county (No. 29), and pertains to the Hudson River formation.

The Trenton limestone as quarried near Fountain, is found in the bottom of the formation, within ten feet of the St. Peter sandstone, in hori-

*In some cases even styling it *granite*.

zontal strata, and is exposed along the railroad cut east of the village. It is stratigraphically the equivalent of the beds quarried more extensively at St. Paul and Minneapolis, but the stone differs from the latter in being nearly free from shaly impurities. It is of a drab color, but passes to a bluish color on being opened more deeply, and has a very compact or dense texture. There are here beds of shale, but they are distinct from the limestone beds. They facilitate the operations of the quarrymen, but do not impair the quality of the rock. In quarrying the layers rarely exceed five inches in thickness. On the weathered bluff they appear even thinner than that, being apparently not more than two inches. They are tough and hard, and when broken they often fracture chonchoidally and in unexpected directions. The same kind of stone is quarried at Chatfield, in the upper bluffs, also near Faribault and Northfield, both in Rice county. In passing northward, however, and thus approaching the old shore-line of the palæozoic ocean, more argillaceous shale is found mingled with the rock; so that, even in those comparatively quiet times, when marine animals flourished and on their death supplied a calcareous deposit, there was present so much shaly (or clayey) sediment that the resulting rock is not so pure a limestone as further south. At the southern points the quiet, lime-producing epochs were less characterized by this impurity, but were separated more distinctly by periods of agitation when large amounts of shale were deposited. Hence in this formation at Minneapolis and St. Paul the argillaceous ingredient is distributed with the calcareous and also constitutes heavy beds of itself; while, at Northfield and Faribault, the calcareous layers are more nearly pure, and at Fountain are almost free from alumina and silica. At the same time in passing toward the south the purely argillaceous beds become thicker as the calcareous become thinner. This is unfortunate for the cities of Minneapolis and St. Paul which have to depend very largely on the Trenton limestone for building material, or to import from other places, but it is fortunate for those towns in the southern portion of the state which have to use the same strata.

The quarries near Faribault are in the town of Cannon City, about two miles east of Faribault. A small creek (Fall creek) here unites with the Straight river at its northern bend, and in its bed and along its bottoms the strata appear in a horizontal position. The quarry, owned by Philip

Cromer, was opened in 1865, but was not much worked till 1867. The beds quarried attain an aggregate thickness of about twelve feet and an individual thickness of a few inches to three feet. They are easily wrought, and have been extensively used at Faribault where the principal buildings have been constructed of them. The uppermost stratum, which is about eight inches in thickness, has been termed "marble", and some ornamental pieces have been cut from it. It is susceptible of a fine and uniform polish, has a compact texture and gray color. The polished surface shows various markings due to the contained fossils, but its composition and origin are the same as the other strata, except that it probably would be found on analysis to contain more carbonate of magnesia. At Faribault the following structures were made of this stone, though not perhaps wholly from this quarry: the state asylum for the deaf and mute, the Shattuck school and surrounding buildings, the Episcopal church and the public schoolhouse.

Some of the stone used in construction at Northfield, in Rice county, is from the same place (Cromer's), but the quarries opened in the valley of Prairie creek, in the eastern part of the same county, supply a stone of the same kind and equally good. Here are numerous quarries, but they are not wrought so extensively as those near Faribault. Willis hall, of Carleton college, is built of the Trenton quarried near Dundas, the sills and caps of the doors and windows and the steps at the entrance being from the Faribault quarries.

Microscopic characters of No. 26. Throughout the section can be seen the forms of sections of fragments of fossils. They are characterized by a transparency that is not seen in the rest of the rock, due to the pure and crystalline condition of the calcite that constitutes them. It seems as if much of this rock were derived from comminuted shells and corals, since it cannot be resolved into granules that show individual crystallization, but rather remains an amorphous or confused substance through which, at crossed Nicols, a few isolated rays of light can be seen to penetrate. It has scattered particles of pyrite.

Microscopic characters of Nos. 27 *and* 28. Most of this rock, at least the compact calcareous portions, is exactly like the rock from Fountain. The figure (Fig. 4 on plate C) shows disseminated crystals of calcite in the general amorphous mass of calcareous matter, somewhat in the manner of porphyry, drawn from a section of the rock from St. Paul, and magnified forty diameters.

The quarries in the Trenton limestone at St. Paul are on both sides of the river. The principal owners are Wm. Dawson, A. Gotzian, Breen and Young, M. Roche, Wm. Zollman and W. F. Davidson. The rock lies horizontal, in beds that vary from a few inches to about two feet in thickness, though the thickness of the bedding at individual quarries is an element that is very indefinite, and varies according to the length of time the rock has been exposed to the weather, and the depth to which the excavation has been carried. The heaviest beds now wrought were split into several, much thinner, when the quarries were first opened, but as the work has progressed the thin beds have gradually become consolidated. The quarries near the state capitol, owned by Messrs. Breen and Young, M. Roche, and Wm. Zollman, were opened in 1856, and have been in uninterrupted use ever since. Those of Wm. Dawson in West St. Paul, were begun in 1858, those of the Fort street road in 1870, and those on Dayton's bluff in 1869. Mr. Gotzian's quarries on Dayton's bluff were opened in 1870.

As has already been stated under the head of *dolomitic limestones*, this rock contains a considerable amount of bluish, shaly matter coarsely disseminated throughout even the calcareous layers, rendering it an inferior building stone. For that reason it is not now generally employed in first-class structures, except in the foundations and inner walls where it is protected from disintegration under the weather. The stone itself has an attractive and substantial aspect, when dressed under the hammer the variegations due to the alternating shaly and limy parts giving the face a clouded appearance as of gray marble, without being susceptible of a uniform polish. When protected from the weather the shale will endure and act as a strong filling for the framework of calcareous matter for a long time; but under the vicissitudes of moisture and dryness, and of freezing and thawing, it begins to crumble out in a few years. This result is visible in some of the older buildings, both in St. Paul and Minneapolis, and has provoked a very general inquiry for some suitable substitute in those cities. The natural color of the stone, on deep quarrying, is blue, but it is often faded to an ashen drab to the depth of several feet, depending on the ease with which water and air find access within. The porous layers are apt to be most faded. The long-weathered surface is of a light-buff color, or if iron be present in dripping water, or contained in the stone as pyrites, so situated as to be oxydized, the color is sensibly deepened to a rusty yellow, and at the same time the stone is rendered more enduring on account of the irony cement. The protoxide of iron, also, which is in the shale, and constitutes one of the elements of weakness in the rock, is changed to a peroxide on weathering. This change of color is noticeable in the rock of the river-bluffs wherever they were cut out before the last glacial epoch. The layers there have endured the exposure of a much longer period than in the river bluffs between Fort Snelling and Minneapolis, where the strata have been cut by the falls since the last glaciation. The shaly portions in particular, when closely mingled with the calcareous are so stained and hardened that the rock seems almost another formation. It becomes separated into layers of two or three inches, which have a dirty yellow color. The quarries near Minneapolis, situated near the Anoka county line, exhibit this condition perfectly. Some of the first large buildings erected in St. Paul, were made largely or wholly from such iron-stained and weathered parts of this formation, and, although they do not present that uniformity of color and appearance of solidity and strength that the dark blue stone lately quarried gives to a building, the stone itself has withstood the climate and storms of this latitude more successfully than later buildings constructed wholly of the blue stone. Toward the southern portion of the state this changed condition is not so noticeable, indeed is not so possible. The beds are more compact and calcareous, and have less protoxide of iron, and the effect of the elements is more superficial. Hence, while this formation as a building material at its northern outcrops at St. Paul and Minneapolis is rather inferior, at its southern exposures it furnishes a dark blue stone of excellent quality. Nothing can be more suitable for heavy walls, and especially for foundations below the water table, and for all Gothic structures, than the blue limestone taken from it at Fountain or at Faribault.

Some of the principal buildings made wholly of this stone in St. Paul may be mentioned, viz., the walls of the United States custom house and post office are of this stone, the Catholic cathedral and the German Catholic church are built wholly of it, also the Fire and Marine Insurance building, the McQuillan block, Dawson's bank building, and many other business blocks and several other churches, the St. Paul Roller mill, and the Washington and Franklin school-houses.

At Mendota Gen. H. H. Sibley in 1836 built the first stone residence in Minnesota. It is still in good condition. It is constructed of the Trenton limestone, but shows the light yellow or buff color common to the old stone buildings of St. Paul. The first stone structure in the state was

PLATE G.

EXPLANATION.

Universalist Church, Minneapolis.......... ....p. 175
Erected in 1873–75.
Built wholly of the blue limestone quarried at Minneapolis.

UNIVERSALIST CHURCH
MINNEAPOLIS

Julius Bien & Co. lith. N.Y.

erected in 1820, of the Trenton limestone. It was a portion of what subsequently became Fort Snelling.

The common-building stone of St. Paul is represented by No. 28 of the general table.

What has been said concerning the Trenton limestone as seen in St. Paul, and its qualities as a building-stone, is true of it at Minneapolis, where it is abundantly wrought in the numerous quarries along the river bluffs below the falls, and on Nicollet island. The quarries first considerably wrought were opened in 1856, and are situated a short distance below the university on the east side of the river. In 1857 the first portion of the state university was constructed of stone from this quarry. In 1864 the quarries were opened on the west side of the river, particularly that owned by Weeks and Holscher. Mr. W. W. Eastman's quarries on Nicollet island, were begun in 1865, Mr. Franklin Cook's in 1873. Several others were begun in 1878, and in 1879.

The towers of the suspension bridge over the Mississippi at Minneapolis are constructed of this limestone, and most of the flouring mills of the city, as well as numerous business blocks and dwelling houses. The Universalist church, erected in 1873–75, and dedicated in 1876, is wholly constructed of this stone. It is shown in plate G. The regular building-stone layers of the Trenton in Minneapolis, are represented in the table by No. 27, taken from Nicollet island.

In the use of the Trenton limestone quarried at St. Paul and Minneapolis, regard should be had constantly to its laminated structure. The beds quarried now are as they were originally deposited, and as cut for use embrace in every block many layers of from one-half to two inches in thickness. These consist of alternating clayey and calcareous portions, the latter constituting the hard and enduring part of the stone. These layers are not always distinct and continuous over large surfaces, but they blend or shade into each other every few inches. Yet in process of time, under natural weathering, they get separated so as to fall apart, the clayey parts disintegrating first and causing the calcareous structure, which sustains the whole, to break up into small sheets or fragments. Hence this stone should never be placed on edge, but in the same position it occupied in the quarry. It should never be allowed to form projecting or exposed parts of a building.

Most especially if it be on edge. and in a projecting cornice or capital, it is a source of weakness to the structure, as well as of danger to all passers, from the dropping of sheets or fragments as the weather by wet or frost separates them from each other. The color of the Trenton makes it very suitable for foundations, and for the ranges below the water-table, but even there it should be well bedded in mortar and protected by the water-table in order to keep out the water.

The limestone quarried at Clinton Falls, near Owatonna, in Steele county, belongs to the Lower Silurian. It is from strata higher than the Trenton as seen at Faribault, and has been parallelized with the Hudson River formation. The strata are from two to six inches in thickness and are broken by frequent joints. The stone is of a bluish-drab color, and uniform character of texture. It is useful for common construction, but owing to the thinness of the bedding it cannot be used for first-class buildings and heavy masonry. It is associated in the stratification with much shale, and the stone itself is affected by considerable argillaceous matter, which causes it to be damaged by freezing and thawing, and by corroding vapors in somewhat the same degree as the Trenton stone at St. Paul and Minneapolis. The shale, however, is minutely disseminated throughout the rock, instead of being in lenticular interlaminations as in the Trenton. The chief quarry is owned by Messrs. Lindersmith & Son, and its product is principally used at Owatonna, and in the surrounding country.

Microscopic characters of No. 29. In thin section under the microscope this has very much the same appearance as No. 26, but has a few distinctly formed crystals of calcite porphyritically distributed.

6. SANDSTONES.

The stone quarried at Hinckley in Pine county, by the St. Paul and Duluth railroad (No. 30), bears so strong a resemblance to that quarried near Fort Snelling in Dakota county (No. 31), by the Chicago, Milwaukee and St. Paul railway, both in general outward appearance and in its chemical and physical characters, that it may on these grounds be supposed to belong to the same formation. And since there are no stratigraphical nor structural difficulties opposed to such a reference, but rather evidences of such irregularities as to require it,* they are here considered as belonging to the

*See tenth annual report, 1881. *Geology of a deep well at Minneapolis.*

Potsdam formation, near the horizon of its passage into the St. Croix. The Hinckley rock is but slightly exposed, and has not been much wrought, but on account of its evidently very superior qualities, it will be sought for more for general building than heretofore, and hence it is probable that some of its exposures farther down the valley of the Grindstone river will be opened for that purpose. The present quarry is situated on the left bank of the Grindstone river where the railroad crosses it, the rock rising about eight feet above the water. The railroad bridges along the *dalles* of the St. Louis river have foundations of this stone, and some other railroad works have been made with it. Its color is light-yellow or sometimes with a pinkish tint, and its grain is uniform and arenaceous. Its strength under pressure is very great, amounting to 17,500 pounds per square inch when placed on edge, and 19,000 pounds per square inch when on bed.

Microscopic characters of Nos. 30 *and* 31. The largest of the individual quartz grains composing this rock are about one-half millimeter in diameter, but in general they are about one-tenth millimeter. They are rounded as by attrition among themselves, and their shape is subangular. Their exterior is minutely roughened and in these depressions is deposited the cement which furnishes the bond of the rock. Many of the grains also are interpenetrated by impurities which are ferruginous and give them a yellowish tint, but for the most part the quartz is pure and perfectly clear. Cavities in the quartz grains are sometimes in parallel lines. While the exterior of the quartz grains is coated with a sprinkling of yellowish ochreous impurities, the cementing bond is largely calcareous, but so meager that there are interstitial cavities between the grains of quartz. Figures 5 and 6, plate C.

The sandrock No. 31, quarried near Fort Snelling, has occasionally a grain of feldspar mingled with the quartz, and some of the quartz contains small acicular crystal inclusions that resemble apatite. Otherwise it is exactly like No. 30. It has, however, a little more copious and darker-colored cement, with an occasional rounded grain of magnetite.

Rock No. 31 has been used in the foundations of the railroad bridge at Fort Snelling, one of the piers of this bridge being constructed mainly of this stone, and in the piers of the new highway bridge at the same place, crossing the Mississippi river. The quarry is on an island near Fort Snelling, so near the water level of the Minnesota river that it can be operated only in the winter, when the blocks can be hauled away on the ice. The Fort Snelling quarry was opened in 1869, but was not used very much, after the construction of the railroad bridge over the Minnesota, till 1878, when the highway bridge over the Mississippi was constructed. The strata are homogeneous, horizontal and about two feet thick as quarried, the color being a rusty yellow with some broad banding of lighter yellow. It is liable to inequalities in hardness and durability. Its color gives it an attractive exterior, and renders the tall piers of the Fort Snelling bridge an object of admiration to all architects.

The sandrock quarried at Dresbach, in Winona county (No. 32) is largely feldspathic, and rather soft, but it becomes harder on the drying out of the water which it contains in the quarry. It belongs to the St. Croix formation and very near its lowest part. The great anticlinal of that formation crosses Winona county, bringing to view lower strata of the St. Croix than can be found along the Mississippi in any other county in that part of the state. These lowest beds cannot be found in the Mississippi bluffs further south, nor north. They probably might be opened in numerous places in the valley of Root river and its tributaries, in Houston and Fillmore counties, in the direction of the anticlinal, which enters the state from Wisconsin. In the valley of Black river, at Black River Falls, thirty-three miles from the Mississippi, east of Winona, the crystalline granites and schists appear, brought to the surface by this anticlinal.

The stone is evenly granular, gray, and of a medium-sized grain, very much resembling the Berea sandstone of Ohio. It is in beds that are quarried out from six inches to three or four feet thick. It is free from nodules of pyrite or of coarse quartz pebbles. It can be sawn easily, and dressed with great facility with a hammer and chisel. Its strength in crushing pressure is 6,500 pounds per square inch when placed on its bedding plane, and 3,750 pounds when placed on its edge. Though ranking somewhat lower than the Berea stone in that respect, it will become stronger as the quarries progress, the present working not having penetrated beyond the effects of long weathering, while the stone from the Berea quarries with which it has been compared was from old and much used quarries where the stone shows its best estate. Its strength is ample for the largest structures, and its durability under the weather is evinced by the projecting terrace-like shoulder which it causes along the base of the Mississippi bluffs. Its naturally gray color is found at a depth of a few feet from the weathered surface, the weathered and faded condition of the same strata being seen in the quarries at Dakota (No 36) about a mile above Dresbach. It then becomes lighter, both in weight and in color, absorbs moisture much more readily, is more affected by freezing and thawing, and also is less able to maintain itself intact in case of fire followed by water thrown upon it. It also loses from one-sixth to one-third of its crushing strength.

The Dresbach quarry is owned by J. F. Tostevin, Jr., and was opened in 1881. It was the direct result of a visit by the state geologist, who, in examining the "lead mine" of the Winona mining company, called attention to the quality of the excavated stone, comparing it with the Berea sandstone of Ohio now largely imported to the state. The stone has not yet been extensively introduced, but has been put into several buildings in St. Paul and Minneapolis, and in the trimmings of Ladies Hall, one of the buildings of Carleton college. It is confidently asserted by the owners that this stone will successfully compete with the Ohio stone not only in the country west of the Mississippi but even in the markets of Chicago and Milwaukee. The Catholic church at Rollingstone, in Winona county, is built from the St. Croix, but not quarried at Dresbach.

Microscopic characters of No. 32. The grains are angular or sub-angular, and include some that are feldspathic. The latter retain a trace of cleavage in the parallel disposition of the lines of minute impurities which darken them, and occasionally also show a minute striation as if triclinic. The stone shows, in thin-section, frequent grains of green sand which have a closely netted internal structure, which in high powers shows an aggregation of globules. Scattered through the section are conspicuous, elongated, nearly parallel, somewhat club-shaped, brown grains which are probably sections of fragments of phosphatic bivalves. An occasional aggregation of minute pyrite crystals may also be seen in reflected light. Muscovite is the only mica, and that is in very rare scales. Ocher is nearly wanting in the gray-colored stone of Dresbach, but is much more frequent in the weathered stone quarried at Dakota (No. 36) in the form of irregular clouds and patches.

The stone quarried at Jordan, in Scott county (No. 33), is from the typical locality of the Jordan sandstone formation, and is very similar in all respects to the rock from Dresbach, except that it has a greater amount of insoluble matter, and less of calcareous cement; its alumina also is in greater proportion. This rock is but little quarried in the state. Its line of outcrop is quite narrow, being situated between two firm and persistent limestones. Hence its superficial exposure is mostly confined to a turfed slope along the bluffs of rivers near the top, just below the Shakopee limestone. It is thus seen in numerous places in Fillmore, Olmsted, Winona and Houston counties, at points some miles away from the Mississippi river. It is not known at any place in the bluffs of the Mississippi south of Hastings. It can be seen at Stillwater, in Washington county, and probably exists in the second terrace flat at Nininger in Dakota county. Its outcrop at Jordan is along Sand creek, and rises but few feet above the water. No other rock formation is visible, and were it not for the relation in which it is placed by the dip of the formation as seen at the islands in the river, and at Louisville, its true position in respect to the outcrop at St. Lawrence would not be made out correctly. The principal quarries are owned by F. Nicolin and Philip Kipp; the former opened in 1858 and the latter in 1862. From these quarries was taken the stone used in the construction of the Jordan City mills and the mill of Foss and Wells, at Jordan. The strata are from two inches to two feet in thickness, but cut by rather frequent joints; still there is no difficulty in obtaining blocks as large as needed for ordinary construction.

When the rock is taken from below the water level, or from deep excavation, it has the gray color of the Dresbach stone, but that put in the Jordan City mills is much stained in stripes, parallel with the sedimentation, with iron-rust. This probably renders it firmer, as well as darker, and gives it much the appearance of the rock quarried near Fort Snelling already mentioned (No. 31). The crushing tests that have been made on rock of these two colors from the same quarry (Nos. 33 and 35) show the greater strength of the rusty layers. They also show that the rusty stone absorbs moisture more rapidly, and is easily destroyed by corrosive and other vapors, at least in the case of those portions containing considerable lime and magnesia, rendering them less valuable as a building stone.

Microscopic characters of No. 33. This stone has no greensand grains, or very few; some of the grains are of orthoclase feldspar; occasionally a muscovite scale can be seen; films of ocher are common, some of them being square, as if the product of changed pyrite. The most of the rock consists of fine quartz grains which are rounded or sub-angular, some of the largest being a fifth of a millimeter in diameter.

The red sandstone from Fond du Lac, St. Louis county (No. 34), is of the Potsdam formation, and extends along the south shore of lake Superior eastward, forming the bluffs of the Apostle islands and of the mainland at numerous points. At Siskiwit bay, near the west end of lake Superior, the rock No. 39 was taken from it. This rock is of the same formation, presumably, as the quartzyte that has been described near New Ulm and in Pipestone county (No. 12). The layers are tilted, at Fond du Lac, toward the southeast. They are associated with, and overlie, a vast amount of soft red shale which passes sometimes to a shaly red conglomerate, the same that in other places about lake Superior is in contact with the igneous rocks and becomes copper-bearing. This red sandstone is well known in Milwaukee, Chicago and Detroit. The quarries in it further east furnished the red sandrock used in the Milwaukee court house, and a great many brown stone fronts in that city and in Chicago were obtained from it. It was formerly quarried on the south side of Siskiwit bay, on Isle Royale, and sold in Detroit as *Isle Royale brownstone.* While it consists largely of quartz, the grains are not so firmly cemented or united as to render it objectionably hard except when it has been subjected to metamorphic agencies, a , in Pipestone county and in some of the analogous knobs seen in the northern part of the state.* On Isle Royale, when quarried, it is fine-grained and rather brittle, being more metamorphosed than at Fond du Lac. At some points it has a mottling of red and gray, as at Sault St. Marie, at the eastern end of lake Superior, where the ship canal is cut in it, and largely built of it. At Fond du Lac it has also a mottling of green, particularly at the quarry on Mission creek. In some places it is so loosely cemented as to crumble and to be rendered useless for building, and in others it contains pebbles, and even stones several inches in diameter, of white quartz, or even becomes wholly conglomeritic. Nearly all these features can be seen at Fond du Lac, but there is still at that place a great abundance of fine stone of the best quality. Its strength under pressure is from five to eight thousand pounds per square inch, tested for the survey by general Gillmore.

At Fond du Lac this stone, while in general of a reddish-brown color, is variously marked with spots and stripes of lighter shade. It also has occasional grains of quartz as large as a pea, or even as large as a hen's egg, distributed especially through the lighter colored portions, but not much of it is conglomeritic. Sometimes flattened lumps of red shale from two to five inches across are seen arranged in belts coincident rudely with the stratification. The strata are of all thicknesses up to three or four feet, and very large blocks are obtainable. The principal quarry is owned by Mr. M. Boyle. It is situated in the bluff of the St. Louis river a short distance above Fond du Lac, at the first rapids, and was first opened by Mr. M. E. Chambers in 1870. The stone appears, and has been worked, on both sides of the river, but the principal excavation is on the Minnesota side from twenty to forty feet above the water, near the St. Paul and Duluth railroad. It is also opened on Mission creek, north of Fond du Lac, by James G. McDonald, where some

*Tenth annual report, p. 101. Nos. 784, 785.

very fine stone has been taken out. The product of this quarry is sent to Winnipeg, where a Manitoba college is trimmed with it.

This sandrock is seen in the Clark and Hunter blocks at Duluth, but the principal structure of this material in the state is the Westminster church at Minneapolis, illustrated by plate H. It has been used as trimmings in a few buildings both in Minneapolis and St. Paul.

Microscopic characters of No. 34. About two-thirds of this rock consists of rounded and subangular grains of quartz, the most of it being pure and limpid, but some of it having numerous globular inclusions. Nine-tenths of the remainder may be regarded as feldspar. This is often crowded and darkened by ocher and ferrite but is sometimes white and kaolinic. Occasionally can be seen a fibrous, light-green, angular grain that has apparently resulted from hornblende or from augite. A few fibrous serpentinous partings surround and separate some of the feldspars. Apatite spicules cut some of the quartz. A few black grains are magnetite. A little calcite is distinguishable.

The sandrock which has been somewhat quarried and used at Taylor's Falls (No. 37) is very similar to that obtained at Jordan. It is of a light color, rather friable on first quarrying, hardens on exposure, and is in heavy natural strata from which blocks of any desired size may be taken. It belongs to the St. Croix formation, and is extensively exposed in the bluffs of the St. Croix and Mississippi rivers, but in a higher horizon than the Dresbach stone.

7. STONES FROM OTHER STATES.

Owing to the use of several building stones in St. Paul and Minneapolis, and to some extent in Hastings, Faribault, Red Wing and Winona, from other states, it has been thought best to include in the tests that have been made, samples of these stones, in order to ascertain their qualities and comparative merits. The results are given in the general table. The pieces selected for these tests were obtained from the blocks that have been sent to Minnesota for use in some prominent structure, and may be taken as rather above the average for quality for the respective stones. The tests were made in exactly the same manner, and frequently in the same solution, and at the same moment, as the tests made of Minnesota stones.

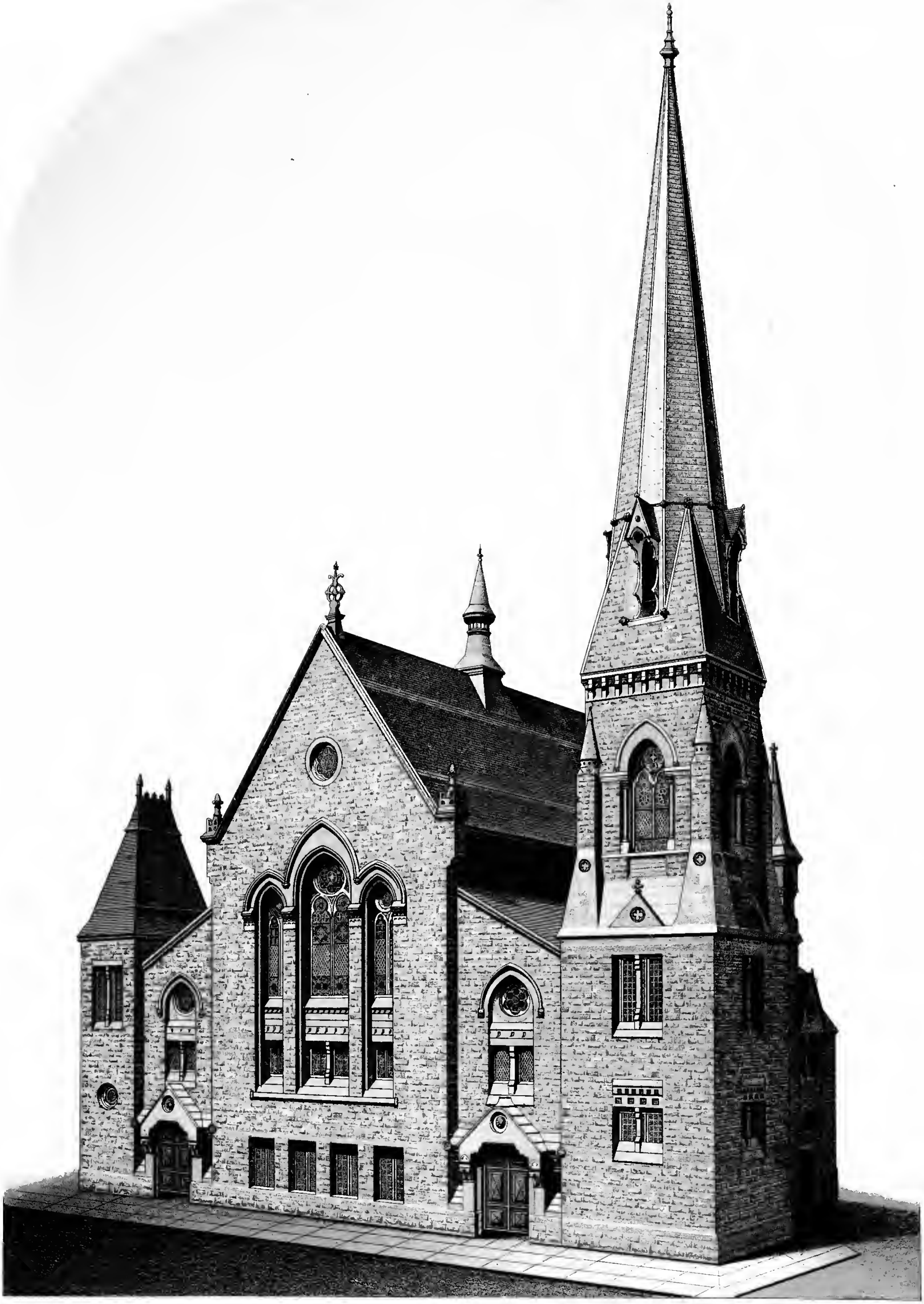
Of these the Lemont stone (No. 38), also frequently known as the Joliet stone, from the Niagara formation, in Illinois, comes through the series of tests with a higher rank on a scale of 100 than any of the others, being in that respect on a par with the Minnesota dolomite (No. 13) furnished by the

PLATE H.

EXPLANATION.

Erected in 1881–83.

Built wholly of the brown sandrock quarried at Fond du Lac.



WESTMINSTER PRESBYTERIAN CHURCH.

MINNEAPOLIS

quarries at Frontenac, in Goodhue county. They both stand 77. This stone has been employed in the fronts of several large business blocks in Minneapolis, the principal being the Casey block, between Washington avenue and Third street, on Nicollet, and the Hennepin block on Hennepin avenue.

The Stone City stone, from Iowa (No. 40), is from the same formation as the Lemont stone, but it has lost its original color (which is that of the Lemont stone) by long exposure in the bluffs of the river where it is wrought. The acquired color penetrates the formation there to a depth greater than that reached by any of the quarries. It is now light buff, which is the color of nearly all of the limestones, where exposed in the "driftless area," whatever they may be where they are buried under the drift sheet at other places. As quarried at Stone City (in Jones county) the Niagara seems to be much more a magnesian limestone than at Lemont in Illinois, the insoluble portion being less than one per cent., and its content of lime and magnesia together being over 95 per cent. As compared with the Lemont stone for purposes of construction, the tests that have been made by the survey show the Lemont stone is much stronger under pressure,* but that it weathers much more rapidly, The latter is probably due to its larger percentage of alumina, which gives it a finely striped surface when dressed on the edges of the bedding, and produces, but much more slowly, the same laminated disintegration as is seen in the Trenton limestone (No. 27). The Stone City dolomitic limestone was employed in the construction of the Boston block and the Windom block, at Minneapolis, and for the curbing of the paved streets.

The Berea sandstone, Number 41 of the table, is one that has a wide reputation in the United States for its excellence in all kinds of building. It has a uniform color and rather fine and arenaceous grain, with occasional feldspar (?) and muscovite particles, the cement being carbonate of lime. This may be seen in numerous buildings in St. Paul and Minneapolis, as well as in Stillwater, Red Wing, Winona and other cities. The Syndicate block, at Minneapolis, is the largest in the state wholly faced with this stone.

*The Lemont stone is exceptionally strong for a limestone.

(B.) GENERAL TABLE OF QUALITATIVE TESTS OF MINNESOTA BUILDING STONES.

For the purpose of reaching results that would serve as a basis for comparing the building-stones of Minnesota with each other, and with those from other states, average samples were obtained and subjected to such physical tests as could be devised that would represent the intensified natural action of the weather. These physical tests were performed by Prof. J. A. Dodge of the University of Minnesota, and the chemical analyses of the same stones were also done by him, or under his direction by Mr. C. F. Sidener. At the same time duplicate two-inch cubes were subjected to pressure at Fort Wadsworth, Staten Island, under the direction of Gen. Q. A. Gillmore, one cube being crushed in the direction of the bedding, and the other in a direction across it, between steel plates. The results of these tests are brought together for comparison in the *Systematic table of the qualities of Minnesota building stones*, already referred to.

In the same table these results are carried out into mathematical expressions, by a series of credits on a scale of ten, the final results being placed on a scale of rank from 100 downward, so that each stone stands in the final result wherever the sum of its credits may warrant. In getting these credits of the individual stones, in each case the highest attained result has been taken as 10 and the lowest as 1. The intermediate results have been distributed proportionately between 10 and 1. In those cases where the first results, are not expressed by figures, an estimate has been made and expressed in figures, the highest rank (10) being given to those stones that stood the test in question most successfully. This comparison is made on the assumption that all the tests included in the credit columns are of equal value in indicating the comparative worth of the stones, but in reality some are of much more value than others. It is evident that specific gravity may be reckoned either a favorable or unfavorable element. In some situations, or for some uses, it is desirable to have a light stone, and in others a heavy one. The same is true in regard to some of the other qualities. Those elements, in general, which go to make up a very durable building-stone, and thus act affirmatively for the stone as a part of the structure, also go to make it incorrigible in the builder's hands, and to that extent act negatively. For these reasons specific gravity has not been included in ascertaining the individual credits of the stones, but another element, not included in the physical tests, has been introduced, viz., *facility of dressing*, which plainly is governed by the hardness or the toughness of the rock; the former depending on its content of free silica, and the latter on the crystalline texture, or the nature of the cement in the case of sedimentary rocks. This operates disastrously on the crystalline rocks, and wholly to the advantage of the softest rocks. Yet there is good reason for allowing this, though this quality has, perhaps, less to do with the actual value of the stones as material for building, since an excess of hardness (or crushing resistance) at least up to 25,000 pounds per square inch, which is equally unimportant in ordinary construction, has been allowed to act in its full capacity in favor of the crystallines. The variation of texture induced by lamination, or accompanied by it, is a very important element in sedimentary rocks.

In forming any judgment of the comparative value of these building-stones for individual markets, other elements should be included along with these physical tests, such as ease of quarrying, accessibility of the quarry, facility of transportation and permanence of the supply.

THE METHODS OF THE PHYSICAL TESTS.

The detail of the methods of the physical tests, as given by Prof. Dodge, is as follows:

Determination of specific gravity. This was executed by the usual method for solid bodies, with the use of an analytical balance. The specimens were nearly of the same size and approximately cubical, having been split out by hammer and chisel. They measured from an inch to an inch and a half on a side, and weighed on an average about 50 grammes. They were in an air-dried state, having been allowed to lie on a table in a warm and dry room for several weeks before their specific gravity was determined. They were then severally weighed. They were then immersed in water and allowed to remain about twenty-four hours, when all evolution of air bubbles had ceased. They were then weighed in water, suspended by a thread. The weight in air was divided by the loss of weight in water, and the result was taken as the specific gravity.

Determination of the absorption of moisture from a damp atmosphere. The samples of stone were placed in the cells of a hot-water bath for several days, to expel their hygroscopic moisture. They were then allowed to cool in desiccators, over sulphuric acid, and were weighed. They were then placed upon a set of glass shelves standing in a pan of water, and a tight cylinder was inserted over the shelves, the mouth of the cylinder being sealed by the water, after the manner of a gas holder. The apparatus remained thus in a room whose temperature was pretty uniform, from 60° to 70° Fahrenheit, for seven weeks, the water being replenished from time to time, so as to maintain a constant closure of the cylinder. Then the stones were removed to bell-jars in which they were supported over water, and thus taken to the balance and weighed. The stones submitted to this test were somewhat larger than the pieces used for making the determination of specific gravity. They had an average weight of about 70 grammes. They were roughly shaped. The minimum absorption of moisture .03 per cent. of the weight of the stone, is so small in amount as to be practically nothing. The maximum, 3.94 per cent of the weight of the stone, seems quite considerable. It seems probable that, in the atmosphere saturated with moisture in which they were kept for seven weeks, some of the stones absorbed all the moisture they were capable of taking up, while others by a longer exposure to the same conditions would have shown still higher figures.

Determination of the absorption of water by soaking. A third set of stones with an average weight of about 70 grammes, approximately rectangular and measuring from an inch to an inch and a half on a side, were dried in the hot-water bath to expel moisture. They were then cooled in the desiccator and weighed. They were then placed in a large porcelain dish of water and allowed to soak for four days. They were then severally taken from the water, and after the water had been removed from their surface by pressing bibulous paper upon them, they were weighed as expeditiously as possible to avoid loss by drying. The increase of weight is expressed in percentage figures. The increase of weight thus shown, especially by several sandstones, is in some cases very considerable. In other cases the absorption of water by soaking is scarcely greater than the absorption from a damp atmosphere after the lapse of some weeks.

Determination of the action of carbonic acid. A set of pieces, similar in size and shape to those used in the previous determination, were dried for six days at 212° Fahrenheit, then weighed. They were then suspended by strings in a glass vessel of water, not in contact with one another, and a stream of carbonic acid gas was run through the water for several hours at short intervals, so as to maintain the water pretty well saturated. The gas was washed before entering the vessel containing the stones. The water was changed every few days by use of a siphon. The action was continued for six weeks. The stones were then soaked in pure water, wiped, dried at 212° F. for six days and weighed. The loss of weight is given in percentage figures. Two glass vessels were used in the experiment. The limestone pieces were placed in one, the sandstone and granite in the other. The two were treated as nearly alike as possible. The stones suffered scarcely any *visible* change. But the water in the vessel holding the limestones became highly impregnated with carbonate of lime; that in the other much less so.

Determination of the action of strong acid fumes. Another set of pieces of stone, similar in size and shape to the preceding, were dried for six days at 212° F., then weighed. They were then placed in an apparatus similar to that used for determining the absorption of moisture, constructed of glass and porcelain. the porcelain pan containing strong muriatic acid, and a bottle containing nitric acid being placed within the apparatus, as also a bottle containing muriatic acid and black oxide of magnanese, for the purpose of evolving chlorine. In this apparatus, exposed to the strong fumes, the stones remained during seven weeks. They were then removed and placed in water to soak, this water being repeatedly changed. When free from acid they were dried for six days as at first, then weighed. The loss of weight is given in percentage figures.

The design of this test was to determine the disintegrating and staining effects produced by oxydizing agents, representing the action of the atmosphere intensified in degree and concentrated in respect to time.

Determination of the effect of frost. In this determination the pieces which had been used to test the absorption of water by soaking, whose weight dry had been previously learned, were placed in a shallow iron pan, nearly covered with water, and exposed outside the building in a sheltered place to freezing and thawing from February 4th to April 1st, eight weeks To thaw, they were occasionally brought into a warm room for a few hours. During the time stated very little intense cold was experienced, but the water in the pan was in a frozen state nearly all the time. After this exposure, the pieces were carefully examined, then dried for six days as usual and weighed. The figures show the *loss of weight* caused by slight crumbling of edges, etc., by the action of frost.

Determination of the effect of heat. For this determination a muffle furnace was made use of. The temperature of the muffle was raised to a red heat; then the samples of stone, one after another, were exposed to the heat of the muffle, being at first placed near the open mouth of the muffle, then gradually moved inward until they came into the hottest part and were heated to redness. Observations were made of the effect of the heating. They were lifted out with tongs once or twice and closely inspected. After the heating test in the muffle, the pieces were severally removed from the muffle and while still very hot, but at a temperature below redness, they were immersed in a tank of water for a few minutes. The action of the water, in crumbling or cracking the heated stones was observed and noted. The pieces used were in size rather larger than those used in previous tests, being from one and a half to two inches on a side for the most part. They had been well air-dried at the time this test was made with them. In these observations, as in those of the preceding tests not depending on the balance, correctness depends much, of course, on the judgment of the operator.

(C.) GENERAL CONCLUSIONS RESPECTING THE QUALITIES OF BUILDING STONES.

The weathering of a building-stone which results in its final demolition is partly physical and partly chemical. These processes aid each other. A stone that is easily rent by frost, or is washed and eroded rapidly by rains or hail, or wind, will quickly prove an element of weakness in a building; and one that is able to resist these physical agents successfully, when aided by the invisible action of rapid chemical change, will also soon disintegrate when favorably exposed to all these forces. For instance, if a limestone be so placed in a building as to be protected from the physical action of wind and rain, it becomes coated with a film of dirt which results both from its own chemical change and the accumulation of dust. This film acts to protect the stone from the chemical changes due to the vapors or acids that float in the air, or that are in solution in rainwater; if, however, the same stone be freshly washed by every pelting rain, its corners become rounded and its entire exterior surface slowly wears away, under the unobstructed action of both chemical and physical forces. The same is true of sandstones, especially those having a calcareous cement, and also of the crystalline rocks. In the case of granite, however, the change is so slow that the co-operation of chemical and physical forces can only be seen and estimated in their natural beds where there has been time sufficient for the change of one mineral to another by the substitution of different elements and the removal of some of those which were there at first. After this change has been effected, if physical causes remove the weakened mineral a fresh surface is presented for the continuance of a slow chemical change. The glacial epochs have thus operated to keep the crystalline rocks fresh in northern latitudes, while further south, and beyond the limit of glaciation, the decayed material of the crystalline rocks has frequently accumulated to great thicknesses.* The crystalline rocks of Minnesota, so far as they have been quarried, and tested by the survey, seem to show the freshness of the glaciation that has passed over them in their remarkable strength under pressure.

*Compare the report of R. W. Raymond on the mining resources of the United States, 1874, p. 335. The Silver City mining district of New Mexico.

It is evident therefore that the value of a building-stone depends both on its chemical constitution and its physical structure. A rock so constituted that either of these is liable to rapid attack by the weather, is necessarily a poor one for construction.

A stone that *absorbs moisture* abundantly and rapidly is apt to be injured by alternate freezing and thawing. Hence clayey constituents are injurious. An argillaceous stone is generally compact, and often has no pores visible to the eye. Such will disintegrate rapidly either by freezing and thawing, or by corrosive vapors.

A stone that is *compactly and finely granular* will exfoliate by freezing and thawing more easily than one that is coarse-grained.

A stone that is *laminated in structure*, so as to absorb moisture unequally, will expand by heat and contract by cold unequally, and especially by freezing and thawing. Such a stone will gradually separate into sheets coincident with its laminated structure.

A stone that has *a granular texture*, as contrasted with one that is crystalline or fibrous, will crumble sooner by frost and by chemical agents, because of the easy dislodgment of the individual grains.

A stone which *has an open texture* will serve as a lodging place for floating particles of dust, and lichens and fungus growths will appear on its surface. These give off by their decay organic acids which attack the carbonates, of which the rock may be largely composed, and unless removed they will cause the decomposition of the stone to some depth, and its conversion to a loose powder. A loose-textured stone, however, does not transmit heat so rapidly as a dense one ; and in cold climates, especially if they are also dry and free from dust, it would be a warmer building material as well as perhaps more durable, than a dense stone.

A *dolomitic limestone* is more durable than a pure limestone. The limestones of Minnesota are all of them somewhat magnesian, but the Trenton is not sufficiently so to be distinctively denominated a magnesian limestone. Nearly all the others are so highly magnesian as to reach occasionally more than forty per cent. of carbonate of magnesia, when they have been classed as dolomites in the accompanying table.

A *siliceous rock*, other things being equal, is more durable than a limestone; but the durability of a siliceous rock plainly depends on the state of aggregation of the individual grains and their cementing bond, as well as on the chemical relation of the silica to the other chemical ingredients. For instance, a nearly pure arenaceous rock of quartz, like the St. Peter sandstone, containing about ninety-eight per cent. of quartz, is still so fragile that it is easily excavated with the fingers alone, there being no sufficient cementing material to bind the grains to each other. The same kind of sandstone, however, with a sufficient cement, makes a very fine building material, as the stone at Hinckley in Pine county, No. 30. If furthermore there be a partial chemical union between the silica and the other elements, as in the Pipestone quartzyte (No. 12), the stone is rendered more durable still, and more firm under pressure. And if the chemical union be complete, so as to result in a perfect crystallization of the rock, the stone becomes one of the granites or syenites and necessarily takes the highest rank in the comparative scale of values.

A stone that has a *high percentage of alumina* (if it be also non-crystalline), or of organic matter, or of protoxide of iron, will generally disintegrate rapidly. Such stones generally are of a bluish color.

A stone of rather poor quality by reason of a weak physical structure or an unfortunate chemical composition, *is improved by the absorption of iron.* The sesquioxide of iron furnishes a bond to hold the grains together, in case of an originally weak cement, and it takes the place of the protoxide of iron, or of organic impurities.

A stone of high grade, having a crystalline texture, or a superior chemical constitution, *is impaired by the absorption of iron* through the process of weathering. The first effect of weathering in granites is visible in the loss of transparency of the individual grains either of feldspar or of some of the other minerals, the result of the penetration of ferruginous matters within them. A dolomite which is changed in color by this means is also weakened. This is apparent on comparing No. 19 with No. 23, or No. 38 with No. 40.

A stone that *has no very weak element* in the list of its credits, will be found more valuable than one that reaches an average result perhaps higher, but has one or more very low points on the scale of credits. The ultimate usefulness of a stone in average construction, depends on its weakest element.

Durability, texture, color. These are the essential qualities to be considered in the discussion or selection of a building-stone. The more nearly these three are combined in favorable degrees in the same stone, the more valuable that stone becomes.

Previous to the opening of a quarry the rock in its natural beds should be carefully examined, and a full and scientific description, including a comparison of the different layers, ought to be made of the appearance of the rock in the hands of nature, as testimony to its weathering power. The enduring formations are the sources of our best building-stone, and the individual layers will be found conspicuous, or hid by the decay of their own forms, in proportion as they have been able to withstand the alternations of heat and cold and of moisture and dryness. There they have been subjected to these vicissitudes for thousands of years.

Permanence of color, and the presence of pyrite, may be determined best by the appearance of the natural outcrop. Before demolition by the weather a rock assumes different colors. Whatever may be the color of a stone fresh from the quarry, it can not be permanent. Most of our limestones show three different colors, according to the degree of exposure and the ease of access within for air and water. For instance, the Galena limestone, in the southern part of the state, as seen along the river bluffs, is of a dark buff or rusty-buff color on the long-weathered surface. This color pervades that portion of the stone that is undergoing rapid disintegration in its natural position, and is generally not more than half an inch in depth. Under that is the light buff color seen in most of the stone quarried from that formation, and it pervades the stone to a great depth. Where the texture is open this color has apparently gone through all the beds, but it is an acquired color produced on the rock by atmospheric causes. The same effect is produced on all magnesian limestones, the depth of the change depending largely on the percentage of argillaceous impurities the rock may contain. Deep within the rock may finally be seen the natural color, where exposure has not yet produced any change. It is blue, and at first is seen only in the centre of the layers, surrounded by a layer of the light color. These different colors can be seen in the Trenton at St. Paul and Minneapolis; but owing to the close and clayey nature of this formation, the blue color is better preserved, and is that seen in the stone now most used. Formerly the stone used was of a dirty-drab or yellowish color, very largely, as the quarries had not penetrated below the natural weathering.

(D.) THE USE OF STONE IN MINNESOTA.

STONE BUILDINGS IN ST. PAUL AND MINNEAPOLIS.

The use of stone for construction in Minnesota has but fairly begun. This is owing to the lateness of the settlement of the country by Europeans, and the ease with which other material has been obtained. Pine lumber and brick are both abundantly and cheaply supplied. From the log house of the pioneer to the elegant stone mansion of his successor of to-day there is necessarily a slow change, in most of the western country, but in many parts of Minnesota this change has been so rapid that a single generation has witnessed both. For the purpose of making a punctuation-point in this transition, so that the future may look back on a definite stage in what is now the present, in the growth of the two principal cities, the following statement of the use of stone in St. Paul and Minneapolis is given, based on an enumeration made in 1881.* Every business front was considered a building; and if a corner block had also an important entrance from the cross street, that entrance was estimated as a building.

Stone buildings in St. Paul in 1881.

Composed entirely of limestone quarried at St. Paul (No. 28), 324.

Of these three have iron fronts, three have granite trimmings, and four have Kasota trimmings; and several have the rear walls of brick. This class includes many of the largest structures in the city: the Catholic cathedral, the Unitarian church, St. Paul's Episcopal church, St. Mary's (Catholic) church, the United States custom house and post office, the Adams, Franklin and Washington schools, the county jail, and other schools and churches.

Composed entirely of Kasota stone (No. 23), 2.

These are the Baptist church and the residence of Mr. N. W. Kittson on St. Anthony hill.

Composed of Trenton limestone walls and fronts of Kasota?

If any such exist they were counted either as wholly of Trenton or as of brick walls with Kasota fronts.

Composed of Trenton limestone with Frontenac fronts?

If any such exist they were counted either as wholly of Trenton or as of brick walls with Frontenac fronts.

Composed of Trenton limestone walls and brick fronts, 82.

Two of these have Kasota trimmings. The Windsor House is in this class.

Composed of brick walls with fronts of Trenton limestone, 9.

Composed of brick walls with Kasota fronts, 1.

This is the Greve block, on Third street between Minnesota and Robert.

Composed of brick walls and fronts of Frontenac stone (No. 13), 3.

Composed of brick walls and fronts of granite from Minnesota, 3.

These are the fronts of Nicols and Dean, on Third street.

Composed of brick walls and fronts of Berea sandstone, 4.

*The main results of this enumeration have also been furnished the United States census bureau, for 1880.

These include the Manheimer block and the German American Bank. One has partly granite. The Manheimer block has a Kasota base.

Composed of brick walls with trimmings of Trenton limestone, 208.

Of these six have partly granite in the trimmings. This class includes the capitol,* and some school-houses.

Composed of brick walls with Kasota trimmings, 107.

Of these five have trimmings in part of granite. In this class are the Drake and the Davidson blocks, the headquarters building of the Chicago, St. Paul, Minneapolis and Omaba railway, the market house, three of the engine houses of the fire department, and two school-houses.

Composed of brick walls and trimmings of Frontenac stone, 49.

Eleven of these have some granite in the trimmings. In this class falls the block of Auerbach, Finch and Van Slyck.

Composed of brick walls and trimmings of Fond du Lac sandstone (No. 34), 7.

Three of these also include some marble in their trimmings.

Composed of brick walls with trimmings of Berea sandstone, 30.

Five have partly granite trimmings.

Composed of brick walls with white marble trimmings, 1.

This is a residence on Dayton's bluff.

Buildings partly trimmed with granite, 28.

Total number of buildings in the city (estimated at one for every six inhabitants), 6912.

Total number of stone buildings, 326.

Percentage of stone buildings, $4\frac{3}{4}$.

The *school houses*, in St. Paul, are built generally of brick. The following list embraces all but the frame buildings, viz: *Madison school*, Bluff street west, is of red brick, with Trenton base and trimmings. *Lincoln school*, on Collins street, cream-colored brick, with Trenton trimmings and base. *Van Buren school*, on Bates street, Dayton's bluff, is of cream-colored brick, with Kasota trimmings and Trenton basement. *Adams school*,† on Tenth street, wholly of Trenton limestone. *Webster school*, corner of Sibley and Laurel avenues, is of cream-colored brick with Trenton basement and Kasota trimmings. *Jackson school*, on University avenue, is of red brick, with Trenton base and trimmings. *Jefferson school*, on Pleasant avenue, is of cream-colored brick, trimmed with Trenton limestone and iron. *Monroe school*, on Fort street, is of red brick, with Trenton basement and trimmings. *Washington school*, corner of Olive and Eighth streets, Trenton limestone? (stuccoed), with Trenton trimmings. *Franklin school*, corner of Broadway and Tenth streets, wholly of Trenton limestone.

Stone buildings in Minneapolis in 1881.

Composed entirely of Trenton limestone quarried at Minneapolis (No. 27), 155.

This includes the largest structures of the city, such as the Washburn A, B and C flouring mills, the Pillsbury A flouring mill, the University of Minnesota, the College hospital (formerly Macalester college), the Universalist church, the Irish and the French Catholic churches, and several of the school-houses of the city.

Composed of Fond du Lac sandrock (No. 34), 1.

This is the new Westminster Presbyterian church; its inner walls are of Trenton limestone.

Composed of Trenton limestone walls and fronts of Berea sandstone, 5.

Composed of Trenton limestone with brick fronts, 34.

Composed of Trenton limestone with Kasota trimmings, 9.

Composed of Trenton limestone and trimmings of Minnesota granite, 12.

Composed of Trenton limestone with trimmings of brick, 8.

Buildings of brick with fronts of Berea sandstone, 5.

Buildings of brick with fronts of Joliet (or Lemont) stone, 8.

Buildings of brick with Stone City stone (No. 40), 4.

Buildings of brick with trimmings of Trenton limestone, 177.

Buildings of brick with trimmings of Berea sandstone, 60.

*This capitol building was burned in the winter of 1880-81.

†This has since been torn down, and in its place has been erected a new High school building of brick, with Kasota stone for trimmings.

Buildings of brick with trimmings of Frontenac limestone, 13.
Buildings of brick with Joliet (or Lemont) trimmings, 3.
Buildings of brick with Fond du Lac sandstone trimmings, 48.
Buildings of brick with Kasota trimmings, 11.
Buildings of brick with granite trimmings, 6.
Buildings partly trimmed with granite, 21.
Buildings of brick with white marble trimmings, 1.
Total stone buildings in the city, 224.
Total buildings in Minneapolis (estimated at one for every six inhabitants), 7814.
Percentage of stone buildings, $2\frac{7}{8}$.

In several residences artificial stone (concrete) is found for window-caps or other trimmings, but with Trenton sills, basement and water-tables. Lemont water-tables are seen in a few buildings which have other stone for trimmings. Kasota steps and water-tables are frequently put in buildings that have other stone for trimmings. There is probably not a foundation laid in Minneapolis of any other stone but the Trenton limestone. There are perhaps twenty other brick buildings with artificial stone trimmings, of which no account has been made.

The city buildings. The *city hall* building is made of the Trenton limestone trimmed with St. Cloud granite. The *fire department* buildings are as follows: corner Second street and Third avenue north, two fronts, cream brick walls, with granite water-tables and Trenton trimmings; between Sixth and Seventh avenues south, on Third street, cream brick walls, artificial stone trimmings and granite water-tables; Washington avenue south, between Fourteenth and Thirteenth avenues south, two fronts, cream brick with Berea sandstone trimmings, and granite door-corners; on Plymouth avenue, cream brick, with artificial stone trimmings and granite door-corners; on Second street S. E., near Central avenue, cream brick, Trenton limestone sills and keystone; Main street and Thirteenth avenue N. E., Trenton limestone, cream brick front, artificial stone trimmings. The *school buildings* are as follows: Washington school, Fourth street and Third avenue south, wholly of Trenton limestone; the High school, Trenton and Kasota trimmings; Monroe school, Franklin avenue and Twenty-fourth avenue south, cream brick with Berea sandstone trimmings, slate roof, and Kasota steps; Winthrop school, in East Minneapolis, wholly of Trenton; Marcy school, East Minneapolis, cream brick walls and Trenton trimmings; Jackson, corner of Fifteenth avenue south and Fourth street, cream brick walls, iron caps and wooden window sills, no water-table, Trenton basement; Jefferson, Seventh street and First avenue north, cream brick with trimmings of artficial stone, slate roof, Trenton basement, shows the poor architecture of a granite column and pedestal standing on a base of artificial stone; Webster school, in N. E. Minneapolis, cream brick walls, Trenton base, Berea sandstone water-tables and trimmings; Sumner school, Sixth avenue north, between Nineteenth and Twentieth streets, cream brick, with Trenton base and sills; Humboldt school, cream brick, Trenton limestone base, artificial stone water-tables and trimmings; Adams school, cream brick with Trenton trimmings; Garfield school, on Chicago avenue, cream brick, Berea trimmings, granite sills, slate roof and Kasota steps; Everett school, Sixth avenue north and Third street, East Minneapolis, cream brick, Trenton trimmings and basement; Madison school, Fifteenth street, between Fifth and Sixth avenues south, cream brick, Trenton basement, iron trimmings; Clay school, Fourth street and Twentieth avenue south, cream brick, Berea trimmings, slate roof, Kasota steps; Franklin school, Fourth street and Fifteenth avenue north, cream brick and Trenton base and trimmings; Lincoln school, Washington avenue north, between Sixth and Seventh avenues, cream brick, Trenton basement and iron trimmings; Hennepin county *jail and sheriff's residence*, Trenton limestone; *court house*, cream brick with Trenton trimmings; *city market*, cream brick walls, trimmed with artificial stone and red brick, inner walls of Trenton stone; *city lock-up*, Trenton limestone; *water-works*, Trenton limestone; the piers of the *suspension bridge*, and its anchorages, are of Trenton limestone trimmed with granite; the piers of the other *highway bridges*, and of the railroad bridge over the Mississippi, are of Trenton, though the arched bridge across the east channel of the Mississippi, has Red Wing stone in the angles.

Buildings belonging to the State of Minnesota.

The capitol, at St. Paul, is described on page 163, and is illustrated in plate D.

The university, at Minneapolis, embraces two buildings. The principal or general academic

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building was partly erected in 1857, and the rest in 1874–5. The building which accommodates the Agricultural Department was erected in 1874-5. The former structure is built of the Trenton limestone quarried at Minneapolis, and the latter of cream-colored brick trimmed with Trenton limestone.

The state prison, at Stillwater, was begun in 1852 and has been enlarged at different times. It is composed almost entirely of the dolomitic stone quarried at Stillwater, but has some trimmings of the pinkish Kasota stone.

The insane asylum at St. Peter was begun in 1867. Portions were built in 1868, '69, '71, '73 and '74. It is all built of the Kasota and St. Peter stone, and lined with brick. The only contrast in the trimmings is made by cutting them finer than the other stone.

The asylum for the deaf and mute, at Faribault, is constructed and trimmed of limestone quarried near Faribault. It was erected at intervals of time as money was appropriated by the legislature, each addition being five years later than the preceding, beginning in 1866 and ending with 1881.

The second insane asylum, at Rochester, is made of brick, with windows and chimney-caps of stone quarried about three miles east of Mantorville. The basement is of the Trenton. The building was begun in 1877–8, but was more than doubled in size in 1882.

The reform school, at St. Paul, was erected in 1862 and consists largely of the Trenton limestone, quarried at St. Paul. Some of the subordinate buildings are of brick trimmed with Trenton.

The school for the blind, at Faribault, is a frame building veneered with red brick, with trimmings of the same, erected in 1874.

The school for idiots and imbeciles was erected in 1881. It is located at Faribault, and was built of the Trenton limestone quarried near that city.

The foregoing pages are intended to give some idea of the quality of Minnesota building stones. All builders and architects of the state ought to have regard for the products of our quarries, and to avoid the importation of foreign stone when suitable material can be got within the limits of Minnesota. There seems to be no reason to believe that the state is deficient in stone suitable for all styles and kinds of architecture. On the contrary almost every kind of stone can be got. The stone to be obtained at Dresbach, in Winona county, is so nearly identical in color and grain and all outward characters, to the sandstone imported from Ohio, that it can be employed with it in the same structure. It is to be hoped that the present fashion of using the Ohio stone, at great cost for transportation, will be only temporary, and that influential builders will see to it that our equally good stones are not allowed to remain unused. It cannot be anything more than a sentiment that prefers foreign products over domestic, that will cause the continued importation of stone from abroad.

SYSTEMATIC TABLE

OF THE

QUALITIES OF THE BUILDING STONES

OF MINNESOTA.

SYSTEMATIC TABLE OF THE QUALITIES

Number.	Geol. survey. Field number.	Museum register number.	Chemical series number.	Locality.	What quarry.	Formation and kind of rock.	SPECIFIC GRAVITY Dodge.	SPECIFIC GRAVITY Gillmore.	STRENGTH IN POUNDS. Of 2-inch cube.	STRENGTH IN POUNDS. Per square inch.	Weight in pounds per cubic foot.
						1. CRYSTALLINE.					
1	......	.....	113	E. St. Cloud, Sherburne county.	Breen & Young's.	Fine-grained gray syenite.	2 70	2.692	On bed 112,000. On edge 105.000	On bed 28,000. One edge 26,250.	168 2
2	1	......	114	Duluth, St. Louis Co.	Rice Point.	Gabbro. *Cupriferous.*	2 79	2 802	On bed 109,000. On edge 105,000.	On bed 27,250. On edge 26,250.	175.1
3	820	190 and 524	108	Taylor's Falls, Chisago county.	Railroad cut.	Traprock. *Cupriferous.*	3.00	3.000	On bed 105,000. On edge 105,000.	On bed 26,250. On edge 26,250.	187.5
4	.....	......	109	Sauk Rapids, Benton Co.	Collins, Mitchell & Searle's.	Fine-grained gray syenite.	2.71	2 683	On bed 86,000. On edge 100,000.	On bed 21,500. On edge 25,000.	167.7
5	526	......	116	Beaver Bay, Lake Co.	Wieland Bros.	Red fine-grained syenite. *Cupriferous.*	2.65	2.603	On bed 106,000. On edge 103,000.	On bed 26,500. On edge 25,750.	162.7
6	803	......	111	E. St. Cloud, Sherburne county.	Breen & Young's.	Red syenite, quartzose.	2.63	2.609	On bed 112,000. On edge 105,000.	On bed 28,000. On edge 26,250.	163.1
7	835	......	112	E. St. Cloud, Sherburne county.	Breen & Young's.	Gray quartzose syenite.	2.63	2 609	On bed 105.000. On edge 103,000.	On bed 26,250. On edge 25,750.	163.1
8	120 and 637	.....	119	Beaver Bay, Lake Co.	Wieland Bros.	Labradorite feldspar. *Cupriferous.*	2.69	2.704	On bed 83,000. On edge 83,000.	On bed 20,750. On edge 20,750.	169.0
9	805	......	110	Watab. Benton Co.	Saulpaugh Bros.	Light colored coarse syenite.	2 73	2.659	On bed 100,000. On edge 95,000.	On bed 25,000. On edge 23,750.	168.4
10	806	...	......	Watab, Benton Co.	Saulpaugh's.	Red syenite, quartzose.	2.63	2.606	On bed 103,000.	On bed 25,750.	162.8
11	57	.....	115	Near Duluth, St. Louis Co.	Tischer's creek.	Traprock. *Cupriferous.*	2.95	3.005	On bed 105,000. On edge 105,000.	On bed 26,250. On edge 26.250.	187.8
						2. QUARTZYTE.					
12	.....	4245	95	Pipestone, Pipestone county.	The Pipestone Quarry.	Quartzyte. *Potsdam.*	2 74	2.729	On bed 111,000. On edge 108,000.	On bed 27,750. On edge 27,000.	170 6
						3. DOLOMITES.					
13	.....	3365	113	Frontenac, Goodhue county.	Tostevin's.	Vesicular dolomite. *St. Lawrence.*	2.63	2 421	On bed 45,000. On edge 50,000.	On bed 11,250. On edge 12.500.	151.3
14	....	.....	98	Stillwater, Washington county.	Hersey, Staples & Hall.	Compact dolomite. *St. Lawrence.*	2 77	2.762	On bed 100,000. On edge 100,000.	On bed 25,000, On edge 25,000.	172 6
15	.....	......	100	Winona. Winona Co.	Charles H. Porter's.	Compact dolomite. *St. Lawrence.*	2.67	2.450	On bed 65.000. On edge 65 000.	On bed 16,250. On edge 16,250.	153.1
16	......	4029	121	Lanesboro, Fillmore county.	Mill Company's.	Dolomitic limestone.(vesicular) *St. Lawrence.*	2 67	.. ..	....	....	......
						4. DOLOMITIC LIMESTONES.					
17	...	.....	99	Red Wing, Goodhue county.	Sweeney's.	Compact dolomitic limestone. *St. Lawrence.*	2 75	2 595	On bed 92,000. On edge 93,000.	On bed 23,000. On edge 23,250.	162 2
18	......	....	97	Stillwater, Washington county.	Hersey, Staples & Hall.	Vesicular dolomitic limestone. *St. Lawrence.*	2 69	2 567	On bed 43,000. On edge 51,000.	On bed 10,750. On edge 12,750.	160 4
19	.....	.....	96	Kasota, Le Sueur county.	Brackenridge, Stewart and Buttars'.	Arenaceous dolomitic limestone. *Shakopee.*	2.64	2 519	On bed 74,000. On edge 67,000.	On bed 18,500. On edge 16.750.	157.4
20	....	....	101	Mantorville, Dodge Co.	Hook's.	Vesicular dolomitic limestone. *Galena.*	2 65	2.310	On bed 38,000. On edge 40,000.	On bed 9,500. On edge 10,000.	144.3
21	......	4029	120	Lanesboro, Fillmore county.	Mill Company's.	Dolomitic limestone, (compact.) *St. Lawrence.*	2 73	......	....	....	.....

OF THE BUILDING STONES OF MINNESOTA.

Number.	Ratio of absorption. Gilmore.	Absorption of moisture in 7 weeks. Dodge.	Absorption of water in 4 days. Dodge.	Visible effect of frost in 8 weeks.	Per cent. of loss by frost in 8 weeks.	Visible effect of dry heat up to redness.	Visible effect of water on the heated stones.	Effect of carbonic acid. 6 weeks.	Visible effect of strong corroding vapors. 7 weeks.
1. CRYSTALLINE.									
1	traces.	Increase of weight. 0.17 p.c.	Increase of weight. 2 59 p. c.	Very slight	0 02	No change.	Moderately cracked.	Loss of weight. 0 02 p.c	Slightly stained.
2	1/335	0 06	0.07	Very slight	0 02	*No effect*, even in red heat.	No change, even in color. *No cracks.*	0 06	Somewhat stained.
3	*	0.03	0 03	Very slight	0 01	No change, even in red heat.	Very little effect; color somewhat browned.	0.03	Somewhat stained
4	1/183	0 11	0.19	Very slight	0 03	Cracked moderately.	More cracked and disintegrated.	0.03	Somewhat stained
5	1/141	0.40	0 47	Very slight	0 01	No change in moderate heat; in red heat slightly cracked.	More cracks.	0.11	Somewhat stained
6	1/212	0.19	2 39	Very slight	0.01	No change, no cracks.	Considerably cracked.	0 04	Somewhat stained
7	1/208	0.05	0 08	Very slight	0 18	Slightly cracked in red heat.	More cracked.	0.19	Somewhat stained
8	1/340	0.12	0.14	Slight	0.04	No effect.	Slightly cracked and scaled.	0 06	Little changed.
9	1/162	0 19	2 35	Very slight	0 02	In moderate heat no effect; in red heat badly crac'd&crumb'd	Completely broken up.	0 05	Somewhat stained
10	1/193	0.11	0.23	Very slight	0 08	Considerably cracked.	Badly crumbled.	0.10	Slightly corroded. Slightly stained.
11	1/336	0.15	0.28	Very slight	0.07	Badly cracked and divided into thin pieces.	Not further changed.	0.12	Somewhat stained
2. QUARTZYTE.									
12	1/366	0.14	0.15	Very slight	0.01	Turned dark and cracked moderately.	Not much further change.	0 01	Considerably stained
3. DOLOMITES.									
13	1/21	0 23	3.49	Slight	0.11	No effect.	Moderately cracked.	0.38	Not much changed
14	1/251	1.26	2.19	Slight	0.05	No change in moderate heat; in red heat cracked somewhat.	Further cracked and superficially disintegrated.	1 32	Considerably crumbled. Somewhat stained.
15	1/21	0 27	2.88	Very slight	0 05	No change in moderate heat; in red heat cracked somewhat.	Superficially scaled off.	0 23	Moderately corroded otherwise not much changed.
16	...	1.38	2 65	Slight	0 15	No effect.	Somewhat cracked.	0 35	Somewhat crumbled otherwise not much changed.
4. DOLOMITIC LIMESTONES.									
17	1/40	1.14	2 95	Slight	0 06	No change in moderate heat; in red heat cracked slightly.	Little more cracked, but scaled superficially.	0.22	Somewhat crumbled. Slightly stained.
18	1/40	0.53	2 19	Slight	0.08	No change at first; very slight effect.	Superficially disintegrated.	0 42	Moderately corroded Somewhat stained.
19	1/28	2 13	2 51	Very slight	0 30	No change at first; later slightly cracked. Color became whiter.	Cracked and disintegrated badly.	0 67	Slightly stained.
20	1/18	1 39	5 37	Slight	0.12	No change, even in red heat, except burned lighter colored.	Superficially crumbled.	0.67	Little changed.
21	...	1 16	3 92	Slight	0.17	Slightly cracked.	More cracked.	1.01	Moderately corroded, otherwise but little changed.

*Scarcely appreciable.

SYSTEMATIC TABLE OF THE QUALITIES

Number.	Loss of weight by corroding vapors. 7 weeks.	Insoluble in hydrochloric acid.	Soluble in hydrochloric acid.	Water.	Silica.	Alumina.	Iron oxide.	Calcium carbonate.	Magnesium carbonate.	Calcium oxide.	Magnesium oxide.	Potassium oxide.	Sodium oxide.	Total of chemical ingredients.
							1. CRYSTALLINE.							
1	0.53 p.c	....	....	......	65 12	16 96	4.69	....	....	4 77	1.99	2 18	3 07	98.78
2	1.93	....	....	......	50 43	23.83	**17 63	....	.. ..	4.79	2 46	0 34	2.06	101.54
3	0.44	....	....	......	35 83	......	††48.45	....	....	9 35	3.12	0 22	1.66	98.63
4	0.53	....	....	..	64.13	‡21 01	....	....	......	6.90	1 26	1.22	3.31	97.83
5	0 32	....	.... ..	......	71 81	12.82	6 02	....	....	2 26	0 56	1.92	2 51	97.90
6	0 49	....	......	......	74.43	12 68	3.82	....	....	1.28	0.25	2.33	1 55	96.34
7	0 39	....	....	......	74.72	12 30	3.19	....	....	1.51	0.25	2.25	1.91	96.03
8	1.38	....	....	......	48.32	‡35.95	....	....	....	12.05	0 25	0.19	2.98	98.74
9	0 56	....	....	....	62 66	19.29	4 67	....	....	5.93	3.06	1.62	2.45	99.68
10	0.15	*	....	0.43	78 12	11.14	2.68	....	....	0.62	Traces.	4.48	3.33	100.97
11	2.64	....	....	.....	48.51	13 79	19.34	....	....	8 34	4.81	0 19	1.67	97.15
							2. QUARTZYTE.							
12	0.09	*	.. ....	2.31	84 52	12 33	2 12	....	....	0 31	Trace.	0.11	§§0.34	....
							3. DOLOMITES.							
13	6 45	2.93	98.19	.....	.....	0.31	.36	54.78	42.53	.....	....	0.03	0.18	101 12
14	7.89	4.52	95.10	.....	... ..	...	‡‡1.11	53.50	40.21	.....	....	Trace.	0.28	99.62
15	10 06	6.32	93.86	......	.....	......	‡‡0.96	51.23	41.33	......	....	0.12	0.22	100.18
16	12.14	3 45	92.74	.....	......	0.33	0.37	49.66	42.06	......	....	0.02	0.30	96.19
							4. DOLOMITIC LIMESTONES.							
17	9 22	10.94	86 01	......	......	0.34	0.55	50 68	33.61	......	....	0.15	0.68	96.95
18	9.83	8.54	89.31	......	.....	§0.64	0.78	50.22	37.39	......	... .	.. ..	0.28	97.85
19	7.80	†13 06	88 30	.....	......	.....	‡‡1.09	49.16	37.53	.....	....	0.02	0.50	101.36
20	5 54	6.33	91.09	.....	......	......	‡‡1.77	50.20	38.96	.....	....	....	10.6	97.42
21	8.28	7.35	91.95		....	......	‡‡1.05	62.14	28 49	......	....	0 02	0 24	99.30

*Analyzed by W. A. Noyes. †Analyzed by S. F. Peckham. ‡With a small amount of iron. §With some silica. **With traces of titanium—(Noyes). ††With a small amount of alumina. ‡‡With traces of silica and alumina. §§With a minute trace of lithia.

OF THE BUILDING STONES OF MINNESOTA.

CREDITS ON A SCALE OF TEN FOR THE VARIOUS QUALITIES.

1. CRYSTALLINE.

Number.	Crushing strength. On bed.	Crushing strength. On edge.	Ratio of absorption.	Absorption of moisture in 7 weeks.	Absorption of water in 4 days.	Frost 8 weeks. Visible effect.	Loss of weight by frost.	Visible effect of dry heat up to redness.	Visible effect of water on dry stone.	Effect of carbonic acid. 6 weeks.	Visible effect of corroding vapors.	Loss of weight by strong corroding vapors	Facility of dressing.	Total credits on a scale of 10.	Rank on a scale of 100.	REMARKS.
1	10	10	10	10	8	10	10	10	5	10	9	10	5	117	90	The kind now most used.
2	10	10	10	10	10	10	10	10	10	10	7	9	1	117	90	Known as "Duluth granite."
3	10	10	10	10	10	10	10	10	9	10	7	10	1	117	90	Analyzed as a silicate.
4	9	10	10	10	10	10	10	7	4	10	7	10	5	112	87	The sample crushed on bed was apparently imperfect as it split in 3 pieces at 86,000 pounds.
5	10	10	10	9	10	10	10	7	5	10	7	10	3	111	85	Forms the promontory on the west side of Beaver bay.
6	10	10	10	10	8	10	10	10	3	10	7	10	2	110	85	Has much quartz.
7	10	10	10	10	10	10	9	7	5	9	7	10	2	109	84	Has the look of the Rice Point gabbro, but differs from it in having much quartz.
8	8	8	10	10	10	7	10	10	6	10	10	9	1	109	84	
9	10	9	10	10	8	10	10	1	1	10	7	10	3	99	76	
10	10	10	..	10	.....	....		......	....	... ..	......	......	2	....	...	Used in the Bismarck bridge of the Northern Pacific R. R.
11	10	10	10	.....	10	10	10	.....	. ..	....	....	......	2	......	....	From a dyke.

2. QUARTZYTE.

Number.	On bed.	On edge.	Ratio of absorption.	Absorption of moisture in 7 weeks.	Absorption of water in 4 days.	Frost visible effect.	Loss of weight by frost.	Dry heat.	Water on dry stone.	Carbonic acid.	Corroding vapors.	Loss of weight by corroding vapors.	Facility of dressing.	Total credits.	Rank.	REMARKS.
12	10	10	10	10	10	10	10	5	10	10	4	10	4	113	87	This rock from Sioux Falls is used at Omaha under the name "Sioux Falls granite."

3. DOLOMITES.

Number.	On bed.	On edge.	Ratio of absorption.	Absorption of moisture in 7 weeks.	Absorption of water in 4 days.	Frost visible effect.	Loss of weight by frost.	Dry heat.	Water on dry stone.	Carbonic acid.	Corroding vapors.	Loss of weight by corroding vapors.	Facility of dressing.	Total credits.	Rank.	REMARKS.
13	5	5	7	10	8	7	10	10	5	9	10	7	7	100	77	In Wabasha county becomes oolitic.
14	10	10	10	7	8	7	10	9	4	6	2	7	7	97	75	The preferred stone at Stillwater.
15	6	6	7	9	8	10	10	9	4	9	5	6	7	96	75	
16	est. 4	est. 5	est. 8	7	8	7	9	10	4	9	5	5	7	88	68	The usual stone at Lanesboro and below there, in the Root river valley.

4. DOLOMITIC LIMESTONES.

Number.	On bed.	On edge.	Ratio of absorption.	Absorption of moisture in 7 weeks.	Absorption of water in 4 days.	Frost visible effect.	Loss of weight by frost.	Dry heat.	Water on dry stone.	Carbonic acid.	Corroding vapors.	Loss of weight by corroding vapors.	Facility of dressing.	Total credits.	Rank.	REMARKS.
17	9	9	8	7	8	7	10	9	4	9	4	6	7	97	75	
18	4	5	8	9	8	7	10	10	4	9	5	6	7	92	71	Used for heavy work in bridge piers.
19	7	7	8	5	8	10	9	7	1	8	8	7	6	91	70	Light-colored.
20	4	4	6	7	6	7	10	9	5	8	10	8	7	91	70	
21	est. 6	est. 6	est. 7	7	7	7	9	7	5	7	6	7	7	88	68	This is less common than number 16.

SYSTEMATIC TABLE OF THE QUALITIES

Number.	Geol. survey. Field number.	Museum register; number.	Chemical series number	Locality.	What quarry	Formation and kind of rock.	Specific gravity. Dodge.	Specific gravity. Gillmore.	Strength in pounds. Of 2-inch cube.	Strength in pounds. Per square inch.	Weight in pounds per cubic foot.
						4. DOLOMITIC LIMESTONES.					
22	.....	762	48 and 88	Minneapolis (W.)	Weeks & Holscher's.	Dolomitic lime-st'e. Upper beds of the *Trenton.*	2.77	2 496	On bed..... On edge 87,000.	On bed......... On edge 21.750.	156.0
23	......	2548	91	Kasota, Le Sueur county.	Brackenridge, Stewart and Buttars'.	Arenaceous dolomitic limestone. *Shakopee.*	2.76	2.536	On bed 52.000. On edge 32.000.	On bed 13,000. On edge 8,000.	158 5
24	.....	......	......	Minneapolis (E.)	Foley & Herbert's.	Dolomitic limestone. Bottom of *Trenton.*	2.76	2.604	On bed 72,000. On edge 46,000.	On bed 18,000. On edge 11,500.	162.7
25	.....	3371	93	Centr'l Point Goodhue Co.	Baker Harrison's.	Dolomitic and aluminous limestone. *St. Croix.*	2.70	2.384	On bed 31,000. On edge 39,000.	On bed 7.750. On edge 9,750.	149 0
						5. LIMESTONES.					
26	.....	2379	47 and 90	Fountain, Fillmore Co.	Taylor's.	Limestone. *Trenton.*	2.68	2.622	On bed 105,000. On edge 100,000.	On bed 26.250. On edge 25,000.	163.8
27	.....	3632 and 3583	46 and 87	Minneapolis (Nicollet I.)	Eastman's.	Aluminous limestone. *Trenton.*	2.71	2.655	On bed 70,000. On edge 68,000.	On bed 17,500. On edge 17,000.	165.9
28	.....	.....	102	St. Paul. (W.)	A. Rau's.	Argillaceous limestone. *Trenton.*	2.71	2 634	On bed 78,000. On edge 70,000.	On bed 19,500. On edge 17,500.	164 6
29	.....	4397	117	Clinton Falls Steele Co.	Lindersmith's.	Impure dolomitic limestone. *Hudson River.*	2.73	.....	....	....	......
						6. SANDSTONES.					
30	......	3811	107	Hinckley, Pine Co.	St. Paul and Duluth R'y.	Pinkish-yellow sandrock. *Potsdam.*	2.47	2.229	On bed 76,000. On edge 70,000.	On bed 19,000. On edge 17,500.	139.3
31	.....	4400	103	Near Fort Snelling, Dakota Co.	Chicago, Mil. and St. P. Railway.	Yellow sandrock. *Potsdam?*	2.51	2.221	On bed 57,000. On edge 80,000.	On bed 14,250. On edge 20,000.	138.8
32	......	4398 and 4112	106	Dresbach, Winona Co.	Tostevin & Co.	Gray sandrock. *St Croix.*	2.38	1.880	On bed 26,000. On edge 15,000.	On bed 6,500. On edge 3,750.	117 5
33	......	.....	105	Jordan, Scott Co.	Philip Kipp's.	Gray sandrock *Jordan.*	2.34	1.825	On bed 15,000 On edge 12,000.	On bed 3,750. On edge 3,000.	113.1
34	443	3754	94	Fond du Lac St. Louis Co.	Boyle's.	Brown sandrock. *Potsdam.*	2.52	2.245	On bed 35,000. On edge 23,000.	On bed 8,750. On edge 5,750.	141 3
35	......	......	104	Jordan, Scott Co.	Philip Kipp's.	Rusty-striped sandrock. *Jordan.*	2.59	1.901	On bed 19,000. On edge 16,000.	On bed 4,750. On edge 4,000.	118.9
36	......	4399	92	Dakota, Winona Co.	Hartley's.	Sandstone. *St. Croix.*	2.38	1.872	On bed 19,000. On edge 12,000.	On bed 4,750. On edge 3,000.	117.0
37	......	......	......	Taylor's Falls, Chisago Co.	?	White sandrock *St. Croix.*	....	1.876	On bed 22,000.	On bed 5,500	117.2
						7. STONES FROM OTHER STATES.					
38	......	......	123	Lemont, Illinois.	?	Dolomitic limestone. *Niagara.*	2.78	2.645	On bed 108,000. On edge 105,000	On bed 27,000. On edge 26,250.	165.3
39	......	......	122	Siskiwit bay. (Wis.) W.end L.Sup.	McIntire & Wells'.	Light brown sandrock. *Potsdam.*	2.44	2 018	On bed 14,500. On edge 23,000.	On bed 3,625. On edge 5,750.	126 1
40	... ..	4672	125	Stone City, Iowa.	A. J. Green's.	Dolomitic limestone. *Niagara.*	2.56	2.175	On bed 45,000. On edge 39,000.	On bed 11,250. On edge 9,750.	135.9
41	......	......	124	Berea, Ohio.	?	Gray sandrock. *Berea.*	2.49	2.101	On bed 40,000. On edge 27,000.	On bed 10,000. On edge 6,750.	131 3

OF THE BUILDING STONES OF MINNESOTA.

4. DOLOMITIC LIMESTONES.

Number.	Ratio of absorption. Gillmore.	Absorption of moisture in 7 weeks. Dodge.	Absorption of water in 4 days. Dodge.	Visible effect of frost in 8 weeks.	Per cent. of loss by frost in 8 weeks.	Visible effect of dry heat up to redness.	Visible effect of water on the heated stones.	Effect of carbonic acid. 6 weeks.	Visible effect of strong corroding vapors. 7 weeks.
22	1/24	Increase of weight. 1 28 p. c.	Increase of weight. 2 36 p. c.	Considerable.	2 21	Turned dark at first; then yellowish. Not cracked.	Slightly cracked and scaled off.	Loss of weight. 0.23 p.c.	Moderately corroded. Moderately stained.
23	1/29	1 44	2 96	Slight	0.05	Little changed till red hot; then cracked considerably.	Cracked further and scaled.	0.39	Moderately corroded.
24	1/44	2 26	3.11	Moderate	0 19	Blackened; then cracked and burned white.	Cracked further.	0 43	Considerably corroded. Considerably stained.
25	1/22	3 74	5 14	Considerable.	1 29	Blackened moderately; then brown; cracked slightly.	Little further change.	0.92	Badly crumbled. Badly stained.
						5. LIMESTONES.			
26	1/68	0.41	0 46	Moderate	0.07	Blackened, cracked and burned white.	Superficially disintegrated.	3 58	Somewhat corroded.
27	1/98	1.04	1 28	Moderate	0 50	Turned dark at first; then white. Not cracked.	Splintered somewhat.	3 08	Considerably corroded. Considerably stained.
28	1/59	0.73	0 93	Slight	0.37	Slightly cracked.	Slightly cracked further.	1.17	Badly corroded and stained.
29	..	1.91	3.20	Considerable.	1.07	Slightly cracked.	More cracked.	3.27	Considerably corroded and stained.
						6. SANDSTONES.			
30	1/17	0.05	4.88	Very slight	0.03	In moderate heat slight blackening; in red heat no cracks.	Cracked and somewhat crumbled.	0 02	Little changed.
31	1/16	0 04	3 09	Very slight	0 01	Dark'd in moderate heat; burned lighter; no change; no cracks	Greatly disintegrated; color changed to red.	0.04	Somewhat stained.
32	1/8	0.74	11 48	Very slight	0.05	No change for a time; later cracked somewhat.	Not much further change.	0 32	Very little changed.
33	1/8	0 61	12 69	Slight	0.06	No change even in red heat.	Cracked and somewhat disintegrated.	0 25	Somewhat crumbled. Considerably stained.
34	1/16	3 94	6 17	Moderate	0 36	No effect in moderate heat; later cracked badly.	Little further change.	0 07	Much stained.
35	1/8	1.78	9.18	Moderate	0.57	Very little affected.	Superficially disintegrated; color little different.	2 30	Badly corroded. Somewhat crumbled.
36	1/9	1.52	11.08	Slight	0.09	Little changed till red hot; then cracked badly.	Considerably crumbled and disintegrated	0.62	Considerably crumbled. Much stained.
37	1/8	... ..	....	....	....	....	....	.....	....
						7. STONES FROM OTHER STATES.			
38	1/48	1.87	1 95	Slight	0.08	Slightly scaled in red heat.	Considerably cracked.	0.13	Slightly crumbled. Somewhat stained.
39	1/10	0.95	8 76	Very slight	0.07	Turned dark; no cracks.	Considerably disintegrated.	0 05	Somewhat stained.
40	1/13	0.84	8 66	Slight	0.12	Slightly cracked in red heat.	Considerably cracked; color not changed.	0.46	Moderately corroded. Very little stained.
41	1/13	1.97	5 76	Moderate	0.18	In moderate heat black'd, & gave off gas which blazed; in red heat cracked somewhat.	More cracked	0.04	Not much corroded. Badly stained.

SYSTEMATIC TABLE OF THE QUALITIES

4. DOLOMITIC LIMESTONES.

Number.	Loss of weight by corroding vapors. 7 weeks.	Insoluble in hydrochloric acid.	Soluble in hydrochloric acid.	Water.	Silica.	Alumina.	Iron oxide.	Calcium carbonate.	Magnesium carbonate.	Calcium oxide.	Magnesium oxide.	Potassium oxide.	Sodium oxide.	Total of chemical ingredients.
22	8.86 p. c.	*16.22	83.78	0.375	......	‡3.16	‡0.90	54 533	36.002	......	....	Alkalies, a trace.		94.97
23	5.83	*13.85	....	.....	......	......	**1.49	47.904	35.227	......	....	Undetermined. Water & alkalies. 1.529.		100.00
24	13.94	29.93	71.80	.....	......	......	**4.03	41 880	24.550	.....	....	0.22	1.12	101.73
25	23 89	39 33	58.91	.....	34.00	‡4.92	‡0.33	33 000	18.540	.....	....	0.92	2.28	98.24

5. LIMESTONES.

Number.	Loss of weight by corroding vapors. 7 weeks.	Insoluble in hydrochloric acid.	Soluble in hydrochloric acid.	Water.	Silica.	Alumina.	Iron oxide.	Calcium carbonate.	Magnesium carbonate.	Calcium oxide.	Magnesium oxide.	Potassium oxide.	Sodium oxide.	Total of chemical ingredients.
26	7.31	*9.89	90.11	0.240	......	......	††1 30	86.107	0.470	.....	....	Alkalies. 0.44		99.447
27	10.38	*14.45	85.55	1.600	......	......	††1.70	75.482	6.810	......	....	Alkalies, a trace.		100.043
28	12.70	†13.39	86 61	.....	8.16	2.67	1.63	79.18	6.420	......	Organic matter. 0.80	Alkalies, a trace.		98.86
29	9.61	25.51	74.92	......	....	....	**1.94	57.03	15.90	...	....	....	....	100.43

6. SANDSTONES.

Number.	Loss of weight by corroding vapors. 7 weeks.	Insoluble in hydrochloric acid.	Soluble in hydrochloric acid.	Water.	Silica.	Alumina.	Iron oxide.	Calcium carbonate.	Magnesium carbonate.	Calcium oxide.	Magnesium oxide.	Potassium oxide.	Sodium oxide.	Total of chemical ingredients.
30	0.01	98.82	1 18	....	98.69	§1.06	......	......	....	0 42	Mg. ox. 0.01	Trace.	0.17	100 35
31	0 04	99.15	0.85	......	97.67	1.31	0 55	....	....	0 41	0.21	0 02	0.15	100 32
32	3.34	92.40	7.60	......	81 47	§8 90	....	....	....	1.90	0.50	4.29	0.39	97.36
33	1.39	96.66	3.33	......	81.19	§10.44	....	....	....	0.56	0.40	3.60	0.66	96.85
34	0.52	87.94	12 06	....	78.24	10.88	3.83	....	......	0.95	1.60	1.67	0.06	97.23
35	21.78	42 33	....	.....	38.41	5 77	1.79	35.87	18 54	......	....	0.12	0.29	100.79
36	16.72	95 47	4 53	.....	81.55	10.00	1 41	....	....	1.15	0.30	1.76	1.03	97.20
37	....	......	....	......	......	.....	....	.....	....	.....	....	....	....	....

7. STONES FROM OTHER STATES.

Number.	Loss of weight by corroding vapors. 7 weeks.	Insoluble in hydrochloric acid.	Soluble in hydrochloric acid.	Water.	Silica.	Alumina.	Iron oxide.	Calcium carbonate.	Magnesium carbonate.	Calcium oxide.	Magnesium oxide.	Potassium oxide.	Sodium oxide.	Total of chemical ingredients.
38	8.69	21 36	79.78	.....	.....	1.43	0.64	42.97	34.30	...	....	0.21	0 23	101.14
39	0.17	97.48	2.52	....	90.86	4 76	1.58	....	......	0.15	0.59	1.06	0.45	99.45
40	5.97	0.98	96 44	......	.....	0.01	1.28	57.86	37.29	......	....	....	....	97.42
41	1.15	92.93	7.07	......	84.40	7.49	3.87	....	....	0.74	2.11	0.24	0.56	99.41

*Analyzed by S. F. Peckham. †Analyzed by W. A. Noyes. ‡Alumina and iron determined by W. A. Noyes. §With a small amount of iron. **With traces of silica and alumina. ††With traces of alumina and ferric phosphate.

OF THE BUILDING STONES OF MINNESOTA.

Number.	Credits on a scale of ten for the various qualities. Crushing strength: On bed.	Crushing strength: On edge.	Ratio of absorption.	Absorption of moisture in 7 weeks.	Absorption of water in 4 days.	Frost 8 weeks. Visible effect.	Loss of weight by frost.	Visible effect of dry heat up to redness.	Visible effect of water on dry stone.	Effect of carbonic acid. 6 weeks.	Visible effect of corroding vapors.	Loss of weight by strong corroding vapors.	Facility of dressing.	Total credits on a scale of 10.	Rank on a scale of 100.	Remarks.
4. Dolomitic Limestones.																
22	10	9	8	7	8	2	1	7	6	7	5	7	8	85	65	Generally rejected by builders at Minneapolis.
23	5	3	8	7	8	7	10	3	4	9	5	8	6	83	64	The pinkish or "fawn-colored" rock of Featherstonhaugh.
24	7	5	8	5	8	4	9	3	5	8	3	4	8	77	59	Very bottom of Trenton limestone, 10 inches thick; always used by builders, with No. 27.
25	3	4	7	1	6	2	5	3	10	7	1	1	10	60	46	The stone used at Lake City.
5. Limestones.																
26	10	10	9	9	10	4	10	8	6	1	4	7	8	91	70	One mile east of Fountain, by the railroad.
27	7	7	9	8	9	4	8	7	5	2	3	6	8	83	64	The usual building stone of Minneapolis.
28	8	9	9	......	......	....	..	.. ..	......	.....	......	.. ..	8	... ..	...	The usual building stone of St. Paul.
29	est. 4	est. 4	est. 6	6	8	2	6	7	5	4	3	6	8	69	53	The usual stone at Owatonna.
6. Sandstones.																
30	8	7	6	10	7	10	10	8	4	10	10	10	10	110	85	Grindstone river.
31	6	8	6	10	8	10	10	9	1	10	7	10	10	105	81	Analyzed as a silicate.
32	2	1	1	8	2	10	10	7	10	9	10	9	10	89	68	
33	1	1	1	9	1	7	10	10	4	9	2	9	10	74	57	
34	3	2	5	1	6	4	8	1	10	10	3	10	10	73	56	Samples obtained at Westminster church, Minneapolis. Analyzed as a silicate.
35	2	1	1	6	3	4	8	10	5	4	1	1	10	56	43	
36	2	1	1	7	2	7	10	1	2	8	3	3	10	55	42	Analyzed as a silicate.
37	2	est. 2	1	......	.....	....	..	.....	......	....	......	......	10	......	....	Rather soft white sandstone.
7. Stones from other States.																
38	10	10	est. 9	6	9	7	10	7	3	10	6	6	8	101	77	Samples obtained from stone yards in Minneapolis.
39	1	2	3	8	4	10	10	8	3	10	7	10	10	86	66	Samples obtained from the owners of the quarry.
40	5	4	4	8	4	7	10	7	4	8	6	8	8	83	64	Samples obtained from owners of the quarry.
41	4	3	4	6	6	4	9	5	5	10	5	10	10	81	62	Samples obtained from stone yards in Minneapolis.

The reader is referred to the various county reports for particulars respecting the individual quarries of those counties.

COUNTY GEOLOGY.

The counties are described in order, beginning at the southeastern corner of the state and crossing the state westwardly in tiers of two.

CHAPTER IV.

THE GEOLOGY OF HOUSTON COUNTY.

By N. H. WINCHELL.

Situation and area. This county (see plate 8) is the most southeasterly in the state, and contains sixteen government towns, forming very nearly an exact square. Its area is about 568.75 square miles or 363,998.07 acres.* It contains no lakes, but there are low lands along Root river, and along the Mississippi, between the high bluffs, which are flooded most of the year. These lands, when meandered by the original survey, and the water area of those rivers within the county, should be added to the aggregate acreage as above stated. The county seat is Caledonia. Houston, Hokah, and Brownsville are the other principal towns, the last being the oldest in the county, having been settled in June, 1848.

SURFACE FEATURES.

Natural drainage. The general drainage is toward the Mississippi river which lies along the east side of the county. Through the northern tier of towns Root river passes to the Mississippi. Thompson's creek joins it from the southwest at Hokah. It receives Money creek, Silver creek and Storer creek from the north, while Pine creek passes though the township of La Crescent and joins the Mississippi from the northwest a few miles below the village of La Crescent. Winnebago and Crooked creeks drain the southeastern portion of the county. There being no foreign drift in this county, these streams run in their ancient channels and several hundred feet below the general upland level. The loam which covers the county is

*The areas of counties as given in this report are those computed for this purpose by Hon. H. H. Young, secretary of the State Board of Immigration.

generally almost impervious to water, so that these deep drainage courses do not operate to abstract the moisture from the surface soils so disastrously as they would in more sandy soils. It is only along the immediate river bluffs that any injury to the soils from this cause is noticeable. These streams furnish water power at frequent points, even more than have been improved. At some of these points the following flouring mills have been erected:

Mills in Houston county.

At Riceford, on Crystal creek, one custom mill, by Oatman & Co., having a power of 18 feet head. This creek issues from the rock bluffs within a few miles of Riceford, nearly all in one volume.

At Riceford Mr. V. T. Beebe also has a custom mill with 12 feet head of water.

There is a custom mill on Bear creek, near the state line, (sec. 34, Spring Grove) owned by Mr. Swartzhoff.

At Freeburg, on Crooked creek, is a custom mill owned by Hill and Graff, with 16 feet head of water, and a saw mill owned by Wm. Oxford. Here are also two other mill privileges.

On Winnebago creek, (sec. 22, Winnebago) is a stone mill owned by B. F. Barbour, and on section 15 a custom mill owned by McMillin, Johnson & Clark.

At Sheldon, on Beaver creek, is a mill of 12 feet power, owned by John Blain, and another of the same power, by Snyder Brothers.

J. & C. B. Howe have a saw mill on section 24, Yucatan.

Nathan Vance has a flouring mill on section 12, Money Creek, with 12 feet fall. Fox and Perkins have another on sec. 30, with 10 feet power, from which shipments are made by railroad.

There is a mill at Houston with 7 feet fall, in the Root river, belonging to Mr. Grorsland.

There is a shipping and custom mill, southeast ¼ section 23, Houston, with 20 feet power, owned by Wm. McSpadden.

At Brownsville are two mills, one by Shaller Bros., of two run of stone and 12 feet power, for shipping flour, and the other by J. Hankey, of five feet power and one run for custom.

At Hokah all the mills ship flour. One is owned by C. Fischer, situated on Thompson creek, and has 24 feet of water fall; another by White & Brothers, and a third by E. Thompson. The last two have a fall of 9 feet in Root river. At Hokah the railroad machine shops, and the plow factory also run by water power.

There is also a mill on Pine creek, near the county line (sec. 3, La Crescent), with four run of stone (one for feed), and 13 feet fall and 16 horse-power, owned by Groff & Co., for custom and shipping; has one Leffel and one Michigan turbine wheel; and another on the same creek southwest quarter section 9, by J. D. Cameron, having 9 feet fall and four run of stone, for shipping.

The Toledo woolen mill, by Fletcher and Webster, southwest quarter of section 5, La Crescent, on Pine creek, has 7 feet power. This is built of stone quarried near.

The topography of Houston county is very similar to that of the eastern, and particularly that of the northeastern part of Fillmore county, and of much of Winona county. Taken altogether it is produced by the same causes. The strata cover the same geological horizons, at least the same in the non-drift-covered portions. It varies from undulating to rough and hilly. The surface of the rock was channeled by numerous canons, each with its tributary gorges, prior to the spreading of the loam. These gorges are

not so narrow as in much of the western and central parts of Fillmore county, but are of the same character as those in the Shakopee and St. Croix areas—broader and smoother, allowing the loam, when deposited, to enter their deepest recesses and to spread itself evenly over the whole. While the loam itself becomes thicker and more clayey toward the Mississippi river, it has so effectually and so deeply covered the whole country that generally a rolling or undulating surface has resulted which is almost free from the familiar sink-holes so common in the Trenton area, but is characterized by deep, wide valleys and long ridges. The bluffs that enclose the valleys are sometimes tillable, or at least turfed over from top to bottom. They are of all hights from the mere shallow depression sufficient for ready drainage, to valley lines over five hundred feet deep. The whole of Root river valley, which is in the St. Croix sandstone, is over five hundred feet in depth, with limestone capping the bluffs. Some of its tributary valleys are equally deep and wide, but the smaller tributary valleys become shallower and more rocky as the gorges ascend in the St. Lawrence limestone—the whole system making a series of deep valleys along the river and of alternating vales and ridges at greater distance from the main valley. The county is nowhere destitute of excellent natural drainage. There are very few of the characteristic sink-holes of the Trenton, that formation having but a small superficies in the county, and that not within the reach of important drainage courses which were capable of producing the pre-glacial gorges. Within the Shakopee area have been seen three or four similar sink-holes, but they differ from the Trenton sink-holes in being more plainly a part of continuous ravines and in being broader in comparison to their depth.

If the valleys excavated by drainage were filled up the county would be very nearly flat, the highest part being in the southwestern corner, in the area of the Trenton limestone. The great diversity of surface that appears, arises entirely from the effect of erosion by streams and atmospheric forces, on the rocks, which consist of alternating sandstones and limestones. This effect would be still greater, or rather would be still more apparent, were it not that the loess-loam, which is very thick in this part of the state, tones down with its overspreading canopy, the roughness which the rocky surface really possesses, leaving it actually one of an undulating or rolling character except along the immediate river bluffs, where the rocks frequently appear in craggy bluffs and cause precipitous or steep hillsides.

The valleys excavated by the streams are remarkable and instructive. Not only have the large streams cut gorges of enormous depth in the rocky floors on which they run, but every little creek and tributary runs in a gorge which shows the same rock-sculpture. Even the freshet creeks, and the rivulets born of every summer shower, dry entirely the greater part of the year, find their way to the main valleys through rock-bound, canon-like valleys. This makes the county present the usual characters of southern latitudes where the northern drift sheet has not been spread. There is nothing more evident than that these valleys antedate the great ice age. In other portions of the Northwest where the drift does prevail, larger streams than those found in Houston county have generally worn their channels only through the drift sheet. The Mississippi river itself, above the falls of St. Anthony, has no rocky bluffs. It very rarely strikes the rock. It is occupied still in dissolving and removing the materials of the drift which covers that portion of the state. It would require a great many inter-glacial periods, or pre-glacial periods, to excavate it as deeply as the same valley is wrought in the southeastern portion of the state. In the limestone areas the valleys are narrow and more generally rock-bound; they widen out so as to inclose good farm lands on the bottoms in the sandstone areas. This distinction, however, is less evident than in Fillmore and Winona counties, where the St. Peter sandstone plays a more important part in bringing about the present topography. It is, however, well illustrated in the upper portion of many of the tributaries of Root river. In descending one of these valleys from the upland the first descent is rocky and very impracticable. This is caused at first by the cut through the Shakopee limestone. The Jordan sandstone that underlies the Shakopee sometimes relieves this ruggedness a little, but its thickness is so small compared to that of the whole series of strata involved that it is barely observable in this way. Through the underlying St. Lawrence limestone the descent is also rough and the valley narrow, with little or no arable land in the valley. On reaching the horizon of the top of the St. Croix sandstone the change introduced into the aspect of the valley is very noticeable. It widens, the rock is seen exposed in a nearly continuous escarpment along the tops of the now more distant bluffs, the descent is easy, the stream flows with a winding course, and is perhaps fringed with a small shrubby growth, the lower slopes of the bluffs on either side are turf-covered, and finally a rich alluvial soil, spreading out over the bottoms, shows here and there as a spot that has been cleared and cultivated. This character then extends to, and follows, the whole course of Root river to its mouth, the valley constantly increasing in width, and showing a terraced condition, where ancient floods or periods of high water have stood, and whence, after vast accumulations of alluvium, have retired, reducing the river at last to its present insignificant dimensions. This is the general character of the valleys tributary to Root river, but this succession of changes can be seen within Houston county only in those tributary valleys on the south side of Root river. Those on the north side enter on the St. Croix sandstone before leaving Winona county. The best agricultural portion of the county is in the center and southwest quarter. The valleys throughout the county are generally wooded, and in the eastern part of the county a great deal of the upland is also wooded. Taken altogether the county may be denominated rolling, broken and hilly, though there are also some fine prairies that are simply undulating. All the farms are well drained naturally.

Elevations on the Southern Minnesota division of the Chicago, Milwaukee and St. Paul railway.*
From George B. Woodworth, assistant engineer, La Crosse.

	Distances in miles from La Crosse.	Hights in feet above the sea.
Low water in the Mississippi river at La Crosse		618.5
Junction with River division west of bridge	0	645.
La Crescent	0.7	639.
C., D. & M. Junction	3.0	633.
Root river bridge	4.2	640.
Hokah	6.2	641.
Root river bridge	11.0	655.
Mound Prairie	12.2	652.
Root river bridge	14.0	661.
Houston	18.7	671.
Root river bridge	22.3	695.
Money Creek	23.2	691.

Elevations on the Caledonia and Mississippi railroad.

This road runs from the Mississippi river westward fourteen and one-fourth miles up the valley of Crooked creek. These levels were furnished by Mr. Till, engineer of the road. The datum is the level of the track of the C. D. & M. railroad just north of Crooked creek, section 35, town **102** north, range **1** west.

*All elevations above the ocean in this report are referred to mean tide sea-level, and are corrected in accordance with the recent determination of the elevations of the great lakes and Chicago by the U. S. lake survey, under Lieut.-Col. C. B. Comstock.

Datum,	0.
Freeburg,	21.92
Water at Oxford's dam, Freeburg,	42.95
Crossing of Crooked creek at sec. 36, **102** N., R. **1** W. (Powlesland's), bottom	56.32
Crossing of Crooked creek at sec. 36, **102** N.. R. **1** W. (Powlesland's), grade	65.32
Crossing of Crooked creek, S. E. ¼ sec. 26, **102** N., **2** W. below the junction of the south fork, bottom	76.74
Crossing of Crooked creek, S. E. ¼ sec. 26, **102** N., **2** W. below the junction of the south fork, grade,	86.74
Surface of water at crossing of Crooked creek, N. E. ¼ sec. 22, Mayville,	152.13
Crooked creek, N. E. ¼ sec. 22, Mayville, bottom of creek	151.85
Bottom of creek at second crossing below John Molitor's, sec. 16, Mayville,	236.70
Crooked creek at second crossing below John Molitor's, sec. 16, Mayville, grade	244.87
Bottom of creek at first crossing below John Molitor's, sec. 16, Mayville,	250.77
Crooked creek at first crossing below John Molitor's, sec. 16, Mayville, grade,	256.72
Dorsh's quarry, sec. 17, Mayville, grade	333.10
Natural surface, at the Methodist church, Caledonia,	551.18
Summit, natural surface, N. E. ¼ sec. 13, Caledonia	571.57

Elevations on the Houston, Hesper and Southwestern railroad.

(Proposed.)

This line runs from Houston, on the Root river, where it intersects with the Southern Minnesota railroad, southwestwardly, ascending the valley of Beaver creek, through Sheldon, Caledonia and Spring Grove townships. The following data were furnished by Dr. F. Worth, president of the company. The datum point was at Houston, on the grade of the S. M. R. R. where it crosses the line between sections 33 and 34, six hundred and seventy feet above the ocean.

	Sections.	Above Houston.	Above the ocean.
		Feet.	Feet.
Crossing township line between	4 and 9	6	676
Crossing section line between	8 and 9	7	677
Crossing section line between	7 and 8	7	677
Crossing section line between	7 and 18	9	779
Crossing section line between	18 and 19	23	693
Crossing section line between	19 and 30	29	699
Crossing section line between	30 and 31	49	719
Sheldon village plat, on section 31	....	79	749
Crossing section line between	31 and 32	76	746
Crossing section line between	32 and 5	82	752
Crossing section line between	5 and 6	87	757
Crossing section line between	6 and 7	109	779
Crossing section line between	7 and 12	118	788
Crossing section line between	12 and 13	119	789
Crossing section line between	13 and 24	167	837
Crossing section line between	24 and 25	248	918
Crossing section line between	25 and 26	269	939
Crossing section line between	26 and 35	331	1,001
Crossing section line between	35 and 34	384	1,054
Crossing section line between	34 and 3	395	1,065
Crossing section line between	3 and 4	422	1,092
Crossing section line between	4 and 9	428	1,098
Crossing section line between	9 and 8	457	1,127
Crossing section line between	8 and 17	494	1,164
Crossing section line between	17 and 20	500	1,170
On section 17, highest point	....	524	1,194
Crossing lines between sections	20 and 19	456	1,126
Crossing lines between sections	19 and 30	462	1,132
Crossing lines between sections	30 and 25	476	1,146
Line between Houston and Fillmore county	....	462	1,132
Crossing section line between	25 and 26	437	1,107
Crossing section line between	26 and 35	442	1,112
State line west of center of sec. 35, Newburg township	....	465	1,135

The following measurements by aneroid barometer will show the depth of some of the valleys below the immediate upland at the points named.

Section 17, Caledonia, three miles south of Sheldon. Beaver creek, at the great spring, is 230 feet below the tops of the bluffs; which embrace the Shakopee limestone, Jordan sandstone and a part of St. Lawrence limestone.

At Sheldon the bluffs are 420 feet high.

At Houston the bluffs north of the city are 520 feet above the level of water in Root river in summer.

At Hokah Mt. Tom rises 530 feet above the flood-plain of Root river.

On section 11, Union, the ridge between Thompson creek and the railroad, at the sculptured rock, rises 355 feet above the highway directly south of the ridge.

At Brownsville the hight of the bluff above the flood-plain of the Mississippi is 495 feet. Mr. Fred. Gluck, of Brownsville, measured the same by triangulation in the winter season, and obtained 486 feet as the hight above the ice. Railroad surveyors are said to have obtained 483 feet as the hight of the same bluff. The most of this hight is made up of sandstone, there being but 105 feet of limestone in the upper part of the bluff, belonging to the St. Lawrence formation.

Mean elevation of the county. From the contour-lines shown on the county map the average elevation of each township above the sea may be estimated, with the following result:

La Crescent, 900 feet above the sea; Hokah, 875; Brownsville, 1000; Crooked Creek, 900; Jefferson, 850; Mound Prairie, 950; Union, 1025; Mayville, 1075; Winnebago, 1050; Houston, 925; Sheldon, 975; Caledonia, 1125; Wilmington, 1175; Money Creek, 950; Yucatan, 1000; Black Hammer, 1025, and Spring Grove, 1175. The mean elevation of the county, derived from these figures, is approximately 990 feet above the sea.

The soil and timber of Houston county. The soil of the county is formed by the loess-loam. It is very fertile, and apparently very enduring. It is mainly a clayey deposit, without stones or gravel, but yet in some places becomes arenaceous, the sand grains being very fine. The loess is hardly pervious to water. In the scarcity and costliness of common wells, many farmers resort to the expedient of retaining the surface water, after rains, in open reservoirs produced by throwing a low dam across some of the shallow drainage valleys that intersect their farms, thus forming with the common loam a small pool or lake for the use of their stock. Except on the brows of the bluffs which enclose the valleys, this loam is thick enough to make a reliable subsoil as well as surface soil. In some of the valleys it is very thick, but here it is apt to be influenced by the causes that produced the river-terraces and to mingle with the ordinary alluvium. On the uplands generally where it may not have been reduced by wash, its average thickness might reach thirty feet, but in some of the valleys material of the same aspect is sometimes encountered to the depth of over one hundred feet.

In the valley of the Root river, and also along the Mississippi, the soil of the alluvial terraces, greatly resembling that of the loam in the uplands, is apt to be more sandy, and sometimes becomes very light and very poor. These materials are generally seen to lie in obliquely stratified layers, and to embrace, in the Mississippi valley, small gravel stones of northern origin. The immediate flood-plain of these rivers presents still another variety of soil. While it is generally sandy, and often very light, it is also a very rich soil, and is apt to be enduring by reason of the Nile-like overflows to which it is subjected, and the decomposition of large quantities of vegetation. This variety of soil sustains some of the heaviest forests to be found in the county.

Trees and shrubs. The county is supplied with plenty of timber for fuel, and with some that is useful for lumber. The following list comprises a nearly, if not quite, complete catalogue of the trees and shrubby plants of the county.

Quercus coccinea, *Wang.*, var. tinctoria, *Bart.* (Black oak).

Quercus macrocarpa, *Michx.* (Bur oak.)

[These two oaks are common in the uplands. As brush and small trees they often form thickets. There seem to be two varieties of the former in some places, but in others the characters are blended in one. There is a plain popular distinction between the red and the black oak, and solitary trees of the latter are often seen of large size standing in the midst of brush, belonging apparently to a former forest growth now destroyed, and at the same time this species is very abundant as small trees or underbrush, often presenting some of the popular characteristics of the red oak. The red oak is a graceful, open tree with smoother bark and larger leaves and acorns than the black oak.

Quercus alba, *L.* (White oak).

Quercus rubra, *L.* (Red oak).

Populus tremuloides, *Michx.* (Aspen).

Populus grandidentata, *Michx.* (Great-toothed poplar.)

Populus monilifera, *Ait.* (Cottonwood.)

[Of these poplars the first two are by far the most common, but in proportion to their numbers make fewer large trees than the last. They rarely exceed six or eight inches in diameter, while the cottonwood sometimes becomes two or three feet in diameter, as seen in the Root river valley at Houston. The cottonwood has a rough bark. The bark of the aspen may be distinguished from that of the great-toothed poplar at a distance by the fact that the former becomes white, or mottled with white, as the tree gets the size of three or four inches in diameter, while that of the latter maintains its greenish or dingy-yellow color.]

Populus balsamifera, *L.* (Balm of Gilead). [Common in cultivation. There are some fine large trees of this kind at Mr. Powlesland's, sec. 36, Crooked Creek.]

Populus dilatata, *Ait.* (Lombardy poplar). [Only seen in cultivation.]

Acer rubrum, *L.* (Red maple).

Acer saccharinum, *Wang.* (Sugar maple).

Acer saccharinum, *Wang.*, var. nigrum, *Gray.* (Black sugar maple). [Sometimes known as *rock maple.*]

Ulmus Americana, *L.* (*Pl. Clayt.*) *Willd.* (American elm).

Ulmus fulva, *Mich.* (Slippery elm).

Ulmus racemosa, *Thomas.* (Corky elm.)

[The first named elm is very common, and acquires a very large size in the bottom lands of the Root river, but the slippery elm is comparatively rare. The corky elm seems to be that which is commonly known as rock elm. It is likely to be confounded with the American elm. It grows more slowly, and has a thick corky bark, particularly on its young twigs. Its bud-scales are downy-ciliate, while those of the American elm are glabrous.]

Tilia Americana, *L.* (Basswood).

Carya amara, *Nutt.* (Bitternut hickory).

Carya alba, *Nutt.* (Shag-bark hickory).

[Of these hickories the former furnishes the great bulk of the hoop-poles for flour-barrels, cut in the southern and central portions of the state, the latter being a much more rare tree. It is only in eastern Houston and Winona counties that the shag-bark hickory is known to occur generally. It is exceedingly rare in Fillmore county, and does not occur in the Big Woods.]

Juglans nigra, *L.* (Black walnut).

Juglans cinerea, *L.* (White walnut, or butternut).

[The former is comparatively rare, but the latter is one of the most common trees along valleys.]

Fraxinus Americana, *L.* (White ash).

Fraxinus sambucifolia, *Lam.* (Black ash).

[The former is often seen as a large tree, but the latter is rare, having been noted only in the timbered bottoms of the Root river at Houston.]

Prunus Americana, *Marsh.* (Wild plum).

Prunus Pennsylvanica, *L.* (Wild red cherry).

Prunus Virginiana, *L.* (Choke cherry).

Prunus serotina, *Ehr.* (Black cherry.)

Pirus coronaria, *L.* (American crab-apple).

Negundo aceroides, *Mœnch.* (Box-elder).

Cratægus coccinea, *L.* (Thorn apple).

Cratægus tomentosa, *L.* (Black thorn).

Celtis occidentalis, *L.* (Hackberry).

Betula lutea, *Michx.* (Gray birch).

Betula nigra, *L.* (Red birch or River birch. [River bottoms, La Crescent.]

Betula papyracea, *Ait.* (Paper or canoe birch).

[Of these birches the last is quite common but the first is rare. The outer bark of the paper birch is snowy white, and the tree rarely becomes larger than three or four inches in diameter, and indeed is usually less than two. It frequents rocky banks and sterile soils, being rarely seen except along a hillside, where its white, small trunks make it very noticeable. The former has been seen only in rich, moist lowlands, with large timber surrounding, and is apt to grow, unless injured, to a large tree of a foot or two in diameter. Its twigs and bark are so aromatic as to cause it to be mistaken for the black, or cherry birch, of the middle and eastern states, which has not yet been reported as occurring within the state of Minnesota. The red birch has been cut considerably for fuel at La Crescent. It forms a large and shady tree suitable for ornamental purposes, when growing alone, but in the bottom-land it is not a handsome tree.]

Prunus Strobus, *L.* (White pine).

[On Crooked creek, at La Crescent; on Beaver creek; on Winnebago and Money creeks].

Ostrya Virginica, *Willd.* (Ironwood).

Salix—sp? [Various species; one species becomes a large tree, as seen in the bottoms at Houston.]

Gymnocladus Canadensis, *Lam.* (Kentucky coffee-tree).

[The coffee-tree occasionally is seen, even eighteen inches in diameter, and is used for lumber. It was particularly noted about Houston.]

Larix Americana, *Michx.* (Tamarack). [Only known on Pine creek.]

Cornus circinata, *L'Her.* (Round-leaved cornel).

Cornus sericea, *L.* (Silky cornel).

Cornus paniculata, *L'Her.* (Panicled cornel). [Along the ravines.]
Cornus alternifolia, *L.* (Alternate-leaved cornel).
Gaultheria procumbens, *L.* (Wintergreen). [Seen only at Mound Prairie.]
Alnus incana, *Willd.* (Speckled alder).
Diervilla trifida, *Mœnch.* (Bush honeysuckle). [Along the bluffs of the Mississippi.]
Rhus typhina, *L.* (Stag-horn sumac). [Rare; seen at Brownsville.]
Rhus copallina, *L.* (Dwarf sumac).
Sambucus Canadensis, *L.* (Common elder).
Castanea vesca, *L.* (Chestnut). [Cultivated; seen on sec. 29, Union.]
Robinia Pseudacacia, *L.* (Locust). [Only cultivated.]
Staphylea trifolia, *L.* (Bladder-nut.)
Gleditschia monosperma, *Walt.* (Water-locust.) [Only in cultivation; seen at Hokah.]
Rosa blanda, *Ait.* (Early wild rose).
Rosa Carolina, *L.* (Swamp rose). [This is a bushy rose, eight feet high and less.]
Rhus glabra, *L.* (Smooth sumac).
Rhus Toxicodendron, *L.* (Poison ivy).
Rhus venenata, *DC.* (Poison sumac).
Abies balsamea, *Marshall.* (Balsam fir). [Only in cultivation].]
Rubus strigosus, *Michx.* (Red raspberry).
Rubus villosus, *Ait.* (High blackberry.)
Rubus occidentalis, *L.* (Black-cap raspberry.)
Rubus ———? (Low blackberry.) [More or less trailing.]
Juniperus Sabina, *L.* var. procumbens, *Pursh.* (Trailing cedar.) [Hokah and Sheldon.]
Juniperus Virginiana, *L.* (Red cedar.)
Apocynum androsæmifolium, *L.* (Dogbane.)
Carpinus Americana, *Michx.* (Water beech).
Spiræa opulifolia, *L.* (Nine-bark).
Xanthoxylum Americanum, *Mill.* (Prickly ash.)
Amorpha canescens, *Nutt.* (Lead plant.)
Lonicera parviflora, *Lam.* (Small honeysuckle).
Amelanchier Canadensis, *Torr. and Gray.* (Juneberry.)
Vitis cordifolia, *Michx.* (Grape.)
Ampelopsis quinquefolia, *Michx.* (Virginia creeper.)
Celastrus scandens, *L.* (Climbing bittersweet.)
Clematis Virginiana, *L.* (Common virgin's-bower.) [Common in the valley of Root river, below Hokah.]
Viburnum Lentago, *L.* (Sheepberry).
Viburnum Opulus, *L.* (Highbush cranberry).
Ceanothus Americanus, *L.* (Jersey tea.)
Menispermum Canadense, *L.* (Moonseed.)
Ribes Cynosbati, *L.* (Gooseberry).
Ribes floridum, *L.* (Wild black currant).
Ribes rotundifolium, *Michx.* (Gooseberry).
Corylus Americana, *Walt.* (Hazel-nut.)
Symphoricarpus occidentalis, *R. Br.* (Wolfberry).
Dirca palustris, *L.* (Leatherwood.)

[This was found along the bottoms of Beaver creek in Caledonia township, in the neighborhood of the great spring. The wood, instead of being "very brittle", as described by Gray, was pliable and spongy, resembling a green cornstalk. This was in the month of July.]

Smilax rotundifolia, *L.* (Common greenbrier.)

[This was seen growing very luxuriantly in the sandy alluvium of the Root river bottoms, below Hokah, associated with the virgin's-bower and the climbing bittersweet. In the same vicinity were also the wild grape, the Virginia creeper, and a number of herbaceous vines. The leaves on the different parts of the greenbrier differ very noticeably. Those on the large annual shoots which run ten or fifteen feet, are ovate and heart-shaped, large, three inches long; those of the fruiting stems or branchlets, are rarely heart-shaped, but are ovate, and less than half the size of the former. Both sorts are rough on the edges and on the prominent ribs beneath, and are barely pointed. The carrion-flower, *Smilax herbacea*, *L.* was identified in the ravines on the north side of the valley at Houston.]

It is noticeable that many of the valleys, particularly those running east and west, as Crooked creek valley, have the bluffs along the north side of the creek destitute, or nearly so, of timber. but are heavily timbered along the opposite bluffs, on the south side. This may be due to warm days in winter or early spring when the sap may have started in the trees on the north bluffs, followed by severely cold weather, before the actual setting in of steady warm weather. Of course the sun's heat would be quickest felt on the bluffs facing south. This process repeated for a good many years, would injure and at last destroy the timber on the north bluffs, if it were ever possible for trees to have come to maturity there, while timber on the south bluffs would escape these sudden changes, owing to the shaded condition of the bluffs during the warmest portion of the day, and would only experience a steady increase of warmth due to the progress of the season.*

At La Crescent Mr. J. S. Harris has an apple-tree that has been growing twenty-six years. It was planted in 1857, and is probably the oldest of its kind in the state. Its diameter is seventeen inches at eighteen inches from the ground. It spreads thirty-six feet and has a hight of eighteen feet. Its fruit is known as the *St. Lawrence* apple.

THE GEOLOGICAL STRUCTURE OF HOUSTON COUNTY.

The rocks of Houston county are embraced wholly within the Lower Silurian and Cambrian ages. They are as follows:

The *Hudson River shales* and *Trenton limestone*, confined to the south-western quarter, being of the Lower Silurian.

The *Cambrian*, made up of a succession of alternating friable sandstones and magnesian limestones, as follows, in descending order:

(1) *St. Peter sandstone*, in an irregular area surrounding the area of the Trenton above.

(2) The *Shakopee limestone*, in the upper river valleys.

(3) The *Jordan sandstone*, in the upper portion of the river valleys.

(4) The *St. Lawrence limestone*, in the bluffs of the rivers.

(5) The *St. Croix sandstone*, in the river bluffs.

The accompanying map of the county, plate 8, shows the superficial areas to which the most important of these formations pertain. The *Jordan*, *Shakopee* and *St. Lawrence* are represented by a single color, as they are closely associated in the production of important topographical characters. Owing to the frequent deep valleys the geographical boundaries of the formations make very crooked and tortuous lines. Although these valleys

*Carver noted this peculiarity in the distribution of timber (second edition of *Carver's Travels*, p. 34). He says: "In many places pyramids of rocks appeared, resembling old ruinous towers; at others amazing precipices, and what is more remarkable, whilst this scene presented itself on one side, the opposite side of the same mountain was crowded with the finest herbage, which gradually ascended to its summit."

are filled more or less with the loess-loam the topography still is so marked, pertaining to and even caused by the rocky outlines, that the limits of each formation are very evident to the observer. There is more or less doubt about the position of the boundary between the St. Peter sandstone and the Shakopee limestone. The incoherency of the St. Peter causes it to crumble easily, and to leave no evidence of its final dissolution where the exact contact between the formations cannot be examined; and the loam generally securely hides this horizon.

The Trenton limestone. This formation, as known in Houston county, consists of limestone layers that amount to a thickness of not more than fifteen feet. These layers are overlain by beds of shale and fossiliferous shaly limestone which reach an unascertained thickness, but probably not exceeding twenty-five feet. These shaly beds have been denominated "Green shales", in the reports of progress of the survey, but they seem to belong to the Hudson River age, of New York. They are overlain in Fillmore county, and in northeastern Iowa, by firm calcareous strata which attain a thickness of fifty or sixty feet, which seem to fade into the *Galena* formation of Iowa, as may be seen by consulting the chapters relating to the geology of Fillmore and Goodhue counties.

This formation is found in Spring Grove and Wilmington townships. It runs also in a narrow, but interrupted, belt nearly to Caledonia, where it may be seen distinctly in its peculiar features, and its flat-topped mounds, or tables, a mile west of that village. There is reason to suppose that it formerly extended much further east than it does now, covering the most if not the whole of the county, and being continuous with the horizon of the same formation east of the Mississippi river in Wisconsin.

The usual characters of the Trenton, both lithological and palæontological, were the only ones noticed in Houston county. It has been opened for quarries only in the vicinity of Spring Grove. It generally presents a stained and long-weathered aspect, as if split and dissolved by the action of water. The layers are at first about an inch in thickness, but become thicker, by union with each other, on being wrought to some depth, and possess a blue color.

The St. Peter sandstone. This lies next below the Trenton. Its area embraces not only the slope from the high table-land of the Trenton area, but also a belt extending in width from the foot of that slope over the more level country surrounding, so that its irregular area is often a mile or two in width. As already remarked, while its upper limit has a very easily recognized location, by reason of the terrace-like topography of the Trenton, its lower horizon is often very uncertain on account of the very easy and gradual destruction of its layers, and the prevalence of the loess-loam.

The characters of the St. Peter sandstone are pretty well known to geologists. It spreads into Iowa, Wisconsin and Illinois. Toward the east, in northern Wisconsin, Prof. T. C. Chamberlin has traced it to the Michigan state boundary, though there it is reduced to a thickness of no more than twenty feet.* It contains but the merest traces of fossil remains. It consists of nearly pure silica, in rounded grains, with so little cement that the rock can generally be crumbled in the hand. It is nearly white; and the soils which are situated near its line of outcrop are apt to be loose and arenaceous from its disintegration.

It was noticed, however, that for some reason it is more frequently hardened by iron, or lime and iron, in Houston county, into a firm rock, which causes it to sustain a weathered exposure without crumbling rapidly away, than in counties further north or west where the northern drift prevails. This, however, is purely an accidental and surface quality, the interior of the formation being about the same as at other places. The cement which it possesses in Houston county, in its exposed portions, in excess of the same at other points, is no doubt due to the water by which it has been submerged and stained during the deposition of the loess-loom.

The thickness of the St. Peter sandstone was very satisfactorily ascertained on S. W. ¼ sec. 17, Wilmington. The well of Mr. O. A. Bye is situated near the Trenton bluff, and by uniting the known depth drilled in the sandstone with aneroid measurement of the bluff, the St. Peter was found to be between seventy-five and eighty feet thick, the Shakopee below having a thickness of sixty-four feet.

The Shakopee limestone. The continuity of this formation from the Minnesota valley to the Mississippi, and its idenity with the limestone at Shakopee, where it was first recognized as a distinct member of the Cambrian in Minnesota, was fully established in the survey of Houston county.

*Geology of Wisconsin, Vol. II, p. 289.

It is everywhere distinct as an important limestone formation, and is everywhere separated from the other great calcareous member of the same formation by a sandstone as distinct and continuous, and as clearly recognizable, as the St. Peter sandstone. There seems much reason to believe also that it exists across the Mississippi, in the state of Wisconsin, but at this time there is no distinct published notice of its occurrence there. The Lower Magnesian in Wisconsin has been divided by Prof. R. D. Irving, of the geological survey of Wisconsin, into three parts, as exemplified near Madison (*American Journal of Science and Arts,* June, 1875,) but there is reason to believe that his proposed subdivisions do not include the Shakopee limestone at all, and that the distinctions which he mentions are wholly confined to the St. Lawrence limestone of Minnesota. This subject was discussed by the writer in the *Bulletin of the Minnesota Academy of Natural Sciences,* for 1875, when this hypothesis was first published. It is rendered still more plausible from the fact that even in Houston county the St. Lawrence exhibits variations of composition and lithology which are comparable to those Prof. Irving describes.

The characters of the Shakopee in Houston county are not noticeably different from those in counties further west. The aggregate thickness, however, is less than seventy-five feet.

This formation does not appear in the bluffs of the Mississippi river, in Houston county, nor in those of Root river generally; but its line of strike is some miles back in the country away from the immediate bluffs. This is due to the more crumbling nature of the Jordan sandstone, which underlies it, and which operates, in that respect, to tear down the Shakopee in the same manner, and for the same causes, as the St. Peter on the Trenton. To this fact, and to its general resemblance to the St. Lawrence limestone, may be attributed the non-discovery of this limestone by the United States geologists who have reported on the geology of the state, or by others, whose examinations were largely confined to the main water-courses, before the general settlement of the state and the construction of good roads. Its area is embraced on the colored map of the county, in the same color with that of the St. Lawrence limestone and Jordan sandstone.

This limestone may be seen frequently in the central portion of the county, in the upper reaches of the ravines which radiate in all directions from the vicinity of Caledonia. It is seldom quarried, or used for any purpose, for the St. Lawrence limestone is generally accessible in the immediate neighborhood, and that is much more desirable for building-stone, or for lime-making. In descending the ravine toward the quarries east of Caledonia the Shakopee is the first limestone seen exposed. The quarries are much lower, and in the St. Lawrence. It may be seen also in the upper tributary valleys that feed Badger, Beaver, Crystal and Thompson creeks. It causes the first rugged or rocky portion of these valleys. It is exposed in the tops of the bluffs at the great spring, sec. 17, Caledonia, three miles south of Sheldon. Its thickness at Mr. O. A. Bye's, sec. 17, Wilmington, when drilled through, was found to be sixty-four feet, which is probably about its average thickness throughout the county.

The Jordan sandstone. The lithological features of this sandstone, are nearly the same as those of the St. Peter, but it has only about one-half the thickness of the St. Peter. Its area of outcrop is quite small, and its exposures are few. As it lies between two hard limestones, which are apt to form perpendicular, walled bluffs, its line of outcrop is known by a belt of non-exposure of rock separating the Shakopee from the St. Lawrence, which is less steep in the ascent, and perhaps turfed over. It often becomes rusty and firm from a cement of iron, when it endures long exposure, and is seen as detached blocks in the valleys. Some blocks of this kind are visible by the roadside in the ravine that descends to the quarries of Aiken and Molitor, a mile east of Caledonia.

The outcropping area of the Jordan is also frequently evinced by the occurrence of blocks of firm sandstone in considerable abundance near the tops of the bluffs. In ascending one of the numerous ravines of the county after passing the precipitous outcrop of the St. Lawrence limestone, upon ascending a gentler slope still higher, perhaps along a roadway, will occasionally be seen such blocks of sandrock, varying from a few inches to a foot or two feet in diameter, while the beds from which they are derived can rarely be seen *in situ;* occasionally, however, they can. In some instances the overlying Shakopee limestone, resembling greatly a weathered exposure of the St. Lawrence, will also be found adjacent by pursuing the search in further ascent of the same ravine. Mr. Moses Strong has reported similar scattered blocks of sandstone at a level higher than the St. Lawrence limestone, in Wisconsin,* notably on N. W.¼ sec. 22, T. 7, R. 4 W., but he has referred them to the St. Peter sandstone.

The St. Lawrence limestone. This is the most important formation in the county. It not only occupies a greater superficial area of outcrop than any other, but it takes the most prominent part in causing the varied topography of the county. It surmounts the St. Croix sandstone, an easily eroded rock, into which the valleys are deeply and rapidly cut, and maintains a bold and sharp outline along their tops. It is the immediate cause of a great many hills and ridges. It confronts the observer in every nook and on every promontory, along the whole course of the Root river, and down the Mississippi bluffs as far as the state line, and it is especially conspicuous in the little valleys that ascend from those streams and that often are more rocky than the larger valleys.

The thickness of the St. Lawrence, in Houston county, is about 200 feet, though Prof. J. D. Whitney has reported it as 250 feet thick on the Upper Iowa river.† It is a dolomitic, or magnesian limestone. Its layers, while generally regular and useful as a building-stone, are also sometimes very much brecciated, rendering it at once more firm but also more refractory. This feature pertains to its uppermost thirty or forty feet. It furnishes more stone for building than all the other formations of the county combined. It is of a light, lively color and endures the weather perfectly, showing not the least change in the oldest buildings in which it has been used.

The bedding in the upper portion of this formation is apt to be disturbed by cherty, or concretionary, masses, which on the weathering away of the bluffs become detached and fall into the bottom of the valley, where they lie long after the non-siliceous portions of the rock have dissolved and disappeared. Such cherty lumps are often a foot, or even two or three feet, in diameter. They are roughened by cavities opening on the surface, by solution and removal of the calcareous parts, and by the natural openings and pores they acquired in the act of formation. They are the only portions of the formation in which fossils have been found in Houston county. These masses sometimes show surfaces of drusy quartz crystals,

*Geology of Wisconsin, Vol. II. 1873—77, p. 672.
†Geology of Iowa, Vol. I, p 333, 1858.

also amethyst crystals, and great quantities of pyrite oxydized and hydrated so as to produce limonite, the form of the crystal alone remaining to indicate the original mineral. A careful study of these fossils has not yet been made. From Houston county have been obtained from such cherty lumps, an *Orthoceras* resembling *O. primigenium*, H., but having an oval section and oblique septa; an *Orthoceras* with septa nearly directly transverse to the direction of the shell, much more resembling *O. primigenium*, H., and several species of spiral univalves including some of *Ophileta* and some of *Pleurotomaria*.

The St. Croix sandstone. This name was applied in the first annual report provisionally to the light-colored and often friable sandstones which occur along the Mississippi river in Minnesota, and which have by some been regarded as the stratigraphical equivalent of the Potsdam sandstone of New York. This was done because, in the existence of another formation, of different lithology, affirmed also to be the equivalent of the New York Potsdam, it was necessary to have some designation for each of them. It seemed, from considerations there given, that the lower of these two sandstones was the probable equivalent of that formation in New York.

Since that report was published considerable more time and observation have been given to the same question. Numerous facts from the northern part of the state, where the lower of these two sandstones appears abundantly, have been gathered, and some of them, with theoretical and mineralogical considerations, have been published in succeeding reports of the progress of the survey.* They all go to affirm the essential correctness of the distinction brought forward in the first annual report. Hence the designation *St. Croix sandstone* is retained. The reasons in full for this can not be given here. Meantime if, before the final discussion of this subject, the reader desires further facts bearing on it, he is referred to the annual reports, particularly to the ninth and tenth.

Although these sandstone beds occupy the river bluffs along the Mississippi and the Root rivers throughout the county, they afford but very few opportunities for satisfactory examination. They are in the lowest part of the bluffs and are generally hid by a sloping talus that is usually turfed

*Ninth and tenth annual reports.

over. The only point at which a useful section of their composition could be had was at Hokah. The general section at this place, as nearly as it could be made out, is as follows, in descending order.

General section at Hokah.

	Feet.
St. Lawrence limestone, about	200
Slope—unseen (probably transition, argillaceous beds)	30
Sandstone, line of constant exposure	30
Slope, rock unseen, (probably crumbling sand)	30
Whitman's quarry made up as follows:	
1. Broken, shaly, and sandy, crumbling and fragmentary	10
2. Shale bed, greenish with remains of trilobites	1
3. Tough, persistent layers, like an undurated, arenaceous shale, with green sand, in thin layers	12
4. Crumbling sand, in oblique stratification.	3
Rock very similar to Nos. 3 and 4 extends downward, covering the horizon of an old quarry east of Hokah, now abandoned as worthless, embracing a thickness that is generally a turfed slope of about	150
Rusty, coarsely arenaceous sandrock with *Lingula*	10
Crumbling, white sandrock, massive	25
Variegated, arenaceous quartzyte, purple, and white, hard and persistent, level with the top of the dam,	2
Massive white sandrock	20
Total rock, about	523

The hight of Mt. Tom, at Hokah, by aneroid, above the flood-plain, was found to be 530 feet.

At an old quarry east of Hokah, and across Thompson's creek, now abandoned because the rock is worthless for all purposes, the general aspect of the layers is much like that at Whitman's quarry, but the sand is less firmly cemented, making a stone not so good. It is a shaly and arenaceous sandstone, of coarse and fine grain, marked with fucoids and abundant greensand, and is below the stratigraphical level of Whitman's. In the same bluff, about twenty-five feet higher, is a blind shoulder or terrace which is more likely to contain the layers of Whitman's quarry. This stone, as taken from Whitman's quarry, although very shaly, becomes firm and enduring on exposure.

At Houston, the bluffs north of the village are 520 feet in hight, and of this the lower 420 feet at least belongs to the St. Croix sandstone. They probably contain the St. Croix twenty feet further up, shown by the toppling over of huge blocks of St. Lawrence limestone, from the crumbling out of friable sandrock along the salient angles of the bluffs. The interval of these sandstone layers is mainly turfed over so as to render an inspection of their contents impossible except at points near the top and near the bottom. There is a line of nearly constant exposure about forty feet below the top of the St. Croix, occupying an interval of thirty or forty feet, which is particuticularly noticeable along the north side of the river, and is again mentioned in the report on Fillmore county. There is another exposure of these beds near the level of the river at the dam at Houston. The former consists of a hard, firm sandrock, and the latter is soft and crumbling, with cross stratification. Above the line of constant exposure, about twenty-five feet, is a blind terrace which occasionally reveals the rock which causes it. It is a sandstone, and is included in the foregoing thickness of 420 feet.

At one mile north of Sheldon there is an apparent dip in the outcropping upper edge of the St. Croix, as it strikes across the bluffs. Its direction is perhaps a little west of south, and amounts to two or three degrees. It is entirely local, and the corresponding upward dip in the opposite direction is invisible. The bluffs south and north have their usual hight.* No such dip was noticed in any other part of Houston county, but it is very likely this is on the strike of the noticeable disturbance in these formations which has been mentioned by the geologists of Iowa as occurring in the bluffs of the Mississippi river at McGregor and Lansing, in the state of Iowa.

In section 2, Caledonia township, the following section was taken :

Section covering the junction between the St. Croix and the St. Lawrence.

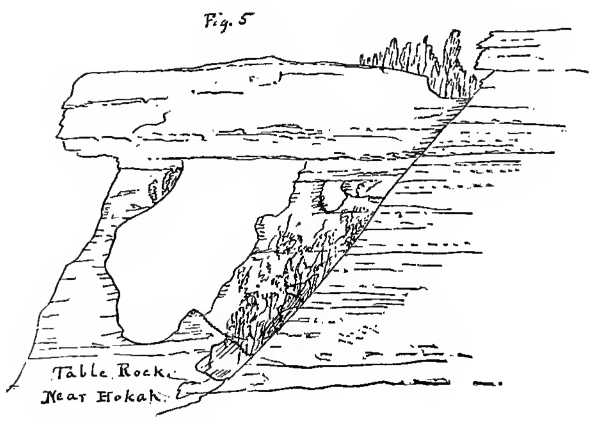
	Feet.
Slope, covered with large blocks of limestone,	200—300
Even layers of limestone, quarried,	12
Hid, mainly limestone, like the next,	40
Limestone, with broken and curling bedding, cherty, arenaceous or massive, with some greensand,	25
Lime and sand, lumpy with irregular concretions, mainly massive,	15-20
Soft sand, with cemented or quartzitic lenticular lumps,	10
Soft, massive sand, (causes the blind terrace at Houston),	25

The line of constant exposure mentioned as occurring at Houston, near the top of the St. Croix sandstone, lies below this section. This line is more evident in the north than on the south bluffs,—due, probably, to the erosive action of the prevailing winds—which are from the southwest, and to the greater scarcity of timber on the north bluffs as already noted under the head of *Soil and Timber*.

*Compare Geology of Iowa, Hall & Whitney, 1858, Part I., p. 51; and the Winona county report, where a similar dip is described in the Shakopee and St. Peter.

The fossils that have been gathered from this formation consist very largely of trilobite remains. They were obtained from the quarry of Mr. Whitman at Hokah.

On section 11, Union township, the sandstone which has been mentioned as having a nearly constant line of exposure, is sculptured, along the north bluffs, into isolated columns and tables, with some rounded buttresses which present a very conspicuous and highly interesting instance of atmospheric erosion. There can be no doubt that the bluffs themselves are the result of the erosion of the valley by water by a process that began thousands of years before the glacial epoch, but the present condition of most of the curious forms, like that of the "sculptured bluffs," is certainly due to the effect of wind in conjunction with moisture and frost. There are also cavities and sheltered nooks, and deep, crooked passages and sharp niches, in which the wind could barely enter, and from which there could not have been any wind exit sufficient to have maintained a current capable of producing the most of this sculpture, which,



moreover, are lichen-covered, and bear an aspect of age and roughness that forbids their reference to any present atmospheric forces. They can be explained only by the solvent action of water in agitation, and are comparable to the purgatories that are often seen about the rocky shores of lakes or of the ocean. But where the rock shows a recent, fresh erosion, and is soft and crumbling, the present forms are due to more recent causes, and can only be assigned to wind and frost. Table Rock, represented in figure 5 from a pencil sketch, is one of the results of wind erosion, seen in the valley of Thompson's creek, near Hokah, situated near the top of the St. Croix sandstone.

THE DRIFT.

The true northern drift is not spread over this county. It contains no drift clay, nor boulders of foreign origin. There is a thin deposit of foreign gravel at Riceford, in the extreme southwestern part of the county, and there is a terrace along the Mississippi river that is made up of gravel and sand of northern origin, but the county wholly escaped the operation of those forces which spread the well-known drift clay and boulders over the most of the state. Whether any former glacial era caused it to be covered with the ice of a northern glacier cannot be determined, since the materials left by that era, if any there were, may have been decomposed, and may have entered into the stratified clays and the soils of the Mississippi valley further south, under the combined influence of time and the destructive forces of later eras.

There is to be seen occasionally a local drift, or debris derived from the rock of the country round about, and this sometimes has a deceitful resemblance to true northern drift, yet it can always be distinguished from it on examination. On the northwest quarter of section 25, Caledonia, along the road, near the brow of the Shakopee limestone, there is a bank of such loose materials. There is a cut of about three feet, which consists mainly of rusty loam, rather sandy, embracing large masses of black quartzyte, which also vary to a lighter color but show very little, if any, lime. Other lumps consist of pyrite crystals, now converted to limonite, and of rusty, hardened sandstone, perhaps from the Jordan. These last indeed comprise perhaps a majority of the stony masses. There are also large quantities of ordinary chert and an occasional piece of water-worn limestone. The bank shows no stratification, but consists of these materials simply mingled with the loam. The whole appears red and rusty, but discloses not a single piece that cannot be referred to the Cambrian rocks.*

Alluvial terraces. There is a marked alluvial terrace that accompanies the Mississippi and Root rivers, and ascends their lower tributaries, but it

*As to the cause of the "driftless area", compare the fifth annual report, p. 35.

does not seem to be true that the streams are terraced above the level of this terrace. The highest point at which the terraced condition of Root river has been observed is Preston, in Fillmore county, but it must certainly extend several miles farther up that valley. By aneroid measurements, united with levels of the Southern Minnesota railroad, the hight of this terrace at Preston is found to be about 300 feet above the Grand Crossing of the S. M. R. R. near the mouth of Root river, while the same terrace at Hokah, likewise near the mouth of Root river, is only about one hundred feet above the flood plain. It is also probable that the loam terrace, as seen at La Crescent, is the same continued to and coalescent with the Mississippi terrace; and there it is ninety feet above the Mississippi flood plain. This would necessitate a fall of about two hundred feet in the Root river at its highest stage, in a distance of fifty miles in a right line. Root river valley, between the rock bluffs, has an average width, through Houston county, of about two miles.

There is, besides this high loam-terrace, a second terrace level, visible specially at La Crescent, on the Mississippi, which there rises fifty feet above the flood plain of the river and spreads out in a pleasant plateau on which the village has been located. This terrace is made of gravel and pebbles of northern origin, and was identified only along the Mississippi. The largest stones it contains are about three inches in longest diameter. It is passed through in wells, and seems to be entirely pervious to water, as all the wells on it get water at about the level of the flood plain of the river. This material is used for grading and road-bed, on the C. D. & M. R. R. and elsewhere. It consists entirely of rounded water-worn materials, the main part being the usual parti-colored quartzyte pebbles, granitic, hornblendic, amygdaloidal and lamellar, as well as uniform and massive. A great many of them have a red color, or some shade varying from red. The coarsest pieces are rare, found only in the upper portions of the *debris* of alluvial fans.

The following more special observations were made on these terraces in Houston county.

At Sheldon, six miles from Root river, in the valley of Beaver creek, the terrace on which the Newberry House stands is thirty feet above the water of the creek below the dam. The materials of the terrace at this place are sandy loam horizontally stratified, with more clay near the top, and less evident stratification.

At Houston the only observable terrace, measured about a mile west of the city, is sixty-five feet above the flood plain. The track of the railroad is about one foot above the flood plain of the river, which is eighteen feet higher than the water below the mill-dam.

At Money Creek the terrace rises thirty feet above the flood plain, which is twenty feet above low water below the mill-dam. The contents of the terrace are stratified. On sec. 30 in this town the contents of the Root river terrace and their arrangement, are shown by the following sketch, which was taken on the spot.

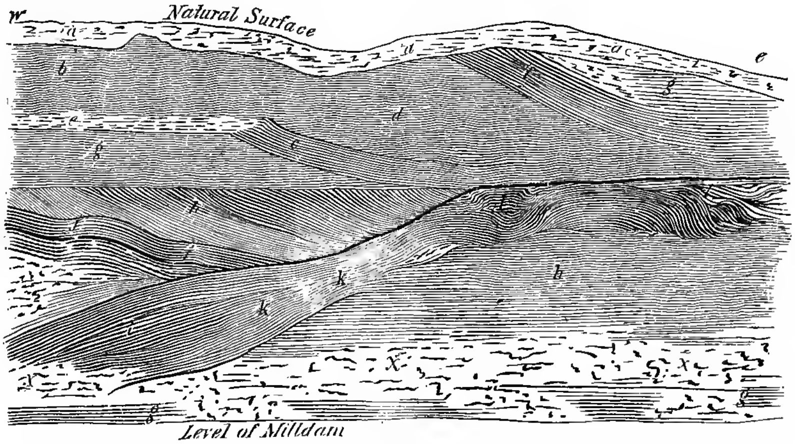


FIG. 6. SECTION OF THE ALLUVIAL TERRACE, SEC. 30, MONEY CREEK.

Explanation.

a. Mixed and broken stratification, roots, soil, &c., 2—4 ft.
b. Loam and sandy loam. 3—6 feet.
c. Oblique strata of light sand.
d. Loam and light sand
e. One layer of sand—blown out. 8 in.
f. Oblique layers of sand.
g. Horizontal strata of fine sand.
h. Strata of fine sand or clay.
i. Sloping clay layers, damp, rusty.
j. Dry, blowing sand.
k. Wet clay with rusty lumps.
l. Contorted, curling, or massive strata.
x. Hid from veiw by debris.

The full hight of the bank is about twenty feet where the section is taken. At a point farther to the right than is shown in the sketch a couple of bones were found, but in the confused and broken uppermost layer. They were where that layer comes down to the river, and about three feet below the surface, or five feet above the water of the dam, the surface of the bank sloping about forty-five degrees.

At Hokah the village is on a terrace sixty-five feet above the flood plain of Root river, and there is a distribution of loam about the bluffs at a higher level (as well as at many other points along Root river valley), reaching to a hundred feet, or a little more, above the flood plain. This loam appears in indistinct benches or terrace levels, or patches of terrace, rising often with a slope, far up the rock-bluffs. It very rarely appears level, as a well-marked terrace. It suggests rather a worn-out old terrace level, the upper surface of which has suffered erosion, by being gullied out and smoothed off toward the river. It is generally cultivated for farms, and has good wheat-fields; consisting of the same materials as the lower terrace. Its actual hight is difficult to ascertain.

S. W. ¼ sec. 22, La Crescent. By the road-side appears a terrace rising about fifty feet, which at the top consists of the fine loam of which the foregoing terrace is composed, showing at least eight feet of such material, while its lower twenty feet are of drift-gravel which is coarse and obliquely stratified, the coarsest pebbles being but one or two inches in diameter. This occurs on the rounded point of the rock-bluff which faces both valleys.

The village of La Crescent stands on a beautiful terrace of drift gravel, generously laid out, with wide streets and alleys, fifty feet above the flood-plain of the Mississippi. This terrace slopes gradually back toward the high rock-bluffs. It is surmounted, along the bluffs, by another terrace rising forty feet higher, which consists of loam.

This drift gravel must be attributed to the agency of the river. It has every feature of a water-worn alluvial deposit. It is not found in Houston county in any of the valleys of other streams, back from the Mississippi. It antedates the loess loam, as that is terraced above it, and probably bears the same relation to an earlier glacial epoch, as the terraced loam does to the last.

At Brownsville the loam terrace is eighty feet above the flood-plain of the Mississippi.

At Yucatan the terrace flat is forty feet above the present flood-plain of the south fork of Root river. The flood-plain is six feet above low water.

At Freeburg the terrace is twenty feet above the flood-plain of Crooked creek, which is five feet above the water of the creek.

Wells in Houston county.

A few wells situated in the valley of Root river have disclosed vegetable remains at about the level of the flood-plain, and probably the terraces generally cover a layer of vegetable remains that was caused by the decay and burial of preglacial plants. This has only been detected, so far as known, at Hokah and at La Crescent. At the former place the well of Isaac West was filled again because the "muck bed" rendered the water unfit for use. The same is true of William Wykoff's and W. F. Weber's, and a number of others. Probably the characters of Mr. Pidges, as given below, are those common to most of them.

B. F. Pidge's well, at Hokah.

It is situated on the lower terrace.

Loam and sand	50 or 55 feet.
Vegetation, leaves, sticks, muck, &c.	4 feet.
Sand, with some coarse pebbles "literally filled with snail shells"	4 feet.
White sand, yielding water	5 feet.

The water of this well tastes rather peculiar, and at first it was not fit for use. Sometimes still it comes up black, but by use it becomes clearer and is used for all domestic purposes, without injurious effects. Sugar of lead causes it to become milky white. Acetate of potassa produces no change; sulphate of zinc no change. When it rises in the bucket it is not clear, but somewhat cloudy, as if with clay.

Wells in Houston county.

Owner's Name and Location.	Loam, feet.	In the rock, ft.	Total feet.	Kind of water.	Remarks.
Timon Gilbertson, Spring Grove	7	40	47	Good	
Mons Fladager, Spring Grove	8	122	130	"	Drilled.
Ingval Miller, Spring Grove	10	30	40	"	On lower ground.
Nels Hendrickson, Spring Grove	8	77	85	"	
O. Thompson, sec. 7, Wilmington	8	65	73	"	
I. Dailey, N. E.¼ sec. 34, Caledonia	28	72	100	....	No water.
Public well, Caledonia	25	245	270	Good	
W. N. West, Caledonia	20	50	70	"	
A. Calmus, Caledonia	20	23	43	"	
M. Creagan, Caledonia	20	23	43	"	
O.A.Bye, S.W.¼ sec.17, Wilmingt'n	18	77	95	"	Two feet sandrock; sixty-four feet limerock; eleven feet sandrock
W. H. Harris, Caledonia	18	33	51	"	
M. Newberry, Sheldon	36	......	36	"	The rock has never been struck at Sheldon.
J. B. Williams, Sheldon	36	......	36	"	
Cottrell Hotel, Houston	16	......	16	"	Eight feet to water—all alluvium.
W. R. Anderson, La Crescent	57	......	57	"	At fifty-four feet struck leaves, &c.
D. Gurley, La Crescent	49	......	49	"	Gravel and sand.
Sawyer House, La Crescent	45	......	45	"	Gravel and sand.
James Day, La Crescent	50	......	50	"	Gravel and sand.
James Brown, La Crescent	45	......	45	Bad	Sticks and leaves; refilled.
J. Knapp, La Crescent	68	......	63	Good	Gravel and sand.
William Miller, La Crescent	30	......	30	"	On lower ground.
Charles Oldenbaugh, La Crescent	20	......	20	"	On low ground, near the rock bluff.
Thomas Minshall, La Crescent	37	11	48	"	On low bench.
Joseph Garner, La Crescent	30	......	30	"	On low bench.
Nicholas Prive, sec. 31, Caledonia	12	2	14	"	Four feet of water.
B. Smitz, sec. 32, Caledonia	12	10	22	"	Ten feet in sandrock.
N. Charles, sec. 32, Caledonia	12	......	12	"	
G. Anderson, sec. 4, Wilmington	......	......	40	"	Drilled.
John Prive, sec. 33, Caledonia	12	90	102	"	
M. Blasen, sec. 33, Caledonia	12	36	48	"	
Ole Hanson, sec. 4, Wilmington	15	55	70	"	Drilled.
Peter Carrier, sec. 32, Yucatan	55	......	55	"	In the valley; no rock struck.

Throughout the county are numerous springs, some of which are very large, and gush out along the valleys. They seem to be the outlets of subterranean streams. Those above Riceford furnish the water for the flouring mills at that place. There is also a large one on section 17, Caledonia, three miles south of Sheldon. They seem to frequent an horizon about eighty feet below the top of the St. Lawrence limestone, and indicate a shaly, or otherwise impervious, layer there in that formation.

MATERIAL RESOURCES.

The rocks of the county do not contain any valuable minerals. They are everywhere abundantly exposed, and are quarried at many places for ordinary building-stone and for quicklime.

Building stone. At Spring Grove the Lutheran society is building a large church, of brick, the basement being from the Trenton, in layers of four to six inches, taken from quarries near the village. The heavy trimmings are from the St. Lawrence limestone. The quarries are owned by George Timansen and Ole Tostenson.

The Toledo woolen mill, of Fletcher & Williams, section 5, La Crescent, is built of the St. Lawrence, quarried near.

At Caledonia the St. Lawrence is extensively used for building, quarried about a mile east of the village. The German Catholic church is the principal structure made of it, being also the largest in the place. The county jail is a fine building of the same, the courses being about ten inches thick, rubble dressed, with trimmings of the same. The business blocks of Nicholas Koob, J. J. Belden, John Krantz, Joseph Vossen, Jacob Bouquet and Nix Erstine are also constructed of the same stone. The quarries are owned by John Molitor, John Dorsh, Anton Molitor, Widow Cunningham and John Aiken.

On section 24, Spring Grove, Mr. K. Gilbertson has a two-story stone residence on his farm, quarried from the Trenton.

At Money Creek, Harvey Chapel has a quarry that furnishes good stone for building, though much of that which is used is taken from the surface near the tops of the bluffs, having been loosened and broken up by the weather.

On the N. E. ¼ section 11, Caledonia, is Mrs. M. Brown's stone house, built of magnesian limestone.

Mr. J. Kline has a fine farm-house of stone taken from the St. Lawrence, on section 19, Union. Near Mr. Kline's quarry is another owned by Henry

Snure. There is another on section 29, Union, owned by Michael Wilhelm. L. Svenson's is on section 2, Houston.

The principal quarries at Hokah, now worked, are those of Nath. Whitman, in the St. Croix sandstone, and Widow Prindle. The stone of Mr. Whitman's quarry is a harsh, argillaceous sandrock, in layers a few inches thick, which becomes firmer on exposure. The best building stone lies higher up in the bluffs, and was opened in Mt. Tom by the Southern Minnesota railroad company for the construction of their shops. It is from the St. Lawrence.

At La Crescent the public school house was built of stone from Potter & Taylor's quarry, likewise in the St. Lawrence, north of La Crescent, in the edge of Winona county.

Lang's brewery, section 28, Hokah, is a large stone building near the river, built of limestone from near the top of the bluff.

There is also a fine stone farm-house owned by Wm. Splitter, on section 21, La Crescent, in Root river valley. The Nunnery, section 28, La Crescent, was constructed of stone got from the bluffs near, including also that used for quicklime. These are all from the St. Lawrence.

On Winnebago creek (sec. 22 Winnebago), Mr. B. T. Barbour has a stone flouring mill.

O. T. West has a limestone quarry at Brownsville, which supplied heavy stone for the railroad, and for other uses. Mr. Job Brown's, at the same place, furnished the limestone foundation for the public school-house.

The foregoing are a few of the stone buildings in the county, but there are several others which, though noticed in the progress of the survey, were not carefully located, and cannot be referred to. The St. Lawrence supplies by far the greater portion of the building-stone used in the county. There is not a single known workable quarry in the Shakopee, though exposed as favorably as the St. Lawrence. It is uniformly ignored. It is harder to work, has cherty lumps and siliceous concretions which not only disturb the bedding but render it difficult to cut into desired shapes, and is generally in thinner layers. The color is much the same as that of the St. Lawrence, being buff, or slightly salmon-colored, but the St. Lawrence is, where most used for building, also somewhat open or vesicular in texture. Thus mortar sets firmly upon it, and forms a sutured attachment. When the

St. Lawrence stone is first taken out it cuts more easily than after exposure for a few weeks, a fact which seems to be true of nearly all good building stone.

Sand. The St. Peter formation is excavated for mortar sand by Jesse Scofield, sec. 14, Caledonia, and by John Burns on sec. 26. This white sand is delivered at Caledonia village for $1.25 per load, or occasionally for $1.50.

The St. Croix furnishes a similar sand near Mr. Kline's, sec. 16, Union. These formations will supply a similar sand in any part of the county where they are accessible. The layers in the St. Croix, however, are about two hundred feet below the top of the formation.

At Mr. Scofield's sand quarry, about a mile west of Caledonia, is a large mass of lamellar calcite, lying on the slope of the St. Peter, and nearly covered by the loam. In that respect it is like a similar mass seen near St. Charles, in Winona county, in 1872, and mentioned in the report for that year, but it seems more firm than that (see Winona county report). This appears like a firm, very compact rock, consisting of almost pure carbonate of lime, but somewhat colored. It is mainly massive, and striated or laminated, but shows some crystalline grains. It weathers into undulating or wavy smooth surfaces. There is another much larger mass, weighing many tons, on the land of Mr. Willard, a short distance west. These masses can be burnt into a purely white quicklime of great strength.

The age and origin of this calcite are an interesting problem. When that piece was found in Winona county, in 1872, it was referred hypothetically to the Trenton green shales, or to the worn-out Cretaceous that may have covered that country, making it of rock origin, either Lower Silurian or Mesozoic, but there is much reason to believe these calcite masses are not referable to the rock *in situ*, but are of atmospheric origin, being in short the remains of immense travertine deposits from limy water running down the St. Peter slope from springs that once existed but are now dry. They lie on the slope of the outcropping edge of the St. Peter, just below the green shales which shed all the water that works downward through any overlying limestone; but they are also, so far as discov ered, in regions where no overlying rock now exists, the only remaining portion of the Trenton being that which lies below the green shales. This is strikingly the case near Caledonia, where the Trenton is reduced to mounds and tables, capping the St. Peter sandstone, very far isolated from the main area of the Trenton. To suppose this calcite is due to springs caused by the green shales, a common phenomenon now in Fillmore county, is to require the former existence of a considerable thickness of strata, all over the region of Caledonia, and extending far enough north and east to furnish drainage surface sufficient to maintain such springs. This is not inconsistent with the history of geological changes, nor with the lapse of time since the Trenton rocks were elevated to the condition of dry land. The present existence of isolated patches of the Trenton, both in Minnesota and Wisconsin, can only be explained on the theory that the whole formation was once more largely spread in horizontal strata over those states, than at present. Then an extension of the Trenton so as to embrace in one sheet of layers these isolated patches, is no more than enough to bring also the Hudson River and the Galena into the region of these calcite masses. The present outlines, shape and position of the areas of the Trenton, demonstrate that they are only the relics of once greater areas which have been eroded and removed slowly, and left as they are because they have been better protected against destructive agents. While Root river has been excavating the gorge in which it runs, 500 feet deep and two miles wide, the Trenton limestone, which at first may have extended as far north as to Hokah, has been slowly receding under the operation of denudation and surface drainage. These calcite masses then are relics of pre-glacial time, and perhaps of early pre-glacial time, since the last glacial epoch did not operate in Houston county so as to disturb the older surface.*

Brick. The loam everywhere is suitable for making brick, which are uniformly red. The following establishments were seen:

Stephen Robinson, Money Creek; two miles south of the village.

Fisher & Keller, Caledonia; began in 1875; burnt three kilns, and sold at $8.00 per thousand.

Brick were formerly made at La Crescent.

The Lutheran society, at Spring Grove, manufactured on the spot a fine red brick from the loam taken out to make room for the foundations and basement of their church edifice.

Lime. The Trenton and the St. Lawrence furnish all the quicklime

*See the first annual report, p. 47.

made in Houston county. There are no extensive manufacturers, but the common pot-kiln is found at a number of points, as enumerated below, by which enough is made to satisfy the local demands.

Ole Timro, sec. 24, Money Creek,	St. Lawrence.
Gilbert Nelson, Spring Grove,	Trenton.
Michael Blasen, 1½ miles west of Caledonia,	Trenton.
Peter Kreer, N. E.¼ sec. 29, Mayville,	St. Lawrence.
John Gross, one mile northwest from Brownsville,	St. Lawrence.
John Molitor, one mile east of Caledonia,	St. Lawrence.
George Timansen, Spring Grove,	Trenton.
Ole Tostenson, Spring Grove,	Trenton.
Wm. E. Potter, La Crescent,	St. Lawrence.
Samuel Pound, sec. 12, Hokah,	St. Lawrence.

EARTHWORKS.

At La Crescent are a great many so-called *Indian mounds.* Some have been graded away, but many still exist. They are on the brow of the drift terrace, or lower bench, and none are known on the upper, loam, terrace. They are, as usual, in rude rows, and about three feet high, some of them being four feet. When opened they have been found to contain human remains of men of large stature, and it is said that in grading for the railroad a copper skillet and other trinkets were found at the depth of eighteen feet below the surface.

CHAPTER V.

THE GEOLOGY OF WINONA COUNTY.

BY N. H. WINCHELL.

Situation and area. This county (plate 9) borders on the Mississippi river, and lies north of Houston and Fillmore counties. It is about triangular in shape, the Mississippi river being a hypothenuse, running from northwest to southeast. Its land and water area is 638.92 square miles, or, in acres, 408,909.90. The county contains no lakes, except Winona lake, which is simply a portion of the wide alluvial area of the Mississippi, and subject to flooding at a high stage of that river, though probably sustained principally by springs along the base of the bluffs. Winona is the county seat. St. Charles, Stockton and Minnesota City are the other principal towns.

SURFACE FEATURES.

Natural drainage. The surface waters all pass into the Mississippi, but some of them leave the county toward the north and south before reaching it. The Whitewater is the only stream that actually crosses the county. It runs from St. Charles northwardly, entering the Mississippi at, or near Minneiska in Wabasha county. At Elba it is joined by the Middle and North branches of the Whitewater, and at Beaver by the Beaver creek. The Rollingstone with its various spreading tributaries, is an important stream. Its valleys are wide and contain numerous large and valuable farms within the rock-bluffs that outline the valley proper. This stream joins the Mississippi valley at Minnesota City, and finally reaches its waters through sloughs that cross the wide bottom-lands. Other streams that join the great river in Winona county are small but remarkably permanent in the amount of water they discharge. Pine, Money, Rush and other creeks leave the county in a southerly direction, most of them entering Root

river in Fillmore and Houston counties. There is a slight broad upward swell in the surface of the county, apparently due to the anticlinal condition of the rocks, which enters the state near Richmond, and passing in a west south-westerly course, leaves Winona county about where Rush creek leaves it. It is perhaps the principal cause of the greater elevation of Arendahl township, in Fillmore county.

The streams of Winona county, without exception, lie in deep rocks cut valleys, and are fed, and maintained at a uniform stage, by copious springs that issue along the foot of bluffs. Their water is clear and cool, and adapted to the brook-trout which formerly frequented them, and is still found in limited numbers. Near the western border of the county, in the vicinity of St. Charles, a light spreading of drift begins to appear under the loam, and the valleys are less deep and precipitous, yet still show the rocky substructure in frequent outcrops along the bluffs.

Water-powers and flouring mills. The streams furnish numerous water-powers. They are employed for making flour at many places. Most of these mills are small, but they have generally the most approved methods of manufacture. Some of them are sufficiently large to maintain an important export of flour in sacks or in barrels. Occasionally a large spring is the principal source of water-supply for the smaller of these mills. Of course such springs are really due to the issue of small subterranean streams.

Water-power mills in Winona county.

On Beaver creek, S. W.¼ sec. 15, Whitewater, mill of F. E. Becker; twelve feet head; three run of stones (one for feed); thirty horse-power; capacity fifty barrels per day.

On the Whitewater river at Elba, the *Elba mills;* owned by Meilicke and Hoffman; two wheels, sixty horse-power; nine and a half feet head (can be made eleven); three run of stone (one for feed); one hundred barrels per day; have more water than can be used.

On the north branch of the Whitewater river, S. W.¼ sec. 5, Elba, the *Fairwater mills;* owned by Edward Ellis; ten feet (?) head; two run of stone (one for feed); forty barrels per day.

On the south branch of the Whitewater river, S. E. ¼ sec. 2, St. Charles; owned by——— Lamberton; fourteen and a half feet head, with little water; two run of stone (one for feed); in full water, forty barrels per day.

On the south branch of the Rollingstone creek, at Stockton, owned by A. G. Mowbry; has both steam and water; ten feet head; one hundred and seventy-five barrels per day; known as the *Stockton mills.*

Mosquito mills, N. W.¼ sec. 8, Warren; owned by Porter and W. M. Duncanson; two run of stone (one for feed); turbine wheel with thirty-five feet fall (can run but one buhr at once); twenty-four bushels ground per day.

On the south branch of Rollingstone creek, the *Hillsdale mills;* one mile northeast of Stockton; owned by Pietsch and Furbish; fourteen and a half feet head; thirty-six-inch Leffel wheel; four run of stone (one for feed); capacity sixty to seventy-five barrels per day.

On the Rollingstone creek at Minnesota City, the *Ellsworth mills;* owned by A. D. Ellsworth; nine feet head; fifty-six-inch Leffel wheel; five sets of Stephen's rollers; formerly six buhrs (run one set of buhrs now); hundred and fifty barrels per day.

On the Rollingstone creek, at Minnesota City, the *Winona county mills;* owned by Otto Troost; sixteen feet head (also have steam); Houston wheel (turbine) of one hundred horse-power; twenty-eight sets of Allis rollers (some of Noyes) of which twenty-three sets are double; capacity three hundred and fifty barrels per day.

On the west branch of the Rollingstone creek, sec. 7, Rollingstone, the *Rollingstone valley mills;* owned by Julius Seemann; nine feet head (can be made more); thirty-five-inch Case turbine wheel; twenty-five horse-power; custom; three run of stone (one for feed).

On the west branch of the Rollingstone creek, sec. 23, Norton; custom mill, owned by Wilhelm Rubrecht; eighteen feet head; fifteen horse-power; three single rollers and one buhr.

On Pleasant Valley creek, sec. 1, Wilson; custom mill, owned by M. J. Laird; seventeen feet head; Flenekin's twenty-inch turbine wheel; five hundred and sixty cubic feet of water per minute; fourteen horse-power; three run of stone, all for wheat.

On Big Trout creek, at Pickwick, the *Pickwick mills*, owned by W. Davis and Co.; twenty-inch Flenekin turbine wheel; twenty-eight feet head; thirty-seven horse-power; four run of stone; two sets single rollers: seventy barrels per day, shipped at Lamoille.

On Big Trout creek, N. W.¼ sec. 18, Richmond, feed mill, owned by John Hatch; fourteen feet fall. This is a good power, but not all improved.

On Pine creek at New Hartford, custom mill, owned by Jos. Blumentritt and Bro.; seventeen feet head; twelve horse-power; three run of stone (one for feed); turbine and overshot wheels; also steam for winter.

On Money creek, sec. 20, Wiscoy; mill owned by Overbeck and Pirsch; fifteen feet head; two large buhrs (one for feed); thirty-six-inch American turbine wheel; forty-five barrels per day, shipped at Rushford.*

On Money creek, sec. 16, Wiscoy; small custom mill owned by L. J. Clark; nine feet head two buhrs (one for feed); thirty-inch turbine wheel (La Crosse and Craig).

On Trout run, one mile north of Troy, in Saratoga, custom mill, owned by C. Forket; seven and a half feet water head; seventeen feet dam; one breast-wheel, one buhr, about fifteen horse-power; capacity in barrels unknown.

On Rush creek, sec. 7, Hart. This mill has been abandoned for six years. It is owned now by a gentleman in Winona named Garlick; the dam was carried away by high water, and gradually the mill itself has been torn down; nothing could be learned of the water-power, nor of the capacity of the mill.

On Rush creek, section 29, Hart; custom mill owned by F. Lehnertz; eleven feet head; twenty-four horse-power; two run of stone (one for feed); Mulligan wheel, of Lansing, Iowa; twenty-five barrels per day; market in Winona.

On Pine creek, section 26, Fremont; custom mill, owned by C. M. Miles; eight and a half feet fall; twelve horse-power; "counter-pressure" turbine wheel, patented by Mr. Miles, and made in Lake City; two smooth buhrs (one for feed); ten barrels per day.

On Trout run at Troy; the *Troy mills*; owned by H. Ahrens; custom and merchant mill; eighteen feet fall; one Whitmore wheel and one Houston; twenty horse-power on one wheel and twelve on the other; three buhrs (one for feed); one wheel runs the feed and the other the wheat buhrs; sometimes both wheels are run constantly, depending partly on the water, and partly on the supply of feed; but much of the time only the wheat wheel runs; capacity fifty barrels per day.

On Trout creek, sec. 32, Saratoga, *Hampton mills*, owned by J. O. Rafter and O. S. Morrill; fourteen feet head; eighty horse-power; two turbine wheels (Leffel's and John's); four buhrs (one for feed); fifty barrels per day.

Topography. The surface of this county is undulating, rolling or hilly. It is more uneven in the eastern and northern portions than in the west-

*At the time this mill was visited the dam had been destroyed by freshet, and the mill had been stopped for about a year.

ern and southern, but this difference is owing simply to the fact that the larger drainage valleys are in the eastern and northern portions. The inequalities of surface are wholly due to the excavation by streams into the rocky strata, forming deep valleys and even rocky gorges. The ruggedness which these valleys must have presented originally, has been relieved by the heavy mantle of loam which now covers the whole county, amounting to a thickness of fifty or sixty feet. This mantle serves not only to smooth off the roughness by filling the valleys, but it constitutes an impervious sheet through which waters percolate with slowness, and which constitutes the subsoil of the county.

Although the strata are thus canoned, the surface materials are so abundant that the bluffs do not everywhere show the rock, but they are rounded over and generally turfed from top to bottom. It is only along the deepest gorges, and there chiefly near the tops of those bluffs that face the prevailing winds, that the rocky structure is prominently and constantly exposed. The east bluffs of the Whitewater river, and the north bluffs of the Rollingstone, and especially the bluffs of the Mississippi on the Wisconsin side, illustrate the effect of the strong and prevailing winds in keeping the rock uncovered, and in producing precipitous and picturesque headlands and pinnacles. Such bold and picturesque bluffs are uniformly composed of the St. Lawrence limestone, at least in their upper portions, but along the deeper valleys occasional precipitous portions of the underlying sandstone strata are also included. Figure 7, showing such pinnacled cliffs near Homer, overlooking the Mississippi river, are composed of the upper, brecciated, strata of the St. Lawrence limestone. Numerous similar towers of the same rock are to be seen in the county, particularly in the valley of the South Rollingstone creek above Stockton.

Within the broad valleys are good farming lands. They slope toward the creeks which drain them, but are frequently diversified with terraces of alluvium which maintain a plateau-like outline, gradually descending, for, sometimes, several successive miles. Toward the upper portions of the valleys these terraces are more broken away, and there constitute simply a thickened mantle of surface loam around the bases of the bluffs. The uplands are undulating. They constitute the greater portion of the area of the county. Their general level is pretty constant, when dependent on any one of the formations, being disturbed only by an occasional thickening in the loam under circumstances favorable for its preservation, and by a very gentle dip in all the strata toward the southwest. The uplands in the eastern and northern portions of the county are from three hundred to four hundred feet above the adjoining valleys, and near to the Mississippi they are about five hundred feet above the grade of the Chicago, Milwaukee and St. Paul railway. In the central portions of the county the uplands are from fifty to seventy-five feet lower than in the eastern, and they would be still lower if the drainage forces had been enabled to act there as effectually as along the Mississippi, to carry away the surface loam. This is due

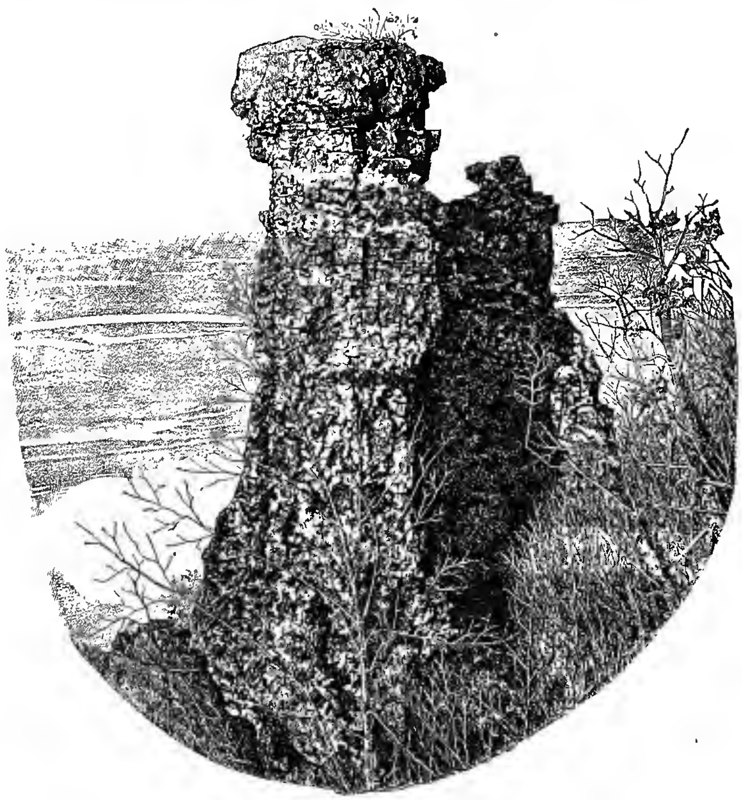


FIG. 7. ROCKS NEAR HOMER.

to the dip of the rocks from the Mississippi westward. Toward the west, however, other higher formations make their appearance, and the actual level of the uplands along the southwestern border of the county is about one hundred feet higher than along the Mississippi. Plate 9 represents Winona county. The tortuous contour-lines sufficiently indicate the unevenness of the general surface, and also the gradual ascent of the upland prairies toward the southwest. The area of the Trenton rocks in Saratoga and St. Charles, is marked by a conspicuous abrupt elevation of about a hundred feet above the surrounding country. This abrupt ascent is followed by a still further gradual ascent of fifty or seventy-five feet within the same area, so that the highest land within the county, reaching about 1325 feet above the ocean, is in the townships of St. Charles and Saratoga. The Mississippi river at the north line of the county is about 642 feet above the sea, and at the south line about 619 feet, these figures representing low water.*

FIG. 8. LOOKING OVER THE VALLEY TOWARD WINONA.

Many landscape scenes within the county have great beauty and grandeur. The broad valley of the Mississippi, which is about six hundred feet deep from the tops of the bluffs to the water level, and from three to six miles wide, separating Minnesota from the state of Wisconsin, is itself as great a phenomenon in nature as the Appalachian mountain range, and has a longer and more wonderful history, and one as fruitful in scientific problems. Between the headlands, which outline the valley in its course, are

*There is a discrepancy of eight feet between these figures and those of the plat of Winona county, due to a correction by the final report of the U. S. lake survey by Lt.-Col. C. B. Comstock, published in the latter part of the year 1882.

tributary valleys which are themselves nearly as deep, and penetrate often many miles westward into the rocky structure of the land; where they are found to terminate in precipitous rocky gorges, perhaps with small rivulets plunging over the cliffs, or in the mouths of copious subterranean streams. These tributaries have sub-tributaries, branching from them in all directions, each one reproducing, but with thousand-fold diversities, the features of its main, embracing the whole country in a network of vales and bluffs. Thus the beholder is constantly enlivened by a shifting panorama, as he travels from "the great river" westward. When he rises finally upon the elevated prairie plateau in the central part of the county, if with an inquiring glance he retroverts toward the east, the relation of cause and effect, which under natural laws has wrought out the valleys, the headlands, the terraces, the narrow gorges, is so evident to his mind that his appreciative sense of the beautiful in the landscape is intensified and also deepened. The valley of the Whitewater river, which is remarkable for its great depth combined with its narrowness, affords many fine landscape scenes in the town of Elba.

Elevations. Numerous observations were made by aneroid barometer for the elevation of bluffs and terraces throughout the county, and on these observations, reduced to the ocean level by connection with railroad stations, the contour-lines of the county map were established. In passing over the country, between railroad stations, and in all lines remote from railroads, the topography was outlined by the eye, estimates being made on the variations from known contours.

The bluffs at Beaver were ascertained in this manner to rise 480 feet above the alluvial flat on which the village is situated. The flat is so near the Whitewater level that it is sometimes flooded, being about eight feet above the river at low water. This hight is reached about a quarter of a mile back from the brow of the St. Lawrence limestone, but does not include the Shakopee limestone. The 950 feet contour-line just about coincides with the top of the St. Croix sandstone at Beaver.

Where the road crosses the south branch of the Whitewater, between sections 2 and 3, St. Charles, the creek is about 1030 feet above the ocean, and the cut in the St. Lawrence is about fifty feet.

Lewiston, at 1211 feet, is about the average hight of the prairie about there. It includes the Jordan and Shakopee formations.

The terrace rises fifty-eight feet above the flood-plain of the Rollingstone, on section 10, near Minnesota City.

The bluffs at Stockton rise 345 feet above the depot at the same place.

The high plateaux between Stockton and Winona rise 456 feet above the upper terrace of the Mississippi in the valley of the Rollingstone at Minnesota City, 525 feet above the lower flat at Minnesota City, and 538 feet above the Milwaukee depot at Winona. This depot is really on the same gravelly plain as the lower flat, above, at Minnesota City, but descending a little toward Winona, and depressed for Winona lake. This makes the highest portions of the bluffs back of Winona about 1200 feet above the sea. This hight is reached some distance back from the immediate brink of the bluff, and in some cases from a half to three-fourths of a mile.

Back of Homer the average elevation of the uplands is about 1232 feet above tide. This is reached at a distance of a couple of miles from the bluff brink. In general, along the Mississippi, the 1200 feet contour-line runs some miles back from the brink in the uplands, the brink itself being about 1100 feet.

The high prairie about Pickwick is 515 feet above the station at Lamoille, or 1167 feet above the ocean.

Gwinn's bluff, sec. 26, Richmond, rises 1176 feet above the ocean, the limerock on the top composing 110 feet, and the St. Croix sandrock 400 feet down to the level of the railroad at Richmond. This is a narrow and precipitous bluff standing near the river, with a valley behind it that sets it off from the rest of the high land in the same bold manner as the Great Palisades on the north shore of lake Superior. This gives it the appearance, as it has the reputation, of being the highest on the river. As it is on the great anticlinal of the formations, this is very likely to be true, but it is of about the hight of the surrounding country, except on the east side of the Mississippi, where there is a broad expanse destitute of the limerock, and therefore much lower, the sandrock itself also being reduced so as to bring the general level but 100 or 200 feet above the river. On this expanse, in high wind, the sand and dust rise in clouds three or four hundred feet in the air. This area of broken down limerock, where the St. Croix sandrock only forms the surface formation, is crossed by the valley of Black river, and extends farthest in a north-northeast direction, the limerock appearing occasionally in the form of isolated table-topped mounds or precipitous peaks, rising very high.

At Dresbach the bluffs reach the hight of 1232 feet, the sandstone rising 430 feet above the railroad, and the limestone being 135 feet thick, including the debris and slope above the brink which seems to contain both the Jordan and Shakopee, though nothing can be seen *in place,* of either of them. Here the valley of the Mississippi is very wide, and about here, or a little further north, must be the axis of the broad anticlinal which comes into the state from Wisconsin. It seems to be a broad bowl-like upward swell in the rocks, which not only causes the limerock to break away extensively, leaving the St. Croix to constitute the surface, but where the limerock is preserved, to make it rise higher in Wisconsin than in Minnesota. This all is proven also by the irregularity of the contour of all the hills. They are more shaped like the drift-hills and knolls of Dakota county, without benches of ascent, though not having any true drift. This upward swell in Winona county is only felt as an effect on the topography, producing wider and more numerous valleys than further north, the grand dip being toward the S. W. or W. S. W. If there be any axis to this upward swell it may be said to occupy most of the interval between Richmond and Dresbach.

The hills south of St. Charles rise nearly 200 feet above the depot, or 1325 feet above the sea. The depot is about on the top of the Shakopee.

The Chicago, Milwaukee and St. Paul railway skirts along the eastern border of the county, near the base of the river bluffs, and its engineers have reported the following elevations of points on the grade.

Elevations on the Chicago, Milwaukee and St. Paul railway.

	Distances in miles from Saint Paul.	Hights in feet above the sea.
Mt. Vernon	89	667
Minnesota City	97	669
St. Peter Junction, crossing C. and N. W. railway	102	668
Winona	103	654
Homer	108	657
Lamoille	112	652
Richmond	115	666
Dakota	121	649
Dresbach	122,5	668

The list of hights on the Chicago and Northwestern railway in this county, given upon the next page, are from Mr. John E. Blunt, engineer, Winona.

Elevations on the Winona and St. Peter division, Chicago and Northwestern railway.

	Distances in miles from Winona.	Hights in feet above the sea.
Low water in the Mississippi river at Winona	0	632
Top of rail on draw-bridge	0	662.5
Winona, passenger depot	0	660
Winona, railroad yard and freight depot	0	641
Minnesota City	5.9	668
Stockton	11.31	745
Lewiston	18.30	1203
Utica	22.74	1162
St. Charles	29.35	1131

Mean elevation of the county. From the contour-lines shown on the county map the average elevation of each township has been estimated, as follows:

Dresbach, 1000 feet above the sea; Richmond, 1050; New Hartford, 1050; Homer, 1050; Pleasant Hill, 1125; Winona, 825: Wilson, 1050; Wiscoy, 1050; Rollingstone, 925; Hillsdale, 1075; Warren, 1125; Hart, 1100; Mount Vernon, 1075; Norton, 1100; Utica, 1150; Fremont, 1125; Whitewater, 1050; Elba, 1075; Saint Charles, 1175; and Saratoga, 1150. The mean elevation of Winona county, derived from these figures, is, approximately, 1070 feet above the sea.

Soil and timber. The soil and subsoil of the county are everywhere formed of the loess-loam, the former being a superficial modification of the latter. On the uplands, where the general surface is undulating or rolling, the surface soil has become blackened and also thickened in the depressions, and perhaps somewhat pebbly with limestone and chert or quartzyte fragments on the hillsides, and the latter especially along the brows of the hills which face the south sun and the prevailing winds. In the main valleys the loess-loam is thicker than on the uplands, and it has been worked over and deposited a second time by the drainage incident to the several valleys. The terraces that are seen in the lower parts of the valleys gradually lose their distinctness in ascending the valleys, and finally become merely a thickened talus along the foot of the rocky bluffs, occasionally showing still their hight and original continuity in island-like areas in the sheltered portions of the valleys. They descend from the upper levels gradually, about at the rate of descent of the valleys themselves. The soil of these terraces is generally very fertile, but sometimes an exposure of their stratification shows their lower portions to consist of sand.

The Rollingstone valley in a fine one, especially in the month of July. It is wide and smoothly contoured from the bluffs downward, the main flat being the same terrace-plain as that already mentioned at and below Stockton, gradually rising toward the west as the stream is ascended, and also passing more abruptly into the slopes, right and left, which descend from the enclosing bluffs. These slopes are cultivated well up the hillsides, as in nearly all parts of the county, and raise oats, barley and even wheat and corn, the more precipitous portions above being pasture fields. There is an insensible change from the main flat to these slopes. The flat itself consists of yellow loam, stratified where exposed in wash-outs along the road, but in the upper slopes becoming gradually replaced by the coarser debris from the hills, and toward Minnesota City becoming the great terrace which is known to accompany the Mississippi all the way from St. Paul. Yet even at Minnesota City it is still covered with a yellow loam of later date.

At Pickwick the loam-clay that constitutes the terrace and forms the subsoil, is seen to be interstratified along the bluff-side, near the mill, with several layers of rotted debris from the bluff, with lenticular patches of regular stratification. The section here exposed is seen in fig. 9.

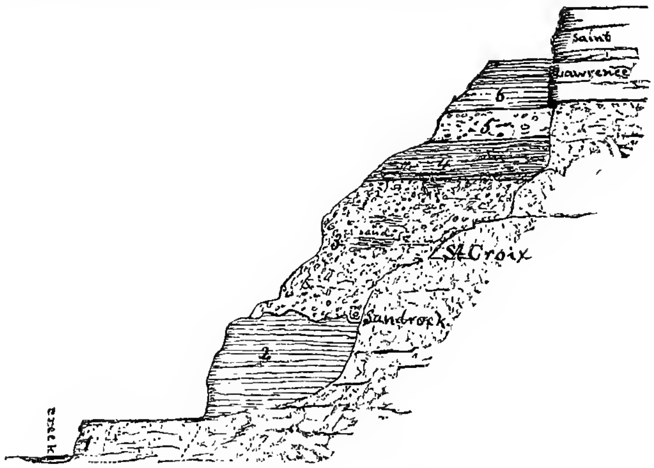


FIG. 9. SECTION AT PICKWICK.

In general throughout the county the loess-loam is clayey, and holds the surface waters in all confined depressions. No stones of foreign origin are found in it to obstruct the plow, or impede the reaper. Indeed it is only in the neighborhood of St. Charles, in the western part of the county, that the true northern drift is found in Winona county. Where it exists it is so completely covered by the loam that only rarely are any signs of it seen at the surface in the form of boulders.

Generally throughout the county there is a liberal supply of native timber for fuel, and in numerous places some of the best trees of oak have been cut for other uses.

Trees and shrubs of Winona county. In the survey of the county the following native trees and shrubs were identified. The trees are arranged in the estimated order of frequency.

Quercus macrocarpa, *Michx.* Bur oak.

Populus tremuloides, *Michx.* Aspen.

Quercus coccinea, *Wang.*, var. tinctoria, *Bart.* Black oak.

These three species make up about nine-tenths of the forest trees of the county, exclusive of the timbered lowlands of the Mississippi. There are large trees of black oak, apparently belonging to a former forest growth, the most of which has been cut or destroyed by fire, and many of the growing shrubs and bushes of oak seem to belong to this species.

Quercus alba, *L.* White oak. The white oak is quite abundant in the southern part of the county. It frequents the limestone slopes and the uplands, and the black oak the sandstone slopes.

Ulmus Americana, (*Pl. Clayt.*) *Willd.* White or American elm. Common in the valleys; makes a very large tree.

Acer rubrum, *L.* Red or swamp maple. "Soft maple" is the name commonly applied in Minnesota to this and the next. This is very abundant in the bottoms of the Mississippi, and generally throughout the county in similar soils.

Acer dasycarpum, *Ehr.* White or silver maple; soft maple. Common in low lands. (This is the species most common as an ornamental tree.)

Tilia Americana, *L.* Basswood. Linden.

Betula papyracea, *Ait.* White or Paper birch. This very rarely makes a tree larger than six inches in diameter in Winona county, though it sometimes exceeds that in favorable situations in rich soils. The most common position for this tree is along the exposed rock-bluffs, where it maintains a hardy and persistent slow growth in spite of the fires that frequently run over the surface, and the unimpeded winds and frosts of the year. It was seen at Winona two and a half feet in diameter.

Various species of willow.

Negundo aceroides, *Mœnch.* Box-elder. Common in the low lands. Seldom more than twelve inches in diameter.

Prunus Americana, *Marshall.* Wild plum.

Populus monilifera, *Ait.* Cottonwood. This makes a large tree several feet in diameter in the Mississippi bottoms.

Fraxinus Americana, *L.* White ash.

Ostrya Virginica, *Willd.* Ironwood.

Juglans cinerea, *L.* Butternut.

Carya amara, *Nutt.* Bitternut hickory.

Fraxinus sambucifolia, *Lam.* Black ash.

Juglans nigra, *L.* Black walnut.

Acer saccharinum, *Wang.* Sugar maple.

Carpinus Americana, *Michx.* Water beech.

Prunus serotina, *Ehr.* Black cherry.

Carya alba, *Nutt.* Shag-bark hickory. This is common along the bluffs from Dresbach at least to Winona and Stockton. It has been cut for fuel for steamboats for many years. Large trees are now very rare.

Ulmus fulva, *Michx.* Red or slippery elm.

Ulmus racemosa, *Thomas.* Corky or rock elm.

Pirus coronaria, *L.* Wild crab-apple.

Populus grandidentata, *Michx.* Rare; but a few trees can be seen in the north part of Pleasant Hill.

Pinus Strobus, *L.* May be seen at Whitewater and Elba, on the bluffs; a large tree grows at the mouth of Pine creek; several are growing at the mouth of the Pine creek that joins the Mississippi at La Crescent; it occurs on sec. 28, Saratoga, at the head of the creek, and on sec. 29, St. Charles; on Gwinn's bluff, near Richmond, and in numerous other places in the county.

Celtis occidentalis, *L.* Hackberry.

Amelanchier Canadensis, *Torr. and Gray.* Juneberry.

Betula lutea, *Michx. f.* Gray birch. This makes a tree sometimes a foot in diameter growing along the bottom-lands of the Mississippi. Its twigs are aromatic, and it may be mistaken for the black or cherry-birch. It grows at Dresbach.

Betula nigra, *L.* River or red birch. This birch is found abundantly along the Mississippi bottoms as far north at least as Minneiska. It has been cut extensively for fuel. It makes a large tree, and when young it is very shapely and adapted to ornamental purposes, especially if it is so situated as not to be crowded by other trees. In the timbered bottom-land, however, the tree is often one-sided and deformed, or nearly limbless. It is abundant in the form of small trees from two to four inches thick, sometimes clustered as if from old stumps. Occasionally an old tree stands. The bark is then not papery but rough. The outer papery bark easily peels off, even when young. It has a faint orange tint, in distinction from the snowy whiteness of the paper-birch, which is also sometimes seen in close proximity.

Juniperus Virginiana, *L.* Red cedar.

Thuja occidentalis, *L.* Arbor vitæ, or white cedar. These cedars both grow on Gwinn's bluff, sec. 26, Richmond, but the former only is distributed generally over the county. It is found in stony places, and sometimes makes a tree twenty or thirty feet high.

Gymnocladus Canadensis, *Lam.* Kentucky coffee-tree. Seen native only near Dakota in the shaded lower slopes of the river bluffs, but it is in cultivation at Beaver and Winona as an ornamental tree. The balm of Gilead is common in cultivation, and occasionally is seen a specimen of honey-locust, the black locust being rather common. The Lombardy poplar is winter-killed, or partly so. The soft maple is the most common shade tree. The next is perhaps the cottonwood; then, in order of frequency, box-elder, Lombardy poplar, willow, sugar maple, white elm, white pine, black walnut, balsam fir, butternut, bass, red elm, white poplar.

Shrubs of Winona county. Rhus glabra, *L.* and typhina, *L.* The smooth sumac is common throughout the county, but the stag-horn is rarely found outside of the immediate valley of the Mississippi. It occurs in Hart, in the valley of Rush creek. At Winona samples were seen of the atter eight inches in diameter. Corylus Americana, *Walt.;* abundant. Corylus rostrata, *Ait.*, rare, seen near Dakota, and in the valley of the Rollingstone. Cornus paniculata, *L'Her*, common. Sambucus Canadensis, *L.* and pubens, *Michx.*, the latter being rare. Cornus sericea, *L.*, stolonifera, *Michx.* and alternifolia, *L;* all these are common. Rubus villosus, *Ait.*, strigosus, *Michx.* and occidentalis, *L.*, the last with white fruit, on the bluffs at Winona. Rubus Canaden, sis, *L.*, Ribes rotundifolium, *Michx.*, Cynosbati, *L.* and floridum, *L.*, Prunus Virginiana, *L.*, common; Prunus Pennsylvanica, *L.*, Clyde. Prunus pumila, *L.*, near the center of section 33, Hart-along the sandy road that runs to the east of an isolated bluff. Although this does not agree with Gray's description exactly, viz. in having the leaves toothed nearly all round, and the flowers (fruit at least) single, it is probably this species. In general appearance it resembles greatly the sand cherry of the northern shores of lake Michigan. Amorpha fruticosa, *L.* Vitis cordifolia, *Michx.* Spiræa opulifolia, *L.* Rosa blanda, *Ait.* Ampelopsis quinquefolia, *Michx.* Cratægus coccinea, *L.*, and Crus-galli, *L.* Viburnum pubescens, *Pursh*, sec. 24, Fremont. Viburnum Lentago, *L.* Celastrus scandens, *L.* Alnus incana, *Willd.* Ceanothus Americanus, L. Juniperus Sabina, *L.*, var. procumbens, *Pursh.* Hamamelis Virginica, *L.*, moist soils between Richmond and Dakota, rare. Acer spicatum, *Lam.*, sec. 22, Richmond, rare. Xanthoxylum Americanum, *Mill.* Pyrus sambucifolia, *Cham. and Schlecht.*, on the bluff-side at Winona. Lonicera parviflora, *Lam.* and grata, *Ait.* Euonymus atropurpureus, *Jacq.*, sec. 22, Fremont. Arctostaphylos Uva-ursi, *Spreng.*, sandy knolls in sec. 12, Saratoga.

The southward facing slopes, as in Houston county, are apt to be destitute of trees and shrubs, while on the opposite side of the same valley the surface frequently is densely timbered.

THE GEOLOGICAL STRUCTURE OF WINONA COUNTY.

The bedded rocks of this county are the same as those of Houston county, given in the last chapter; the thickness of the St. Croix sandstone is a little greater, however, than there, owing to the occurrence of an anticlinal axis which lifts the strata a little higher above the Mississippi in this county than in that. This broad swell extends between Dresbach and Homer, or, more strictly, between Dresbach and Richmond. On the east side of the Mississippi, where the limestones of the Cambrian are wholly broken down and removed, the country is much lower on this anticlinal, and the lower portion of the valley of Black river is located on it.

Plate 9 represents Winona county. The colors and the characters are the same as for Houston county. Although the indurated rocks only are represented by colors, it should be remarked that some glacial drift is found in St. Charles and the north part of Saratoga townships, and that the actual surface everywhere consists of the loess-loam. These are not expressed because the underlying rocks throughout the county are so well known that they should take precedence in the coloring of the geological map. This minuteness of knowledge of the rocks of the state gradually gives place to doubt, and finally to a mere general knowledge, in going west from Winona county, on account of the increase of the drift; and hence in Fillmore, Olmsted and Wabasha counties the drift characters are represented on the county maps, and in some counties still further west the drift only is susceptible of such delineation,

In the coloration of the Cambrian strata on the county map, the St. Peter and St. Croix sandstones, the former the top and the latter the lowest of the Cambrian within the county, are represented by special colors, while the Shakopee, Jordan and St. Lawrence are all colored together as one. This is because the St. Peter and St. Croix are distinctly set off from the rest by certain natural causes, bringing them into bold stratigraphical recognizance, while the three that are associated under one color are also associated in topographic features so closely, that much uncertainty prevails not only as to their individual boundaries, but even as to their individual existence, in many parts of the county.

The Trenton rocks. Within the Trenton period are placed the known

Trenton limestone and the shales and shaly limestone which overlie it in western St. Charles and Saratoga, reaching an aggregate thickness of perhaps seventy-five feet. This thickness, however, is estimated. It may be partly made up of glacial clay and loess-loam, which begin to combine in that part of the county in rendering the geology more uncertain. Within the thirteen-hundred foot contour-line there is something, in St. Charles and Saratoga townships, above the Trenton, amounting to sixty or seventy-five feet. It is probably partly made up of Hudson River shales, but it is superficially composed of loam, with an occasional appearance of a little drift. The best exposures of the shales and shaly limestones referred to are found in the high bluffs in the southern part of St. Charles. The greatest observed thickness is not more than twenty-five feet. They may be seen, S. W. ¼ sec. 29, by the side of the road, where they consist of alternate thin beds of limestone and green shales with numerous fossils. The same, or similar, beds are found at W. H. Shelton's, N. W. ¼ sec. 6, Fremont, whose well and cistern are partly excavated in them, revealing numerous fossils.

The most interesting observation made in Winona county on the rocks of the Trenton period, was in section 29, St. Charles, where there is an apparent unconformity between the Trenton and the underlying St. Peter sandstone. The St. Peter, as exposed, dips about six degrees south-southwest. It is separated from the Trenton by four to ten feet of green shale, which seems to vary, and to lie in a depression in the upper surface of the sandrock. The overlying Trenton is about horizontal. Yet at a point about two miles further north, where the St. Peter rises at least fifty feet higher, the Trenton is still present on the top of it in a thin scalp.

The area occupied by the Trenton rocks in Winona county is small, but nearly all the peculiar features of topography produced by them, as mentioned in the reports on Houston and Fillmore counties, are well exemplified. It invariably produces a rather abrupt ascent in the contour and general level of the country, amounting to about a hundred feet, and it is hence distinguishable by the observer for many miles. This plateau-like elevation is not dry, as might be expected, but the shaly character of the rocks, together with some inequalities of surface prior to the deposit of the loam, serve to retain the surface waters as in tight basins, only allowing them to escape slowly in springs about the border of the plateau, by percolating outward between the loam and the shales. It is frequently the case that wells on this plateau reach water fifteen to thirty feet below the surface, while on the lower prairies adjacent, it is necessary to drill more than 100 feet, or even 200 feet, in order to get water for domestic uses.

The St. Peter sandstone. This formation in Winona county has an average thickness of somewhat less than one hundred feet, though no exact measurement of it has been made. It affords frequent surface exposures in the slopes of the bluffs that outline the area of the Trenton, and also occasionally is seen by the roadside at points some miles from that line of bluffs. In situations similar to the latter, but of course at lower levels, the Jordan sandstone is also frequently seen, and might very easily be mistaken for the St. Peter, since the Shakopee limestone, which separates them, is reduced to about twenty-five feet in the western part of the county, and probably to less than twenty-five feet in the eastern part. The formation lies nearly level throughout the county, and conformably on the Shakopee limestone, so far as observed. To this statement only one exception must be made, as already mentioned under the head of Trenton rocks. About a mile south of St. Charles the St. Peter has a noticeable dip of about six degrees toward the south-southwest, and is apparently unconformable with the Trenton. It cannot be asserted positively that this dip involves all of the Cambrian, but there are some reasons for believing that it does, and that the great anticlinal that enters the county between Dresbach and Richmond in a general west-southwest direction is deflected toward the west-northwest within the county, Root river and its tributaries draining the southward dipping strata and the Zumbro the northward. The river bluffs at Elba are remarkably high, a fact which may be owing to the dip seen in the St. Peter south of St. Charles, affecting the whole Cambrian and throwing the St. Lawrence and Shakopee higher above the sea in the region immediately to the north from St. Charles.

The sandy knolls in sec. 12, Saratoga, have no limestone on their tops, but their contour and elevation, as they now exist, are preserved by a cemented rusty layer which is about eighteen inches thick and lies on the western slopes in large fallen-down blocks, being kept uncovered on that side by the prevailing western winds. It is probable that they exist in a similar manner on all sides of these mounds, but are hid by the loam. These knolls were once capped by the Trenton limestone, as in the adjoining high-lands, and their demolition under natural causes has not proceeded far enough to bring them down to the level of the lower prairies, but seems to have quite destroyed the overlying limestone.

The Shakopee limestone. The best exposure of the Shakopee limestone, within the county occurs at Troy, in Saratoga township. It there presents a thickness of twenty-five feet, along the creek on each side of the dam, and has been quarried for use in the construction of the Troy flouring mill. It has the color and most of the usual lithological characters of the St. Lawrence as seen in Winona county. The Jordan sandstone is visible at the same place immediately below it, and the St. Peter at higher levels in the neighboring bluffs. Further down the creek, in Fillmore county, the St. Lawrence limestone forms a continuous exposure with a thickness much greater. The Shakopee limestone appears at St. Charles, along the creek, and also in the streets of the city, with a dip toward the S. S. W., coinciding with that already mentioned in the St. Peter near the same place.* It is visible at the Quincy mills, where it overlies the Jordan sandstone.† In the central and eastern parts of the county this limestone is seldom seen, and when observed it is under unfavorable circumstances. It can only be said of it that *it exists* as far east as Stockton, and probably as far as Homer and Dresbach on the Mississippi.

The presence of the Shakopee limestone in the highest lands in the north part of Homer is indicated by the occasional occurrence of "sink-holes" which it causes in the loam-covered surface in connection with the Jordan sandstone.

Above Brown's quarry at Dresbach, which is in the St. Lawrence, near the top of the bluff, is a debris in the upper slopes that seems to contain both the Jordan and the Shakopee, but nothing can be seen *in place* of either of them. It is visible in the road between sections 4 and 5, Utica.

It is seen to overlie the Jordan sandstone on the road between sections 13, Utica, and 18, Warren, south of the railroad.

It is occasionally seen in section 30, Fremont, and between sections 32 and 33, Utica.

In general, however, as the county is occupied very largely by the area of the broad Cambrian anticlinal, the Shakopee has suffered by erosive agents, and this only may be the cause of its non-appearance in the Mississippi bluffs. In the same manner the St. Lawrence is reduced in thickness on this anticlinal when it is at the surface.

The Jordan sandstone. This sandstone, which overlies the St. Lawrence limestone quarried at Stockton and Winona, is finely exposed near the Stockton quarries along the railroad, a mile and a half east of Lewiston, S. W.$\frac{1}{4}$ sec. 18, Warren. It is also visible by the highway along the east and

*A similar dip is mentioned in the report on Houston county, in the St. Croix sandstone, at Sheldon.
†See the report on Olmsted county.

west road east of the center of section 23, Utica. In these cases it is a firm, evenly stratified rock, which affords angular blocks for abutments and walls, and at the railroad exhibits a thickness of twenty-five feet. On section 18, Warren, the bottom of the Shakopee overlying is also exposed at points in the highway a little further south in the high land. The strata of the Jordan are from three to four inches, as exposed, but it shows by its rustiness that it is shattered by long weathering. It is broken into square blocks *in situ*, which fall out by the action of the frost. A resident farmer has enclosed some of his land by a handsome stone wall, evenly laid up with blocks of this stone, some of the pieces being one foot in thickness. In a similar way this rock appears along the road between sections 2 and 3, St. Charles, near the top of the hill at the crossing of the South Whitewater river.

The Jordan is also seen in the bluffs at Troy, where it has an exposed thickness of eight feet. It is probably present where the large sink-hole occurs in the road about two miles west of Lewiston, and at one mile south of Utica.

The Jordan is white and siliceous, similar in that respect to the St. Peter, when not long weathered. It is for that reason liable to be mistaken for the St. Peter. But in many places it has been observed to differ from that formation in being firmly and conspicuously stratified, affording durable angular blocks that long resist the weather, and are carried by freshet waters down the ravines with masses of the more durable parts of the limestones. The St. Peter is much less cemented, and in Minnesota has never been known to furnish such blocks.

The St. Lawrence limestone. This formation which, including with some indistinctness the overlying Jordan and Shakopee, Dr. Owen designated *Lower Magnesian* limestone, is still frequently known by that name. It occupies the summits of the bluffs of the Mississippi and its tributaries throughout nearly the whole county, having a thickness of about 160 feet. An unfavorable measurement was made of this limestone in Houston county, which seemed to give it a thickness of about 200 feet, but from numerous measurements made in Winona county it is certainly somewhat less than that in this county. This may be in part due to the anticlinal position in which it is found, making it more susceptible to denuding agencies.

There are two distinct members that prevail in the St. Lawrence limestone in Winona county, that are distinguished by different lithology, though these distinctions are not known to extend very widely, viz.*

1. Brecciated and concretionary.
2. Regular dolomitic strata.

Below these are beds of transition to the St. Croix sandstone, made up of alternating calcareous and sandy layers, aggregating a thickness of nearly fifty feet, which have generally been referred to the St. Croix formation. They are included in the first turfed slope below the precipitous bluffs of limestone.

The upper, brecciated portion of the St. Lawrence varies somewhat in thickness, sometimes reaching seventy or eighty feet, and is not separated from the regular strata by a marked and sudden transition. Indeed, it apparently occurs interruptedly in the same horizon, and then is comparable to the sudden concretionary areas that swell out and obliterate the strata in the other formations, particularly the Waterlime and Niagara in Ohio and Michigan,† and to the *tors* that are found in the limestones of the Carboniferous at North Anston, England.‡ There seems to have been some irregularity in the ocean's bed at the time of deposition, and perhaps some widespread sudden undulations of level which so disturbed the sedimentary deposits at the time of their formation that when consolidated they not only show remarkable differences of composition but also of stratification and texture. This brecciated condition forms the bold buttresses which in many places are seen near the tops of the bluffs, forming their prominent features. It is illustrated by fig. 7, which is a view near Homer. The rock itself is siliceous as well as calcareous, the silica sometimes appearing in the form of arenaceous patches, or drusy geodes, and sometimes in the form of chert of different colors. In the fissures much calcite is occasionally found. The dolomitic portions are sometimes exceedingly fine-grained, and sometimes open and spongy; in the latter case, when exposed to the weather, giving origin to caverns and small openings on the surface. Although the outward aspect of such rock is that of a breccia, yet the re-cementing was not due merely to subsequent sedimentation, but certain chemical and con-

*These distinctions, however, have been mentioned in Iowa by Prof. J. D. Whitney, Geology of Iowa, 1858. Vol. I. p. 333.

†Geology of Ohio, Vol. II., pp. 230, 374; Vol. I., pp. 628–631.

‡British commissioners' report on the selection of stone for the new houses of parliament, De la Beche and Smith.

cretionary forces sprang up which produced segregations and crystallizations that are not found in the rest of the formation.

The more regular beds of the St. Lawrence embrace a thickness generally of about one hundred feet. At Stockton the best quarry layers have an aggregate thickness from thirty to fifty feet. The strata vary from six to thirty-six inches in thickness. They are extensively wrought at the quarry of the Chicago and Northwestern railway between Stockton and Lewiston, at Winona, and somewhat at Dresbach. The stone is light-buff, generally somewhat vesicular, sometimes coarsely porous, and sometimes compact and fine grained. For the quality of the building-stone the reader is referred to a previous chapter where the dolomites and dolomitic limestones of this formation are discussed.

Below these massive layers, which constitute a part of the precipitous bluffs of the county, there is a varying thickness of more fragile indescribable rock, which can best be defined by Dr. Owen's term *siliceo-argillaceous dolomite*, with occasional layers of an inch or two of crumbling white sand. There is also a slow transition from the crumbling sandstone of the St. Croix to the dolomitic firm rock of the St. Lawrence. In the first place siliceous nodules elongated in the direction of the stratification, from a few inches to several feet long, and from one inch to twenty inches thick, begin to appear in the crumbling sand. In these nodules sometimes the individual grains of sand are discernible still, tightly embraced in the siliceous rock which is nearly white on fracture and very hard. A few feet higher in the strata these nodules, while increased so as to coalesce to the right and left, forming nearly complete strata themselves, are seen to be softer, and to embrace other matter besides silica. They are fine-grained and show no rounded quartz grains; or such grains appear only in patches of irregular distribution and form. At ten or fifteen feet higher the rock has assumed that character which is almost indescribable, being greenish and shaly and yet not a shale, calcareous and not a limestone, magnesian but not a dolomite, finely siliceous but not a sandstone. This character continues through a thickness of forty to fifty feet of strata, and is like the rock of the quarries at Hokah and Lake City. By degrees the siliceous and aluminous components disappear from these strata, and they present the finely compact structure of some of the building-stone layers, as seen in the bottom of the quarries at Winona, constituting a highly prized building-stone. These fine-grained layers are quarried at Dresbach by S. V. Brown. They are from ten to twelve inches thick each, even and true, and make a beautiful cut-stone. Above these the strata graduate into the more coarsely textured, and often vesicular heavy stone, that more perfectly represents the average characters of the St. Lawrence. In some places, before the good quarry stone is reached, in ascending the bluffs, there is a series of poor dolomitic irregular beds, somewhat lumpy.

The exact contact of the St. Lawrence with the Jordan was observed along the railroad east of Lewiston. The transition is abrupt from the brecciated and concretionary, firm, upper strata of the St. Lawrence, to the rusty and arenaceous layers of the Jordan.

FIG. 10. VIEW IN GILMORE VALLEY.

On some of the bedding surfaces of the layers quarried near Stockton may be seen not only numerous fucoids, both coarse and fine, but other indistinct traces of fossils, the most conspicuous and distinct of which is a loosely coiled shell about an inch or an inch and a half across from side to side. These could not be detached, but resemble very much the *Ophileta* already mentioned in the report on Houston county. In the same situation was found also the pygidium of a small trilobite.

The St. Croix sandstone. The examinations made in Winona county add somewhat to the knowledge of the stratigraphic composition of this sandstone that was obtained in Houston county. Its main divisions only can be made out, owing to the concealment of its beds by the uniformly heavy, turfed talus that skirts along the foot of all the bluffs. As nearly as can be stated the following downward section exhibits the stratification of the St. Croix in this county. Some of these parts, and probably most of them, extend, without much variation, throughout the southeastern part of the state where this sandstone appears.

FIG. 11. THE ST. CROIX SANDSTONE.

General section of the St. Croix sandstone.

1. Argillaceous, siliceous dolomitic beds, forming the transition layers between the St. Croix and the St. Lawrence. Generally fine-grained, but embracing some thin strata that consist of coarse, loose quartz sand. These embrace a thickness of about forty to fifty feet.

2. Concretionary sandstone. This has many nodules, and even continuous layers of concretionary rock. These lumps are sometimes very fine, no larger than peas, and sometimes they swell out so as to be a foot or more in thickness, constituting nearly continuous layers, and making a very firm rock, since they consist entirely of cemented grains of silica, the cement itself being

apparently siliceous. These beds are in the upper portion of the line of constant rock-exposure in the upper part of the high bluffs of the Whitewater river in Whitewater and Elba townships, and in other places, and sometimes their greater endurance is evinced by a shoulder-like jog in the outline of the turfed slopes, running near the top of the St. Croix. Twenty-five to thirty feet.

3. Loose, massive sand, more or less stained with iron, generally turfed over, or covered with timber. In favorable situations this loose sandy rock forms a line of constant exposure, since its face becomes nearly perpendicular; the overlying quartzitic beds protecting it from denudation. The thickness of this member amounts to forty or fifty feet.

4. Argillaceous and siliceous beds much like No. 1, embracing the quarries at Lake City and at Hokah, generally greenish and often sandy, with remains of trilobites and graptolites. The shaly portion of these beds embraces a large percentage of lime. Thirty to forty feet.

5. Crumbling sand, about fifty feet.

6. Shales and shaly sandrock, generally hid, about eighty-five feet.

7. Sandrock, quarried by Tostevin at Dresbach; including at least one shale bed of six feet in its lower portion, which is generally spring-bearing along the foot of the bluffs; 120 to 150 feet.

8. Shales and shaly sandrock, very fossiliferous; extending to the water level at Dresbach, and including a conglomerate bed of four inches; ten to fifteen feet.

9. Gray sandrock, penetrated by the Winona Mining company at Dresbach below the level of the Mississippi, at least twenty feet.

10. At Dresbach the Davis brothers drilled for coal (!) a few years ago to the depth of 116 feet below the depot level, and found all the way nothing but shale and shaly sandrock alternating. Hence, add for Davis' drill, shales and shaly sandrock below all the above, sixty-eight feet.

Total thickness of the St. Croix in Winona county, 488 to 558 feet.

No. 8, above, contains what may be pteropodous forms, also some that may be orthoceratitic, and fragments of trilobites, and numerous specimens of *Lingula*. One bed of about sixteen inches at Dresbach, is largely made up of linguloid shells. It is fragile. The shales, which are bluish, contain numerous beautiful specimens of mud-cracks, and of stems of fucoids. The conglomerate, which is in No. 8, is composed of fossiliferous pebbles of a gray sandstone, which is apparently only hardened pieces of rock like No. 9, or like No. 7, and is almost quartzyte, showing some mica-scales.

At Beaver, the St. Croix sandstone rises about 300 feet above the river and at Stockton it rises 190 feet above the depot, which is 113 feet above above low water at Winona, giving 303 feet for the thickness of the St. Croix, as exposed at Winona and Stockton, exclusive of any dip in the formation, which cannot amount to more than twenty-five feet.

At Winona, about half a mile above the foot of Observatory bluff, at the base of the bluffs, may be seen a much rusted and hardened sandstone, heavy and massive, the bottom of the exposure being about fifteen feet above the surface of Winona lake. This contains numerous specimens of a species of *Lingula*.

The location of the shaft of the Winona County Mining Company is in the north part of the village of Dresbach, at the level of the Mississippi, between high and low water mark. It is at the same place as the work done here many years ago. Two or three shafts were sunk then on the slope of the bluff, into the shaly and sandy beds of the St. Croix, some hundred or more feet above the river. There is a fault in the formation at this place. This has formed a crevice, and has attracted attention. How much the slip is, cannot be stated, nor in which direction, but there is some reason for supposing the north wall has passed below its former position. The opening of the crevice at the surface is three or four feet wide, some of it being due to erosion by water and frost. The width at fifteen feet below the surface, where this company sunk a shaft, was reduced to about two inches. Drifting alongside of it, twenty-five feet into the bluff, and then penetrating it again, it was found to be made up of a lot of fragments somewhat recemented. The downward sections on the different sides of the fault are as follows:

Section on the south side.

1. Slope, turfed and wooded, about	20 feet.
2. Sandrock,	15 feet.
3. Shale, green or blue,	6 inches.
4. Fossiliferous *Lingula* bed,	6 inches.
5. Shale, coarse and sandy,	6 feet.
6. Slope to the river level,	15 feet.

Section on the north side.

1. Slope, turfed and wooded,	24 feet.
2. Shale, seen,	6 feet.
3. Sandrock,	10 feet.
4. Fine green shale (or blue) seen,	5 feet.
5. Beach to the river level,	15 feet.

Above all these rises a high bluff capped with the St. Lawrence, the top being about five hundred feet above the river.

The galena ore for which this mining was done, occurs on the walls of the fault, accompanied sometimes with pyrite; some of it is found among the *débris* in the bottom, as it was excavated. It is disseminated in the rock, more or less, on each side of the crevice; particularly is it found in the fossiliferous *Lingula*-bearing layer near the bottom of the section on the south side of the crevice. Some of the galena is changed to a carbonate. Galena is also found sparingly in the limerock near the top of the bluff. It is there in seams, and on the faces of the joints, accompanied by calcite coatings.

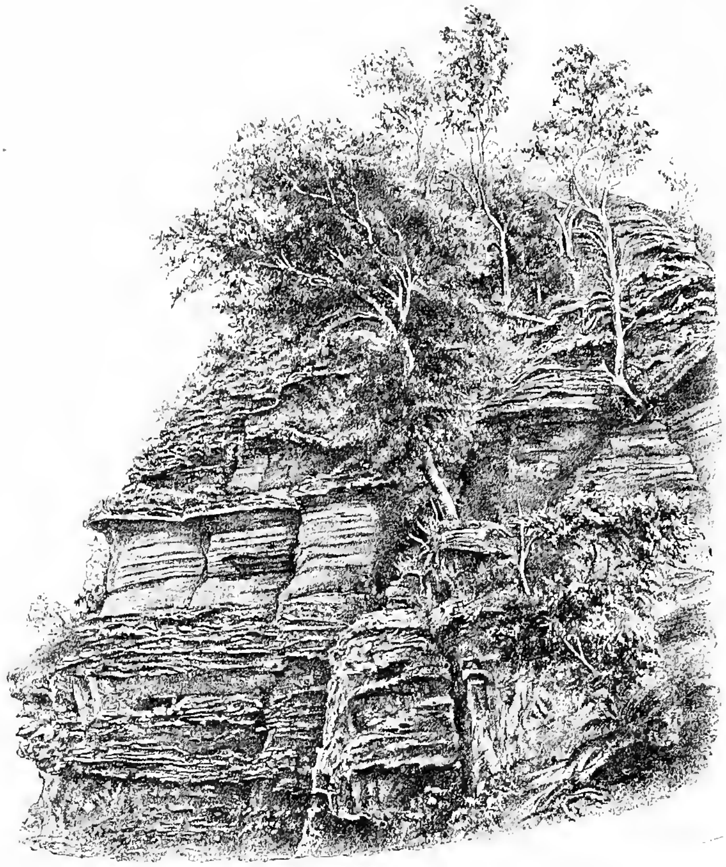


FIG. 12. STRATIFICATION OF SUGAR LOAF, WINONA.

THE DRIFT.

What has been said respecting this deposit in the report on Houston county is almost equally true of it in Winona county. In the western part, however, of this county, the true glacier-drift begins to appear. The map of the county does not represent it, since the rock formations are well known and should be represented rather than the drift. It would be impossible moreover, to define the eastern boundary of the true glacier-drift in Winona county, since it thins out imperceptibly under the loess-loam. A few localities where it can be seen by any observer will here be mentioned, but it is very probable that it will be found in many places farther east than any here designated.

There is an exposure of till with small boulders, N. E. ¼ sec. 33, Elba, by the grading of the road, also in the S. E. ¼ sec. 34. There is a little gravel with stones, and one red quartzyte boulder, about 2½ miles southeast of Lewiston, by the railroad.

There is a plenty of drift one mile south of Utica, in the southern part of section 19.

There is drift-gravel, and some stones at least eight inches in diameter, a mile and a half south of Oak Ridge, by the road, section 5, Norton.

On section 17, Norton, in the valley of the creek, is a boulder of white granite two and a half feet through, the smaller diameter being about a foot and a half, associated with several smaller drift stones, but in general at this place can be seen only the yellow loam.

In the foot of the slope, near the head of Winona lake, are at least two large granite boulders, one of them being rather dark and hornblendic and three feet across. These are so situated that they may have come with the deposition of the material of the terrace, but they are too large to have been brought by water alone. There are also other, finer, drift-stones and gravel, along the bluff road, which may be regarded the remains of the great river-terrace which is found in the protected angles of the bluffs at various places in Winona county.

In the southern part of the county, as far west at least as Money creek, no drift can be seen, except the pebbles along the Mississippi river. Along the valley of Money creek no drift is visible, but on emerging from it to the uplands on section 29, Wilson, a few small foreign pebbles may be seen in the gullies by the roadside.

On section 10, Fremont, (N. W. ¼) are traces of drift in the form of stones and boulder, The soil is also a sandy loam, sometimes a little gravelly.

There are no foreign stones along the valley of Rush creek, nor in the washouts.

In ascending Pine creek valley, in the southern part of Fremont, and thence west to Clyde post office, no drift can be seen, but it probably lies intact on some of the upper swells of the surface, under the loam. Indeed Mr. J. D. Clyde, section 18, Fremont, has a well which struck blue stony clay under the loam, at a depth of ten feet. It is about fifteen feet thick, and has white sand below it. He took out a "lap-stone" eight inches in diameter, from this well. Several other wells in the same neighborhood have encountered the same blue clay.

There is drift, even boulders of granite, at the corners of the towns of Saratoga, Utica, St. Charles, and Fremont, seen in a ravine of the Trenton.

At St. Charles, and a mile or two east of there, the drift under the loam appears thickened obscuring the geological boundaries somewhat. It lies both on the elevated land (above the Trenton) and in the valleys, but is visible, particularly in the former position, or on the upper part of the slope from the table-land. North and northeast of St. Charles there is much evidence of a thicker deposit of drift under the loam than in the rest of the county,

High alluvial terrace. In some places along the Mississippi river may be seen a high alluvial terrace, preserved in the retreating angles of the rock bluff. This plateau also ascends some of the valleys tributary to the Mississippi, particularly the larger ones, and constitutes the principal feature of their topography. It also gives character to their agricultural capabilities, spreading its arable soils high up the bluffs, which would otherwise be precipitous and rocky or too sandy for tillage. The upper portion of the contents of this terrace is frequently a loam undistinguishable from that which everywhere covers the county, but the lower portion consists of coarser sand, and often of gravel.

At Beaver, in the valley of the Whitewater, there is a loam and gravel terrace that rises from forty to fifty feet above the bottom-land, or flood-plain, though it is probably very rare that this bottom-land is flooded by the river.

The gravel terrace rises fifty-eight feet above the flood-plain of the Rollingstone, on section 10, near Minnesota City, and about sixteen feet above the level of the Minnesota City depot, or fifty-two feet above the Mississippi river at low water stage.

At Pickwick the loam-clay that constitutes the top of the terrace is stratified, as may be seen also in numerous other places in the county; but it is difficult to affirm this of the loam, in its original condition, which is spread over the uplands, so far as seen in Winona county. In cases where it is exposed along the roads by grading it does not now show that condition. But the exposures are nearly always along old slopes, where the present condition is due to former sliding down from above, this having destroyed the strata if they once existed.

At Pickwick was taken the section illustrated by figure No. 9, on page 246, which is as follows, in ascending order:

1.	St. Croix sandstone.	
2.	Stratified fine loam, yellowish, with an uneven, eroded, upper surface,	15 feet.
3.	Waterworn, rotted debris from the bluff, with lenticular patches of stratified sand, similar to those seen in the Potsdam conglomerates at lake Superior,	18 feet.
4.	Thin strata of clay, more or less mingled with finer materials like those of No. 3,	4 feet
5.	Same as No 3.	3 feet.
6.	Stratified fine loam,	6 feet.

No. 6 rises, where this section is made, in the slope of the valley somewhat above the level of the valley flat, but seems to consist of the same deposit as the surface of the valley flat Across the creek, but a short distance from the foregoing, is a section exposed in the materials of the valley* flat, covering about eighteen feet of the same interval, and occupying about the level of No. 3. This consists wholly of fine stratified loam; showing either that the present valley was excavated after the deposit of the materials of the foregoing section and subsequently covered over with a stratified fine loam, or that the fine loam was continuously deposited. but was interrupted along the then talus slopes by the accumulation of *gerolle*† from the bluffs, The basin-shaped contour of a section across the valleys, taken in connection with the existence of these beds of coarse material within the loam near the base of the bluffs, seems to indicate the latter as the true hypothesis.

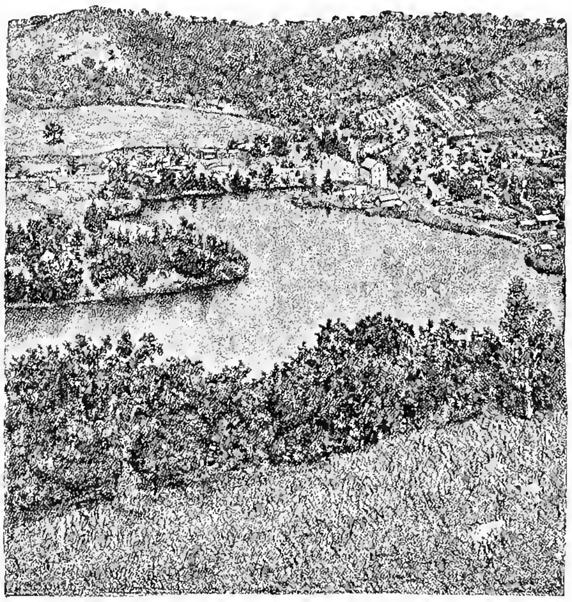


FIG. 13. FROM THE BLUFFS AT PICKWICK.

The loess-loam. The last consideration mentioned above has a bearing on the question of the origin of the loess-loam. If it be true that this

*The flat here designated *valley flat*, is the lowest flat of the valley. It is that which contains the most tillable land. It has no reference to the high terrace; but sometimes instead of being flat it slopes gradually upward on both sides of the valley to the bluffs, or to the foot of the high terrace.

†There is no English word that expresses the significance of this from the German. This deposit is a loose, semi-rounded, quickly accumulated *debris* that is precipitated by freshets down the gorges into the valleys.

gerolle was being accumulated along the bluffs under the influence of freshets, thus interjecting coarse materials within the strata of the loam, and also that the loam was then continuously being deposited, it would seem at first glance that the country could not have been under a lake of fresh water, since that would have protected the bluffs from the wash of freshet floods. The conclusion would then be plausible, that the loam must have originated from atmospheric agents, such as wind and rain, according to the theory of Richthofen. But granting that such *may have been* the origin of these intercalated beds of debris, it is also necessary to admit that they may have been accumulated *sub aqua*, by the same forces, viz., water and wind, just as the rock shingle from an island or beach is carried along by waves and currents, especially by storms, and is distributed on the bottom of the ocean. This of coarse makes a shallow lake, and not a deep one, necessary for the deposit of the loam.

One hypothesis for the explanation of these beds of coarse materials within the loam in the valleys is perhaps as good as the other, but when taken in connection with the horizontal lamination of the loam, which is nothing like the oblique and cut-off stratification seen in wind-blown sediments, it seems as if the preponderance is in favor of the old theory of the lake-origin of the loess.

There is still another point which should not be lost sight of in attributing any cause to these coarse beds, viz., there is some reason for attributing an earlier date to the loam of the uplands, than to the loam of the valleys, the latter being in that case only a redeposited wash from the surface of the upland loam, during a period of high water in the Mississippi* when the high terrace of that great valley was being deposited. Such a high-water stage would fill the tributary valleys with the necessary shallow lakes for the action of waves, winds and currents on the foot of the bluffs that should rise above it, and at the same time leave the uplands uncovered and liable to the freshets that are necessary for the production of the coarse material within the loam. Thus both materials (fine, stratified loam and coarse, unstratified *gerolle*) would be accumulating simultaneously within the valleys. This will explain the phenomena of the section given, and generally of the main valleys of the county, and yet not require anything

*See the report on Houston county.

but an earlier more extensive fresh water lake for the production of the upland loam.

Fossil remains in the alluvium. At Minnesota City the remains of a mastodon were taken out of the alluvium, and logs and "sea mud" are found in deep wells at Dresbach, within the Mississippi valley, but at the mouths of ravines descending from the uplands.

Springs. Of the numerous copious springs in the county which issue from the base of the bluffs, almost invariably at the level of one of the shaly members of the St. Croix sandstone, it is only necessary to allude specifically to that of Mr. F. C. Bryan, which has acquired a local repute for medicinal qualities. This is located near the centre of section 15, Rollingstone. The water of this spring has been analyzed by Dr. W. A. Noyes for the geological survey, and has been found to contain the following mineral ingredients. The sample here reported also contained sulpuretted hydrogen gas. A second sample received later, gave no reaction for sulphuretted hydrogen.

Analysis of water from F. C. Bryan's spring, near Minnesota City, obtained in October, 1882.

Composition of residue from evaporation.

	Parts per 1,000,000.	Percentage.	Grains per gallon.
Silica	16.3	5.2	0.95078
Alumina and oxide of iron	2.5	.8	0.14583
Carbonate of lime	182.0	57.7	10.61606
Carbonate of magnesia	104.3	33.0	6.08382
Carbonate of lithia	trace.	....	....
Carbonate of potash	1.6	.5	0.09333
Sulphate of potash	.7	.2	0.04083
Nitrite of potash	trace.	....	....
Sulphate of soda	7.7	2.4	0.44914
Chloride of sodium	.5	.2	0.02917
Total	315.6	100.0	18.40896

Iodine and bromine, absent; phosphates, traces; borates, absent; hardness, 11.5 degrees.

The water rises in a peat bog on the slope from the foot of the terrace on which the village of Stockton is situated. This terrace rises fifty feet above the spring, and contains white limy concretions and a bed of red clay at the level of eighteen feet above the spring, visible at another place, which probably runs through the terrace. Beneath the peat bog is a sloping bed of blue clay, the result, presumably, of the denudation and redeposit from the high rock bluffs that enclose the valley, of the shales of the St. Croix.

This underlying blue clay is the cause of the accumulation of the peat-bog, since it sheds the surface waters as effectually as the beds of shale within the strata. It is highly probable that the water of the spring derives its qualities mainly from the bog through which the water slowly seeps after its issue from the St. Croix formation. This is rendered more probable from the fact that at many other places where springs rise from the same formation, their water shows no such qualities; and especially from the fact that other springs near the same place, situated so that their water does not pass through this bog before rising to the surface, though they feed the bog along its upper margin, do not in any known case possess these qualities.

MATERIAL RESOURCES.

Stone quarries in Winona county. The principal quarries of the county are at Winona, in the lower strata of the St. Lawrence limestone. These have been prosecuted for many years (since 1854), both for building-stone and for quicklime.* They are owned by John O'Dae, C. H. Porter and E. O. Wallace, and they supply an excellent material for building-stone and for quicklime. The character of the stone has been sufficiently described in giving the characters of the St. Lawrence limestone. The quarry in the same formation at Dresbach is owned by Mr. S. V. Brown. Outside of the city of Winona but little use has been made of stone for construction in Winona county. Brick is more common. Mr. Bottle Ringley has a stone farm house, about two miles east of Utica. The Pickwick flouring-mill is built of stone quarried at Pickwick on land owned by the mill company. The flouring-mill at Troy is constructed from the Shakopee limestone at that place.

The new quarries in the St. Croix sandstone at Dresbach and Dakota, which promise to become very important to the county and to the state, have been fully described in the proper place in the chapter on the building stones of the state. There are a few quarries also in the Trenton in the southwest part of the county, which supply stone to St. Charles.

Quicklime. The lime burned at Winona, and generally in the county, has the superior qualities that dolomitic limestones impart. It is slow to slack and set, evolves less heat, and is believed to be more enduring when

*Compare the chapter on the building-stones of the state.

suitably handled in the mortar, than lime derived from pure limestones. This industry is carried on extensively at Winona, by Messrs. Porter and O'Dae, and to some extent in several other places in the county. John Diedrich burns lime, section 8, Elba, supplying a local demand.

Brick. Throughout the county the clays of the loess-loam make red brick. The principal manufacturers are the following:

John Groff, three miles south of Winona; produces from six to seven hundred thousand per year; sells for eight dollars per thousand; oak wood costs from \$4.50 to \$5.00 per cord; uses the loam of the upper slope from the bluff.

O. Biesanz, west of Winona, thirteen hundred thousand per year; sells at \$8.00 per thousand; wood \$4.00 per cord; uses the loam of the country, which there has no limy concretions.

Sherwood and Johnson, Dresbach; in good weather make 30,000 per day; two millions were made in 1881; sell at \$6.00 per thousand, loaded on the cars; oak wood is \$3.00 per cord, soft wood \$2.50; ship by cars and by river; steam machinery for molding.

Mosse and Dresbach, Dresbach; sell hand-mold brick at \$6.00 per thousand, on the the cars ; this is a new firm.

Williams and Schmidtz, a new firm, sell for the same price.

The brick-yards at Dresbach are in active and flourishing condition, and they furnish a fine quality of red brick, some of them being a superior pressed brick, equal in texture and fineness to those from St. Louis, but not yet their equal in the mechanical execution of the molding and handling. The loam used is free from limestone and from concretions. It lies directly on the sandstone of the St. Croix, but has in its upper portions (which are rejected) layers of dèbris, like Nos. 3 and 5 of the section at Pickwick.

Archæology. At Dresbach have been found interesting implements in making excavations in the loam for extending the brick-yards. It became necessary to remove several of the ancient earth-mounds, and in so doing two copper implements were obtained, together with fragments of chert and pieces of human skull, and of ancient pottery. The skeleton accompanying these specimens was stated by Mr. Geo. B. Dresbach, Jr. and by Mr. Mosse, to have measured eight feet in length. This also agrees with a statement made by Col. George B. Dresbach, concerning the size of a skeleton exhumed several years ago from a mound situated on the high loam-terrace of the Mississippi, near the same place. From the latter mound were taken several skulls and other human bones, a lot of flint arrow-points, and one copper hatchet, the edge of which was said to have been hardened by some process.

Minerals. An impure limonite, pseudomorphous after marcasite, is frequently seen lying loosely on the tops of the wind-worn bluffs along the Mississippi, among other fragments of siliceous rock and of quartz. Sometimes it is in cock's-comb aggregations, and sometimes irregularly spreading and hepatic in outline, or botryoidal or mammillated. It seems to be mainly at the bottom of the debris covering the rock.

At St. Charles was formerly a large piece of lamellar calcite, very dense and firm,* lying on a sloping surface underlain by the St. Peter sandstone. It was originally four or five feet across, and about a foot thick, but has been broken up for hand specimens and carried away. It very nearly resembled argentine and had a wavy and curly internal structure, in layers, giving it much the appearance of woody fiber, and it was regarded as a specimen of petrified wood for a number of years after its discovery.

FIG. 14. PROFILE ROCK, WINONA.

*See the Houston county report for an account of similar deposits in that county.

CHAPTER VI.

THE GEOLOGY OF FILLMORE COUNTY.

BY N. H. WINCHELL.

This county is shown on plate 10. It is situated next west of Houston county and borders on the Iowa state line. Its area, including land and water, amounts to 555,014.44 acres, of which 1,912.54 acres are water. It contains no lakes, this water area consisting of the actual water surface of the larger streams, as meandered by the United States surveyors. The most of the county is suitable for farm tillage. The county seat is Preston, in the valley of the south branch of the Root river. Lanesboro, Spring Valley, Chatfield and Rushford are its other principal towns.

SURFACE FEATURES.

Natural drainage. The surface waters of the county are removed almost wholly by the various tributaries of Root river, the only exceptions being in Beaver, Bristol, Harmony and Canton townships, where a few small valleys are drained by the Upper Iowa river, which skirts along the state boundary in this county. Root river, flowing toward the east, spreads out its tributaries toward the north, west and south, like the rays of a fan' crossing the entire county from west to east. Many of these tributaries rise in the counties next west and north, in a tract of country covered by the northern drift. After passing the county line they soon enter canon-like valleys, the drift at the same time becoming much lighter. They then converge toward the main valley, following deeply cut rocky valleys, and leave the county in one volume a little east of Rushford, in the northeastern corner. These streams furnish frequent water-power, and in a number of places this has been improved in the erection of mills.

Water-power and water-power mills in Fillmore county.

At Chatfield, T. Dickson's mill has thirty horse-power; twenty feet head; making forty barrels of flour per day. The main mill has a 26-inch Mulligan wheel. There are also one 17½-inch Leffel wheel, 4 run of stone (one for feed) and one set of smooth rollers. John Cozzen's mill has 20 or 25 horse-power, with a twelve-foot head, making from fifteen to twenty barrels per day; has a 40-inch Dayton (Ohio) wheel, one set of smooth rollers and two run of stone, one being for feed.

The mill of Dickson, Easton and Johnson has a capacity of one hundred barrels per day of 24 hours; 13 feet head, four Mulligan wheels (30 36-inch), two run of stone (none for feed), four sets of double, corrugated rollers, and three or four sets of smooth rollers There is also a woolen-mill at Chatfield run by water-power. It is owned by Marsden and son, and has a 48-inch turbine wheel, giving 20–25 horse-power- The dam is 6 feet 9 inches. The factory has one 40-inch set of woolen machinery.

On section 34, Sumner, the *Tunnel mill* on Bear creek has a head of 26 feet, with an average of 39 horse-power in summer. During one-third of the year this power is doubled, and in freshet stage of the river it sometimes amounts to a hundred times that. There is about one-third more water in Bear creek at the *Tunnel mill* than at Odell's.

On Bear creek, above the *Tunnel mill* are the following powers: At Hamilton, one mill, 14 feet fall, with nearly as much water as at Lime City; at Lime City, the old *Frazer* mill-site, with twelve feet head. By the use of the possible tunnel here this power might be improved. This tunnel, when constructed, would produce a fall of 16½ feet, and would be 400 feet in the rock, and 500 feet from water to water. With a six-foot dam this fall may be increased to 21 feet. The *Tunnel mill* dam "flows back" to the old *Frazer* site.

Below the *Tunnel mill* on Bear creek are the following powers: *Stone mill*, has one-fourth more water than the *Tunnel mill*, with ten feet head, with a possibility of twelve; an unimproved power (12 feet head); *Washington mill*, 8 feet head, and double the water at the *Tunnel mill; Greiner's mill*, water about the same as at the *Washington mill*, head 14 feet: *Yearing's mill*, head 13½ feet, same water as at Greiner's; *Thompson's mill*, 12 feet head, and ten per cent. more water than at the *Washington mill.*

On Deer creek are the following: *Weisbach's mill*, S. E. ¼ sec. 11, Spring Valley, fall 5 feet; *Olds' mill* and *Pritz' mill.*

On Rush creek, sec. 3, Rushford, Gore and Company have a flouring mill. with saw-mill machinery connected. It has forty horse-power, 12 to 15 feet head of water, two Leffel wheels, and three run of stone (one for feed).

At Clear Grit, on the Root river, sec. 22, Carrollton, one flouring-mill.

At Preston, on the Root river, are one flouring-mill and one woolen-mill.

At Carimona, on the Root river, is one flouring-mill.

There is one also at Forestville, on the same stream.

At Etna is a flouring-mill run by a tributary of the south branch of Root river.

At Fillmore, on the middle branch of Root river, are two mills.

At Baldwin's bridge, sec. 21, Forestville, is one mill on the south branch of Root river.

De For's flouring-mill is on sec. 24, Bloomfield, on the south branch of Root river.

There are three flouring-mills at Rushford, one at Peterson, two at Whalen, two at Granger, and three on the south fork of Root river.

The *Hammer mills* are owned by Dr. Hammer. They are on Trout run, in Pilot Mound, have eight horse-power, two tribune wheels, three buhrs (one for feed) and 18 feet head, making forty barrels per day.

At Lanesboro the horse-power of the mills is estimated as follows: Seven cubic feet of water per second, under 26 feet head, is reckoned as one power. Ten of these constitute the capacity of the Lanesboro Company's dam, at lowest water; ordinarily there are four more of these powers available here. James Thompson's mill has the same water, under 17 feet head. The others at Lanesboro are: White, Nash and Co., six powers; White and Beynon, four powers.

At two miles south from Lanesboro is *Durschee's mill.* This is run by the water that gushes out from the bluff in a single spring. It has a 15¼-inch Leffel wheel and 28 feet head, and is capable of about 26 horse-power, but as a considerable quantity of the water is wasted, only about fifteen horse-power is actually used. It carries three run of stone.

At the *Tunnel mills*, sec. 24 Sumner, advantage has been taken of the winding course of Bear creek. The creek is enclosed on both sides by high rocky walls. A tunnel has been cut through a narrow neck, excavated in the rock, admitting the water, which falls again into the river on sec. 34, producing a fall of 26 feet in 600 feet. The cut in the rock is 600 feet long, for the tunnel, and 100 feet for tail race. At G. Weisbach's mill a similar opportunity is offered. This is on sec. 11, Spring Valley. By a tunnel of 70 feet through the "hogsback", a fall of 17 feet 10 inches may be secured, and at the limekiln of Mr. J. H. Hall, near Weisbach's, a tunnel of

125 feet will furnish a power of 20 feet. About twenty rods from Weisbach's, a tunnel of 45 feet will afford 64 feet head of water. The rock is limestone, in horizontal bedding.

Topography. That portion of the county which is covered with a thick deposit of foreign drift presents the usual monotony of surface characteristic of the drift latitudes. This includes the most of the range of townships across the western end of the county, and some portions of the next range east. There are, however, even within this drift area, a number of narrow, deeply cut valleys, with precipitous rocky bluffs, having very much the nature of cànons, like those of the driftless territories of the west. Toward the east these deeply cut valleys are more numerous. All the little streams, and a great many narrow valleys that have no running water in them, have high rocky bluffs along their whole course. These valleys and streams, constituting the drainage system of the county, converge toward the valley of Root river. The valley of this stream with its principal tributaries presents some of the most remarkable and instructive phenomena of erosion to be found in the state. It passes nearly at right angles across the strike of the formations. These are alternating limestones and sandstones, with an occasional bed of soft shale. The Trenton limestone, underlain by the easily eroded St. Peter sandstone, the same as at the falls of St. Anthony, although about a hundred and sixty feet in thickness, is eaten into by the retroaction of the water as it plunges over the falls at the point where the streams cross the line of its superposition over the St. Peter, until they have each excavated in the Trenton a deep channel from fifteen to thirty miles in extent. Through the line of the strike of the St. Peter these valleys are widened out, the surface of the low ground within the bluffs being usually one of rich meadow with undulating surface, from one to two hundred feet below the general level. The Cambrian formations are entered upon by the streams while they are yet a good many miles within the general area of the Trenton. As these formations consist of two limestones, separated and succeeded by sandstones, they repeat the succession of phenomena witnessed in the erosion of the Trenton and St. Peter. As the water leaves the Shakopee limestone and enters upon the Jordan sandstone, it passes over a series of rapids, or a fall of several feet perpendicular, which falls or rapids undergo a process of recession under the same causes as produce the recession of the Trenton-St. Peter falls. Again when the stream passes from the St. Lawrence limestone upon the St. Croix sandstone the same conjunction of circumstances causes another rapid or waterfall. Thus by a series of steps more or less evident, the branches of Root river descend from the area of the Galena limestone to the St. Croix sandstone. The valleys widen in the sandstone areas, and become abruptly narrow in the limestone belts. In passing down a stream, within a sandstone area, where the valley is perhaps half a mile wide, with tilled farms in the bottom land, the high bluffs being remote from the stream, the first indicacation of an approaching change in the formation is the rise of a terrace along the immediate river bank, with an occasional exposure of limerock facing the water. This terrace, which becomes almost continuously rocky, rises slowly till it exposes the full thickness of the rock which causes it. On the other hand the first evidence of a change from limestone to sandstone, visible in descending the stream, is the occurrence of a waterfall or rapid. Such changes produce water-powers, many of which have been improved. Hence the location of a flouring-mill, on one of these branches, is an intimation to the geologist that at that point one of his boundary lines crosses that stream. Around these points gathered the first village settlements. Preston is located where the water-power formed by the descent of the river from the Shakopee to the Jordan induced the construction of mills. The water-power at Chatfield is formed in the same way. Near Fillmore the branches of Root river, known as Deer and Bear creeks, afford good water-powers by their descent from the Trenton to the St. Peter. Mills have been built at both points. On the south branch of Root river, above Forestville, the stream leaves the Trenton, and the waterfall has been improved in the same manner, at Baldwin's mill. The same fact is illustrated by a great number of eastward flowing streams in the eastern border counties, between Fillmore county and the falls of St. Anthony at Minneapolis. Of course rapids are also likely to be formed, specially in small streams, when passing through the areas of rocks of uniform hardness. Such water-powers, and others that are formed by the construction of dams, do not fall into this class.

While the immediate valleys of Root river and its tributaries are apt to be rocky, the country that spreads out in either direction, after leaving the valleys, is not rough. It is rolling, or undulating. In the eastern portion the rocks are covered by a heavy deposit of rich, clayey, loam, known as the *loess*, which fills up many depressions and lends a uniform and remarkable fertility to the soil. It constitutes the soil. The farms are all well drained, naturally. The county contains no lakes. In York township there is a slough which on some maps is represented as a lake. It is about a quarter of a mile across. The Trenton area is distinctly separated, topographically, from that of the St. Peter and the lower formations. From the Trenton to the Shakopee the surface descends by a step or terrace, about 125 feet. Some of the Trenton areas are isolated from the main area, and constitute small tables or mounds, which are well known as "Trenton mounds", in the early reports. Some travelers have referred them to the agency of the ancient "mound-builders", and a good many of the residents, who are not aware of the causes that have produced them, still believe that they are artificial instead of natural.

From some of the elevated Trenton areas, overlooking the river valleys, magnificent views of landscape may be had. From the elevated Trenton area, in Newburgh township, the eye looks over the valley of the south fork of Root river, and can almost discern the Trenton bluffs on the opposite slopes of Root river in the northern part of the county. From the peninsula of the Trenton running north between Camp and Willow creeks in Preston township, the village of Fountain is plainly discernible across the valleys of the south branch of Root river and Watson's creek, with a wide expanse of alternating timber and prairie between, while on either side is a broad undulating valley of prairie land. On the east is Camp creek valley, and on the west is that of Willow creek. These valleys are deep and wide, but owing to the thickness of the loess-loam the slopes are gentle and broad; and, in the fall of the year, when the industry of the farmer is exhibited in the plowing of his wheat fields, and the threshing of his last crop, in every direction may be heard the rattle of threshers, often running by steam, and a hundred teams may be seen preparing for the next harvest. Another magnificent view may be obtained from the Trenton peninsula on sections 10 and 15 in Carrollton. From here the view extends north over the valley of Root river to the Trenton bluffs along the north boundary of the county, a distance of over forty miles, and toward the south over the valley of the south branch of Root river, looking over Preston and Lanesboro, which are situated within the river bluffs, so far below the general level of the country that they can be seen but a short distance before reaching them.

Further down Root river valley, the gorge in which the river runs becomes wider, being at Rushford about two miles in width, with fine farm lands in the bottoms. The bluffs are rounded off with age and have a thin soil, generally turfed, though showing frequent rock exposure. The river is there 565 feet below the tops of the bluffs, as measured by aneroid. At Whalen, in Holt township, the river is by the same measurement, 470 feet below the top of the Trenton terrace on section 20. Whalen's bluff is 250 feet high above the river. At Lanesboro, in Carrollton, the river is 285 feet below the immediate river bluffs, which consist wholly of the Cambrian formations, and about 440 feet below the top of the Trenton terrace on section 20, Holt. At Preston the river at the stone mill is 335 feet below the Trenton terrace, which forms the general level about a mile south of the village. At Isinour's station the river runs 145 feet below the top of the Shakopee limestone, which forms there the brow of the immediate river bluffs. At Forestville the hight of the country north of the village, above the river, is 285 feet. The immediate river bluffs are 190 feet above the mill pond. At Chatfield the river is about 222 feet below the general level of the country. At Fillmore the prairie upland is 200 feet above the river level. From Fountain to Isinour's station the track of the Southern Minnesota railroad descends 401 feet, passing from the Galena to the St. Lawrence, and entering the latter formation about twenty-five feet, the rocks all lying nearly horizontal. At Weisbach's mill, on Deer creek, section 11, Spring Valley, the river is 205 feet below the general level of the country. There is here a little drift, but the cut is mostly in the Galena and Trenton limestones. The village of Fountain is about 350 feet higher than the terrace at Preston on which the Stanwix House stands. These measurements might be multiplied, but enough have been given to show the unevenness of the surface due to erosion. The rocks lie everywhere nearly horizontal. The varied topography of the county is due to the influence of running water, and atmospheric forces, on the rocks, combined with their alternations of limestone with soft sandstone. The limestones are firm, and resist these forces much longer than the sandstones. They alternate in the following manner in descending order:

Trenton limestone.
St. Peter sandstone.
Shakopee limestone.
Jordan sandstone.
St. Lawrence limestone.
St. Croix sandstone.

The limestones form the prominent features in the topography. They have the most frequent outcrops. They project along the summits of the bluffs and constitute the brows of benches or terraces that diversify the county. The sandstones never, or very seldom, appear in the tops of the bluffs. They outcrop in sheltered nooks, or below the line of the limestone exposure. They are more likely to be hid by soil and turf. The Lower Trenton is overlain by a layer of about twenty feet of easily eroded green shale, which, outcropping by roadsides, introduces a series of springs and muddy spots, being impervious to water, that invariably follows that boundary line wherever it goes. It withstands the disintegrating action of the elements even more successfully than the limestones themselves. For that reason it protects the Trenton which lies below it, long after the Galena limestone which lies above it has been entirely denuded.

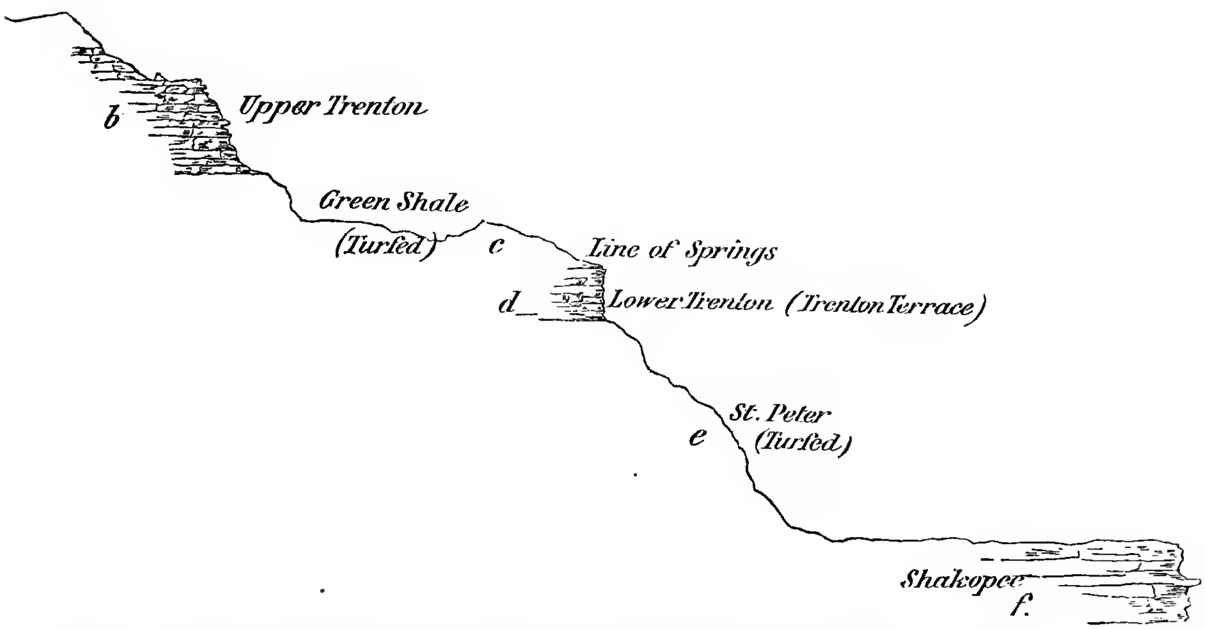


FIG. 15. SHOWING THE EFFECT OF THE TRENTON AND GREEN SHALES ON THE TOPOGRAPHY.

Explanation.

At *a* the Galena and Trenton have their full thickness, about 160 feet. Such a point may be found at Fountain; *b* represents an outcrop of the Galena, or Upper Trenton, as seen along the gorges that are frequent in the Galena area. Such an outcrop is visible at the "Big Spring" a few miles northwest of Fountain, where the water rushes out in a great volume near the base of the bluff, and probably on a level with the top of the green shale. At *c* is a marshy tract, or one that is gently sloping, having a springy margin, near the brow of the lower bluff. Such spots are visible particularly at Chatfield, in the northern part of the village, near Jacob's limekiln, and west of there. A fine illustration of the effect of this shale on the surface drainage may be seen in section 35, Holt, where a copious spring issues from near the top of the mound of Trenton, the water being shed by the shale overlying, and gathered by troughs into a tank for watering stock. *d* represents the outcropping edge of the Trenton. It is this which is seen in the summits of the isolated mounds, and which forms the conspicuous shoulder that exists wherever the strike of the Trenton crosses the county. The slope *e* is occupied by the St. Peter sandstone. Sometimes this is quite precipitous, and its upper forty or fifty feet are very apt to be, but its lower portion is very gently descending, so that it is impossible to determine where it is replaced by the Shakopee which underlies it. The horizontal distance between *b* and *d* is sometimes several miles. This is apt to be the case along the eastern margin of the Trenton area. Indeed the detached Trenton areas in Holt and Amherst, and notably that in Pilot Mound, townships comprise only this lower portion of the Trenton. The Shakopee limestone, *f*, underlying the St. Peter, is that which occurs along the tops of the immediate bluffs of the river, as at Preston, Lanesboro, Clear Grit, and Whalen. At Chatfield it is seen at the mill, and rises about thirty feet above the river.

The strike of the Galena and Hudson River formations is often driven back several miles from that of the Lower Trenton. The limerock which lies below this shale is about twenty feet thick. The singular Trenton mounds, which have already been mentioned, are composed of the Lower Trenton, protected by a greater or less thickness of this green shale, and a portion of the St. Peter sandstone. The preceding diagram illustrates the manner of weathering down of the Trenton and St. Peter. Instances of this may be seen in almost any square mile, in the loam-covered area, along the out-running strike of the Trenton.

Throughout the Galena and Upper Trenton areas are found a great many depressions that are well known as "sink-holes". These consist of broken down spots in the drift, or loam, where it had been spread over a preexisting canon in the rock. In some places they are very numerous, but they are confined, so far as known, with but very few exceptions, to these limestone areas. They throw some light on the condition of the rocky surface prior to the period which witnessed the spreading of the drift. The rock was wrought, at least in Fillmore county, in very much the same manner as we now see it along the river gorges. The immense valleys of erosion which we see, not only in Fillmore county but also throughout the tract that has been denominated the "driftless area", were excavated before the glacial period. Where the streams of the present time run in such gorges they have been so located by the exigencies of surface drainage and erosion since the last glacial epoch. That these gorges antedate the last ice period is shown by their existence beneath the glacial drift. These sink-holes sometimes occur in lines, and with increasing frequency and size toward a large valley, and at last coalesce so as to form a continuous valley, though frequently without running water, that becomes tributary to the larger gorge. These gorges under the drift can sometimes be traced for some distance by a series of successive sink-holes. Sometimes streams are lost in them, and re-appear at lower levels. There are several well-known subterranean passages in the county. Lost creek, in Jordan township, and the Brook Kedron, in Sumner, both have underground passages for several miles. Canfield creek, south of Forestville, runs underground about twelve miles, and, finally, the south branch of Root river sinks in the N. E. ¼ sec. 19, Forestville, and runs underground, except in high water, to about the center of section 21, where it re-appears. These underground passages are in the area of the Galena. They indicate the corrugated appearance the country presented prior to the overspreading of the drift and the loess-loam. The Galena cannot be supposed to have been any more subject to such causes as produced this channeling in the rock than the formations of the Cambrian. There is some reason, however, why these gorges are found almost entirely confined to that limestone. As has been said, the Cambrian consists of alternating sandstones and limestones, which conduces to their breaking down laterally, the sandstones easily crumbling out. The Galena limestone, on the other hand, in conjunction with the Trenton, while they have a thickness of 160 feet, more or less, have, near the bottom, a bed of impervious shale which prevents the downward infiltration of the surface water, and protects the underlying sandstone. Hence the erosions that operate laterally, in tearing down the Cambrian formation, are occupied in the Galena and Trenton limestone area, in cutting narrow perpendicular gorges. For this reason the Galena area is everywhere the highest in the county. From the eastern boundary of the Trenton, looking east, one beholds a broad landscape, lying several hundred feet, in some places, below him, the effect of the more rapid denudation of the rocks in that portion of the county. Into such narrow gorges neither the drift nor the loess-loam, however deposited, would enter with such compactness as to close up the pre-existing water courses; and when partially closed up, as they were wherever sink-holes have since appeared, they have been undergoing ever since a process of re-excavation. This process is revealed in the occasional collapsing of the surface soil, and thus the formation of a new sink-hole, and in the enlargement of others, since the settlement of the county.

Elevations in Fillmore county on the Southern Minnesota division, Chicago, Milwaukee and Saint Paul railway.

From George B. Woodworth, assistant engineer, La Crosse.

	Distances in miles from La Crosse.	Hights in feet above the sea.
Rushford,	29.9	714
Peterson,	31.5	748
Whalen,	43.4	778
Root river bridge,	46.0	793
Root river bridge,	47.5	816
Lanesboro,	48.0	833
Root river bridge,	51.7	865
Isinour's,	53.6	891
Fountain,	59.3	1294
Depression, grade,	60.6	1251
Summit, grade,	64.7	1322
Wykoff,	66.5	1302
Summit, grade,	68.5	1359
Spring Valley,	73.6	1258

Mean elevation of the county. From the contour-lines shown on the map the average elevation of each township is estimated as follows:

Rushford, 1025 feet above the sea; Norway, 1150; Preble, 1050; Newburgh, 1150; Arendahl, 1075; Holt, 1050; Amherst, 1150; Canton, 1175; Pilot Mound, 1025; Carrollton, 1050; Preston, 1125; Harmony, 1200; Chatfield, 1100; Fountain, 1200; Carimona, 1175; Bristol, 1250; Jordan, 1200; Fillmore, 1225; Forestville, 1225; York, 1275; Sumner, 1275; Spring Valley, 1275; Bloomfield, 1300; and Beaver, 1300. The mean elevation of Fillmore county, derived from these figures, is approximately, 1170 feet above the sea.

Soil and timber. The soil of the county is generally very fertile. The immediate surface is a loam. This varies in color and composition, as well as in origin. That portion of the county covered with the northern drift has primarily a drift soil, which consists of gravelly clay. Where this forms the immediate surface, which is the case only on knolls and on the brows of the river bluffs, it affords a soil of an ashen color, if dry. In timbered belts it is more stony or gravelly. In the open prairies, and in low ground, it is covered with a loam. This is believed to have resulted from the natural decomposition of the coarse materials of the drift, under the calcining influence of the prairie fires, and the frosts of the ages. It has never been stratified, or arranged with any regularity that would indicate its having been deposited either by standing or running water. In most cases, specially on the open prairie, it is nearly black. As it is mingled with the drift clay it becomes lighter colored. In the low grounds it is much thicker, and also of a black color. Overlapping the drift area in a belt about five miles wide, is a soil formed by the mingling of the loess-loam with the drift. The loess-loam is later than the glacial drift, and in the process of deposition it is modified by contact with the drift clay. The loess-loam is indistinctly stratified, though it usually appears massive, and consists of fine, often clayey sediment. The soil derived from it, usually sandy and light colored or rusty, is sometimes so clayey as to make, when wet, a fine and very slippery mud. The soil derived distinctly from the loess-loam covers at least one-half of the county, and is supposed to extend to the Mississippi river. It makes a rich and apparently strong soil, as it supports a cropping of wheat from year to year. It is impossible to define its western limit. If it were derived from a long-standing inland lake some beach-lines would be found indicating its western boundary. No beach-lines have been found. That it was deposited from standing water can hardly be questioned. It thins out westwardly gradually, passing through a confused or mixed condition resulting from the mingling of the drift materials with the sediment, or by its overlapping the drift. While the essentially loess-loam soil of the eastern part of the county, can be distinguished easily from the drift soil of the western, no line of demarkation separating them has been noticed. A line drawn from the southeast corner of Bristol to the northeast corner of Jordan would roughly set off the area that has a distinctively loess-loam soil. West of that is a belt of five or six miles wide, in which the loess-loam soil mingles with the drift soil. The rest of the county toward the west is occupied with a distinctively drift soil, or drift-loam soil.

Trees and shrubs of Fillmore county.

The following list embraces such native trees and shrubs as were seen in the survey of the county. The trees are arranged in the estimated order of frequency. The area covered by native timber is steadily increasing. A large proportion of the county is covered with bushes which are composed of hazel, aspen, oak (two sorts) and, where these are wanting, a species of low willow which seems to come up first after the prairie fires are stopped. After the willow, hazel and oak and aspen gradually come in, and in time convert the original prairie to a bushy or timbered region. Over some large tracts in the county this process is going on. There are thousands of acres of young native timber, not exceeding five or six inches in diameter, due to this gradual change since the suppression of the prairie fires.

Quercus macrocarpa, *Michx.* Bur oak.

Quercus coccinea, *Wang.*, var. tinctoria, *Gray.* Black oak.

This is the oak that is abundant as underbrush, and small trees. It often forms thickets skirting the outlines of a prairie. Large trees are found in the heavy timber in the northwestern portion of the county.

Populus tremuloides, *Michx.* Aspen. Generally small, and on the borders of prairies.

Quercus alba, *L.* White oak. Common in the timber in Spring Valley and Jordan townships, and generally along the valleys of the principal streams.

Prunus Americana, *Marshall.* Wild plum.

Populus grandidentata, *Michx.* Great-toothed poplar. Very frequently mistaken for the American aspen.

Ulmus Americana, *L.* (*Pl. Clayt.*), *Willd.* American elm.

Tilia Americana, *L.* Bass.

Fraxinus Americana, *L.* White ash.

Pirus coronaria, *L.* American crab-apple. Common along the margins of prairies and in open valleys.

Ostrya Virginica, *Willd.* Ironwood.

Acer dasycarpum, *Ehr.* Soft maple; white or silver maple.

Acer saccharinum, *Wang.* Sugar maple. Common in the heavy timber in Spring Valley and Jordan townships.

Populus monilifera, *Ait.* Cottonwood.

Prunus serotina, *Ehr.* Black cherry. Trees generally small.

Carya amara, *Nutt.* Bitternut.

Juglans cinerea, *L.* Butternut. Seen most abundant in the heavy timber in the northwestern part of the county.

Prunus Pennsylvanica, *L.* Wild red cherry.

Cratægus coccinea, *L.* Thorn apple.

Cratægus Crus-galli, *L.* Cockspur thorn.

Betula papyracea, *Ait.* Paper or canoe birch. Trees small; generally on stony soil, or along rocky river banks.

Juglans nigra, *L.* Black walnut. In the heavy timber of the northwestern part of the county.

Negundo aceroides, *Mœnch.* Box-elder.

Juniperus Sabina, *L.*, var. procumbens, *Pursh.* Trailing cedar; savin. Along the rocky river bluffs.

Pinus Strobus, *L.* White Pine. An occasional large tree is seen along the river bluffs, but the most of it suitable for lumber has been cut.

Carpinus Americana, *Michx.* Water beech.

Carya alba, *Nutt.* Shagbark hickory. Seen in the valley of Root river, and in the tributary gorges, at Rushford.

Rhus glabra, *L.* Smooth sumach.

Cornus paniculata, *L'Her.* Panicled cornel.

Cornus circinata, *L'Her.* Round-leaved cornel.

Symphoricarpus occidentalis, *R. Br.* Wolfberry.

Lonicera grata, *Ait.* American woodbine.

Amelanchier Canadensis, *Torr. and Gray.* Juneberry.

Corylus Americana, *Walt.* Hazelnut.

Rubus villosus, *Ait.* High blackberry.

Rubus strigosus, *Michx.* Red raspberry.

Rubus occidentalis, *L.* Black raspberry.

Rosa blanda, *Ait.*, and R. lucida, *Ehr.* Dwarf wild rose.

Vitis cordifolia, *Michx.* Frost grape.

Ampelopsis quinquefolia, *Michx.* Virginia creeper.

Spiræa opulifolia, *L.* Nine-bark.

Viburnum Lentago, *L.* Sheep-berry.
Rhus typhina, *L.* Staghorn sumach. Rare.
Celastrus scandens, *L.* Climbing bitter-sweet.

Trees in the order of abundance at Lime City. Mr. L. G. Odell estimates the trees about Lime City in the following order of abundance. Black oak, basswood, sugar maple (largely cut off), aspen, white ash, ironwood, white elm, white oak, red elm, rock elm, black ash, butternut, bitternut, hackberry, white pine, red cedar, box-elder, cottonwood, black cherry, water beech, black walnut, bur oak (on the outskirts of the timber), juneberry, black haw, stag (or spotted) alder, juniper (a shrub that hangs over the bluffs, growing in clumps), balsam fir, whitewood (also called yellow poplar, formerly cut into lumber, now nearly gone, probably the *Populus grandidentata*), leatherwood (on the tops of the bluffs), and doubtfully the American yew.

THE GEOLOGICAL STRUCTURE.

The rocks of the county belong to the Devonian, and to the Silurian and Cambrian ages. The Cretaceous also appears in Sumner township, in the extreme northwestern corner of the county. They occur as arranged in the following order, with their approximate thicknesses.

1. Cretaceous, thickness unknown, perhaps twenty-five feet, lying unconformably over the older rocks.

2.	Upper Devonian, Hamilton,		100 ft ?
3.	Lower Devonian, Corniferous ?		
4.	Niagara, of the Upper Silurian,		100–150 ft.
5.	Maquoketa, of the Lower Silurian,	Hudson River, and Utica slate ?	75–100 ft.*
6.	Galena, of the Lower Silurian,		75–100 ft.
7.	Trenton, of the Lower Silurian,		160 ft.
8.	St. Peter,	Cambrian,	122 ft.
9.	Shakopee,		75 ft.
10.	Jordan,		25–40 ft.
11.	St. Lawrence,		200 ft.
12.	St. Croix,		Exposed 375 ft.

With the exception of the Cretaceous these formations have a *strike* across the county northwest and southeast. They have a gentle dip, at least theoretically, toward the southwest, though no general dip is perceptible. The oldest rock in the county is the St. Croix sandstone, which appears in the northeastern corner of the county. The latest, except the Cretaceous, is the Devonian, in the southwestern part of the county. The areas of outcrop are shown by the colored map of the county (plate 10) accompanying this report. The boundary between the Trenton and the St. Peter is the

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most accurately defined, owing to the terrace which marks it. The boundary between the St. Peter and Shakopee it is impossible to ascertain certainly, because of the universality of the loam, which acts, in that respect, just the same as a heavy drift deposit, and also because of the persistency of the Shakopee compared to that of the St. Peter. When the friable rock is below a hard and persistent one, as the St. Peter below the Trenton, the boundary between them can be traced out easily by the resulting topography; but when the soft one is uppermost it wedges out imperceptibly under the loam, or drift, and one can not say when it is all gone. In the western part of the county the lines are all obscured by the prevalence of the drift. The Maquoketa shales have but little exposure in the county. They are visible in the bluffs of the Upper Iowa river, at Lime Springs, about three miles south of the state line, and continue through Fillmore county, in the strike of the Lower Silurian, appearing at Spring Valley.

The St. Croix sandstone. The area of the St. Croix sandstone is small. It occupies the lower portion of the river bluffs, and the bottom-land included between them, from the county line, near Rushford, to near Lanesboro. This bottom-land is sometimes two miles, or more, in width, but it is an alluvial deposit and never reveals the rock. The only rocky outcrops are in the slopes of the bluffs. This sandstone also enters the county in a similar manner, in the valley of the south branch of Root river, and extends about three miles west of the county line.

Its *general lithological character* is all that can be learned of this rock from its exposures in Fillmore county. The opportunity for examination is very unfavorable. The bluffs, over the interval occupied by it, are almost universally turfed, and a heavy talus rises nearly or quite to the lower level of the St. Lawrence limestone. It is in general a light-colored sandstone, with alternations of limestone, and some shale, in its upper portions. The sandstone layers crumble easily. Some of the beds are of a very coarse grain, but the quartz is generally white, almost transparent. The limestone layers are like that of the St. Lawrence, and contain a few fossils, none of which have been studied yet with care sufficient for reliable specific identification. At Whalen about ninety-five feet of the St. Croix sandstone is included in the lower slopes of the bluffs. This thickness of bedding disappears below the river level before reaching Lanesboro. At Rushford the sandstone and talus, which is supposed to consist mainly of sandstone, rise 375 feet above the river. Near the upper portion of the sandstone a conspicuous terrace or line of frequent exposure, producing a shoulder, may be seen along the creek in entering Rushford from the south.

The St. Lawrence limestone. This is the lowest portion of the *Lower Magnesian* formation of Dr. D. D. Owen. In the annual report for 1873 the geology of the Minnesota valley is given. It is there announced that the great formation to which the name *Lower Magnesian* had been applied, consists of three distinct members—two limestones separated by a sandstone—and the names of the localities where these members have their characteristic outcrops, in that valley, were applied to distinguish them, as they were certain to play an important part in working out the detailed geology of the eastern portion of the state.

The *area* of this limestone is embraced in one with that which on the accompanying plate includes also the areas of the Jordan and Shakopee formations. Along the river bluffs nearly to Rushford it is found only in the lower portion of the limestone belt, as the Jordan sandstone and Shakopee limestone are both preserved and overlie it, but toward Rushford this limestone begins to be the only one that is found in the bluffs, the upper members of the Cambrian having a strike across the country some miles in either direction away from the immediate valley, There are places, however, even further east still, where the overlying Jordan and Shakopee are preserved and appear in the tops of the river bluffs. The St. Lawrence extends in the bluffs of the Root river to some distance above Isinour's station, and nearly to the lower mill at Preston. The valley of Watson's creek at Isinour's station is cut about twenty-five feet into the St. Lawrence. At Lanesboro the amount of the St. Lawrence visible is about 195 feet. At Whalen 155 feet are seen in the upper portion of Whalen's bluff. At Rushford the uppermost 190 feet of the bluffs are of the St. Lawrence. The thickness of the formation is not far from two hundred feet.

The St. Lawrence in Fillmore county is a *dolomitic limestone*, with some of its layers distinctly arenaceous, and stained with green sand. In general its bedding is regular and evident, but there is a thickness of about fifteen feet near the bottom of the formation in which the bedding is confused, or the layers are lost horizontally Below this confused bedding are, however, about twenty-five feet of regular beds, which have a fine even grain, and though not plainly arenaceous, yet have a very fine grit. On fresh surfaces it is of a buff color, varying to cream color. The upper portion abounds in patches of white calcite. There are also in the upper portion spots that show thin, concentric, though wavy laminations, as if from concretionary forces, or the result of silicified masses of *foraminifers*, reminding the observer of the laminated masses of limestone from the *Laurentian* containing the *Eozoon Canadense* of Dr. J. W. Dawson. Though the most of the rock of this formation is vesicular, often coarsely so, it is much used for building, for which it furnishes both large blocks for the heaviest masonry, and fine-grained stone that can be cut into delicate forms. When cut for window caps or sills the cut surfaces are nearly white. The bedding varies in thickness from two or three inches to two or three feet, and sometimes embraces thin beds of shaly, light-colored, fine-grained rock that is useless for all purposes.

At Clear Grit mills, in the valley of Root river, the St. Lawrence begins to show a continuous line of bare rock, in the river bluffs, running along the lower slopes, and causes a shoulder or terrace in the general descent. A quarry near the mill-dam shows about fifteen feet of even layers. Above these are the layers represented in the railroad cut near that place. These are light-colored, dolomitic, vesicular, abounding in patches of calcite with some chert and siliceous concretions, the latter sometimes covered with limonite, pseudomorphous after pyrite or marcasite. The annexed profile exhibits the cut and the materials exposed.

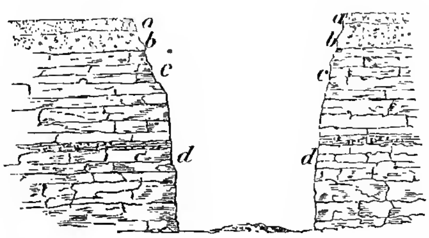


FIG. 16. RAILROAD CUT AT CLEAR GRIT.

Explanation.

a.	Loess-loam, red	3 feet.
b.	Drift-gravel, red	4 feet.
c.	Jordan sandstone, red	16 feet.
d.	St. Lawrence limestone	30 feet.

At Whalen the St. Lawrence is finely exposed in the bluff that stands in the valley about half a mile below the village. It has here been considerably quarried, and furnishes a very good stone for buildings. It lies in even layers which are easily broken into desirable size and shape, furnishing a good cut-stone of close grain, without openings. Of the 155 feet that here overlie the St. Croix sandstone, only the lower portion is well exposed. The exposed layers are separated from those seen at the quarry at Clear Grit by an interval of fifty feet. They consist of the following parts, aggregating sixty feet.

Section at Whalen.

1.	Slope, hid by turf (St. Lawrence),	95 feet.
2.	Heavy beds, even-grained, vesicular, the best general building stone,	20 feet.
3.	Bedding confused, not evident, lenticular,	15 feet.
4.	Fine grit, regular beds, dolomitic,	20 feet.
5.	Hard, arenaceous, projecting, fossiliferous with the remains of trilobites,	5 feet.

At Lanesboro the St. Lawrence has been used in the construction of the principal buildings. The quarries are owned by the Lanesboro Mill Company. The stone presents the usual characters, but has associated masses of marcasite, largely converted to limonite, showing orthorhombic and other forms of crystallization. In some of the cherty nodules are found small orthorhombic crystals of hydrated iron peroxide formed by the conversion of marcasite into limonite. This iron ore is quite plentiful, but seems not to be a native of the rock. It embraces crag and bog-ore deposits, and is referable to the drift period. (See under *drift.*)

The Jordan sandstone. The sandstone lying next above the St. Lawrence limestone, is not so frequently seen along the river bluffs. It is most commonly embraced in that interval of slope that comes between the two lines of limestone outcrop, which is mostly turfed over, as in the bluffs at Lanesboro, and at points between Preston and Lanesboro. Farther down the river, where the strike of the Shakopee runs back from the river a few miles on either side of the valley, it occupies the undulating surface between the immediate river bluffs and the boundary of the Shakopee, as at Rushford.*

In Fillmore county the thickness of the Jordan is not so great as it is

*This sandstone in the Minnesota valley has been mistaken for the Potsdam. the overlying Shakopee being supposed to be the lower portion of the Lower Magnesian. *Owen's geological survey of Wisconsin, Iowa and Minnesota.* pp. 481—495. See, also, Prof. James Hall's "*Notes on the geology of some portions of Minnesota from St. Paul to the western part of the state,*" 1865.

in the Minnesota valley. It seems to vary from twenty-five feet to forty feet. It is uniformly a coarse-grained quartzose, crumbling and light-colored sandstone. It is sometimes locally stained with iron from surface water, when it presents a reddish or rusty color, and is apt to be much harder. It has in such cases a shell or thin coating of harder rock about half an inch in thickness on the weathered surfaces, on penetrating which the grains are loosely cemented and even crumbling. In other places it presents internally a streaked appearance, due to the stoppage of iron filtering through its strata. No fossils have been found in it in this county.

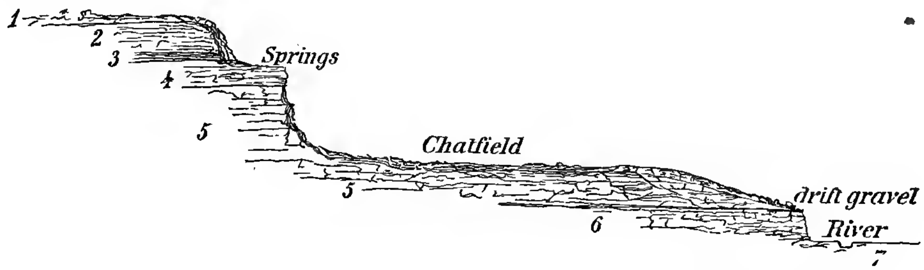
One of the best exposures for examining this sandstone may be seen at Preston, where it rises twenty-five feet above the level of the river opposite the stone mill, and is surmounted by about thirty-five feet of the Shakopee limestone. The bluff itself rises about ninety-five feet above the river, but the contents of the upper portion, though probably of the Shakopee, are not certainly known. The loam covers it. The bedding of the stone here is regular, though in some places a little wavy, and is of all thicknesses from a foot to three or four inches.

At Lanesboro the Jordan exhibits, near the top, a finely concretionary structure. The balls vary from a few inches to nearly a foot in diameter. Some of them are elongated, and several are frequently united. The rock itself is generally friable and crumbles out, leaving the concretionary shapes visible. They are often loosened and roll down the bluff. They lie in approximate layers for a thickness of four or five feet. Some of them are pendant from the projecting shelf, and stud the whole under surface. They are generally spherical, but when they are lengthened perpendicularly they show the original lamination that ran through the rock, in the form of rings and furrows.

At Clear Grit the Jordan is twenty-five feet thick, and is exceedingly ferruginous. At Lanesboro it is about forty feet thick.

The Shakopee limestone. This is so named from the village of Shakopee in Scott county, on the Minnesota river, where it was first identified as a distinct member of the great Lower Magnesian formation of Dr. Owen.* In Fillmore county it is more frequently seen along the valley of Root river

*Dr. Owen's detailed descriptions apply the name *Lower Magnesian* to the St. Lawrence limestone, and Dr. Shumard's to the Shakopee, as these limestones were regarded as one. Wherever they saw the Jordan sandstone they mistook it either for the St. Peter or the St. Croix, though in the latter case supposing it to be of the age of the Potsdam and its tributaries than any other formation. As it lies between two sandstones, each of which easily crumbles away under the operation of the elements, it is made to have a prominent position in giving form to valleys and river bluffs. The north branch of Root river enters it about six miles northwest of Chatfield in Olmsted county; the middle branch near the town line between Chatfield and Jordan, and the south branch but a short distance below Forestville. South Root river strikes it near Henry in Amherst township. Thus throughout about two-thirds of the county it is the constant companion of the traveler along the river valleys, and it meets him often in the uplands, and in the valleys of little creeks. Its effect on the topography is to render the valleys narrow, rocky and abrupt. East of the general area of the St. Peter sandstone and the Trenton limestone it produces a shoulder in the descent from the uplands to the valley. The following diagram, taken at Chatfield on the northern boundary of the county, illustrates in general the effect of this limestone in producing a terrace along the lower slopes of the river bluffs.



FIG, 17. PROFILE OF THE NORTH SIDE OF THE VALLEY AT CHATFIELD.

Explanation.

1. Loam.......6—10 feet.
2. Upper Trenton.......20—50 feet.
3. Green shale....... 15 feet.
4. Lower Trenton....... 20 feet.
5. St. Peter.......122 feet.
6. Shakopee....... 30 feet.
7. Flood plain.

The descent from the general level of the country at Chatfield (No. 1) to the river (No. 7) is about 222 feet, of which about thirty feet are of the Shakopee, the Shakopee being at the river. The broad terrace on which Chatfield stands is constituted of the Shakopee overlain by irregular thicknesses of the St. Peter, with some drift and loam. The lithology of the Shakopee is very much the same in Fillmore county as has been described in reports on Houston and Winona counties. It is very similar to the St. Lawrence, with much less of green-sand. It contains at Chatfield considerable disseminated sand, and nodules of calcite. The calcite is sometimes purely transparent, so as to exhibit the double refraction of Iceland spar, parting into large rhombohedrons, but the most of it is opaque. It is sometimes interspersed with sand grains taken up in the process of crystallization. These are so abundant as to make, of some crystalline masses, a sandstone which is then nodular and hard, with warty projections.

At Parsley's ford, center of section 15, Chatfield, a bridge has been built over the river, the abutments being of the Shakopee stone taken out near the ford on Mrs. Doyle's land. At the ford the river is on the Jordan sandstone. There has been considerable stone cut off the bluffs, in the Shakopee, for use in the railroad bridge near the same place, and laid up in heavy blocks; but much of the Shakopee is in irregular and thin layers, unfit for such use.

At almost any point east of Chatfield and Carimona the Shakopee can be seen by one crossing the valley of the Root river, exhibiting its peculiar tendency to narrow the valley, and forming a conspicuous bench or shoulder. The following diagram of a general profile section of the valley illustrates its form at points between Preston and Lanesboro; also between Chatfield and Lanesboro along the north branch. At Preston the rocks show a dip to the south.

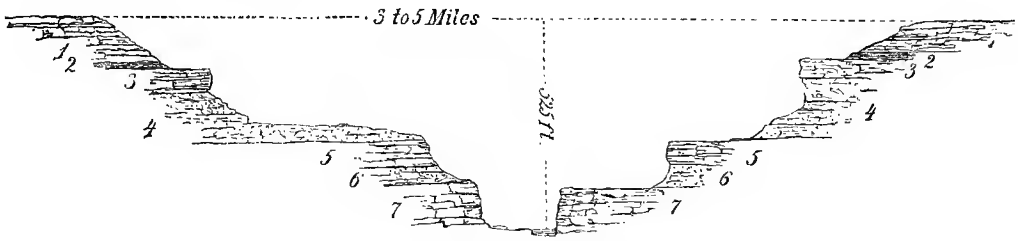


FIG. 18. GENERAL PROFILE SECTION ACROSS THE VALLEY OF ROOT RIVER.

Explanation.

1. Galena or Upper Trenton limestone.
2. Green shales.
3. Trenton limestone.
4. St. Peter sandstone.
5. Shakopee limestone.
6. Jordan sandstone.
7. St. Lawrence limestone.

At Isinour's station the battlements of rock that enclose the valley, rising about thirty feet above the water, are of the Shakopee. There is an undulating ascent thence over the St. Peter to near the Trenton terrace, which rises nearly perpendicular about fifty feet. Beyond that is a flat, running sometimes but eight or ten rods, but not unfrequently a quarter of a mile, when a further gradual ascent begins, covering the Green shales and the Upper Trenton. This last ascent, with the loam that here covers the country, generally makes about 175 feet.

VIEW AT LANESBORO
SHOWING THE SHAKOPEE AND ST. LAWRENCE
FIG. 19.

At Carimona the Shakopee is visible in the banks of the river, rising twenty-five or thirty feet. Its average thickness is about seventy-five feet.

The St. Peter sandstone. The thickness of this well-known formation in Fillmore county does not vary much from 125 feet. At Chatfield it measures, by aneroid, 122 feet. In lithological characters it is uniformly a clean, white sand that easily crumbles. Near Fountain an exposed section near the top of the formation afforded fragments of an unknown species of *Lingulepis*, the first and only fossil of any kind that had ever been reported from this rock.* The following section was taken at this place. It includes the overlying Trenton and the Green shales, as seen at the old quarry of Mr. Joseph Taylor, section 13, Fountain.

Section near Fountain. Quarry of Joseph Taylor.

No. 1. Green shale, embracing lenticular slabs of limestone that are eminently fossiliferous, seen 3 feet.

No. 2. Limestone, of a bluish-gray color, in beds four to six inches thick, free from shale, though the layers are sometimes thinly separated by shaly partings, 10 feet.

No. 3. Arenaceous and ferruginous shale, alternating horizontally with firmly cemented patches of sandstone, 2 feet.

No. 4. Massive, coarse sand; white, except when iron-stained; containing irony, quartzyte pebbles, and fragile remains of bivalves.

No. 5. Green shale, with some arenaceous and calcareous laminations, 3 feet.

No. 6. Cemented sandstone, the cement being shale and lime, forming when the bluff is weathered, the floor of a bench, 1 foot.

No. 7. White sand in beds that are about one foot thick and horizontal, 6 feet.

No. 8. A course in the sandstone more firmly cemented, forming a table, but less persistent than No. 6, 1 foot.

No. 8. Massive sandstone, in some places showing an oblique lamination, seen 6 feet.

*Prof. T. C. Chamberlin has since reported organic remains, consisting of the tubes of Scolithus and fucoidal markings, in the St. Peter sandstone in eastern Wisconsin. *Geology of Wisconsin*, Vol. II., 1873-7, p. 288. See also the Dakota county report.

The Southern Minnesota railroad here enters on its descent to the Root river valley.

The species of *Lingulepis* mentioned is found in No. 4 of the foregoing section. The remains are exceedingly fragile, and as the grains of sand in which they are embraced are feebly cemented together, it is nearly impossible to transport or even to handle them without their falling to pieces. These fragments, for no entire specimens were obtained, are arranged promiscuously in the coarse sand, and are all confined within three feet of the top of No. 4. They seem to have suffered the attrition and fracture incident to coarse sedimentary transportation.

The remarks that have already been made on the topography of the county, and the diagrams that have been given, will sufficiently elucidate the nature of the St. Peter sandstone, and its important part in the causes that have diversified the surface of Fillmore county.

The Trenton limestone. That which has been described hitherto, in this volume, as the Trenton limestone, embraces a thickness of strata amounting to not more than twenty-five feet. These calcareous strata are overlain in Houston and Winona counties, by a series of shales and shaly strata, embracing some lenticular layers of very fossiliferous limestone, likewise belonging to the Trenton period, amounting to perhaps twenty-five feet, which have been referred to the Hudson River epoch of that period. In Fillmore county, above these shaly strata, appears a considerable thickness of other calcareous strata belonging to the same period, which are the equivalent of the Galena limestone, and of the strata which in the reports of progress were distinguished as Upper Trenton, amounting to about 125 feet. The exact position of these strata in the Trenton period it is not possible to state, but there is some reason to include them all within the Hudson River epoch, with some evidence of the presence also of the horizon of the Utica slate.*

It has already been stated that the "green shales" of the annual reports seem to belong to the Hudson River group of New York. This is based mainly on the lithological resemblance; yet the Trenton fossil *Columnaria alveolata*, Goldfuss, was taken from these shales near St. Charles, in Winona county. If this coral be regarded as diagnostic of the Trenton epoch, the

*Compare Transactions of the Albany Institute, Vol. X. June, 1879. *The Utica Slate and Related Formations.* C. D. Walcott.

Trenton proper is increased to a thickness of about 160 feet, and the Galena formation only can be thrown with the epoch of the Hudson River, as a possible equivalent of the Utica slate.* The proper arrangement of the rocks of the Trenton period in the county may be expressed thus:

1. Maquoketa shales of Iowa, seen about 15 ft.
2. Galena limestone, vesicular and magnesian, and Upper Trenton, about 125 ft.
3. Shales and shaly limestone, containing *Columnaria alveolata*, 20–25 ft.
4. Trenton limestone, 20–25 ft.

Of these, the first at least belongs to the Hudson River group of New York.

There seems to have been little mention made of the "green shales," as such, in northeastern Iowa, in any of the geological reports of that state, although Prof. James Hall says that "a large admixture of shaly matter often marks the Black River limestone, which in some of its bands contains *Ormoceras tenuifilum*, and *Gonioceras anceps*," and that, "instead of alternations of calcareous and shaly laminæ at the base of the group, there are beds of shale of considerable thickness without defined limestone bands."†

Dr. John Locke, also, noted a series of strata at Prairie du Chien, in 1839, of which he observed a thickness of thirty feet, made up of blue fossiliferous limestone, abounding with its characteristic fossils, and having the usual external characters, alternating with blue clay-marl, the layers of stone being very thin and "apparently corroded," which he believed to be identical with the rocks of the Cincinnati group, or the Ohio blue limestone.‡ These beds lie, according to Dr. Locke, immediately above the "buff limestone," which is twenty feet thick, non-fossiliferous, and lies upon the St. Peter sandstone. This horizon of green shales is brought out distinctly after it enters the state of Minnesota, by reason of the part it bears in producing the peculiar mounds of the "mound limestone."

The transition from the St. Peter sandstone to the Trenton is quite abrupt. There is but little commingling of qualities from the Trenton downward into the St. Peter, although a shaly layer of about two feet separates them. The limestone always projects boldly beyond the sandstone, and the

*See the reports on Goodhue and Rice counties.
†Report on the geological survey of Iowa, Vol I., part I., p. 55 57.
‡Owen's report of a geological exploration of part of Iowa, Wisconsin and Illinois. 1839, as published by the U. S senate in 1844, p. 135.

sandstone becomes immediately white and friable, with a very slight calcareous cement. The Trenton plays the most important part in producing the marked topographical characters of the central portions of Fillmore county, since by its superposition over the crumbling St. Peter, it constitutes the edge of the shoulder or terrace that marks their line of superposition, and not unfrequently spreads out on the top of an isolated table or mound, thinly overlain by the lower layers of the green shale. Under the head of *surface features* this point has been mentioned already, and the reader is referred to that section.

In Fillmore county the Lower Trenton, known sometimes as the "buff limestone," which corresponds in horizontality with the limestone quarried at Minneapolis and St. Paul, is much less affected by disseminated shale than in those cities, and hence makes a much more desirable building stone. The color is light blue, and in quarrying the layers rarely exceed five inches in thickness. On weathered bluffs the bedding appears even thinner than that, being apparently not more than two inches. When these layers are opened and considerably quarried they combine, and produce layers that are from four to six inches in thickness. They are generally tough and hard, though when broken they often fracture conchoidally, and in unexpected directions. The most striking fossils are species of *Orthoceras*, often regarded by the quarrymen as the remains of huge snakes, though really oceanic shell-fishes, a beautiful species of *Lingula*, named *Lingula Elderi* by Mr. R. P. Whitfield, *Orthis tricenaria*, Con., *O. perveta*, Con., *Strophomena alternata*, Con., and numerous other brachiopods.

The following details concerning this limestone will further elucidate this formation as it appears at various places in the county.

S. E. ¼ sec. 23, Spring Valley, quarry of John Kleckler. The rock here is a gray limestone, with interlaminations of shale. This is very different from the Devonian limestones, as seen at Spring Valley village. It is compact, and, with the exception of the thin laminæ of shale, consists entirely of limestone. Exposed about ten feet.

S. E. ¼ sec. 23, Spring Valley, Jos. Lester has a quarry in the valley of the middle branch, very similar to Kleckler's. That of Henry Prosser occurs on S. E. ¼ sec. 14.

North part of sec. 25, Spring Valley. At Mr. H. Perkins' saw-mill the same rock is visible and has been wrought. From this point the banks of this creek become continuously rocky.

G. W. Knight's quarry is near Fillmore, sec. 10. The stone is hard, gray, compact, brittle and fossiliferous, in beds of all thicknesses, depending on the weathering and exposure, up to eight or more inches. It is situated along the ravine, approaching Fillmore.

Geo. Shepherd's quarry is also near Fillmore, on N. E. ¼ sec. 9, and seems to consist mostly of isolated even layers in the shale that so frequently accompanies the Trenton. In this shale are *Chætetes*, *Rhynchonella* and *Strophomena*. The stone is not of much account, owing to its being encumbered so heavily with the shale, but is very desirable for the uniformity of its thickness. S. C. Pettit has a quarry of the same kind, N. E. ¼ sec. 10.

At Chatfield the Trenton appears in the highest bluffs on the north side of the village. It is made up very largely of shale, but affords also some even layers that are wrought. These have the same stratigraphical horizon as the stone at Minneapolis and St. Paul, but do not contain so much argillaceous matter. They are much firmer and more compact, though not so thick in the aggregate. Below these layers the St. Peter sandstone is seen. The Trenton at this point has a gentle dip N. E., while the Shakopee at the mill by the river dips N. W. The brachiopods so common at the falls of St. Anthony, are here seen in great numbers, and an occasional specimen of *Lingula Cobourgensis*, Bill. The section at the quarry of Dennis Jacob is made up of seven feet of limestone and shale, crumbling away, underlain by about eight feet of limestone.

The old quarry of Mr. Joseph Taylor, sec. 13, Fountain, has been mentioned already under the head of the St. Peter sandstone, and the exposed section given. At this quarry very large cephalopods have been taken out, and some fragments of galena have been encountered. The strata which belong to the Trenton at this point may be more fully described thus:

Section of the Trenton near Fountain.

1. "Upper Trenton" strata, -	10 feet.
2. Green shales, containing various species of coiled shells, brachiopods, corals, lamellibranchs and a small trilobite. Some of the calcareous layers embraced in this shale are charged with oolitic brown hæmatite, giving them a very rusty color when disintegrating,	20 feet.
3. Limestone, of a bluish gray color, with some shaly layers,	10 feet.
4. Arenaceous and ferruginous shale,	2 feet.

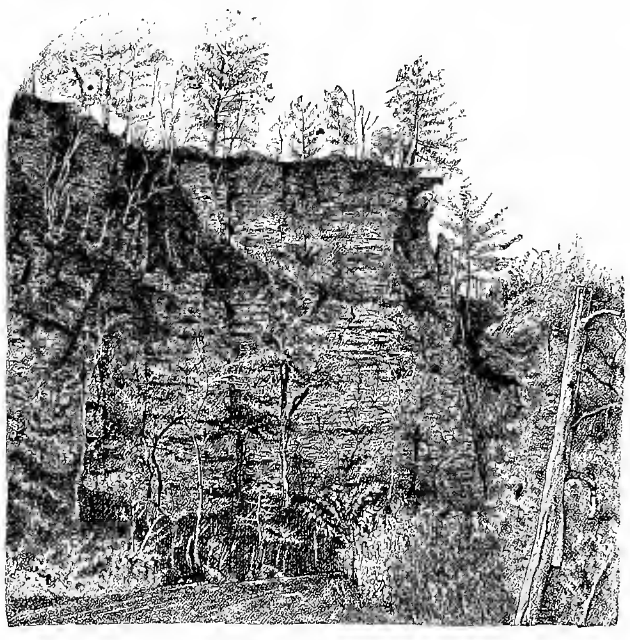
The quarry of Mr. Enoch Winslow is on the same horizon as Mr. Taylor's. It is situated on the bank of Sugar creek, S. W. ¼ sec. 4, Fountain. Another on the same horizon is that of John Johnson, two miles south of Fountain.

The green shales. The interval covered by the *green shale* (20 feet) is not often seen well exposed. The uppermost layers have been seen in Fillmore county only at Mr. Taylor's quarry above, but the lower layers are visible in many places where the Trenton is quarried. When wet constantly this shale becomes a plastic clay. Along the brow of the Trenton terrace it colors the earth in nearly all roadways that cross it, and produces, by shedding the surface water, very muddy spots, in which teams are sometimes mired. This shale always lies in thin layers, and sometimes embraces continuous beds of blue limestone which are exceedingly fossiliferous. It also sometimes holds fragments of limestone of the same kind, in the form of slabs. A great many fragments of *Chætetes Lycoperdon* accompany this shale and roll down the face of the weathered slope, besides crinoidal fragments, and species of *Orthis, Leptæna* and *Strophomena.*

The Upper Trenton and Galena. By the Iowa geologists the Trenton limestone has been considered as embracing not only the lower calcareous beds, and the green shales, but also a part of the overlying limestone strata, fading off to the Galena formation upward by a gentle lithological change in the rock. But since the Hudson River horizon actually covers everything of the Lower Silurian above the Trenton (in the absence of the Utica slate) this distinction between the "Upper Trenton," of the annual reports, and the Galena limestone, becomes one of much less importance, and of still less importance in counties farther north where the distinctive lithology of the Galena fades out altogether. Hence for the sake of convenience, if any designation besides Hudson River, be needed, the term Galena may include all the calcareous strata above the green shales, belonging to the Lower Silurian.

These calcareous beds, which have in part been denominated Galena, and in part Upper Trenton, include a thickness of about 125 feet, and consist of a bluish, or grayish, evenly bedded limerock varying from fine-grained and compact, in the lower part, in layers of a few inches, to more vesicular, sometimes arenaceous, and often magnesian, beds of one to two feet, toward the upper portion. They contain but little shale in Fillmore county, and that is near the base and near the top.

This rock forms a great many precipitous bluffs. It appears in the form of mural faces along a great many creeks and canons in the central portion of the county. It generally rises nearly perpendicularly from the top of a short talus to the summit, exhibiting a continuous section of the bedding. Its area is pre-eminently the region of sink-holes. The canons that are so frequent in it run out in ascending the valleys, and disappear in a succession of sink-holes which become smaller and smaller, and more and more distant, till the general prairie level is reached. While in general its ithological characters are quite uniform, near the top the layers begin to alternate with layers that exhibit the characteristic lithology of the Galena, and are accompanied with some thin layers of green shale. It seems to pass gradually into the Galena, or rather to assume the features that have been ascribed to that formation.



VIEW ON DEER CREEK (NEAR WEISBACH'S MILL.)
FIG. 20.

The accompanying views represent the manner of weathering of the Galena and Upper Trenton. At Weisbach's dam, on Deer creek, S. E. ¼ sec. 11, Spring Valley, the face of the bluff which rises perpendicnlarly abont a hundred feet, is wrought into a series of majestic pilasters running from the bottom to the top of the escarpment, as shown in figure 21.

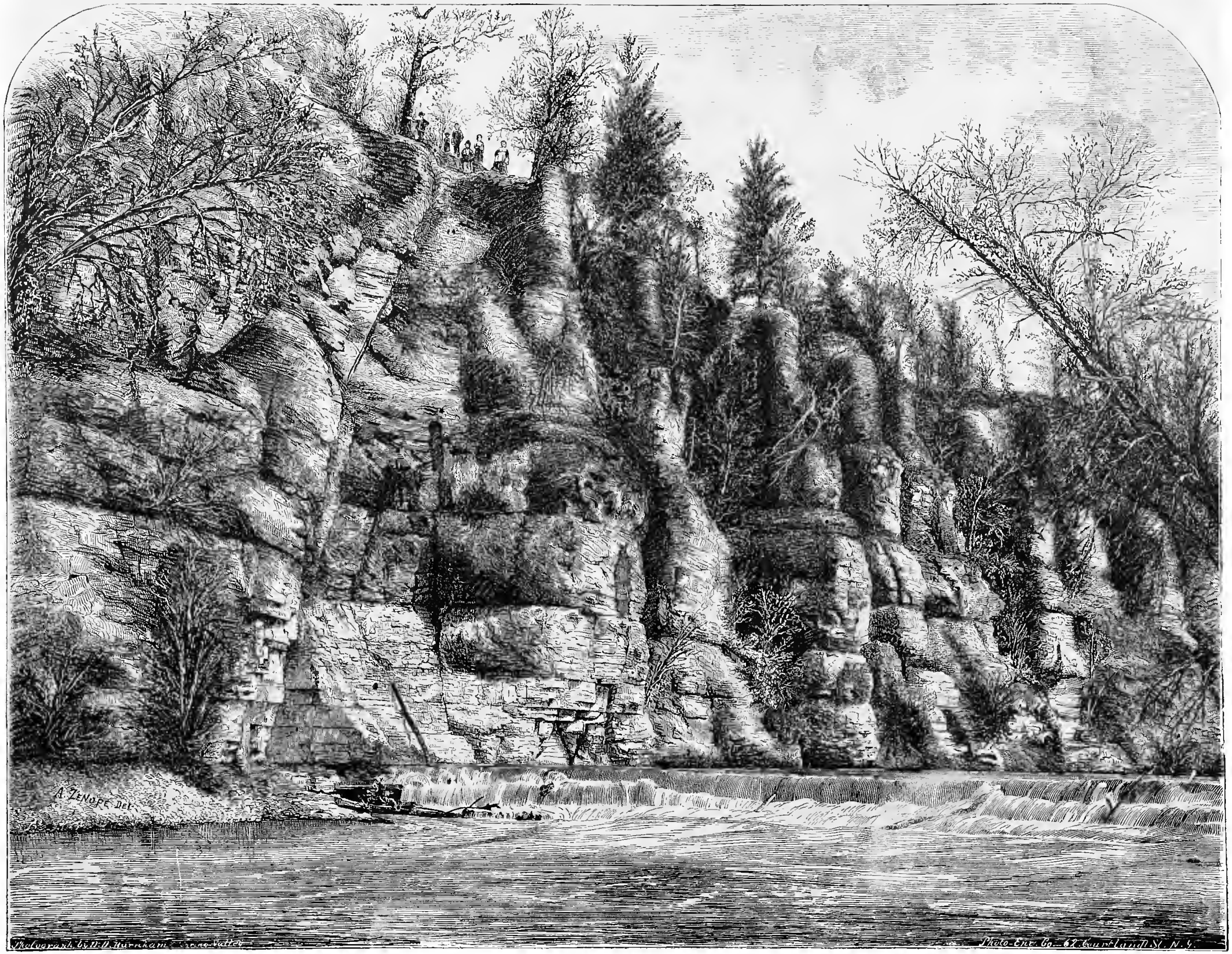


FIG. 21, VIEW OF THE GALENA BLUFF AT WEISBACH'S DAM
(From a photograph by D. D. Burnham, Spring Valley.)

The weathering and erosion of the Galena and Upper Trenton have left many scenes of picturesque beauty in the county. The following are some of the most noteworthy. Fig. 22 shows the Eagle Rocks, situated in the valley of the south branch of Root river, on sec. 27, Forestville. They stand isolated in the valley, but do not rise higher than the common rocky walls of the valley.

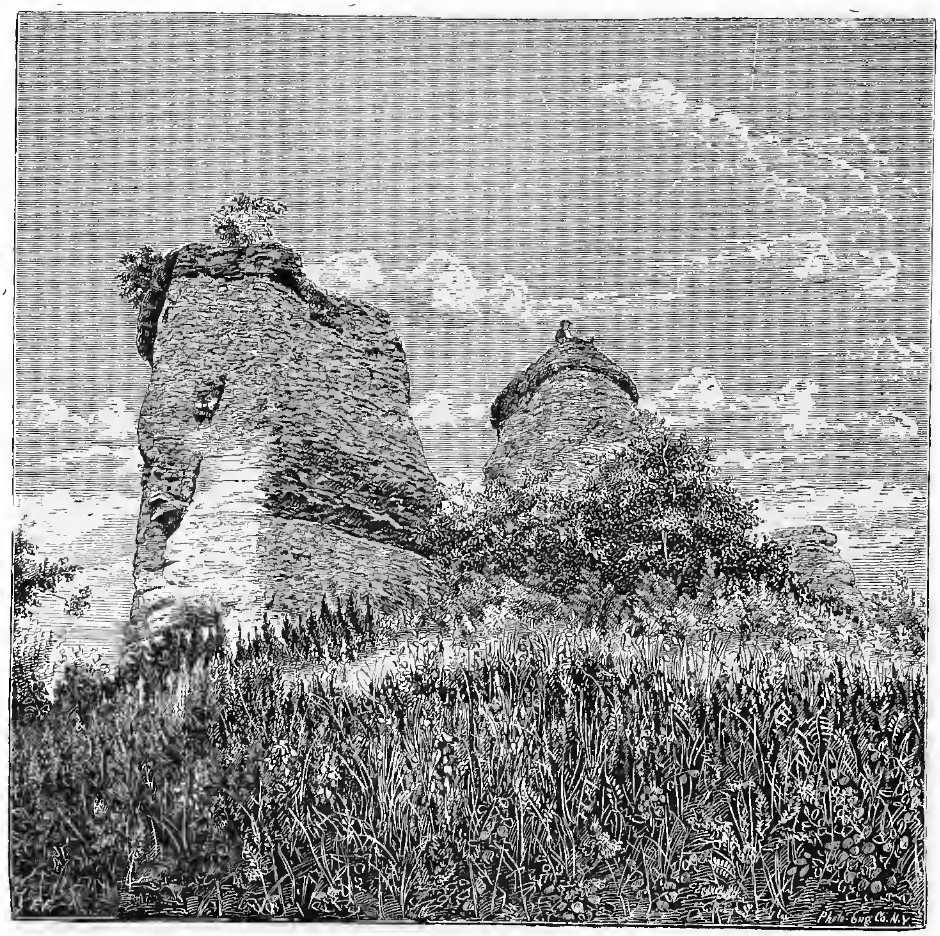


FIG. 22. EAGLE ROCKS.

Chimney rock is on the side of the bluff of a ravine, tributary to the south branch of Root river, on sec. 27, Forestville. A crevice, originally due probably to a plane of jointage, enters the rock at a small angle with the face of the bluff, and has been widened by frost and water till it will admit a man. The detached, wedge-shaped mass, has been broken through near the foot of the bluff, and by the falling out of repeated fragments an opening having a fancied resemblance to an oven with a low chimney has resulted.

Sometimes the Galena shows, on freshly opened quarries, along the bluffs, almost a white color. This is particularly the case on the N. ½ sec. 35, Sumner, where an opening in a long-weathered "hogsback" reveals a very light-colored limestone, in beds of about three inches, of a fine grain and compact texture, not much crystalline and evidently impure with argillaceous and siliceous qualities.

Extensive working and burning of the Galena into quicklime is carried on along Bear and Deer creeks, the banks of which are continuously rocky, rising perpendicularly from one to two hundred feet from the water, in Sumner and Spring Valley townships. These quarries are described under the head of *Economical Geology*. The Galena is also wrought at Forestville and near Carimona, presenting no exceptional features. At Forestville it contains *Receptaculites* and *Strophomena*, and exposes a thickness of about 140 feet.

The same rock appears in the S. E. ¼ sec. 6, Forestville, along a little ravine, and is slightly opened by John Hipes. It also appears at other points between there and Spring Valley.

At Baldwin's dam, sec. 21, Forestville, 130 feet of these calcareous strata are seen.

S. E. ¼ sec. 30, Forestville. In some fragments thrown out in the digging of a well a fine-grained rock occurred, resembling the fine shale seen in the race at De For's mill, which crumbles to pieces in the weather. It here lies below some heavy calcareous beds seen in the hills enclosing the valley, and contains doubtfully species of *Graptolithus*, *Orthis* and *Orthonota*.

At Granger the Galena only occupies the bluffs; but at two miles west of Granger, where the river enters the state for a short distance, the bluffs are high, and are made up of the Galena with a topping of fifteen or twenty feet of the Devonian.

N. W. ½ sec. 36, Bristol. Hiram Andrews has a quarry in the Galena, which alone occupies at this place the river banks, though the beds of the quarry are apparently in the upper portion of the formation. The layers are thicker than usual, somewhat vesicular, and present some of the conventional aspects of the Galena. The rock shows a slight dip to the south. Mr. Andrews has built a stone barn and stable.

The only separating horizon between the "Upper Trenton" and Galena limestones is a lithological change in the rock. There is no unconformability between the layers of the formations, and there in no known difference of fossil contents. Near the upper portion of the calcareous strata, occasional layers appear that are much more porous and have a light buff color. They are also much thicker than the layers of the Upper Trenton, reaching, after the change is fully established, a thickness of four or five feet. Mingled with these heavy magnesian layers are thinner layers of green shale. When these heavy magnesian beds are near the top of a bluff they give it a roughness but at the same time a persistence of outline which the thinner beds alone do not possess. This rock is sub-crystalline. It contains numerous cavities of irregular shape, some due to the weathering out of carious material and some to the absorption of fossils. It holds considerable masses of calcite, and sometimes lumps of galena, from which it has derived its name. Although the "Galena limestone" near Dubuque, in Iowa, is stated by Prof. J. D. Whitney to be about 250 feet, (*Geology of Wisconsin,* Vol. I., p. 172), the distinctive Galena characters enter Minnesota with a thickness much less than that. From all that can be seen of the strata in Fillmore county, they appear to be less than seventy-five feet thick. The Trenton, on the other hand, is given by the same authority, at seventy feet, average thickness, at Dubuque.

The characters that distinguish the Galena are not constant. In Fillmore county the "lead fossil", *Receptaculites,* pervades the strata as low as the green shale, at least, although regarded as characteristic oi the Galena; and the *Lingula quadrata* (or its near ally, with which it seems to have been confounded, *Lingula Elderi,* Whit.,) also said by Prof. Whitney not to appear in the lead region in the "blue" nor the "buff," is found throughout both. A very fine specimen was obtained, of *Lingula Elderi,* at Mr. Taylor's quarry near Fountain, from the Trenton ("buff limestone" of Prof. Whitney), and of *L. Cobourgensis,* Bill., from Chatfield from the same horizon. Lithologically also the two limestones appear to merge into one another. The compact, hard, blue limestone, characteristic of the lower beds, gives place near the top to a lighter-colored, slightly vesicular, even-grained, more heavily bedded rock that is very useful for an ornamental cut-stone. This is seen in some of the quarries a mile or two east of Spring Valley, where it is difficult to assign the beds either to one horizon or the other. A short distance farther east the well characterized lithology of the Trenton appears. The lead ore, moreover, which has given name to the Galena, is not confined to that formation. It is found to some extent both in the characteristic Galena and in the underlying more compact strata, though in neither to that extent that will warrant sanguine expectations.

The principal exposures of the typical Galena in the county are on Bear and Deer creeks, and on the south branch of Root river. At J. Shumaker's quarry, one mile east of the valley, about eight feet of the bedding are exposed. The layers here are of a finer and more uniform texture, and are associated with shales. When cut for building they are much whiter than the stone obtained at Mr. Allen's at Spring Valley. Inconsiderable quantities of galena are obtained at Spring Valley. No systematic exploration, however, has been undertaken, the pieces found being at or near the surface. It has been found at a number of other points in the county.

There is a weathered exposure of the Galena on land owned by Mr. Harris, N. W. ¼ sec. 26, Sumner. This outcrop fairly presents the typical lithological features that characterize the formation. By the Galena characters are meant a yellowish, or buff, limestone, vesicular, crystalline, in heavy layers, even on weathered bluffs, having usually a very rough exterior in consequence of atmospheric destruction of the looser portions. When these looser portions are removed, the surface of the rock presents a pitted aspect, becoming covered with thimble holes, and depressions of all shapes, with angular knobs and excrescences separating them, the whole overgrown with lichens. The exposure here shows perpendicularly about twelve feet, in layers from one to four feet thick, piled up on either side of the road in detached mounds, like bridge abutments from which the roadway has been removed. The "lead fossil", *Receptaculites*, appears in these layers.

The following is the composition of the Galena burnt for quicklime at Lime City, sec. 9, Spring Valley.

Oxide of iron,	.73
Calcium carbonate,	70.53
Magnesium carbonate,	23.49
Silica, &c.,	4.57
	99.32

The bluffs at Lime City consist of one kind of rock, being this dolomitic Galena, but rather more even and in thinner beds than is seen in some other places, making good white lime. They rise about seventy-five feet, but the perpendicular rock-bluffs are generally not more than forty. Some of the beds when quarried become three and four feet thick, and are firm and crystalline. They contain the fossils *Murchisonia* and *Maclurea*, and a *Strophomena* which is very prolonged-convex, like *fluctuosa;* also *Endoceras magniventrum*, and another orthoceratite at least nine inches in diameter and circular in section, and the "sun-flower coral."

At Weisbach's the top of the bluff is magnesian, and like that burned for lime at Lime City, amounting to about fifty feet, but below that the rock is more nearly a pure limestone; at least it is sometimes gray and aluminous, and sometimes like the compact rock at St. Charles in Winona county, ashen and brittle and fossiliferous; while in other places it is so aluminous as to disintegrate like that at the railroad cut near Spring Valley. There is perhaps a thickness of a hundred and twenty-five feet of this gray "Upper Trenton" rock below the magnesian beds that are burnt for lime. The level of the dam at Weisbach's must be nearly on the top of the *green shale*, but it can not be seen.

The Maquoketa shales. In Iowa Dr. C. A. White has given this name to a series of shales overlying the calcareous beds of the Trenton and Galena.* These were then believed to be the sole representative of the Hudson River rocks, in the Northwest, but since the underlying shales (the "green shales" of this report) contain well known Hudson River fossils, the whole interval of strata from the Lower Trenton to the Niagara are allied to that geological epoch. While it is very probable that this upper series of shales enters Minnesota from the south, being seen two and a half miles south of the state line, at Lime Springs, it has, as yet, hardly been identified within the limits of the state. Being made up of soft materials its outcropping edge is apt to be hid by the falling down of drift or loam, or of the overlying limestone. It will probably be a long time before any well authenticated localities of its existence are known. The following points may be mentioned at which possibly the upper shales exist in Fillmore county, viz., the shale excavated in the mill race of De For's mill, N. E. ¼ sec. 25, Bloomfield, and N. E. ¼ sec.

*Geology of Iowa. 1870. Vol. I., p. 180.

35, York. At Lime Springs, Iowa, the great shale bed which sheds water, causing the springs which gave name to the place, is supposed to be the Maquoketa.

Besides the foregoing points, the outcrop of shaly rock about a mile east of Spring Valley, exposed by the grading for the Southern Minnesota railroad, presents various interesting features. The fossils here seen consist in part of *Orthis testudinaria*, Dal., *O. subquadrata*, Hall, *Lynx*, Eich., *plicatella*, Hall, *subæquata*, Con., *amœma*, Winch. and *Whitfieldi*, Winch.; also *Strophomena fluctuosa*, Bill., and *Leptæna sericea*, Sow., as well as some forms of *Chætetes*, and of crinoids, indicating sufficiently the Lower Silurian age of the strata. These can be picked up in considerable numbers on the sloping surface which was scraped to obtain the loam for the railroad grading. This is on the north side of the track, but at a point a little nearer Spring Valley these beds are also exposed on the south side in the same way. In passing toward Spring Valley depot the grade descends a little, and reaches the spring-bearing horizon which has given origin to the name of the village. At the same time the argillaceo-magnesian strata of which but little can be seen at one mile east of the depot, are brought out more conspicuously, and are seen in outcrop on the north side of the valley at several old quarries that have been abandoned. Here these beds contain large specimens of *Strophomena alternata* (?), *Leptæna sericea*, Sow., and a small *Rhynchonella* that has not been named. But a little higher, in order of actual level, are the coarse cavernous magnesian layers on the south side of the valley, in the highway near the school-house, that have been parallelized with the Lower Devonian.* The actual superposition cannot be seen, but it is not possible for many feet of strata to intervene between them and the recognizable Lower Silurian strata. The general section at Spring Valley may be arranged as follows in descending order:

Section at Spring Valley.

1. Coarse magnesian strata, containing *Atrypa reticularis*, *Spirifer* and other shells; in outcrop only on the south side of the valley by the school-house, 4-6 feet.
2. Argillo-magnesian strata containing *Orthis alternata* (?) and *Leptæna sericea* and *Strophomena fluctuosa*, Bill., in outcrop on the north side of the valley at the abandoned quarries, in the northwest part of the village, and slightly at the railroad cut about a mile east, - - - - - 20 feet.
3. Shaly and argillaceous, containing numerous species of brachiopods of the Trenton period; seen at the railroad cut, and probably underlying the village, causing springs by its impervious nature. Under it are the limestone beds burnt for lime on Deer creek. Thickness unknown.

*See the Mower county report.

The Niagara limestone. This formation has been indentified in Fillmore county at but one point. It is much more enduring than the shales underlying it, but it enters on a drift-covered area, with small valleys of drainage only, some distance south of the state line. The nearest important point of its known outcrop is at Lime Springs, in Iowa. It differs from the Galena limestone in being much lighter colored, especially when broken or powdered. It is strongly crystalline, and often porous, but it is also, in some parts, a very firm and enduring limestone. It also has a very different and much more abundant fossil fauna. It is separated from the Maquoketa shales, at Lime Springs, by a limestone breccia of about eighteen inches. Its color, in its heavier and close-textured portions, is somewhat grayish, or leaden, and it is interbedded with hard shale which turns nearly white on exposure. This shale, in broken pieces, makes up the larger part of the breccia mentioned, and falls down the bluff in that condition, where it is lost in the weather, the framework of the cement only remaining, making a curious open network or mesh, the partitions and threads enclosing angular apartments. The great bed of shale, which causes the water-power here, may be 75 or 80 feet to the water, at the quarry of Mr. John Smith, though near the mill it is reduced to ten or fifteen feet. Throughout the most of that interval a heavy debris covers it from sight, the overlying Niagara only being visible along the top of the bluff. The Niagara has a dip of five or six degrees to the S. W., and passes below the Devonian limestones which are exposed and quarried at Lime Springs station, about a mile further south. The thickness of the Niagara included in that interval may be 100 or 150 feet. This underlying bed of shale gives rise to springs of limy water that enter the river along the bluff.

In the S. E. $\frac{1}{4}$ sec. 33, York, about forty rods north of the state line is a very small exposure of the Niagara in the bottom of a ravine, with the Devonian in the enclosing hillsides. A slight opening has been made in these beds. which are very porous and light-colored, and about three inches in thickness. Although no fossils were found here to identify the formation, the presence ot a very different rock well known as the Devonian, in the hills and ridges surrounding it, as well as the strong resemblance it bears to the Niagara at Lime Springs, will allow of its being regarded only as the Niagara limestone.

The Devonian limestones. Since the report of the Iowa geological survey of 1870, by Prof. C. A. White, in which the rocks of the Devonian were all regarded as belonging to the Hamilton epoch, various new facts have been brought to light in the Northwest, bearing on the age of the different parts of the Devonian. Prof. S. Calvin has reported the existence of a dark shale at least twenty-five feet in thickness, lying beneath the Devonian limestones at Independence,* which he considers sufficiently similar to the shales at Rockford, which overlie the Devonian limestones, to indicate that all the Devonian strata of Iowa belong to a single group. Mr. W. H. Barris has shown a fossil fauna in strata at Davenport that has a strong general affinity with the Corniferous.† These same strata had in 1858 been assigned to the Corniferous by Prof. James Hall. Some shaly beds at Rockford Profs. Hall and Whitfield have also referred to the Chemung in the Twenty-third report of the New York state cabinet.

So far as the Devonian appears in Minnesota it may be grouped in three parts, but to what particular portions of the New York nomenclature these may belong, it is still impossible to state. 1. *Shales and fine-grained, hard, thin-bedded magnesian limestones.* 2. *Harsh magnesian, heavy-bedded limestones.* 3. *Fine, argillaceous sandstones, becoming arenaceous in some layers and calcareous in others.* Of these only the second is known in Fillmore county, although it is possible that the first also exists beneath the drift in the elevated portions of Beaver and Bloomfield townships.

The Devonian limestones that appear in Fillmore county are very different, lithologically, from those that are found at Le Roy, in Mower county, They have the outward aspect of the Corniferous as seen in the states of Michigan and Ohio, and may be the equivalent of those strata, but owing to the meagerness of outcrops in the county no comparison can be made of their fossils with those of the Corniferous of New York.

The distinctively Onondaga features of the Ohio Corniferous ‡ are the only ones seen in Fillmore county. The color of the limestone is like that of the Galena. Its texture is generally even and non-vesicular, harsh to the feel and granular like most magnesian limestones. The bedding is

*Bulletin of the United States Geological and Geographical Survey of the Territories. Hayden. Vol. IV., p. 725

†Proceedings of the Davenport Academy of Sciences. Vol. II., p. 261.

‡That portion of the Ohio Corniferous here referred to is the lower—as seen at Columbus, Delhi, and Millpoint. The overlying blue beds, seen at Delaware, Marion and Sandusky, are supposed to represent the Hamilton. See *Proceed. Am. Asso. Adv. Sci.*. 1873, p. 100; also *Am. Jour. Sci. and Arts*, Apr., 1874.

generally less than eight inches, though when quarried it is often taken out in heavy blocks more than two feet thick. Its color is yellowish, and it is tolerably free from such impurities as chert or calcite lumps. It is suitable for most purposes in common masonry. It has a few brachiopods, *Atrypa reticularis* being the most common and most conspicuous, and an incrusting bryozoan like *Fenestella.*

At Lime Springs station, Iowa, is a quarry in the Lower Devonian, exposing about ten feet. At Hopkins' quarry, situated two miles west and a little south of Lime Springs, about twelve feet in heavy layers can be seen, without fossils but holding some flint—dip S. E. At Chester similar beds are exposed near the mill, three-fourths of a mile south of the state line. It is here in heavy beds, of a soft, uniform, granular texture and yellowish color, useful for cut stone.

At Foreston, one mile south of the state boundary line, the Devonian appears in the lower river bluffs, and is in very rough and heavy beds. It presents numberless cavities of all shapes, as large as a thimble and larger, and often iron-stained. It here has a noticeable dip to the south. While it is fossiliferous, it is so coarsely and so completely crystalline that the fossils are either entirely absorbed or remain as indistinct impressions or imperfect casts. It contains white calcite in some large masses. The river itself at Foreston is probably on the Galena, the water-power there improved being due to a change from the firm overlying layers to a soft shale indicating the upper portion of the Hudson River group. On the state line, due north from Foreston, a limestone appears in the road, of a coarsely crystalline grain, with calcite and cavities, entirely like the Devonian. It is observable in a number of the hilltops, and extends half a mile, at least, north of the state line, north from Foreston; and a fourth of a mile east (N. E. $\frac{1}{4}$ sec. 35, York) the Galena appears on the northeast side of a ravine, while the Devonian appears on the southwest side, the road running between the two and probably passing over the Maquoketa shales. The rock has a perceptible dip toward the south. The Devonian occupies the high river-bluffs from that point nearly to Granger, on the north side of the river, when it passes to the south and lower beds take its place, both having a dip toward the south. This rock is probably that which is said to appear in the river banks, sec. 34, Beaver, on Jerry Kingsley's land.

S. E. ¼ sec. 20, Beaver. This rock is again seen here, exposed along the banks of Beaver creek; owner's name unknown. It here shows a brachiopod resembling *Orthis*, and a radiating *Fenestella*. It is in the midst of an uninhabited prairie, and only weathered pieces can be found.

S. E. ¼ sec. 18, Beaver. Several years ago a cellar, dug for a farmer's residence, furnished stone of the same kind in sufficient quantity to construct his house. Similar rock again appears in the road, N. W. ¼ sec. 20, Beaver, but is somewhat more vesicular.

Widow Scarrie has a small quarry in a yellowish, fine-grained rock almost non-fossiliferous, and probably of the Lower Devonian, on the S. E. ¼ sec. 28, Bloomfield. Outwardly this much resembles the sandstone exposed at Austin, in Mower county; but it has a doubtful brachiopod that appears like *Atrypa*. Its weathered color, its homogeneity and fineness of grain, and its irregularly rounded cavities containing loose, ochreous dirt, indicate it to be the equivalent of that. It is with some doubt classed as Lower Devonian.

This limestone is found in loose pieces, and often in surface exposures, on the tops of knolls near the state line, in secs. 33 and 34, York, the porous, white Niagara appearing in the ravines.

At a point two miles west of Granger the Devonian is fifteen or twenty feet thick, in the top of the river bluffs. These thick beds give a squareness and prominence to the tops of the bluffs, presenting a perpendicular rock-wall toward the river. Large masses of this rock fall from the bluffs and weather into the usual rough forms. Though this exposure embraces rock that is a little softer than the Devonian at Foreston, yet in color, crystallization and all general characters it is the same.

At the crossing of the south branch of Root river, N. E. ¼ sec. 21, Bloomfield, there is no cut in the rock visible. The river is but about twenty feet below the level of the country, which is in a broad shallow valley; but in the road are a few pieces of rock showing fossils and lithology like the Devonian at Spring Valley. The country here, and toward the southwest, is a broad level prairie, gently rising toward the west.

N. W. ¼ sec. 26, Bloomfield. The south bank of the river, near the west side of the section, has a rock bluff exposed about twenty feet above the river. This is massive, or in heavy layers, and is doubtfully assigned to the Devonian, as it has some of the features of the Galena. It is firm, but porous; of a buff color, and a coarse magnesian grain, with superficial cavities due to the weathering out of fossils. It is on the land of Mrs. Annie Postle. A similarly doubtful exposure, slightly quarried, is owned by Dora Wright near the center of sec. 14, Bloomfield, by the roadside. Wm. B. McNee has also taken out the same stone near his barn, N. W. ¼ sec. 14, and used it in his barn foundation. It here holds considerable calcite.

At Etna Mr. S. S. Belding has a quarry in the Devonian. This is a soft, porous stone, in heavy beds, which once held fossils, but which have been lost by absorption, leaving the rock porous, and finely vesicular. Mr. Belding states that this limestone has a hydraulic quality, but as near as can be ascertained it makes simply a quicklime which endures well under repeated wetting. The rock here seen amounts to eighteen or twenty feet. Other quarries, similar to Mr. Belding's, are owned by O. M. Postle, N. W. ¼ sec. 36, Bloomfield, by George Hoy and Mr. De For, N. E. ¼ sec. 25, and by H. T. Odell, S. E. ¼ sec. 36.

At De For's mill, N. E. ¼ sec. 25, Bloomfield, the rock exposed is fine and even-grained, belonging probably to the lower portion of the Devonian. It embraces one thin layer of a shaly limestone which has turned white. It makes a good quicklime. It is in heavy beds of about eighteen inches, and holds a coarse coralline form (*Syringopora?*) seen also at the quarry of Mrs. Postle, already mentioned. Below these heavy layers is a bed of shale which was exposed in the digging of the mill-race, having a thickness of five and a half feet. Below that thickness the shale becomes arenaceous, and in the weather crumbles to pieces. Among the crumbled fragments are indistinct remains of the buckler of a small trilobite. This shale may belong to the Maquoketa shales of Iowa. At Spring Valley quarries are worked to a greater or less extent by Mr. Willard Allen, Thomas Thayer, Eurylas Parsons and Nelson Smith. These openings are on the south side of the valley and are all in about the same kind of stone. Some of them furnish as yet only rough large pieces, water-worn and rusty, dislodged from their original places. The rock has undergone long weathering and erosion at Spring Valley, and is disintegrated and changed to a considerable depth. Along the road near the public school, a small cut in the shattered crumbling layers has exposed a great number of detached casts of a brachiopod, resembling that of *Atrypa reticularis.* These were regarded with great curiosity by many as "little turtles" petrified.

The outcrops of rock about Spring Valley have unusual geological interest, since they seem to demonstrate the entire absence of the Upper Silurian, and the immediate superposition of the foregoing limestones of the Devonian upon the Lower Silurian. The exposure of rock about one mile east of Spring Valley by the railroad grade, having Hudson River fossils, is overlain by four feet of a carious, evenly-bedded, argillo-magnesian limestone, like the argillo-magnesian limestones seen at Spring Valley on the north side of the creek at about the same actual elevation, where they have been somewhat quarried but abandoned as unfit for masonry. They can be seen by the topography, and by occasional outcrops, to extend from one place to the other. At the latter place they exhibit fossils that indicate their Lower Silurian age, such as *Strophomena alternata* and *fluctuosa,* and another strophomenoid brachiopod. They probably belong to the upper portion of the Lower Silurian, and perhaps represent, with the underlying shaly beds at the railroad cut, the Maquoketa shales of Iowa. They have an exposed thickness of about fifteen feet. Directly across the creek, on the south side, are the nearly horizontal beds of magnesian limestone, containing the coarse casts of *Atrypa reticularis,* which is supposed to belong to the lower portion of the Devonian limestones, having such a topographic relation to the foregoing that no considerable thickness of beds can intervene between them. The strata are all nearly horizontal, the dip being so gentle toward the southwest that it can not be observed in the short lines exposed.

N. W. $\frac{1}{4}$ sec. 16, Jordan. In ascending the south bluff of Lost creek large loose pieces of Devonian limestone are seen in the road, but the Galena is in outcrop at the creek. Similar pieces appear on sec. 31, Jordan. These are on the most eastern limits of the Devonian area, and belong to the lowest layers of the formation.

The Cretaceous. No attempt is made to map out the Cretaceous area in Fillmore county, inasmuch as it is all embraced in the drift-covered portion, and but one or two localities of its existence are known. It probably extends no further east, however, at any point than the east side of the first tier of towns along the western border of the county. Its area is most reliably indicated by the surface features, in the absence of actual outcrops. Guided by this only, it is supposed to occupy the flat and prairie portion of Sumner township, stretching southward through Spring Valley and Bloomfield and crossing the most of Beaver, and perhaps portions of York. Judging from the prevalence of Cretaceous features in the drift-clay exposed in the railroad cut at Lime Springs, it has played an important part in originating the materials of the heavy drift-covering that spreads over not only the western portion of Fillmore county, but all the counties of the state further west.

The lower portion of the Cretaceous, which seems to be that represented in this county, consists of sandstones and lignitiferous clays or shales, the sandstones lying at the base of the formation and being the same that Dr. White has denominated in Iowa the Nishnabotany sandstone, and belonging to the Dakota group, of Messrs. Meek and Hayden. Above this sandstone, which is often white and incoherent, with a thickness of about one hundred feet, so far as observed, is a clayey member of the Cretaceous which has been identified by Mr. F. B. Meek* as the Fort Benton group, of Messrs. Meek and Hayden. These rocks are well exposed in the region of the upper Minnesota valley and contain some impure lignite, and are found in small pieces disseminated, with fossils, through the drift-clay cut at Lime Springs, a couple of miles south of Fillmore county, in Iowa. The Niobrara or chalky member of the Cretaceous, may also exist in the western portion of the state. So far as Fillmore county is concerned the presence of the Cretaceous is known more by certain indirect or secondary evidences, than by the actual discovery of its beds *in situ*.

Near Spring Valley, on David Higby's farm, S. W. $\frac{1}{4}$ sec. 32, is a very fine and tough clay, of a generally bluish color, almost entirely free from grit, which is spread out over a wide area, lying but few feet below the surface. The overlying soil, which is annually plowed, is a black loam (rather clayey), varying below to a yellow, clayey loam. This clay was discovered several years ago, but nothing has been seen that will demonstrate its real origin, though it is evidently not a part of the drift. It has the appearance of being suitable for pottery, or for brick, but would require some sand. A soapy, variegated clay also occurs at J. W. Smith's brick-yard,

*American Journal of Scienee, (3) III. 23.

two miles northwest of Spring Valley, though a drift clay with some gravel is used in the manufacture of brick. A similar clay is met in abundance at Spring Valley village, but it is mingled with limestone fragments and drift materials.

Besides these clayey deposits, which are believed to have resulted from the degradation, or more or less perfect preservation, of the lower Cretaceous clays, there are a number of white sand deposits in the same portion of the county, which probably are referable to the incoherent layers of the Nishnabotany sandstone. One of these occurs north of Mr. J. W. Smith's brick-yard, on sec. 17, Spring Valley. Another is situated on C. C. Temple's land, S. E. ¼ sec. 8, Bloomfield, where it is twenty feet thick at least, having been tested to that depth, the bottom never having been reached. It here occurs in an open prairie country, and is known to spread out over many acres, lying but two or three feet below the surface. It lies on the Devonian limestones, of course unconformably. It is not a purely white sand, like the St. Peter, but yellowish white. It is sometimes very fine, but varies to coarse. Another deposit of this kind is on Mr. Andrew McNee's land, N. W. ¼ sec. 22, Bloomfield, and still another on J. M. Rexford's, N. E. ¼ sec. 36, where it has been opened, as at the other points named, and used for mortar. This is situated in an undulating tract, with some shrubs and trees. These sand beds are not regarded as belonging to the Cretaceous rock *in situ*, but as being copious, local products, under drift agencies, of the Cretaceous. Sometimes they embrace lumps of clay of a greenish color, like the Fort Benton, and sometimes they show oblique stratification. They are entirely uncemented, so as to be shoveled directly into the wagon*. Another singular deposit, in the same manner referable to the immediate presence of the Cretaceous, occurs in the S. W. ¼ sec. 15, Bloomfield, land of Peter Peterson. Here a series of knolls, which embrace, indeed, that in which is Mr. Andrew McNee's white sand pit, and are covered with aspen and hazel brush, are found, many of them, to be composed of a beautiful, coarse gravel, the greater part being white, often limpid, quartz, the size of the pebbles varying from that of a pea to that of a hazelnut. On these knolls are a few northern drift boulders, and no doubt the gravel was also placed in the position it now occupies by the drift forces. This gravel, so

*Compare the Second annual report, pp. 134 and 185.

remarkably homogeneous, like the white sand deposits mentioned, can only be referred to the immediate proximity of the lower Cretaceous. It could not have been far transported without being mixed with other rock material. It distinctly points to the existence of a coarse gravel or conglomerate in the lower Cretaceous, of which traces have been seen in several counties. It indicates also the littoral nature of the Cretaceous beds from which it was derived.

There is still another indirect evidence of the existence of the Cretaceous in the western portion of Fillmore county. There are heavy deposits of limonite iron ore, bearing some unascertained relation to the Cretaceous, or to the drift found in the southwestern part of the county. In the second annual report of the survey mention was made of the occurrence at a number of places in the Minnesota valley, and in that of the Blue Earth, of a coating of iron ore on the Cambrian rocks where they are unconformably overlain by the Cretaceous. Dr. Shumard says of this (Owen's *Geological Survey of Wisconsin, Iowa and Minnesota,* page 487): "The nodules of iron ore have mostly a concentric structure, and appear to be of good quality. The superficial indications render it probable that this bed of iron ore may be both extensive and easily accessible." In Fillmore county a discovery was made by Mr. C. C. Temple in digging a well near his sand pit, already described, and referred to the Cretaceous as its probable source, which throws some light on the manner of occurrence of the limonite referred to. He testifies that *this bed of iron ore is at least thirty-six feet in thickness.* In this well, which is six feet in diameter at the top, he dug down about eighteen feet, when he reached rock, fragments thrown out revealing the Galena limestone. He describes the rock as occupying but about one-half of the diameter of the shaft he was digging, which afforded great quantities of soft limonite or ochre. He drilled into the iron ore a depth of thirty-six feet. A number of wells in the vicinity of Etna, a few miles further southeast, also struck a similar iron ore. On sec. 36, Bloomfield, a great many loose pieces of porous limonite are found in the fields, having been plowed up in the soil. The county surveyor, Mr. J. Gregor, also found it impossible to lay out the quarter sections of that section in the usual manner, by the use of the magnetic needle, though the original United States surveyors record no disturbance of the magnetic needle. Limonite iron ore is regarded usually as non-magnetic. In large quantities, near the surface, it seems to influence the magnetic currents. What relation this ore bears to the Cretaceous is not known, except that it has been found to overlie the Cambrian rocks, or to cover their surfaces with a scale, where the Cretaceous overlies them unconformably.

The Drift. The drift presents some interesting features in Fillmore county. The western limit of that well-known tract denominated *the driftless area*, by Prof. J. D. Whitney, crosses this county. This boundary is not well-defined. There is a very conspicuous absence of the bluish clay and the northern boulders that distinguish the true northern drift-sheet of counties further west and north, throughout the eastern two-thirds of the county, the boundary line running, approximately, from the southeast corner of Bristol township, to the northeast corner of Jordan. West of that line, which is modified in its course by valleys and uplands, is a belt of five or six miles in width which is characterized by an overlapping of the loess loam on the thinning out edge of the drift-sheet. This belt is characterized further by peculiar local modifications of the materials of the drift, due to the underlying rock, as mentioned under the head of *Cretaceous.* West of this belt the true drift becomes prevalent, consisting of clay with many boulders.

That tract which is regarded as driftless* is, so far as Fillmore county is concerned, not without some evidences of having been subjected, at some time, to a force similar to that which is supposed to have deposited the great drift-sheet of the Northwest. There are isolated patches of gravel, with small stones, sometimes cemented into a crag, which have been noted in Fillmore county, scattered sparingly over the eastern part of the county, as the following field minutes will show:

Drift pebbles are in the street north of the school house, S. W. ¼ sec. 25, Amherst.

Drift occurs in the form of gravel and boulders, some of them a foot in diameter, S. W. ¼ sec. 4, Fountain, on the east bank of Sugar creek, in the road; seen in going east from the quarry of Enoch Winslow. At Fountain village there is said to be no drift between the loess loam and the rock.

A little drift may be seen at the Tunnel mills, sec. 34, Sumner.

There is a little fine drift visible along the road, S. E. ¼ sec. 25, Sumner.

At Chatfield there is some gravelly drift with small boulders, visible in the street near the mill-race.

Drift, with pebbles and stones, appears about a mile south of Clear Grit, on the Shakopee terrace along the highway; also on the road to Carimona, near Preston.

*J. D. Whitney, *Geology of Wisconsin*, Vol. 1, pages 114, 139.

About midway between Preston and Carimona a wash by the roadside revealed loam, 8 feet, underlain by gravelly, red loam 3 feet, with no distinct separation, a few small boulders lying in the water-course below.

At Carimona a thin layer of drift is usually found under the loam.

The same is true at Forestville.

At Spring Valley the drift is so prevalent that the surface of the country is smooth, and has a lighter-colored soil, with much more clay. There are but few stones or gravelly patches. The loess loam is hardly noticeable. One large boulder lies at the street corner, half a mile south of the corporate limits.

Between Baldwin's mill, sec. 21, Forestville, and the state line, due south, the country is one of drift prairie, nearly the whole distance, with stones and boulders, some of the latter pretty large.

At Etna, sec. 36, Bloomfield, among a variety of stones pertaining to the drift, may be seen an occasional one that is *glaciated.*

At Lime Springs and Foreston, a few miles south of the state line, on the Upper Iowa river, the drift is abundant.

At Granger there is a light drift, and also where the road turns north to Preston, N. E. ¼ sec. 36, Bristol; but it becomes lighter still, or entirely invisible, in traveling to Preston. In its place a heavy rich loam, rather clayey, covers the country and smooths it off almost as effectually as if drift-covered. A well, being dug about five miles south of Preston, on the high Trenton area, passes through the loam eighteen feet before striking the rock.

The drift is very thin at Lenora, if not entirely wanting.

About four miles southeast of Preston a large green dioritic boulder may be seen lying in the loess loam, in the road, and a red quartzose pebble. The pebbles that appear in the gullies by the roadside, in the loam area, are generally of chert, from the rock of the locality. It cannot be ascertained whether this dioritic boulder lies on other drift deposits, but it is surrounded laterally only by the loam.

At Elliota is a thin drift, in the form of pebbles, the largest being three or four inches in diameter. Thence northwestward to Newburgh, nothing but the yellow loam is observable. Between Newburgh and Riceford, situated on the western edge of Houston county, no northern drift is visible; but at Riceford, which lies in a deep and narrow gorge, a few drift pebbles occur in the street.

About the center of sec. 29, Holt, is a deposit of gravel. It may be seen in descending the hill northward, just before the road forks to Whalan and Lanesboro. It is considerably cemented by lime, forming a crag, large lumps of which, some eighteen and twenty inches thick, have been used for embankment on the lower side of the road. In some parts it is quite fine, and useful for mortar, for which it has been hauled away. It is at least ten feet thick.

There are boulders in the valley of Duxbury creek, sec. 28, Preston.

Sec. 19, Pilot Mound. In the road going to the river from the south, are a lot of boulders and other drift. The same can be seen on the north side, going up from the ford. The deposit seems to be five or six feet thick, gradually mingling with, and finally becoming replaced by the loess loam.

Drift gravel and stones are seen along the road in going down the hill to Isinour, from Preston.

Drift pebbles and clay occur at the crossing of Watson's creek, on the direct road between Fountain and Preston, and on the terrace of the Shakopee limestone, a quarter of a mile south of the creek.

Boulders are seen at Spring Valley, and at Mr. Kleckler's farm, two and a half miles east of Spring Valley.

An occasional boulder is seen in the river valley at Geiner's mill, sec. 31, Jordan; but the most of the surface covering on the rock in the high prairie region, seems to be of the loam.

East of Highland post office in Holt township, sec. 36, is a conspicuous deposit of drift, exposed in the road, in the form of a stony gravel. It lies on the brow of the Shakopee terrace.

It is noticeable that in nearly every instance where drift pebbles occur in the region known as driftless, they lie on or are very near an outcrop of firm rock. They frequent the brow of the terrace formed by the Shakopee limestone. The above named localities are nearly all embraced within the boundaries of the driftless tract as already defined in Fillmore county. These patches of northern drift present the appearance of greater age than the drift of the western portion of the county, and are believed to belong to a glacial epoch that preceded the epoch that produced the great drift-sheet of the Northwest. An "interglacial epoch" separated them. It was probably during that interglacial epoch that grew the peat and coniferous vegetation that has been found in considerable abundance embraced within the great drift-sheet (or at least below fifty feet of drift materials), around its outer margin, as mentioned in the report on Mower county, and as further demonstrated in Fillmore county. It is the older drift that is covered deeply by the loess loam, and *it is within the loam-covered portion of the county that true river-terraces of alluvial composition are found.**

Ancient peat and vegetation in the drift deposits. There were found to be quite a number of places in the western portion of the county where farmers in digging wells have struck a bed of vegetation† similar to that also described in Mower county. No opportunity has been afforded to make a personal inspection of this bed, and owing to the indefiniteness of the information derivable from the farmers themselves, and its contrariety, it is thought best to give only the statements of Mr. Calvin E. Huntley, of Spring Valley, a professional well-driller. Throughout the whole of the county there is much difficulty in obtaining ready water for farm and domestic use, and a great many wells are drilled deeply into the rock. This is owing to the canoned character of the rock surface, both within the drift area and the loam-covered portion. These canons serve as subterranean drains, though they are generally filled with drift in the western part of the county. Mr. Huntley furnished the following facts concerning this bed of vegetation. Some of these localities are within the limits of Mower county.

N. W. ¼ sec. 6, Beaver, land of Andrew Oleson (Early). It was found here at the depth of thirty feet, situated on a ridge in prairie country. It was two or three feet thick, and had a blue clay both above and below it; then struck a limerock.

N. E. ¼ sec. 12, LeRoy, Mower county, land of D. B. Bosworth. This was also on a high

*Compare *Geology of Ohio, Vol. II., Report on Delaware county.*

†For further information on the subject of vegetation in the drift deposits of the Northwest, the reader is referred to a paper by the writer in the proceedings of the American Association for the Advancement of Science, 1875, Detroit meeting.

ridge, with blue clay above and below it, and lay at the depth of about twenty-five feet below the surface. It had a thickness of seven feet, and contained "decayed stuff, like pressed hay."

N. E. ¼ sec. 1, LeRoy, Mower county, land of Ole Knutson (Stoley); found at the depth of thirty feet, five feet thick; blue clay above, and two feet of black clay below; then limerock.

Sec. 30, Bennington, Mower county; on land of Gents Everson. This is situated on a flat, and was found from thirty to thirty-two feet below the surface. It was three feet thick and lay below blue clay. Below it was gravel to the thickness of eight feet, when the well struck limerock.

S. E. ¼ sec. 9, Bennington, Mower county; land of John Meehan. It here had blue clay both above and below it, and had a thickness of two feet. It lay at the depth of twenty feet. The underlying blue clay was gravelly.

It was met in the same town on Robert Cooper's land, at the depth of twenty-five or thirty feet. It was here on a very high ridge. It was in a blue clay, with gravel both above and below, and three or four feet thick. This well was abandoned on account of quicksand.

On the slope northeast from Mr. Cooper's it was reported to have been met with at the depth of six or seven feet from the surface, on the land of Mr. Bap.

Sec. 2, Sumner, land of Wm. Bailey; met a deposit which was embraced between layers of what was then supposed to be limerock. This deposit was two feet thick and consisted entirely of wood. Rock was struck at the depth of eight feet. This wood was thirty-five feet below the surface. The owner called the rock "grindstone rock." This is probably a Cretaceous sandrock embracing a bed of lignite.

N. part of sec. 28, Spring Valley, land of A. B. Hutchinson. An irony deposit having an unknown thickness, was struck at the depth of thirty-five feet.

This was also met in the central part of Racine, Mower county, on the farm of D. Reed, at the depth of twenty-five or twenty-six feet. It came up in chunks which glistened and looked like iron ore.

Under the head of *Cretaceous* the reader will find further statements concerning this iron ore. Two miles west of Spring Valley, on the land of O. H. Rose, is a deposit of conglomerate. This is abundantly cemented with iron, lying on a sloping surface covering twenty-five or thirty square rods, rendering the land unfit for cultivation, in the vicinity of no rock-bluff, and on a prairie country. Iron ore was thrown out of a well on S. W. ¼ sec. 24, Bloomfield. It was said to have come out in lumps, and to be as heavy as iron. It rises to the surface and a plow cannot be passed through it. This is owned by Geo. H. Smith. Again on H. T. Odell's land, sec. 36, Bloomfield, it is found in scattered lumps variously mingled with the soil and with other stone. These surface pieces are impure, and often hold cemented gravel and pebbles. They are also loose and porous, and pass into ochre. Similar pieces occur on sec. 1, Beaver, land of O. A. Boynton.

Wood was taken from two wells in Jordan township, secs. 29 and 30, on land of M. Robbins and Geo. Hare. This is also on a high prairie. In Mr. Hare's well was said to have been a tree.

In order to study further the thickness of the drift, and its lateral extent in the county, a great many observations were made on the phenomena of common wells, and the tabulated list herewith appended will give the results of some of those examinations. It has already been said that there are a great many subterranean streams, especially within the area of the Trenton limestone. Some of these streams gush out along the river bluffs and give rise to copious springs. Wherever there is an open rock-structure, which is not imperviously covered by the drift or by the loam, it acts to receive the surface water and to allow its passage along lower levels to the main river valleys. This necessitates the drilling of a great many wells which penetrate in the rock to a depth, sometimes, of two or three hundred feet before reaching water.

WELLS IN FILLMORE COUNTY.

OWNER'S NAME AND LOCATION.	DRIFT OR LOAM. FEET.	IN THE ROCK. FEET.	TOTAL FEET.	KIND OF WATER.	REMARKS.
Public well, Fountain	12	290	302		Water at 13 ft., but lost it by entering a cavity after drilling 5 or 6 ft. deeper.
Poor farm, sec. 4, Canton	22	30	52	good	In yellow sandrock; last 2 ft clay.
W. H. Strong, Carimona	20	43	63	good	Drilled.
Wm. Holton, Carimona	22	38	60	good	Drilled.
J. H. Hall, NE. ¼ sec. 9, Bloomf'ld	41½		41½	good	Sand and clay.
E. Steffins, Spring Valley	6	80	86	good	"On the ridge."
Col. C. G. Edwards, Spring valley	6	47	53	good	"On the ridge."
Calvin E. Huntley, Spring Valley	7	31	38	good	Very hard water.
Peter Swab, sec. 6, Jordan	8 in.	69	70	good	In a "red sandstone."
Wm. Twiggs, 1½ m. SE Spring V.	10	40	50	good	Three wells. same depth.
S. S. Belding, Etna	10	22	32	good	Hard water.
J.M.Rixford,NE ¼ sec36,Bloomf'ld	20	75	95		
Jas. Smith, SE ¼ sec. 18, Beaver	5	50	55	good	Water in limerock.
A. C. Seelye, Lenora	20	55	75	good	
M. L. Potter, Lenora	90		90	good	No rock.
Old town-well, Lenora	ab't 20		55		" In a large crevice in the rock."
Wm. Barton, 1½ m. N. of Lenora	20	110	130		
Jas. Walsh, sec. 20, Amherst	13	67	80		Sandrock and limestone, water in limestone.
W. Kimber, SW ¼ sec. 29, Amherst	34	82	116		
S. S. Stark, NW ¼ sec. 2, Amherst	28	100	128		Gets dry in summer.
Henry Rose, NE ¼ sec 3, Amherst	25	117	142		Gets dry in summer.
Public well, Highland P. O.			65		
Andrew Vogt, SW ¼ sec 20 Amh'st	7	85	92	no water	Well incomplete.
Mrs. Simmons, sec. 35, Spring V.	8	35	43	good	Last three feet in bluish-green shale.
Public well, Spring Valley	12	2	14	good	
A. N. Hart, Spring Valley	14	6	20		Last foot in bluish limestone; some "oily blue clay."
S. W. Knight, sec. 11, Fillmore	15	95	110	tolerably good	
S. Hoff, Fillmore	18	8	26	good	Eight feet in St. Peter sandstone.
D. S. Hoff, Fillmore	18	0	18	good	Sand and gravel,
J. Kleckler, SE ¼ sec. 26, Spring V.	4	27	31	good	27 feet in Trenton limestone.
F. Greaves, Chatfield	10	40	50	good	40 feet in blue limestone.
Tho. Simpson, Chatfield*	9	31	40	good	31 feet in blue limestone.
W. H. Dunham, Chatfield tp	10	50	60	good	10 feet yellow clay and stone.
E. Leonard, sec. 14, Sumner	17	0	17	good	Six feet of water.
J. B. Silbert, 2 m. E. Spring Val.	19	0	19	good	Two layers of gravel.
C. B. Brocksom, 2½ m. E. Spring V.	16	33	49	good	9 ft. in drift; 7 ft. in loose rock.
F. Lageirg, 3 m. E. Spring Valley	ab't 20	32	52	good	
J. H. Hall, 2 m. S. Spring Valley	27	14½	41½	good	Clay, quicksand and bluish stone.
O. H. Rose, 2½ m. W. Spring Val.	20	29	49	good	Found a vein of Venetian red, 10 ft from the surface,
O. H. Rose, 2 m. W. Spring Val.	8	48	56	good	Soil, gravel and clay.

The loess loam. The greater portion of the county is covered with this loam. It contains no gravel nor boulders, or with very rare exceptions, but consists almost entirely of fine siliceous material which becomes in some places quite clayey, making a very slippery mud when wet. This in outward appearance is of a light yellow or rusty color, and differs in that respect from the loam seen on the drift-covered portion of the county,

*There are but few wells in Chatfield because of the necessity of drilling from twenty to a hundred and fifty feet in the limestone.

which is frequently black, or brown, varying to an ash-color when mingled with a considerable percentage of clay from the drift, and also contains gravel. The surface loam is very homogeneous over wide tracts, while that in the drift area is subject to local and sudden varations. The loess loam is indistinctly stratified, in valleys, but the usual appearance on the uplands is that of non-stratification. This stratified arrangement is rendered the less evident from the great similarity of the materials from the top to the bottom. It does not consist, apparently, in any change from coarse to fine in the sedimentation, but in a *lamination* of the homogeneous clayey loam, and is easily obliterated by exposure, or by trickling water. This condition was noted particularly in the valley at Preston, and indicates that it there was deposited in still, or gently moving water. Where this loam lies over the old northern drift, it passes through a gravelly stage, the materials of the loam mingling with the coarser portions of the drift, and becoming finally replaced by the drift. The drift patches covered by this loam, pertaining to the eastern and central portions of the county, and believed to belong to an earlier drift epoch, are, so far as seen, made up of gravel and sand, with small stones. Very little drift clay, or till, like that which covers the western part of the county, has been seen overlain by the loess loam, to the east of that which pertains to the general drift-sheet of the Northwest, and which occupies a narrow belt, five or six miles wide, where the loam overlaps the later drift. It may be seen at several points between sec. 4, Canton, and Lenora. At one point it is a light-colored, or ashen, gravelly clay, which above is very irony or rusty. Over the surface are numerous fragments of chert, with some small boulders of granite and green-stone, and jasper and quartzitic pebbles. It is covered by several feet of loam. It is seen similarly in the N. E. $\frac{1}{4}$ sec. 12, Canton.

The pebbles that are thus mixed with the lower portion of the loam are smooth and waterworn, not covered with a coating of decayed material of the same nature as the pebbles themselves, as they would be expected to be if the loam were derived from the decay, *in situ*, of the materials of the drift. The thickness of the surface loam sometimes reaches twenty feet in the open upland, and under favorable circumstances, where it might have accumulated laterally, as well as perpendicularly, it is much more. It is thickest in the eastern part of the county.

It has already been stated that there is some reason to assign an earlier date to the origin of the upland loam than to the stratified loess loam of the valleys,* and it is equally true that there is some reason to assign to it a different origin. Indeed, the explanation of its origin advanced by Prof. J. D. Whitney,† in 1862, is applicable over a very large part of the "driftless area" in the state of Minnesota. He says: "The great mass of superficial clay, loam and other loose materials lying on the solid rock in this region, is therefore simply the residuum left after the more or less complete solution and removal of the soluble portion of the rock." It is quite probable that all the instances of lamination that have been seen in the surface materials of the "driftless area" may be referred either to the agency of rivers when existing with larger volume than at present, and flowing at higher levels, or to the effect of local drainage, bringing fine sediment from the higher levels farther west, perhaps at the time of the last glacial epoch, and depositing it both on the pre-existing drift materials and on the older loam. The rotted and disintegrated condition of the surface of the older rocks on the higher levels in the county, the existence throughout this decayed interval, and sometimes extending upward in the loam, of pieces of chert referable to the rock itself, the great uniformity in the character of this loam, and its massive or non-stratified structure, point to this theory for its origin.

Alluvial terraces. At Preston, besides the flood-plain, the river has a high terrace-plain. The Stanwix House stands on it. It consists of loess loam undistinguishable from the loam that covers that portion of the county. The same may be seen at Lanesboro, and at Whalan, but it is not conspicuous. At Rushford fragmentary remains of this high terrace are seen in the valleys of the tributary streams. Along the main valley they are not well preserved. There are two terrace levels, besides the flood-plain. The highest terrace-plain is from seventy to eighty feet above the second, and about one hundred and thirty feet above the river. The lower terrace, on which Rushford stands, is about forty feet above the river, and is probably never reached by the river in even the highest water. Within this lower terrace-plain, which spreads out laterally and forms the most of

*Report on Winona county, p. 262-3.
†Geology of Wisconsin, 1862, p. 126.

the alluvial land between the rock-bluffs, is the river channel, and a still lower flood-plain about twenty feet above the river at low stage. This terraced condition of the valleys of Root river and of the Mississippi, is confined, so far as observed, to the loam-covered area, which nearly coincides with the "driftless area", as defined and described by Prof. J. D. Whitney.

MATERIAL RESOURCES.

Fuel. In addition to the products of the soil, which will always be the chief source of material wealth, Fillmore county cannot expect any important mineral discoveries to augment her material prosperity. She has a good supply of forest for purposes of common fuel, and will not suffer from the absence of coal, as some of the counties farther west have suffered. She will have to depend on her native forest trees, or on those that are being propagated succesfully, for the most of her home fuel supply. There is a marked absence of peat in this county as well as in Mower, but a single locality being noted. That occurs on S. E. $\frac{1}{4}$ sec. 26, Spring Valley, land of John Kleckler and David Broxlem, and is said to be about four feet thick, covering four or five acres. There is no doubt that other, isolated, small areas, of a turf-peat, also exist in the county, but the circumstances which promoted the production of so large a surface of peat in a belt farther west, including Freeborn county, were certainly wanting in Fillmore county. The frequency of lakes and swamps, and abundance of peat, coinciding as they do in Freeborn county, taken with the absence of both in Mower and Fillmore, point to the existence of a common cause for these surface features.

Iron. Throughout the western portion of the county there is a great deal of surface iron, manifesting itself generally in the form of a cement in gravel, forming a dark-colored *crag*. There is also much evidence of the existence of a heavy, continuous layer, or deposit, of limonite iron ore a few feet below the surface, in Bloomfield and Beaver townships. The details of these localities, and of the evidence of iron so far as ascertainable, have been given under the heads of *Cretaceous* and *Drift*. Should this bed prove to be extensive, its actual value for commercial purposes may vary greatly from its intrinsic value. It consists of a loose-textured hydrated peroxide, with ochery impurities, and bears a close resemblence to some bog-ore deposits; but its occurrence on high land, instead of in swamps, necessitates some other explanation for its existence than that ascribed to the occurrence of most bog-ore deposits. It may have originated during that swampy condition of southern Minnesota when the peat grew that is embraced in the drift deposits, as already detailed. It is not probable that it will ever be found valuable for the manufacture of iron. Before the opening up of the vast and richer iron ore beds of Michigan and Missouri, the bog-ores were considerably used in the production of iron, on a small scale, in several of the western states, but the small furnaces that smelted them have all ceased operations many years ago. Another obstacle to the utilization of this deposit in Fillmore county will be the lack of fuel in convenient and sufficient quantities.

Lead. While the Galena limestone, which is eminently lead-bearing at Dubuque and Galena, passes in its northwestern trend across the southwestern portion of Fillmore county, it has not been discovered to afford the same amount of lead as in Iowa and Illinois. Indeed, at points more remote from the Mississippi river, in Iowa, no remarkable deposits of lead have been obtained from it. There is not a total absence of lead from its layers, since a few localities are known to have afforded it in limited quantities. The same is true of the Trenton; which seems to indicate that the presence of lead in the limestones of this region does not depend on the kind or age of the formation, but rather on some later, superimposed conditions that prevailed over the region, subjecting various formations to the same influences.

Quicklime. All the limestones of the county are suitable for quicklime, but by far the greater quantity is made from the Galena. In the townships of Sumner and Spring Valley all the circumstances necessary for the cheap and rapid production of quicklime of the best quality co-exist, viz.: a suitable limestone, abundant exposure, and plenty of fuel. The Galena there forms some of its characteristic outcrops, constituting the bluffs of the streams continuously for many miles, and rising a hundred or a hundred and fifty feet above the valleys. The kilns are built at the foot of the bluff, and the stone is cheaply obtained, without much cost of transportation. Wood is also abundant at present, much of that portion of the county being covered by a heavy forest growth.

The following list of lime-burners with their localities and estimated production for the year, will give some idea of the extent of the business in 1874.

Palmer & Miller, Bear creek, three kilns	2,000 bushels.
N. E. Fetterly, Bear creek, three kilns,	5,000 bushels.
L. G. Odell, Bear creek, three kilns (one draw-kiln)	5,000 bushels.
Charles Gorton, Bear creek, one kiln,	1,000 bushels.
Allen Brothers, one kiln,	1,000 bushels.
J. Finley, Bear creek, one kiln,	2,000 bushels.
Isaac Kegley, Bear creek, one kiln,	600 bushels.
Lem. Stout, Bear creek, one kiln,	2,000 bushels.
T. J. Hammer, Bear creek, one kiln,	2,000 bushels.
Elder Cyrus Young, Bear creek, two kilns,	Not in use.
Harvey McQuillan, Bear creek, two kilns,	Not in use.
Olds & Brakey, sec. 9, Spring Valley, one kiln,	2,000 bushels.
J. N. Cummings, sec. 11, Spring Valley, one kiln,	
J. H. Hall, sec. 12, Spring Valley, one kiln,	3,500 bushels.

These all burn the Galena, and there is no noteworthy difference in the quality either of the rock or of the lime produced. According to the testimony of several, however, there are certain layers near the bottom of the formation which are not suitable for quicklime. Some layers also are arenaceous, and have to be avoided, but the great mass of the rock is exceedingly well adapted to making quicklime.

The kilns used, are, for the most part, of the rudest construction, presenting no improvement over the ancient and well-known "pot-kiln." They have to be emptied and refilled for every burning. Mr. L. G. Odell has the only draw-kiln seen in the county. In this part of the county mixed wood sells for two dollars or two dollars and fifty cents per cord. The average price of lime is twenty-five cents per bushel, but it fluctuates from twenty to forty. In July, 1875, it was selling for twenty cents; but in September it brought forty cents. The lime itself is generally nearly white after being burnt, but in some places it has an ashen white color, though on slacking it is always white. It slacks with rapidity, evolving considerable heat. It requires from sixty to seventy-two hours to burn a kiln, depending on the size of the kiln and somewhat on its shape, and consuming about ten cords of dry, mixed wood. When freshly and thoroughly burnt one bushel by measure weighs about seventy-five pounds, but if not well burnt it will exceed eighty pounds. "Delivered at Spring Valley by weight, it is sold at the same price as by measure at the kiln." When shipped from Spring Valley it generally goes west, to points along the Southern Minnesota railroad, and is known as *Spring Valley white lime.*

Throughout the county, where the Trenton limestone appears, there are other lime kilns that supply the local demand. The following were noted:

At Carimona, owned by William Renslow.
At Forestville, by Frank Turner.
At Chatfield, by Dennis Jacobs.
Sec. 35, Carimona, by Mr. Rollins.
Sec. 25, Canton, by Simon Houck.

The Shakopee is not used for making lime in Fillmore county, though it is extensively burned in the lower Minnesota valley, at Mankato and at Shakopee. The St. Lawrence limestone is somewhat employed for this purpose, and affords a lime that is nearly white, and is said to weigh eighty pounds per bushel of measure. At Lanesboro this lime sells at $1.25 per barrel, or fifty cents per bushel, wood costing five or six dollars per cord. Mr. Sherman's kiln holds about three hundred bushels and requires ten to eleven cords of wood for thorough calcination, burning about forty-eight hours. But little is shipped from here. The lime is about white and slacks perfectly white. The following list embraces all known kilns that were run from the St. Lawrence in 1874.

At Lanesboro, by B. Sherman.
At Lanesboro, by Moses Greer.
At Lanesboro, by Mr. Butler.
At Rushford, by Jos. Otis.
At Rushford, by Wm. Crampton.

Brick. There is no lack of materials for making common red brick. In some places the surface of the drift clay is used, containing some fine gravel, and at others the loess loam. Brick-making machinery was met with in the survey of the county at the following points:

Sec. 20, Spring Valley, J. W. Smith.
Forestville, Michael Shields.
Preston, Franklin Coleman.
Lanesboro, Thomas Dunsmore.
Chatfield, Wm. Stafford.
Lanesboro, W. H. Roberts.
Rushford, Ole Tuff.
Granger (formerly), Mr. Ferris.

Gold and copper. In small quantities gold has been washed, by rude methods, from the drift at several points in the county. It was found on Hugh Hague's land in gravel, N. E. ¼ sec. 26, Spring Valley, and at Yeariton's saw mill, sec. 31, Jordan. There are accounts also of fragments of native copper having been found in the drift. It is hardly necessary to say that these discoveries do not indicate any valuable deposit of the kind in the rocks of the localities where they may be found. They pertain to the drift and have been transported hundreds of miles along with the other foreign substances in which they occur, from the northern part of the state. Such discoveries have sometimes awakened an interest that has culminated in stock companies formed for mining, and in the wasting of thousands of dollars. Similar small quantities of gold can be got by a minute washing of the drift at almost any place where the drift-sheet is attenuated, or where the older glacial drift has been denuded, leaving the gold, which is indestructible either by lapse of time or by the chemistry of the elements, on the rock surface underlying. Almost every geological report in the country makes mention of them, extending at least through Ohio, Illinois, Indiana, Wisconsin and Iowa.

Building stone. With this necessary article Fillmore county is also well supplied, and it has been put to an extensive use. There are hundreds of openings made to supply a local demand, besides a great many more extensive quarries which are known for a good many miles around. A great deal of stone for building is shipped to counties west, which are drift-covered and without accessible building stone. Probably three-fourths of the building stone used in the county is derived from the Galena and Trenton, the other fourth being made up from the Devonian and the St. Lawrence. The Trenton is most frequently employed. This is largely owing to the prominent manner of its outcrops, as shown under the head of *Drainage* and of *Surface Features.* The Galena has been used in the construction of several school-houses and private residences. At Spring Valley the Devonian is principally used; at Lanesboro, Whalan, Peterson and Rushford, the St. Lawrence. The Shakopee and Jordan are but rarely resorted to.

The beds of the Trenton are usually less than six inches in thickness, and they are easily broken to any desired size. It is a hard stone, not easily cut, but can be dressed if necessary. It is not injured by disseminated shale, as much of the Trenton at points farther north, and hence makes a very durable material. The quarry ot Mr. Joseph Taylor, formerly well known, situated near Fountain, has been closed for several years. At Fountain are several buildings constructed of stone from this place.

Besides the quarries in the Trenton that have been mentioned in giving the scientific geology of that formation, a number were visited at which no new facts of interest were noted. Such were Ole Oleson's, N. E. ½ sec. 36, Harmony; Wm. Wilbright's and Martin Quinn's, sec. 15, Forestville; Geo. Drury's, sec. 3, Bristol; Garrett Mensing's, S. W. ¼ sec. 27, Forestville. It would be impossible and unnecessary to mention all the places where this limestone has been wrought. In traveling over the county a number of stone houses for residence were seen, belonging to farmers. Such are O. O'Hara's, S. W. ¼ sec. 18, Amherst, from the Trenton; Mr. Geo. Park's, sec. 37, Bloomfield, from the Galena of Mr. S. S. Belding's quarry. The stone mill at Preston is of the Trenton. Of the quarries in the Devonian at Spring Valley, those of Mr. Shumaker and of Mr. Allen are the most important. The former furnishes a beautiful, fine-grained cut-stone for trimmings, as well as stone for common walls. The latter supplies a darker-colored and coarser stone, which has been considerably used.

From the St. Lawrence limestone a very fine building stone is obtained. It is a fortunate circumstance that very much of this formation is in regular, and often in heavy layers. These are also not so firm as to resist the usual means for quarrying. When the beds are broken the blocks are found to possess often a finely vesicular texture. Their color is a very light yellow or buff, resembling that of the "Milwaukee brick". The principal buildings at Lanesboro, including the Lanesboro Hotel, the flouring mill of Thompson and Williams, the Presbyterian and Catholic churches, the public school-house, and a number of stores, are of the St. Lawrence, quarried at Lanesboro, and from land owned by the Lanesboro company. At Whalan are excellent opportunities for observing this stone in its best condition. It has been somewhat wrought on Whalan's bluff. Quarries in the same are owned at Rushford by Wm. Crampton, Jos. Otis, and Hiram Walker. Mr. Crampton's quarry furnished the stone put into Boyam's store, and also that of A. K. Hanson's. Mr. E. Larson's was built from Mr. Otis's quarry, and that of Mr. Kierland and son from Mr. Walker's. At Amherst P. O. the Jordan is quarried some for foundations, and the Shakopee at Chatfield.

Sand for mortar and concrete. Wherever the St. Peter sandstone is accessible it is employed for making mortar. It is equally good for hard-finish, being, when taken from some depth, purely white and of very uniform firmness. There are, however, some portions of the county where it is much more difficult to obtain a sand suitable for common mortar. In the western part of the county a white sand, or one nearly white, is obtained from deposits referable to the Lower Cretaceous. These have been mentioned under the head of *Cretaceous*. They are found on the land of C. C. Temple, S. E. ¼ sec. 8, Bloomfield; on sec. 17, Spring Valley; on Andrew McNee's land, N. W. ¼ sec. 22, Bloomfield; and on J. M. Rexford's, N. E. ¼ sec. 36. Mr. Temple delivers sand at Spring Valley for $1.75 per load of two tons. One team can haul five such loads per day, but generally hauls three. From three to five hundred dollars worth are taken from Mr. Temple's sand pit annually. Besides these sources for mortar sand, the Jordan sandstone which is often as incoherent as the St. Peter, can be used to advantage, though it is rather more apt to be cemented by iron. There can be no question that the compact and impervious nature of the green shales of the Hudson River have preserved the incoherency of the St. Peter, by preventing the downward percolation of ferriferous and calcareous waters which certainly would have left their impurities in the form of cement among its beautiful white grains.

The proximity and cheapness of lime and sand have suggested the building of houses by mixing these substances in the form of a concrete. Several such are found at Fillmore, also in Jordan and at Rushford; but this method is not general. The material is cast in the form of large brick, having the color of common brown mortar, and these blocks are laid up much like common brick walls. Patent presses are used to make the concrete blocks.

Calcareous tufa. At Chatfield there is considerable travertine in the bluffs on the north side of the creek, and on the limestone layers, in the seams. It has become crystalline in some cases, and lies in successive laminations that have a color like brown sugar, and resembles the lamellar calcite of Houston county.

CHAPTER VII.

THE GEOLOGY OF OLMSTED COUNTY.

BY M. W. HARRINGTON.*

Situation and area. This large and wealthy county (plate 11) lies in the second tier of counties north of Iowa, and is separated from the Mississippi river by only Winona county on the east. Its form is nearly that of a rectangle, with five ranges of townships east and west and four ranges north and south. This geometrical figure is rendered irregular by Wabasha county which takes two townships from the northeast corner. This irregularity is further increased by the addition of an east and west row of twelve sections on the western part of the south side of the county, which extend also half a mile farther west than the rest of the county.

The land area of the various townships is given in the subjoined table derived from the records in the office of the state auditor:

NAME.	TOWNSHIP N.	RANGE W.	ACRES AND FRACTIONS.
Elmira	105	11	23,008.69
Dover	106	11	23,019.01
Quincy	107	11	23,038.81
Orion	105	12	22,992.53
Eyota	106	12	22,983.90
Viola	107	12	22,977.97
Pleasant Grove	105	13	23,020.18
Marion	106	13	22,963.10
Haverhill	107	13	23,005.91
Farmington	108	13	22,810.11
High Forest	104 105	14 (6 sections) 14	26,804.42
Rochester	106	14	22,973.76
Cascade	107	14	22,915.45
Oronoco	108	14	22,968.06
Rock Dell	104 105	15 (6 sections) 15	26,809.22
Salem	106	15	23,002.35
Kalmar	107	15	22,990.60
New Haven	108	15	23,057.89

*To the original survey and report of Prof. Harrington (fourth annual report) considerable new material has been added.

The area of Olmsted county embraces 658.42 square miles of land, or 421,391.08 acres; its water area is 3.94 square miles, or 2,520.20 acres; making a total of 662.36 square miles, or 423,911.28 acres.

SURFACE FEATURES.

Natural drainage. Streams are plentiful and their fall is moderate. The central, northern and western parts of the county are drained by the Zumbro river. This stream runs north into Wabasha county, where it turns east and makes its way to the Mississippi. It comes into Rochester from the southwest, and within the city limits Bear creek from the southeast, Silver creek from the east and Cascade creek from the west, empty into it. Near the north line of the county it receives quite a stream, resulting from the union of the middle and north forks of the Zumbro. The southern tier of townships are drained by Root river, which, very sinuous, takes a generally east course to the Mississippi. This has no affluents of much size in the county, except at Chatfield where a small stream known as Mill creek joins it from the north. On the eastern border of the county some small branches of the Whitewater river reach within the county.

There are no lakes in this county, but it contains a few small ponds which in no sense deserve the name of lakes. Streams which sink into the ground and disappear are occasionally met with. They occur in Farmington, Elmira, Haverhill and Viola townships, and are especially frequent where the sandstones of the Cambrian have combined with the magnesian limestones to produce a gorged and broken condition of the strata in preglacial times, followed by a thin spreading of till or of loam. The same conditions produce sink-holes and subterranean streams in the area of the Galena limestone wherever the drift is light so as not to have filled compactly and completely the pre-existing gorges.* These phenomena are more particularly noted on a subsequent page where these formations are discussed.

Living springs of cool, pure water, of the best quality, are not rare. They are by far the most common on the south or west sides of the bluffs where the green clay derived from the lower rocks of the Trenton period comes to the surface. This clay is impervious to water. The formations

*Compare the report on Fillmore county.

dip slightly toward the southwest. The layer of clay forms a nearly level floor of which the southern and western sides are lower than the others. The water consequently appears at the surface on these sides. These springs are frequently of large size. The phenomenon of a row of springs some distance up the side of a bluff, while the base of the bluff furnishes no springs, is by no means a rare one. Spongy earth, and sometimes calcareous tufa, are apt to collect about these springs. When filled with water the earth is soft and very miry. In former times where the roads crossed such spots, bad mudholes were formed. They have now been generally tapped and drained, though they are still occasionally met with on the less-traveled roads.

Water-power. Olmsted county is more than usually favored with good water-power. This results from the large number of streams, the swiftness of their currents and the favorable nature of the banks and bottom. The Zumbro river, in some of its affluents, has a descent of about three hundred and fifty feet within the county, from Rock Dell to Oronoco, while the main stream descends about two hundred feet in the same distance. The Root river falls three hundred feet within the county in passing through Rock Dell, High Forest, Pleasant Grove and Orion townships.

Water-power mills in Olmsted county.

Name of mills.	Owner.	Location.	Stream.	Feet of head.	Run of stone.	Capacity per day.
Rochester City mills	Olds & Fishback	Rochester	Zumbro	16	4	100 bbls.
Zumbro mills	Jno. M Cole	Rochester	Zumbro and Bear creek.	10	4	100 bbls.
Cascade mills	Lyman Tondro	Rochester	Cascade cr.	17	2	50 bbls.
Woolen mills	Wm. Bartley	Rochester	Bear creek	17	......	50 horse power, only partly improved.
Oronoco mills	Allis, Gooding & Hibbard	Oronoco	Zumbro	15	7	150 bbls.
Middleton's mill	R. Middleton	Kalmar	Zumbro	6½	2	35 bbls.
Saw mill	Jas. Button	New Haven	Zumbro	6	.....	
Stewartville	Chas. Stewart	High Forest	Root	12	......	50 bbls.
......	J. Fugle	Orion	Root	8	.....	50 bbls.
Custom mill	—English	Orion	Root	small.	small.	
Quincy mills	......	Quincy	Whitewater	10	2 or 3	
Saw mill	—Ambler	New Haven	Zumbro	10	......	

There is quite a number of unimproved water-powers in the county; some are between Rochester and the north boundary of the county, where the difficulties of the banks prevent their ready improvement. There are said to be two good mill privileges between the Oronoco mills and the main stream; another is at Genoa, and another at High Forest. The mills at Chatfield are enumerated in the preceding chapter.

Topography. The surface is much diversified, and the natural scenery very pleasing to the eye. The surface is generally rolling or undulating. The contour-lines of the county plate express the frequency of changes in the elevation of the surface. Along the streams bluffs are found sometimes nearly two hundred feet high. These bluffs are usually steep, level-topped, and characteristic of the rock-formation that makes them. They are most common in the central and eastern parts of the county. Rochester lies in a valley, with bluffs all around it, rising gently at some distance on all sides except toward the west where it climbs the bluff. Dover Center, Marion and Chatfield lie in similar valleys. Eyota and Byron are on elevated undulating prairies nearly thirteen hundred feet above the ocean. Curious isolated mounds are common, especially along the east side of the Zumbro in Farmington and Haverhill townships. They are also found in Elmira. In the western portion of the county the surface is nearly level but also more elevated. Much of Rock Dell township is like the prairies just south and west of it, but in its northern part are narrow rocky gorges formed by the south branch of the Zumbro, which gave name to the town.

Elevations. The following elevations are mostly on a proposed line of railroad from Wabasha to Austin, from notes of Horace Horton, the surveyor who ran the line. They have been referred to sea-level by comparison with elevations determined at Plainview, Brownsdale and Austin.

Elevations, from the notes of Horace Horton, C. E.

	Above the Mississippi river at low water at Wabasha.	Feet above the sea.
Head of East Indian creek, five miles northeast of Plainview (Wabasha county)	529	1191
Street of Plainview (Wabasha county)	513	1175
Elgin (Wabasha county)	385	1047
Summit of Lone Mound, sec. 11, Farmington, within 10 feet of Plainview level,	513	1175
Near center of sec. 14, Haverhill,	611	1273
S. W. corner of sec. 24, Haverhill (rock seen some feet above)	547	1209
Base of Sugar Loaf, secs. 31 and 32, Haverhill,	367	1029
College street bridge, Rochester,	317	979
Surface of water beneath,	302	964
S. E. corner sec. 10, High Forest,	644	1306
Low water at High Forest village,	547	1209
Sec. 29, T. **104** N., R. **15** W., Mower county, ½ mile south of John Rowley's house,	734	1396
Dr. Thornhill's farm, 4 miles east of Brownsdale, in Mower county,	707	1369
Southern Minn. R. R. at Brownsdale (Mower county)	609	1271
St. Paul and Milwaukee R. R. track at Austin (Mower county)	535	1197
Pleasant Grove, about	644	1306
Creek near the school-house in sec. 15, Cascade, about	342	1004
N. W. corner of sec. 10, Cascade,	477	1139
Quarter stake, sections 33 and 34, Oronoco,	467	1129
Center stake, sec. 21, Oronoco,	442	1104
Surface of river at Oronoco,	292	954

Elevations on the Winona and St. Peter division of the Chicago and Northwestern railway.

	Miles from Winona.	Feet above the sea.
St. Charles,	28.35	1,139
Dover,	32.19	1,138
Eyota,	36.87	1,237
Chatfield Junction,	37.73	1,275
Plainview Junction,	37.93	1,275
Chester,	42.74	1,122
Rochester	49.26	991
Rochseter and Northern Minnesota Railway Junction,	50.64	999
Olmsted	54.22	1,054
Byron,	58.71	1,250
Kasson	63.87	1,252
Elevations on the Chatfield branch.		
Chatfield Junction,	37.73	1,275
Summit grade	40.75	1,295
Chatfield depot,	48.87	976
Elevations on the Plainview branch.		
Plainview Junction	37.93	1,275
Doty,	40.00	1,310
Viola	43.00	1,129
Whitewater creek,	47.00	1,055
Elgin	48.17	1,069
Plainview,	52.93	1,167
Elevations on the Rochester and Northern Minnesota railway.		
Rochester and Northern Minnesota Junction,	50.64	999
Douglas,	58.35	1,091
Zumbro river,	60.25	966
Zumbro bridge,	60.25	986
Oronoco,	61.72	1,041
Zumbro river,	65.20	984
Zumbro bridge,	65.20	993
Pine Island,	65.86	998

Mean elevation of the county. Estimates of the average hights of the townships of this county are as follows: Quincy, 1150 feet above the sea; Elmira, 1175; Viola, 1225; Eyota, 1250; Orion, 1200; Farmington, 1125; Haverhill, 1200; Marion, 1200; Pleasant Grove, 1250; Oronoco, 1075: Cascade, 1075; Rochester, 1125; High Forest, 1275; New Haven, 1100; Kalmar, 1150; Salem, 1175; and Rock Dell, 1275. The mean elevation of Olmsted county, derived from these figures, is approximately 1180 feet above the sea.

SURFACE FEATURES OF THE VARIOUS TOWNS.

Farmington. This was a prairie town originally. It is quite broken in the southwestern portion, and an isolated mound, rising 150 feet above the surrounding surface, stands in the northeastern. Otherwise the surface is undulating, with fine loam soil, becoming sandy near the bluffs.

Oronoco. The bluffs of the Zumbro and of its western tributary crossing this township give lt great diversity of surface characters. The bluffs are frequently rocky and rise over a hundred feet perpendicular. In other places they are covered with gravelly clay and gravel, so that no rock is visible, or very little, but the valley still is deep and difficult. Outside the valleys, which are generally timbered, the undulating prairies spread out indefinitely.

New Haven. This town is more broken than Oronoco, and more timbered, and from the same causes.

Quincy. This town is almost entirely one of smooth undulating prairie, there being a rather abrupt ascent from the northeastern portions to the southwestern, brought out prominently in the neighborhood of the drainage valleys. Some scattered oaks and aspens are found in the eastern sections between the Whitewater and its northern branch.

Viola. This is mainly a high and undulating prairie, its southern border being about thirteen hundred feet above the sea. Toward the north the surface descends abruptly to the valleys as the outcroping rock changes from the Trenton limestone to the St. Peter sandstone. Some of the streams that rise near the center of this township take their origin from small elevated marshes that lie on the high prairie.

Haverhill. This township is similar to the last, but its general slope is in the opposite direction.

Cascade. This township has great variety of surface, with considerable timber in the northwestern and southwestern portions, but by far the larger part is naturally prairie. Much of the timber is small, especially at some distance from the streams.

Kalmar. About one-half of this township was originally covered with timber, a large tract in the northwestern portion being very heavy and valuable for fuel. The bluffs of the river which crosses it are rocky and frequently perpendicular seventy-five to one hundred feet.

Dover. With the exception of scattered thickets of small trees of aspen or oak this township is one of prairie. Most of it is high, but it has a conspicuous valley running east and west, through the center, occupied by the Whitewater river. Some of the highest land in the county is n the southern part of this township.

Eyota. The most of this township is also high prairie like the southern part of Dover; in its western portion it has a broad belt of heavy timber about the southern tributaries of Bear creek. Along its southern boundary it is somewhat broken by the headwaters of some of the branches of Root river.

Marion. A considerable portion of this township is rolling and lightly timbered; the uplands are prairie. The valleys have a sandy soil, but the prairies have a clay soil.

Rochester. Much of this township is timbered, generally with scattering oaks, sometimes with a variety ot heavy timber. The valleys are sandy and gravelly, but broad and generally tilled. The uplands are sometimes prairie and have a clayey soil. The bluff-slopes are not generally rocky, but are often turfed from top to bottom.

Salem. Much of this township is covered with timber, which is often rather brush than trees, consisting of oaks, hazel and aspens. The uplands sometimes bear marshes which furnish source to the branches of the Zumbro.

Elmira. This is a town of mixed wood and prairie. Its eastern and southern portions are more broken, and descend rather quickly to the valleys which drain them; the northern and western portions are high with scattering timber. The upland is set off from the lower prairies by a conspicuous bench that rises abruptly about a hundred feet, its upper line being about twelve hundred feet above the sea.

Orion has much timber along the valley of Root river. This valley is about two hundred feet below the uplands, and is about a mile wide.

Pleasant Grove. The valley of Root river is here also about two hundred feet below the uplands, but it is narrower and more precipitous than in Orion. In the center of this township is a large area of timber.

High Forest. This is nearly all prairie, but has some wood along the streams. The valley of Root river is less deep, but its banks are sometimes rocky.

Rock Dell. The banks of the Zumbro, in the northern part, are steep and rocky, but those of the Root river are in the drift deposits. This town in general is one of high undulating prairie, with occasional small marshes.

Timber. When first settled this county had a large amount ot native heavy timber, and also much in the condition of "openings". Some of it has now been cut, but it is not probable that the standing trees are less numerous now than then. The suppression of the prairie fires, and the reservation of large areas for the purpose of growing timber, added to the trees that have been artificially raised on the open prairies, have served to favor the forest growth. The brush and the "openings" have been cleared off, but on every prairie farm have been raised hundreds of cottonwoods or poplars, or willows, or maples, box-elders or elms, which have probably more than equalled the number of trees cut for fuel and for farming. The following trees, shrubs and twining plants were observed in the survey of the county.

I. Trees of Olmsted county.

Tilia Americana, *L.* Basswood.

Acer saccharinum, *Wang.* Sugar maple.

Acer rubrum, *L.* Red maple.

Acer darycarpum, *Ehr.* Soft maple.

The first two maples do not usually attain any considerable size, while the soft maple, in a state of nature, becomes a large tree.

Negundo aceroides, *Mœnch.* Box-elder.

This tree is common along streams, and is a favorite in cultivation. In transplanting it is trimmed up too much to easily take root. It is a pretty tree, of a pleasing form and a full light-green foliage.

Fraxinus Americana, *L.* White ash.

Ulmus fulva, *Mich.* Slippery elm.

Ulmus racemosa, *Thomas.* Corky, or rock, elm.

Of the latter elm several trees are seen in the streets at Rochester. It is a common species in dry woodlands.

Ulmus Americana, *L.* (*pl. Clayt.*), *Willd.* American elm, or white elm.

Juglans nigra, *L.* Black walnut.

A grove of these trees was seen in Kalmar.

Juglans cinerea, *L.* Butternut.

Carya amara, *Nutt.* Bitternut, or hickory.

Of the hickory only very small trees were seen. It is said to be winter-killed before reaching a mature size ; further it is extensively cut when small for round barrel-hoops for the large export of Minnesota flour.

Quercus macrocarpa, *Michx.* Bur oak.

Is very abundant. On prairies it is low, 3–8 feet high, forming extensive thickets and fruiting abundantly. In more favorable localities protected from fire it becomes a large tree.

Quercus alba, *L.* White oak.

Is hard to distinguish at a distance from the last. Undoubted specimens were seen near High Forest.

Quercus coccinea, *Wang.*, var. tinctoria, *Gray.* Black oak.

Like all the species of this group of oaks, this tree is hard to identify. It is very common, but its largest specimens are disappearing with the advent of civilization. It is frequently seen dead or dying without apparent cause.

Betula papyracea, *Ait.* Paper birch. Small, along streams in the western part of the county.

Populus tremuloides, *Michx.* American aspen. Very common, usually less than six inches in diameter.

Populus grandidentata, *Michx.* Great-toothed aspen.

Populus monilifera, *Ait.* Cottonwood. A great favorite in cultivation.

Populus balsamifera, *L.* Balm of Gilead.

Populus alba, *L.* Silver poplar.

Populus dilatata, *Ait.* Lombardy poplar. The last three are introduced and very common in cultivation.

Salix——sp? Willows. Several species were seen, some of them becoming large trees.

Pinus Strobus, *L.* White pine. A few straggling specimens appear about the river bluffs.

Robinia Pseudacacia, *L.* Commonly cultivated. Several species of pine, spruce and a larch are also cultivated.

II. Shrubs of Olmsted county.

Xanthoxylum Americanum, *Mill.* Prickly ash.

Rhus glabra, *L.* Smooth sumac.

R. Toxicodendron, *L.* Poison ivy.

Amorpha fruticosa, *L.* False indigo.

A. canescens, *Nutt.* Lead plant.

Prunus Americana, *Marshall.* Wild plum. Apparently several varieties, some of them producing the greatest abundance of pleasant fruit.

P. Pennsylvanica, *L.* Wild red cherry.

P. Virginiana, *L.* Choke cherry.

P. serotina, *Ehr.* Wild black cherry.

Spiræa opulifolia, *L.* Nine-bark.

Rosa blanda, *Ait.* Wild rose.

Rubus strigosus, *Michx.* Wild red raspberry.

R. occidentalis, *L.* Wild black raspberry. Flavor of the fruit is said to be remarkably good.

R. villosus, *Ait.* Common blackberry. Not common.

Cratægus tomentosa, *L.*, var. pyrifolia, *Gray.* Black thorn.

Cratægus tomentosa, *L.*, var. punctata, *Gray.* Black thorn.

Pirus arbutifolia, *L.* Choke cherry.

P. Americana, *DC.* American mountain-ash. Cultivated.

P. aucuparia, *Gœrt.* European mountain-ash. Cultivated.

Cornus stolonifera, *Michx.* Red-osier dogwood.

C. paniculata, *L'Her.* Panicled cornel.

Symphoricarpus occidentalis, *R. Br.* Wolf-berry.

Viburnum Lentago, *L.* Sheep-berry. Wild haw.

V. Opulus, *L.* Cranberry-tree. Is frequently cultivated.

Corylus Americana, *Walt.* Hazel. Abundant on prairies.

Betula pumila, *L.* Low birch. Cold bogs.

Alnus incana, *Willd.* Speckled alder. Along streams.

Juniperus Sabina, *L.*, var. procumbens, *Pursh.* Juniper. Seen only on a rocky bank on Root river, in sec. 35, Rock Dell.

III. Vines in Olmsted county.

Clematis Virginiana, *L.* Virgin's-bower.

Vitis cordifolia, *Michx.* Frost grape.

Ampelopsis quinquefolia, *Michx.* Virginia creeper.

Common wild, and a favorite in cultivation. It is often erroneously called *ivy*, and is frequently known as *woodbine.*

Celastrus scandens, *L.* Climbing bitter-sweet.

Humulus Lupulus, *L.* Hop. Wild and in cultivation.

THE GEOLOGICAL STRUCTURE OF OLMSTED COUNTY.

The outcrops of rock are numerous throughout the county, and are specially frequent along the tops of the bluffs that line the deeply eroded valleys that prevail over several counties in this part of the state. This system of deep valleys tributary to the great Mississippi toward the east, ceases rather suddenly in Olmsted county. The streams and all ravines rise, in the western part of this county, to near the surface of the surrounding country, and flow upon the drift-sheet which grows deeper and deeper as one passes further westward. This material is rather thin in Olmsted county, except in the southwest corner where it is thick enough to conceal the rock features entirely. Eastward it appears only in thin outlines, marking the ragged edge of deposition, or in patches and masses which are remnants left by subaqueous erosion. In order to see to the best advantage, the changes either in the drift, the features of erosion, or the stratification of the rocks, one must cross the county obliquely. The drift is lightest, generally speaking, in the northeastern corner, and thickest in the southwestern corner. On the other hand the southeastern and northwestern corners are much alike in the very features in which the other two corners differ. In a rough way the lines of change cross the county diagonally in a southeasterly and northwesterly direction. This is due to two facts which may have some relation to each other. In the first place the *great river* in the vicinity of the county runs in a generally southeast direction. The erosion-valleys extending from it would tend to take a direction perpendicular to it, and the lines of equal depths of erosion would tend to be parallel to it; again the dip of the rocks of this county is slight toward the southwest; hence the edges of the strata as presented on the surface would tend to be in lines perpendicular to this direction.

There are no signs of noteworthy upheaval, depression or other changes, in the relations of the strata to each other in this county, as in the whole of this part of the state the strata are in general conformable.* The peculiar structure of the bluffs enables one to trace some of the strata at a distance. As far as the eye can follow them their planes occupy the same position with reference to the horizon.

The strata do not lie in a horizontal plane, but they dip slightly toward the southwest—perhaps at the rate of ten feet to the mile.

The stratigraphy of this fine county is easy to read in most cases. The form of the bluffs, the line of springs marking a definite point in the rocks of the Trenton period, the varying solubility of the rock and the consequent occurrence of sink-holes and caves in one formation and not in an-

*See, however, the report on Winona county, p. 250.

other, the notably distinct lithological characters of some of the formations, and the gradual and regular dip of the strata, when taken with the erosion, enable one to decide with certainty the rock over which he is standing, even when it is hidden from view. All these enable one to read the stratigraphical enigma of the county with little trouble. In this study the intimate knowledge of the county possessed by Mr. W. D. Hurlbut aided greatly, as he cheerfully rendered all the assistance in his power. Many of the details of the map illustrating this county were supplied by him.

Olmsted county furnishes an excellent field for teaching stratigraphy to a class of students. The strata are interesting. The characters mentioned above make the reading of them, under their varied degrees of exposure and erosion, easy and instructive. For instrution in geological field-work no district could be better adapted.

The formations found in the county are the following, as known in geological nomenclature.

Lower Silurian.	Hudson River group	Shales, shaly sandstones and impure limestones, the probable equivalent of the *Maquoketa shales* of Iowa. Seen..	15 ft.
	Trenton group	1. Dolomitic limestones of the *Galena* formation.........	40–50 ft.
		2. Calcareous strata, less dolomitic and more argillaceous, sometimes designated *Upper Trenton*................	100 ft.
		3. Green shales with limestone strata....................	40 ft.
		4. Limestone. *Trenton*..................................	15-20 ft.
Cambrian		Sandstone—*St. Peter*.. ....about	110 ft.
		Dolomitic limestone—*Shakopee*..........................	30–40 ft.
		Sandstone—*Jordan*....................................	20 ft.
		Dolomitic limestone—*St. Lawrence*.....................about	200 ft.

Perhaps it would be more in keeping with the actual state of our knowledge to include the Lower Silurian strata all under one designation—the *Trenton period*—than to attempt to express the parallelisms between its parts and any of the New York members of that period, since there is some reason to include not only the Hudson River and Trenton epochs but also the Utica slate and the Black River limestone, among our strata.

The St. Lawrence limestone. The actually known area in which this limestone forms the surface in Olmsted county is small, and on the plate representing the geology of the county it has been designated by horizontal purple bars. It is found in the town of Oronoco, and is abundantly exposed along the banks of the Zumbro and its north-middle branch. In its lithological characters it does not differ essentially from the descriptions that have been given of it in reports on Winona and Fillmore counties. Its beds are quite irregular in some places, and show much chert and other siliceous aggregations. It is sometimes compact and finely granular, but is more frequently vesicular and with sparry cavities. The following section was taken at Oronoco, at the lime-kiln of James Barnett, just northeast of the village.

Section at Oronoco, in descending order.

Calciferous sandstone, much broken in thin layers, buff	14 ft.
Compact, little broken calciferous sandstone, light buff	2 ft.
Sandstone (mostly saccharine) in layers	4 ft. 3 in.
Aluminous limestone, in thin layers, light buff	1 ft. 7 in.
Dark sandstone with numerous blue spots	1 ft. 8 in.
Arenaceous vesicular dolomite	3 ft. 6 in.
Like the second above	4 ft.
Like the second above, but more irregularly bedded	1 ft.
Vesicular, sparry, irregularly bedded dolomite	4 ft.
Total, as far as seen	36 ft.

In the above section no fossils could be found. The lowest layer is employed for making lime. The lime is light buff, slow, and contains considerable cement.

The Jordan sandstone. This sandstone, which was identified in 1873 as a distinct stratum in the Cambrian formations, separating the limestone that Dr. D. D. Owen designated the *Lower Magnesian* into two important and persistent members, has a thickness of about twenty feet in Olmsted county. It can be seen at the mill-dam at Quincy on the Whitewater below the Shakopee, with an exposed thickness of ten feet. It is here a firm sandrock or granular quartzyte. West of Oronoco it is again visible in some of the bluffs and mounds that rise above the Zumbro valley and reach a hight of about 1100 feet above the ocean. About two and a half mile west of Oronoco a slight excavation has been made in this rock for its supposed utility for building. It was done by Mr. Robinson; but the rock was found to be rather poor, some of it being very fine-grained, and susceptible of being carved into delicate forms. The most valuable result of the work was the demonstration of the geological horizon hereabouts. The Shakopee and Jordan cause the undulating country just north and west of Oronoco The St. Lawrence is seen at Oronoco, rising about twenty feet above the main part of the village, its upper line of outcrop running somewhat above the dam. About a quarter of a mile southwest of Robinson's the Shakopee and Jordan combine to form a couple of conspicuous mounds in the river valley, in the same manner precisely as the St. Peter and Trenton combine in so many cases, except that in this instance the effect is somewhat increased by the direct action of the Zumbro's waters.

The Shakopee limestone. The area of this formation in the county is as follows: It follows the larger streams, beginning on them when well in the county, and broadening out until it leaves the county with them. It appears in the beds of the branches of the Zumbro far up in Rochester, Marion, Haverhill and Cascade townships. Rochester lies on a floor formed by the upper surface of this formation. The valley of Rochester city is entirely shut in by bluffs, except where the Zumbro passes out to the north and along a geological valley, now dry, to the northwest. This valley of Rochester city is somewhat crab-shaped, and is formed by the meeting of the various streams which make up this branch of the Zumbro. Cascade township is about half occupied by the Shakopee, the remaining surface being occupied by spurs and islands of the formations above, one of these islands being quite large. Oronoco township is mainly underlain by this limestone, closely associated along the river valleys with the Jordan sandstone and the St. Lawrence. Farmington has a Shakopee floor, except the southern edge and some outliers of Trenton and St. Peter. In New Haven the middle fork of the Zumbro soon rises to the Trenton, while the north fork lies on the Shakopee or Jordan, until it passes into the next county west. A large portion of Quincy and a little of the northeast of Viola are on the Cambrian. An arm of the same appears at the surface in the bed of the river, passing nearly through Dover from east to west. Elmira is also floored with the Cambrian for the most part, as is a small portion of Orion. The village of Dover lies in a Cambrian valley, something like that of Rochester city. The same is true of Chatfield. Something more than 20 per cent. of the county has a floor of these alternating sandstones and dolomites.

Illustrative of the *lithological characters* of this limestone the following section may be taken. It occurs at Quincy. The same broken and confused stratification accompanies the Shakopee throughout the county, and may be seen in some quarries near Rochester.*

Descending section at Quincy, Olmsted county.

No. 1. Dolomitic limestone; quite arenaceous, falling out in huge masses which are rough, distorted in their crude bedding, and unmanageable as a quarry stone, showing much calc-spar.

*See also the description of the Shakopee in Rice and Dakota counties.

Limestone and sandstone are mingled with occasional strips of light-green shale. In general the face presents the appearance of an alternation of horizontal layers of thin and more shaly beds, with heavy, coarse and rough limestone beds. Some green-shale layers alternate with dark, umber-colored (ochreous) shale, neither being more than two inches thick. They are tortuous and not continuous. This phase appears like the tops of the bluffs at Winona, but is at a considerably higher horizon..30 ft.
No. 2. Persistent white sandstone (Jordan) seen..10 ft.

Total exposure..40 ft.

This rock, in connection with the underlying Jordan, produces characteristic *surface features.* When worn deeply into by erosion it presents bold cliffs and craggy, rounded, hills. When not covered thickly by drift, or by the loess loam, it makes a poor surface for agriculture, as may be seen in some parts of Oronoco. Its area is nearly barren, or covered with scant grass, with hazel and scrub oak (in this case a dwarfed growth of *Quercus macrocarpa*), or with small paper birch, and other wood-growth not large enough to be of importance economically. When this floor is covered by drift, as in the beautiful prairie township of Farmington, the soil may be unsurpassed. The most of this township is devoted to wheat, and at the proper season it seems to be one continuous wheatfield.

This rock does not furnish much good building material in this county. It is not of even bedding and homogeneous texture generally. Pieces are sometimes employed at Rochester for window-caps and water-tables. These pieces are found only in the uppermost layers. No general use is made of them.

The St. Peter sandstone. The *area* of this rock is difficult to represent on a map. It is so friable that it will not endure erosion when left to itself. It is only where it is capped by the lower layers of the Trenton that it successfully resists the attacks of water. By itself, uncovered by other formations, it occupies but little space. It juts out beneath the cap of limestone only a few feet or rods. From a projecting spur of limestone it may extend further, as is illustrated in the city of Rochester. A spur of Trenton comes in from the west, and ends near the city limits. The sandstone, however, can be struck in sinking wells almost anywhere in the western portion of the city. Occasionally, where erosion was incomplete, an outlier of crumbling sandstone can be seen not capped by limestone. Such outliers may be found in the southwestern part of Farmington, and in other counties.* Such outliers are not common, and are generally small. Streams of considerable size usually leap from the Trenton to the Shakopee in very short intervals, the intervening St. Peter sandstone having been washed completely away at an early period. Sometimes, however, streams of small size remain in a bed of St. Peter sandstone; in which case the vally is sandy, covered with small oaks and worth little for agriculture. This is seen in the valley of Bear creek and its branches.

The *surface features* caused by the presence of this sandstone are interesting, and have already been referred to in reports on other counties. As the incoherency of this rock deprives it of the power of resisting erosive forces, it is usually carried away cleanly wherever exposed. The consequence is a precipitous descent from the Trenton to the Shakopee. This appears in lines of remarkable, level, bluffs. The hight of these bluffs is usually the thickness of the formation, with fifteen or more feet of limestone on the top. These bluffs are especially noticeable around Rochester. To the east their top is reached by a rugged ascent, to the west by a gradual slope of the surface. The erosive forces have left many small and isolated bluffs, which can be properly described under this head, though the lower layers of Trenton limestone assist in their formation. They appear as rugged mounds rising from the Shakopee floor, and form a striking feature in the aspect of the neighborhood. They are most abundant in southwest Farmington and in Elmira. A few are seen along the railroad, just east of Rochester. Perhaps the most remarkable is "Sugar-loaf mound," about two miles east of the city and close to the railroad. Its shape and relative proportions are those of a sugar-loaf. Another remarkable one is "Lone mound", of sec. 11, Farmington. It is about three miles north from the line of Trenton bluffs. Two or three miles northwest are two similar mounds, called "Twin mounds". They are in Wabasha county, but have no limestone capping.

The thickness of the St. Peter was ascertained with an aneroid barometer, near Rochester. The upper layers of the Shakopee were found on Bear creek, near the woolen mills. The upper surface of the St. Peter was ascertained as carefully as might be near Whitcomb's quarry, and near Jenkins' quarry. Three comparisons were made. The proper allowance

*See reports of Wabasha and Dakota counties; also p. 251.

having been made for dip and atmospheric change, the value of 111 feet was obtained for the thickness of this formation.

The lithological character of the St. Peter is uniform and simple. It is a rather coarse, friable sandstone, pure white except where contaminated by foreign substances or percolations from the formation above. It contains no fossils so far as could be seen in this county.

This formation is *useful* in several ways. When with a tight, magnesian floor, it holds water, and furnishes a good supply to wells. It is sometimes excavated where it comes out on the face of a bluff. Excellent cellars, dry and of uniform temperature, are thus formed, which are used especially for the preservation of vegetables. In the rear of the second Insane Asylum at Rochester is a fine root-cellar in the St. Peter sandstone. Mr. W. D. Hurlbut, of the same place, has an extensive silo embracing over 150 feet of chambers, wholly excavated in this rock. It supplies an inexhaustible amount of pure white sand, round-angular, and excellent for mortar or glass-making.

The rocks of the Trenton period. The highest rocks, stratigraphically considered, belonging to this series are found at High Forest, and at two miles west of High Forest. These are shaly, both aluminous and arenaceous, sometimes indurated and bedded and sometimes easily crumbling. On sec. 35, Rock Dell, they appear along Root river, having a light buff color, breaking like a hard shale, sometimes arenaceous, even so much so as to become a coarsely arenaceous white sandstone, and at other times somewhat calcareous, with a very fine grit, worthless for lime and for all other uses. It was tested for quick-lime by Mr. Brewer some years ago. In the winter it is cracked to pieces by frost; bedding never more than four inches thick, some of it very thin and clayey. The total thickness seen here is about ten feet, but at High Forest, at the quarry of Russell Williams, this shale is seen overlying a body of limerock which at the village rises into perpendicular bluffs twenty-five to forty feet high, and is extensively quarried for building purposes. In this shale no fossils have been found at High Forest, except an indistinct valve of a small brachiopod like *Leptæna sericea*, but reminding one of the *Spirifer* family by its eared extremities and its beaked hinge-line. The shale here so far as seen amounts to fifteen feet, contains *no beds* of white sandstone, but is gritty and even arenaceous. It is mostly at this point a soft, clayey shale, with concretions and harder laminated patches which are probably more calcareous, showing, parallel with the curving and wavy laminæ, rusty lines that are due to the arrangement of the irony layers, or to the stoppage of iron in ferriferous water that trickles through the rock. These concretions appear also in the limestone on old surfaces, though not distinguishable on freshly broken surfaces.*

The underlying limestone, which probably represents the strata that have been well known as Galena limestone, has an exposed thickness in the vicinity of High Forest amounting perhaps to forty feet. This is heavily bedded, very firm and of a buff color, with cloudings of gray, and even of blue on some of the deeply quarried beds, and a magnesian aspect. It contains almost no fossils besides crinoidal stems, but shows rarely impressions of a large *Orthoceras;* at other places it is non-fossiliferous, as at Garrick's quarry.

The same lime-rock appears more abundantly in the bluffs at Stewartville. In the loose materials along the south bank of the stream, in the vicinity of Stewart's mill, are found numerous specimens of *Maclurea,* of which there seem to be two species, one of which is probably that of professor James Hall, *M. Bigsbyi,*† although in a somewhat higher horizon than the "buff limestone" of Mineral Point, in which that species has been found. These are the same as found in the Galena limestone at Lime City, Fillmore county. This limestone underlies Rock Dell and portions of Salem, Rochester, High Forest and Pleasant Grove. It extends into Marion and Orion, and even into Eyota, and westward into Kalmar. It may be seen in Garrick's quarry, sec. 18, Rochester. Its lower and upper edges cannot be accurately traced.

In *lithological character,* this rock is a heavily bedded, buff dolomite, fine grained, or coarse and porous. It contains often small pieces of iron pyrites, which, by weathering, give it ferruginous stains. Lead has not been found in place in the rock, but farmers sometimes find it isolated on the surface, evidently left behind when the rest of the rock material was weathered away. It often contains crystals of spar; sometimes irregular

*See Mower county report for further concerning this shale.
†Report of the superintendent of the Wisconsin geological survey, Jan. 1, 1861.

cavities are found. Under the influence of the weather the rock is seen to vary in solubility. The result is frequently sink-holes of varying dimensions. Such holes, a few feet deep, are common on the bluffs of this formation. Another result of this unequal weathering is the craggy appearance of the bluffs formed by the Galena.

This limestone is well displayed in this county at Thomas Garrick's quarry, sec. 18, Rochester township. The floor of this quarry is about thirty feet above the Trenton. To the top of the quarry is about thirty-five feet. The rock is a sparry, magnesian and more or less arenaceous limestone. It is in beds one to three feet thick, separated by very thin layers of light blue shale. The beds are massive and yellowish, somewhat stained with iron arising from the decay of iron pyrites. The upper portions are most arenaceous and fossiliferous. In the crevices is found abundance of satin spar, and in the largest ones stalactites may be found.

R. Williams's quarry, on the north bank of Root river, sec. 31, High Forest, is in this formation. This rock is exposed for twenty-five feet, and is dolomitic, more or less concretionary, with small, spar-lined cavities. It is sparingly fossiliferous. The upper six feet are much broken up. The remainder is compact and unevenly bedded. The concretionary structure is not visible on fresh surfaces. It is brought out by weathering and especially by burning, and then appears in the form of fine rusty lines.

On the left bank of the same stream, about one mile west of Williams's quarry. is an exposure of yellow thin-bedded, broken, uneven, dolomitic limestone, of which only eight or ten feet are visible.

The same rock is well exposed in the ravines of Salem and Rock Dell, where it is quarried to some extent for building.

As to *economical value*, this formation produces one of the best building stones found in the state. It is much used in Rochester, but has been mostly derived from Mantorville, in Dodge county. It will be further described in the report of that county. At Russell Williams's quarry near High Forest it is burned for lime.

Below these magnesian strata there is an interval occupied with more or less shale, or with alternations of shale with limestone. At the same time the limestone loses its distinctive lithological characters, and its magnesian composition, and becomes more nearly a pure limestone. It is more compact, but also is sometimes arenaceous, particularly near the bottom. These beds appear in the banks of Root river in Pleasant Grove. They are observed on secs. 8 and 16. They are cut by the railroad grade in the north part of Orion township. They consist, in general, of the following rocks, in descending order, seen in Pleasant Grove.

Section on sec. 16, *Pleasant Grove.*

1. Perpendicular escarpment, showing generally a thin-bedded and often shaly rock, the thin shale partitions being as thick as one-half or one and a half inch............37 ft.

2. The descent then is irregular over beds of argillaceous limestone and shale, mostly hid from view. Some of these shale beds are six and eight inches thick, and from them, where crmbling under the weather, fragments of fossils fall out, such as *Chætetes*, *Pleurotomaria* and *Orthis*. The limestone weathers rough and thin-bedded, and shows *Receptaculites*. This interval includes about............. ....47½ ft.

3. Then there is a broad shoulder making a talus and including a heavy bed of green shale which overlies, as disclosed further down the river, the limestones of the "Lower Trenton" as seen at Rochester.. ....42 ft.

The rock-cuts along the railroad north of Chatfield are in sec. 35, Eyota. They are included in the foregoing section of the Trenton rocks, and consist of alternations of limerock and shale each about eighteen inches in thickness, the rock predominating; the whole thickness being about twenty feet. There is considerable drift in this region, but below this point the valley widens out more, so that it soon shows the outlines and width characteristic of valleys cut in the St. Peter sandstone, though there is no sandstone exposure till within about a mile of Chatfield depot. This depot is above the Shakopee but near its upper limit.

The heavy mass of green shales (No. 3 of the foregoing section) is a familiar feature to the geologist who examines Olmsted county, on account of the effect it has on the topography of the county, in preserving the underlying limestone beds from solution and removal by percolating waters. It may generally be seen near the brow of the bench which marks the outrunning strike of the Trenton, just before the general surface drops down to the floor of the Shakopee. It contains numerous fossils, mainly brachiopods and small gasteropods, and an occasional coral. The coral *Chætetes* is abundant at most of the outcrops. Its thickness seems to reach at least forty feet, but generally not more than six to ten feet can be seen at any one place. In this shaly horizon are embraced thin lenticular sheets of pure limestone that are eminently fossiliferous, their upper and lower surfaces being frequently studded with brachiopods and gasteropods, as well as encrusted with bryozoans, which stand out in relief, with only partial or slight attachment to the calcareous mass.

It has been suggested that the clay derived from the green shales would would make good brick or pottery. The grain is very fine, but the presence of small calcareous fossils injures it for these purposes. A pottery factory, in which this clay was employed, started some years ago, had to be abandoned on this account.

The limestone strata which have been known distinctively as the *Trenton*, or "Lower Trenton", have a thickness of about twenty feet in Olmsted county, and lie at the base of the Trenton group here described. The uppermost layers of this limestone are frequently interbedded with the green shale above, so that the transition from one to the other is similar to that from the Galena to the shales overlying. In Olmsted county this limestone is compact, heavy, very firm, resonant when struck with a hammer, fracturing conchoidally, fossiliferous, and in beds from four to six inches. Its color when weathered is drab, but when deeply quarried it is blue. It contains many large cephalopods, numerous crinoidal stems, remains of trilobites (*Isotelus* and *Calymene*), and many brachiopods, including *Lingula Elderi*, Whit.

This rock is much quarried, particularly in the vicinity of Rochester, where many foundations and several stone buildings have been constructed from the Trenton quarries near by. The quarry of W. Jenkins just within the city limits has furnished a large amount of this stone.

The Drift. This covers much of the county. It thins out toward the northeast. It is of considerable thickness in the southwest. Its edge is ragged, but its irregularities do not conform with the present drainage system. It consists of a stony blue clay, washed or yellow clay, stratified gravel and sand and boulders.

The blue clay is by no means continuous. It is found in limited areas and bands in various parts of the county, and quite generally in the western portions. Sometimes it forms distinct ridges, as in western Rochester city, and in the valley directly east of Rochester. The washed clay, as its name indicates, has been worked over by water since its deposition in the drift. It occupies low pond-like spots, or abuts on the bluffs. It is usually of a uniform reddish-yellow color and quite arenaceous. Sometimes it is in colored layers of red, yellow and green. In this case its derivation is probably from the green shale of the Trenton as well as from the drift. The washed clay is used for brick.

The exposures of sand and gravel are not extensive in the parts of the county examined by me. Where seen they exhibit the usual characters. The boulders are entirely absent in most parts of the county. In many scattered localities, again, they are abundant; and in the southwest corner of the county they are often found of great size.

About a mile and a half northeast from Marion are scattered boulders of siliceous iron ore, having the characters of the iron ores seen in the Mesabi iron range, and similar to some siliceous iron seen in the Black hills.* These pieces are not frequent. They lie on the brows of the Trenton terrace, and are associated with other drift boulders. Some of them show really very little iron, but partake more of the nature of the non-ferruginous quartzyte of the Potsdam, though still of a reddish color. There is not that topographic surface here that indicates the immediate presence of the formation in outcrop, but these pieces are on the Trenton and among the drift, which rather shows that they have come with other drift from some point farther north.

In the museum of the University is a magnetic boulder of siliceous iron ore, known as *lodestone*, presented in 1875 by James Hinton, said to have been found in the neighborhood of Quincy, Olmsted county. Between St. Charles and Quincy are many evidences of northern drift in the form of hornblendic and granitic boulders. They are often met in wells and cellars, though the country there is covered with a loam-soil of a black color.

The following table of wells will be useful for an analysis of the drift. The facts were furnished by O. Sprague, practical well-digger:

*Report of a reconnoissance of the Black hills, Ludlow, 1874, pp. 50, 52.

Wells in Olmsted county.

Location; section and township.	Owner.	Depth in feet. Drift.	Rock.	Total.	Water.	Remarks.
35, Farmington....	C. E. Stacy........	22	31	53	good.	5 feet black soil; then reached clay.
35, Farmington....	W. H. White......	20	24	44	good.	Yellow clay and blue rock.
36, Farmington....	E. Raymond......	11	..	11	good.	Blue clay.
25, Farmington....	W. Searls.........	44	..	44	good.	14 feet black heavy soil; remainder blue clay.
30, Haverhill......	J. P. Simonds.....	25	10	35	soft.	25 feet sand; 10 feet hard sand-rock.
9, Haverhill......	P. H. McGovern...	40	50	90	good.	Red, hard drift.
32, Haverhill......	J. E. Brown.......	25	..	25	good.	4–5 feet soil, then sand.
11, Haverhill......	B. F. Bulen.......	12	..	12	plenty.	Red, hard drift.
14, Salem.........	Z. Holt..........	25	..	25	good.	Sand all the way.
14, Salem.........	J. D. Fuller.......	40	..	40	good.	Sand all the way.
26, Salem.........	J. P. Fosdick......	30	6	36	soft.	White, hard rock.
21, Salem.........	Ole Severson......	27	..	27	good.	Sand.
16, Salem	C. Peterson.......	25	..	25	good.	Sand.
16, Salem	Nils Jacobson.....	25	..	25	good.	Sand, foot of bluff.
16, Salem	T. Thompson.....	57	16	73	good.	Red, hard drift; white limestone.
28, Salem	....	32	..	32	good.	Twenty feet blue clay.
30, Pleasant Grove	Fred Sibeck.......	61	..	61	good.	Forty-eight feet blue clay.
29, Pleasant Grove	J. Collins.........	21	..	21	good.	Fifteen feet blue clay.
25, Pleasant Grove	D. W. Hymes.....	20	40	60	good.	Sandy, red clay.
11, Cascade.......	T. C. Cumings.....	30	..	30	plenty.	Twenty-five feet blue clay.
17, Cascade.......	J. H. Hodgman....	25	..	25	plenty.	Sand.
17, Cascade.......	E. Babcock.......	25	..	25	plenty.	Sand.
15, Cascade.......	P. Boardman......	30	..	30	plenty.	Red, sandy clay.
15, Cascade.......	J. Gardner........	30	..	30	plenty.	Red, sandy clay.
15, Rochester......	I. M. Westfall.....	40	..	40	plenty.	Sand.
2, Rochester......	W.L. Brackenridge	18	..	18	plenty.	Sand.
5, Viola..........	D. D. Whipple....	44	50	94	plenty.	

Cedar logs at considerable depths in the drift are found but rarely. Mr. Sprague says they are always under the blue clay. Rotten wood is occasionally found in the blue clay.

It is a striking fact, often mentioned, that water is often found on the bluffs at a much less depth than at their base. The geological formation satisfactorily accounts for this.

MATERIAL RESOURCES.

The soil of Olmsted county is and will always remain its chief source of material wealth. It has great variety. It is arenaceous in some of the valleys, and produces and ripens crops quickly, but it is more clayey on the uplands, and generally blackened by charred grasses and other vegetation—the residue of the prairie fires that formerly raged annually over the most of the county.

Brick of a red color are made at many places in the county, in all cases from the washed clay, which is the same as the lœss loam. It is in deposits from two to ten or twelve feet thick. Although this material is sandy, more sand is usually put in in making the brick. The brick are consequently tender and of poor quality. They vitrify but little when burned.

Gold has been found in the drift along the Zumbro from Rochester and Oronoco down to the Wabasha border and beyond. It is found only on the Cambrian limestones. Murchison calls attention to this fact as generally true. It is found in the drift about the stream, but mostly in the bed of the stream, or in material worked over by it at a comparatively recent date. In the same alluvial material is found a small amount of black magnetic sand, of a specific gravity approaching that of gold. When the gold is obtained by washing, after all the other materials are washed away this heavy black sand remains, and the minute fragments of gold are picked out from it. It is therefore here called the "mother of gold," and the two are thought to be always together, a conclusion which need not necesarily follow.

The gold is in minute, angular fragments. The quantity is so small that it does not pay to work it by the ordinary method of hand-washing. Washing on a more extensive scale might be made to pay. It has been tried two or three times, but never under favorable circumstances, or for periods of much length.

It may be worth while just here to call attention to the fact that gold is frequently found under these circumstances. It has been found over extensive regions in Canada where attempts at obtaining it on a large scale have always failed to pay. It occurs thus in Vermont, Ohio, Indiana, Wisconsin, Iowa, and has been reported in other counties in Minnesota, viz.: Fillmore, Wabasha and Scott.

CHAPTER VIII.

THE GEOLOGY OF MOWER COUNTY.

BY N. H. WINCHELL.

Situation and area. This county, which borders on the state of Iowa, opposite Mitchell county, is bounded west by Freeborn county, and north by Dodge and Olmsted counties, and has an area of 711.18 square miles, or 455,155.75 acres. Of this area 1,352.65 acres are water, and 453,803.10 are land. It is represented by plate 12.

SURFACE FEATURES.

Natural drainage. The western line of towns is crossed in a due southerly direction by Cedar river. From the west this stream receives Woodbury, Orchard and Turtle creeks. Its eastern tributaries are Roberts, Dobbin's, Rose, and Otter creeks. Thus the whole western half of the county is drained into the Mississippi through Iowa. The southeastern portion is also drained toward the south through the sources of the Little Cedar, the Wapsipinicon and the Upper Iowa rivers. The northwestern portion of the county is drained by the headwaters of the Root river toward the north and east. This river flows eastward through Fillmore and Houston counties into the Mississippi near La Crescent. The divide between streams running north and those running south crosses Mower county from S. E. to N. W., nearly through the center, and includes some of the highest land in that portion of the state. The highest point in the county, on the Southern Minnesota R. R., is at Dexter station, in sec. 13, town **103** N., range **16** W., 786 feet above the Mississippi at La Crosse, or 1,412 feet above tide water.

These streams are all small, and some of them become nearly dry during the summer. Some of them furnish water-power at a number of places. This has been improved on the Upper Iowa at Le Roy, and on the Cedar at Ramsey, Austin and at several places below Austin, in the construction of flouring mills.

Water-power and water-power mills in Mower county.

At Lansing on the Cedar is the *Lansing mill*, owned by Alderson and company; head ten feet; thirty horse-power; one "American turbine" wheel of forty-two inches; five sets of rollers (Noyes); capacity, seventy-five barrels per day.

At Ramsey is Matthew Gregson's mill, which has a head of water of nine feet; one forty-two-inch Leffel wheel, with twenty-five horse-power; one other wheel for machinery, giving thirty horse-power; three run of stone; capacity fifty barrels.

At Austin is *Warner's mill* (now owned by C. Alderson), situated on Dobbin's creek, with sixteen feet head; two Huston wheels (17 and 15 inches); fifteen horse-power, more or less, for each wheel; one pair of millstones; five sets of rollers, of Cosgrove's patent; capacity forty barrels. The full capacity of this stream is about twenty-five horse-power.

At Austin on the Cedar is the *Engle roller mill*, owned by Job Engle; has eleven feet head; two Huston wheels (45-inch and 27-inch), giving respectively forty and fourteen horse-power; eleven sets of single (Noyes) rollers; capacity 125 barrels.

Two miles below Austin on the Cedar is Jonathan Gregson's mill, with thirteen feet head; it has one Leffel wheel of forty-two inches, and one "American turbine" of forty-two inches, making together 100 horse power; eight sets of rollers (Case's patent); two buhrs; capacity 125 barrels. This power is not all employed.

Five miles below Austin is W. H. Officer's mill; this has eight feet head, one "American turbine" and one Leffel wheel, each being forty-eight inches in diameter; sixty horse-power; two sets of rollers (Noyes), and three run of stone.

At seven miles below Austin on the Cedar is the old site known as *Tiff's mill*, now owned by Alderson and company. This has not been employed for twenty years, and a part of the dam is gone; but there is here available over 100 horse-power.

There is another available privilege near the mouth of Rose creek, amounting to ten horse-power, not now used.

At Le Roy, on the Upper Iowa river, is Isaac H. Thompson's mill; this has ten and a half feet head; one forty-eight inch Leffel wheel; three run of stone (one for feed); capacity twenty-four barrels.

Topography. This county is one of high prairie. Its surface is smooth, and gently undulating. The broad valleys of the small streams that appear in the eastern and western portions are basin-shaped in cross-section, though they sink, in the towns of Frankford and Racine, from fifty to seventy-five feet below the general level. The summit of the principal N. W. and S. E. watershed is formed by the Lower Devonian strata. Toward the east from this summit, particularly toward the northeast, the view over the valleys of Deer and Bear creeks, introduces a decided change in the landscape as it first appears before the traveler. The expanse is broad, low, and wooded more or less. A similar change is introduced in the southeast, where the Upper Iowa river passes through the township of Le Roy. The western portion of the county is considerably lower than the central and eastern. This is owing to the valley of the Cedar, the effect of which is felt over a wide belt, in depressing the general level. The southern townships of Lyle, Nevada and Adams may be characterized as flat. The same is true of much of Marshall, Windom and Austin. There are extensive tracts of prairie in the central and eastern townships that are still in their pristine condition.

Elevations. The following points of elevation above the ocean will give the average altitude along the railroad lines, and this can not vary much from the actual average for the county, since the roads easily follow the undulations of the prairies with very little of either cutting or filling.

Elevations on the Southern Minnesota division of the Chicago, Milwaukee and St. Paul railway.

	Miles from La Crosse.	Feet above the sea.
Spring Valley (Fillmore county),	73.6	1266
Summit (grade),	80.1	1358
Grand Meadow,	83.0	1338
Depression (grade),	85.2	1317
Dexter,	89.8	1412
Brownsdale,	98.0	1271
Cedar river (water),	102.9	1192
Ramsey (crossing of the Chicago, Milwaukee and St. Paul railway),	103.1	1214
Depression (grade on bridge at Turtle creek),	107.7	1197
Oakland (Freeborn county)	109.9	1265

Elevations on the Iowa and Minnesota division of the Chicago, Milwaukee and St. Paul railway.

	Miles from St. Paul.	Feet above the sea.
Madison,	90.2	1250
Lansing,	93.8	1224
Ramsey (crossing of the Southern Minnesota railway),	96.3	1215
Cedar river (water),	96.7	1185
Cedar river (grade),	96.7	1200
Wolf creek (bridge),	97.7	1203
Austin,	99.3	1197
Dobbin's creek (water),	99.6	1175
Dobbin's creek (grade),	99.6	1194
Austin Junction,	99.8	1194
Rose creek (bottom),	107.3	1222
Rose creek (grade),	107.3	1236
Rose Creek station,	107.7	1245
Summit (grade, cutting 7 feet),	111.1	1301
Little Cedar river (water),	111.9	1252
Little Cedar river (grade),	111.9	1272
Creek bottom,	113.8	1259
Creek crossing (grade),	113.8	1274
Adams,	114.1	1276
Summit (grade, cutting 2 feet),	117.0	1343
Taopi,	117.9	1336
Creek bottom,	122.7	1270
Crossing of creek (grade),	122.7	1285
Creek bottom,	123.2	1268

	Miles from St. Paul.	Feet above the sea.
Crossing of creek (grade)	123.2	1285
Summit (grade, cutting 5 feet),	124.0	1300
Le Roy,	125.4	1280
State line (natural surface and grade),	126.0	1263
Elevations on the Austin and Mason City branch of the Chicago, Milwaukee and St. Paul railway.		
Austin Junction,	99.8	1194
Rose creek (water),	103.1	1165
Rose creek (grade),	103.1	1185
Summit (grade),	104.6	1212
Depression (grade)	109.3	1185
Lyle,	110.5	1199
At state line (grade),	110.9	1186

Mean elevation of the county. Estimates of the average hight of the townships of this county are as follows: Racine, 1,300 feet above the sea; Franklin, 1,320; Bennington, 1,325; Le Roy, 1,300; Pleasant Valley, 1,350; Grand Meadow, 1,360; Clayton, 1,360; Lodi, 1,325; Sargent, 1,360; Dexter, 1,360; Marshall, 1,330; Adams, 1,275; Waltham, 1,340; Red Rock, 1,270; Windom, 1,240; Nevada, 1,230; Udolpho, 1,260; Lansing, 1,225; Austin, 1,200; Lyle, 1,190. The mean elevation of Mower county is approximately 1,300 feet above the sea.

Soil and timber. The county is distinctively one of prairie, yet it has considerable timber along the streams. This is particularly the case along the Upper Iowa river in the southeastern part of the county along the eastern tributaries of the Root in Frankford, and along the Cedar crossing the whole width of the county. There is also an important tract of timber in Nevada township.

The soil of Mower county is everywhere dependent on the nature of the drift. The underlying rock has affected it only so far as it may have mingled with the general mass. It is hence primarily a gravelly clay, that being the character of the subsoil throughout the county. This gravelly clay, however, is not now prominently displayed as the immediate soil of the surface. Indeed, the farmer in plowing rarely penetrates to it. It lies below a rich loam usually at depths varying from zero to two or three feet, or even more. The surface soil itself, which has resulted from it through the agency of theforces of the atmosphere and of vegetation, is of a dark color, and in general may be designated a clayey loam, or a sandy loam, depending on the nature and completeness of the local drainage. In low grounds this loam is thick and of a dark color. It is also apt to be more clayey in low ground than it is on the hillsides or slopes adjoining, and on high hills or steep slopes it is thin or wanting, the wash of the surface having carried it into the valleys. Along streams it often consists of an arenaceous loam variously mingled with the detritus of the flood-plain.

The soil of the county is everywhere characterized by the strength and fertility that the drift soils of the Northwest are noted for. They are the most reliable soils, for all the purposes of the farmer, that are known. The states that are regularly and deeply buried in drift deposits are known as the best farming states of the union. Certain rock soils, endowed with unusual special qualities, may excel in the production of certain crops, especially in favorable seasons, but for general tillage they cannot compete with the homogeneous drift soils, through which are disseminated the good qualities of the various rocks concerned in their production, in the proportions that make stability and diversity equally certain.

In the examination of the county the native varieties of trees and shrubs were noted, and the following list comprises the species that were seen. In respect to the trees it is probably nearly complete for the county, but there are doubtless other species of shrubs.

Trees and shrubs of Mower county.

Quercus macrocarpa, *Michx.* Bur oak.
Quercus coccinea, *Wang.*, var. tinctoria, *Gray.* Black oak.
Populus tremuloides, *Michx.* Aspen.
Ulmus Americana, *L.* (*pl. Clayt.*), *Willd.* American elm.
Salix——? Different species.
Corylus Americana, *Walt.* Hazelnut.
Rhus glabra, *L.* Sumac.
Ostrya Virginica, *Willd.* Ironwood.
Tilia Americana, *L.* Bass.
Sambucus Canadensis, *L.* Elder.
Symphoricarpus occidentalis, *R. Br.* Wolf berry.
Ribes Cynosbati, *L.* Prickly gooseberry.
Cornus (sp. ?) Cornel.
Pirus coronaria, *L.* American crab-apple.
Cornus stolonifera, *Michx.* Red-osier dogwood.
Alnus incana, *Willd.* Alder.
Populus monilifera, *Ait.* Cottonwood.
Cratægus coccinea, *L.* Thorn.
Prunus Americana, *Marshall.* Wild plum.
Prunus serotina, *Ehr.* Black cherry.
Vitis cordifolia, *Michx.* Frost grape.
Celastrus scandens, *L.* Climbing bitter-sweet.
Ribes floridum, *L*, Black currant.
Rosa blanda, *Ait.* Wild rose.
Cratægus Crus-galli, *L.* Cockspur thorn.

Fraxinus Americana, *L.* White ash.

Carya alba, *Nutt.* Shag-bark hickory. At Lansing, and in the valley of the Cedar, one foot in diameter.

Acer saccharinum, *Wang.* Sugar maple.

Carya amara, *Nutt.* Bitternut.

Pinus strobus, *L.* White pine. Along the rocky banks of the streams in the eastern part of the county.

Ulmus fulva, *Mich.* Slippery elm.

Fraxinus sambucifolia, *Lam.* Black ash.

Viburnum Opulus, *L.* High-bush cranberry.

Rubus villosus, *Ait.* High blackberry.

Juniperus Virginiana, *L.* Red cedar.

THE GEOLOGICAL STRUCTURE.

Of the older rocks the lower portion of the Devonian and the upper portion of the Lower Silurian are found within the county, dipping toward the southwest. The western portion of the county is known to be immediately underlain by the Lower Cretaceous, without ascertainable eastern limits. The underlying rock is nearly everywhere hid by the drift, and for that reason the actual position of the boundaries of the formations is unknown. It is possible, indeed probable, that the Cretaceous area extends farther east through the northern part of the county, since traces of it are found in the northern part of Fillmore county. The central and northwestern parts of the county are underlain by the argillaceous sandstone, and associated shales, which are seen at Austin. In Pleasant Valley and Racine townships a limestone which is the extension of the Galena and Upper Trenton is found. This lies below the Austin rock. The Devonian limestones, which overlie the Austin rock, occupy the southern and southeastern townships, and the western portions of Lyle and Austin, on the west side of the Cedar river. The stratigraphy of the formations is as follows, in descending order. Nothing is known of their thickness, except what can be learned from a study of their outcrops in other counties. There is no reason to suppose they vary much in that respect from the descriptions that have been given already of them in Fillmore and Olmsted counties.

Cretaceous.	1. Blue clay. 2. White sandstone. 3. Pebbly conglomerate.
Devonian.	4. Limestone, fine grained, dolomitic. 5. Limestone, coarse grained, dolomitic. 6. Argillaceous sandstone.
Silurian.	7. Calcareous shale. 8. Limestone, dolomitic, with shale beds.

The Cretaceous. The principal exposures of the Cretaceous are found in the valley of the Cedar river, and in the vicinity of Austin. These less indurated strata overlie unconformably, with an immense lapse of intervening time not here represented by any rocks, the older rocks of the Silurian. They have been broken up by the glacial forces, and their materials have been forced into the pre-existing cavities and channels of the older strata. They also lie undisturbed in some of these old cavities. Similar apppearances have been noted in Iowa by Profs. Hall and Whitney and by W. H. Barris,* but in that state they seem not to have been referred to the agency of the Cretaceous ocean.

With respect to the *clay*, which is probably the uppermost of the Cretaceous deposits in the county, it is frequently seen at Austin, and at points below Austin, in the quarries that are opened in the Silurian rocks. A quarry in the left bank of Dobbin's creek, just below the mill of Mr. C. Alderson, opened in the Austin rock, shows the beds everywhere greatly broken. Throughout, the partings and all the interstices are closely filled with this greenish clay. The clay here very rarely has any distinct bedding. It varies from green to reddish, or buff, and is accompanied also with considerable clean white sand. These are both lodged in the cavities of the rock in such a manner that they seem to have been jammed into them. They pertain to no particular horizon, and show no definite arrangement. They are disposed everywhere, from the top to the bottom of the bluff, though the sand seems to be more abundant near the bottom.

At a quarry of Mr. Alderson's, near Austin, the rock was overlain by the following

Cretaceous clays.

1.	Black sandy loam and soil,	2 to 4 feet.
2.	Band of red and variegated compact clay,	6 in. to 4 feet.
3.	Yellow ocherous band of clay	6 in. to 4 feet.

The superposition of these bands of clay is not so regular as indicated by the foregoing section. Occasionally number 3 is broken through, or is wanting, and number 2 lies on the rock, or passes down into its crevices; yet number 3 is generally the first over the rock. They vary in thickness and swell out in shapeless masses, and become very hard when dry. Such hard masses are seen sometimes to embrace bits of angular earthy rock,

*See the second annual report, and the report on Blue Earth county; also, *Geology of Iowa*, Vol. I., pp. 84 and 130; also, *Proceedings of the Davenport Academy of Natural Sciences*, Vol. II., p. 264.

much like ocher, varying in color, from a dark burnt-umber color to a lighter shade, even to buff, and appearing when of a light color much like the mass of number 3. They can be scratched easily with a knife, and however black they may be, they give a red hæmatitic streak. When they are faded the streak also fades into a brown or yellowish-brown like limonite. Intermingled very irregularly with number 2, and sometimes also with number 3, are masses of greenish clay which has in every other respect the same outward characters as number 2. There are here also large, crystalline, detached masses of apparently a siliceous limestone which is very hard and close-grained. In some cases, however, this varies to a porous and nearly white limestone that appears to be very pure.*

In the digging of Mr. L. G. Basford's well, at Austin, the rock quarried at Austin was struck at twenty-four feet and was penetrated eight feet. Overlying this was a deposit of blue clay. This deposit was also found in the crevices of the rock. The clay contained angiospermous leaves. Two distinct varieties of leaf were discovered, one resembling *Diospyros primæva*, Hr., and the other a species of *Sequoia*. The specimen of the latter consists of a branch, apparently of a small herb. It shows an inch and three-fourths of the main stalk. In that distance it gives off four branches, each of which seems to be as large as the main stalk, three on the left and one on the right. The whole specimen is thickly furnished with decurrent, parallel-veined leaves, which have a distinct midrib. The leaves are simple, entire, oblanceolate-linear, and taper-pointed at their junction with the stalk. Their length is a quarter of an inch, varying a little above and below that size, and their width is one-twentieth of an inch. The diameter of the stalk, and that of the branches, is about one-half the width of the leaves. The latter diverge from the branches at an angle of 40° to 45°. A photographic copy of this fossil was submitted in 1874 to Dr. J. S. Newberry, who pronounced it probably a species of *Sequoia;* and Dr. Leo Lesquereux, on examination of the original specimen, regards it as a new species.†

Near the mill of Jonathan Gregson, about two miles below Austin, the palæozoic rock is cut by old channels and other cavities, and these are filled with blue clay of the same character as that containing the angiospermous leaves at Austin. It shows here no fossils nor shells of any kind. It is exceedingly fine and plastic. It is said to run down at least thirty feet, where the stone itself would naturally lie if the strata were continuous. It seems to occupy a trough-like excavation in the rock about a rod wide running east and west, and has been traced by means of an iron rod several yards back from the river bank. This clay below twenty feet is said to become white.

Besides this clay there is a *white sand*, supposed to underlie the clay,

*In connection with this description of limestone masses, it is interesting to note the occurrence at St. Charles, in Winona county, of hard siliceous limestone masses on the surface of the ground, appearing very much like those embraced in this clay, and also in Fillmore county southeast of Spring Valley.

†In the first and third annual reports these fossil leaves were wrongly referred to the Austin rock, and on the strength of that information the Austin rock was regarded Cretaceous. A late re-examination of the locality, and an interview with Mr. Charles Bromwick, have established the fact that they are only found in the clay deposit overlying the rock.

also belonging to the Cretaceous. This has already been mentioned at Alderson's mill on Dobbin's creek, but its most interesting appearance is at Sargent's spring, S. W. ¼ sec. 31, Red Rock. It is below the level of the water of a little pool. Pure, soft (?) water boils up over the area of about a square rod, and sometimes over double that area, and can be seen issuing from the ground, bringing with it clean white sand. The bottom of the pool presents a beautiful appearance. The water is as clear as crystal, and the boiling points which appear by reason of the rising white sand, in the midst of the darker sediment, can be minutely inspected at a depth of five or six feet. Running a stick into the agitated sand, it soon strikes a sandrock which is doubtless the source of the boiling sand, and the same bed that furnished that at the quarry in Dobbin's creek.

There is also a *white pebbly conglomerate*, which passes into a ferruginous grit, found in the eastern part of the county, that is referred, with some doubt, to the Cretaceous age. This has been mentioned in the report on Fillmore county.* It is seen in the north half of section 13, Frankford, in the north-and-south road. It is here a ferruginous, pebbly conglomerate, presenting a small surface outcrop, overlain by loam. It produces a sandy road, and sandy soils in the adjoining fields for a quarter of a mile next north. Again, at the middle of section 12, in the same township, is an exposure of the same in the road. A perpendicular thickness of about ten feet of bedding seems to be here involved, in a weathered down and half-covered outcrop. This is the highest land between the two creeks. The same rock appears again on the N. E. ¼ sec. 11, overlying a disintegrating shaly and limy rock like that under the Devonian limestones in Fillmore county, and the same as that seen in the road about a mile and a half north of Grand Meadow. At this place, however, the heavy magnesian beds are not in outcrop. At the S. E. ¼ sec. 3, in the road running east and west this rusty conglomerate is conspicuous. It is disintegrated so as to make a gravel, as in Fillmore county.

As already intimated, the age of this conglomerate is not established beyond doubt. The appearances will justify its reference to the Cretaceous, and the occurrence of similar rock in other counties where it is impossible to refer it to the age to which it may belong in Mower and Fillmore coun-

*See also the reports on Nicollet, Hennepin and Wright counties. Similar conglomerates appear in the Lower Cretaceous in Guthrie county, Iowa. See *Geology of Iowa*, 1870, Vol. II., p. 100.

ties, confirms that reference. Still, as the gritty conglomerates seen in other counties may not be the same as this, it is necessary to mention another possible explanation of this conglomerate. It may be a representative of the *Oriskany sandstone.* This sandstone lies at the base of the Devonian limestones in New York. It is well known in Ohio where it is sometimes quite coarse-grained, and involves pebbles of the Waterlime* which underlies it. In Illinois it is recognized by the fossils it contains, and has the local designation *Clear Creek limestone,* although its beds are cherty and siliceous. It has not been identified either in Iowa or Wisconsin. As the Upper Silurian limestones are wanting in the series of strata in Fillmore county at Spring Valley, there seems to have been some movement in the ocean level which caused the deposition of the Devonian directly upon the Lower Silurian. Such an agitation of the ocean's bed as would produce a conglomerate in Ohio, burying it under a sandstone like the Oriskany, or an arenaceous dolomite like the Lower Corniferous of that state, must have had its accompanying effects in other portions. The gradual disappearance of the Niagara limestone, the only representative of the Upper Silurian in northeastern Iowa, as it approaches Minnesota, and its entire absence at Spring Valley, seems to indicate an encroaching ocean. Such a movement would necessarily have buried its own beach-deposits beneath the sediments of its advancing oceanic waters, and may have produced a conglomerate stratum like that seen in Mower county. If this conglomerate could be found lying below the Devonian limestones, this hyopthesis would be sufficiently established, but unfortunately the drift and loam are so prevalent that the stratigraphic relations of the two have not been made out; at the same time it must be admitted that all the outcrops of the conglomerate that have been seen in Fillmore and Mower counties are so situated with respect to the strike of the limestones as to allow of the infra-position of the conglomerate.

All of these Cretaceous rocks, whether clay, sand or conglomerate, are comparable with similar rocks seen in the Minnesota valley and its tributaries, situated from seventy-five to one hundred miles west-northwest from Austin.†

*Report of the Geological Survey of Ohio. Part I. Geology, Vol. II., p. 301.
Geological Survey of Illinois, Vol. III., pp. 24, 37, and 62.

†See further respecting possible Cretaceous outcrops, under *Hudson River rocks.*

The Devonian limestones. Beginning with the uppermost of the Devonian strata, we find a *fine-grained dolomitic limestone*, quarried at Le Roy, in the southeastern corner of the county. It is exactly like that seen near Northwood, Worth county. Iowa,* a few miles south of the Minnesota state line. The full thickness of these strata cannot be stated, but about fifteen feet can be assumed for their maximum thickness at Le Roy. They contain stromatoporoid corals, and but very few other fossils. In some quarries a few beds of shale three or four inches thick can be seen between the limestone beds.

Thomas Kough's quarry is three-quarters of a mile east of the village, and exposes six feet of fine-grained beds that have a perceptible dip toward the northeast. The quarries of Joseph Brevier, of which two are opened, are in the left bank of the Upper Iowa river. The rock here is fine-grained, and in beds from three to six inches thick. On the land of F. Brevier, where the highway crosses the river on sec. 27, can be seen the underlying beds that differ much from the stone quarried at Le Roy. They appear at the spring just below the bridge, and exhibit about two feet of strata. They are granular, vesicular, and when wet rather soft; the upper part being confused and indefinite in stratification, in transition from the overlying compact beds and the magnesian rock seen on Beaver creek in Fillmore county and at Chester, Iowa. They show a slight dip to the south. The quarry of Widow Cady Palmer is at the road-crossing of the north fork of the Upper Iowa river on sec. 21, Le Roy. Levi Alsdorf's quarry, S. E. ¼ sec. 21, Le Roy, shows about ten feet of beds, parted by layers of one to three inches of shale, with a slight dip to the southeast. The quarry owned by the heirs of L. Johnson is about forty rods from the state line, in sec. 35, Le Roy. It is in a lightly timbered tract of country, accompanying the Upper Iowa river, and about ten rods south of the river. The beds rise to within a foot or two of the surface, on the the angle of the river bluff, though the bluffs of the river are not conspicuous, the depth of the valley being only about ten or fifteen feet below the general level, and broad and basin-like. The foreign drift about is light, but some large boulders are scattered about. This stone is light-colored (nearly white), hard and fine, exactly like the Devonian seen near Northwood in Iowa, though in heavier beds than that. It would make a beautiful white marble. It is uniform in, texture, and not in the least porous. With the exception of one or two layers of an inch or two of green clay, the beds are all of this limestone, exposed twelve feet. At Judson A. Palmer's quarry, the rock is overlain by six inches of soil, though a hundred rods from the river. These beds are all badly weathered, so far as opened, and show no important variation from the other quarries; exposed three feet. Mr. Palmer's other quarry is in the river bluff and has furnished stone that has been burned for quicklime. The stone is the same as that already described. Drowne's quarry is also in the bank of the river, but shows only about six feet, though there is every opportunity for opening the beds to a greater depth. There is here a more argillaceous and fissile bed than any in the other quarries. It is about eighteen inches thick. This layer, coming about midway in the quarried beds, facilitates the working of the quarry, but is itself of no value. In the debris thrown out, probably from this layer, a globular mass of *Cœnostroma* was obtained. There is an exposure of the limestone in the valley of the Upper Iowa, near the west line of the S. E. ¼ of N. W. ¼ of sec. 29, Le Roy. There is here a boiling spring, coming out of the rock, in the bed of the creek. The rock is also exposed just over the state line in Iowa, on the Little Cedar, and more particularly at Staceyville, two miles south of the line.

Underlying the above is a *granular, often vesicular, dolomitic limestone.*

*At Northwood are numerous walls and foundations built of stone exactly like that of the numerous boulders that are distributed over Freeborn county and counties further northwest. many of which have been burnt for quicklime. The layers are about four inches in thickness. but sometimes are eight inches, very close-grained, and of a light cream-color. Still, in the center of the thick beds is a blue spot, indicating the original blue color of the whole Only a small outcrop of these beds occurs at Northwood but three miles farther south, on the Shell Rock river, these beds appear again and have been opened. They are here horizontal and vary from three to ten inches in thickness. The only visible fossils are badly weathered, and show on the outer surfaces. They are *Favosites*, *Cœnostroma*, *Acervularia*, and perhaps one or two other corals. At Beckett's quarry about six feet of very bard, fine-grained beds are visible.

This appears but slightly at Le Roy, but is found along the Upper Iowa at Chester, seven miles below Le Roy, and on Beaver creek in Fillmore county.* It appears also in the northeastern part of the county, and in the southwestern. Its original line of strike probably crossed the county nearly east and west, through the central portion, and it is possible that this rock reaches still as far north as Brownsdale, but it has been driven southward by the erosive action of meteoric forces, particularly by the "drift" forces, and by the action of the Cedar river, so that it now has a flexure toward the south, even to the Iowa state line, along the Cedar valley, and its area in the county is separated into two parts. As near as it is possible to judge from the facts known, the strike of the lower beds of this limestone is shown on the plate of Mower county.

In the southwestern corner of the county, sec. 33, Lyle, are the quarries of Mr. John Beech, one of which is on the south side of Woodbury creek, east of the north and south road, and the other is on the river bank about twenty rods south of the mouth of the creek. Here are seen about eighteen feet of rough magnesian limestone beds, gradually dipping south and entering the river before reaching the state line. They are the cause of the water-power at Otranto, a few miles south, in Iowa, where flouring mills have been erected. These beds are firm, but very rough and cavernous, curly with concretionary structure and with rusty films that penetrate them. The only fossils discovered are the impressions of a coarsely ribbed *Atrypa,* having all the appearances of the so-called *little turtles,* seen in a similar rock at Spring Valley in Fillmore county. Indeed, the whole aspect of the rock is like that of the coarse rock containing those fossils. This rock here overlies the Austin rock, though the actual *overlie* cannot be seen. Its manner of approach to the river, and the topography toward the south and west, taken in connection with its dip and the relation it bears geographically to known outcrops of the Austin rock, are the only evidences. The strike of this limestone from Beech's quarry northward can be followed on the west side of the river by the terrace elevation which they cause, running about a mile west of the river. Where this terrace is crossed by Orchard creek, sec. 29, Austin, lime was burnt some years ago. Toward the north further this terrace recedes from the river, apparently

*See the Fillmore county report, p. 305.

leaving the county on the south side of Turtle creek. On the east side of the Cedar river a similar terrace, or bench of more elevated land, skirts the valley through the township of Lyle, bearing away from the river toward the valley of Rose creek, where the limerock is again exposed slightly on the land of Andrew Robertson, sec. 26, Windom, in a little valley tributary to Rose creek. The same or similar beds are next seen on the S. W. ¼ sec. 20, Frankford, where Mr. Aaron Bush quarries them in the valley of Deer creek. Here the rock is parted into blocks that are quarried out without blasting or breaking. They are much faded and rotted *in situ*, having over them only a thickness of about four feet of loam. The beds are from six inches to two feet thick, and amount to about ten feet altogether. The stone is very good for all masonry. It is easily dressed and has a yellowish buff color. On the S. E. ¼ sec. 30, Frankford, the same rock was struck in the well of G. C. Easton, and was drilled into sixty or seventy feet. The abutments of the iron bridge (over the pond) on sec. 20, are from Bush's quarry. The stone is firm and quarried in blocks three feet long and about twenty inches thick. There is another quarry not much worked a short distance below this bridge, in the banks of the creek. The rock quarried at Bush's appears in the south bank of Deer creek, at Frankford, nearly on the county line, overhanging and perpendicular, in heavy beds from two and a half to four feet in thickness. It is vesicular, as there, and porous, and even cavernous, rough exteriorly, and presents the aspects of the coarse, magnesian beds of the lower Devonian limestones as seen at Spring Valley, containing also the peculiar atrypoid casts known as *little turtles*. This is on the land of John Hawkins. Again, on the S. W. ¼ sec. 2, west of both crossings of Bear creek, similar heavy beds of magnesian limestone are seen, but nothing can be affirmed of their equivalency with those at Frankford. These appear to be overlain by the rusty conglomerate supposed to belong to the Cretaceous.

The so-called *Austin rock* underlies the foregoing coarse magnesian strata. This stone, as it appears at Austin, is a fine-grained sandrock, or shaly sandrock, that cracks like some shales after exposure to the weather. In some places, further down the river, it is a fine, calcareous sandrock. The texture of the stone itself is close and the grain is homogeneous. Some slabs have been sawn for bases to tombstones. It is more safely sawn to any desired dimension than cut or broken, since it fractures treacherously; yet it is not in the least crystalline. Although a sandstone it contains no apparent grit, and is useful for fine whetstones, or for hone-stones. As seen about the city it is very generally of a dirty buff color to the depth of half an inch or even three inches, depending on the amount of weathering or oxidation. The thinner beds are altogether changed to that color. In the center of the beds, however, in the deeper parts of the quarry, the stone is blue. The presence of occasional concretionary iron-and-mud balls causes a rusty stain ef a yellow color over the surface of many of the slabs. These concretionary balls fall out, or dissolve out when in the water, and leave cavities that become larger still. Some other cavities that have been protected within the homogeneous rock, on fracturing the rock are seen lined with drusy quartz, and the quartz is sometimes coated with a limonite scale. The rock contains very sparingly a few molluscous fossils. These are generally too much absorbed, or too fragmentary, to admit of specific identification. Among these Prof. H. S. Williams has made the following determinations, which, however, are to be regarded "as nothing more than strongly probable," viz: numerous cavities of *Aulopora*, or some allied form, a small shell like *Atrypa reticularis*, and another like *Atrypa aspera*, H., *Cyrtina*, like *C. Dalmani*, but perhaps *C. Hamiltonensis*, several lenticular-shaped shells which are probably *Nucleospira*, a minute terebratuloid shell of *Rensselaeria* type, trace of a crinoid stem, and a trace of a minute *Orthoceras*. At Gregson's mill he has also identified the following, viz: *Productella truncata*, Hall, a minute lamellibranch like a small *Aviculopecten*, and a minute brachiopod of an oval, smooth surface resembling a dorsal valve of *Ambocœlia* or (?) *Nucleospira*. On the strength of these Prof. Williams is of the opinion that the fauna belongs to an horizon near the base of the Hamilton, either below it or in an equivalent position to the New York Marcellus.

At the mill of J. Gregson, about two miles below Austin, a great deal of stone has formerly been taken out, but now the quarries of that neighborhood are nearly all flooded by water of the dam. The chief quarry was just above the present site of the mill and near the dam, on the left side, though just below the dam the rock shows on both sides and has also been wrought. The following downward section was seen at this point.

Section at Gregson's mill.

No. 1. Black loamy soil	7 to 8 feet.
No. 2. Loose fragments of the underlying beds, and clay, mixed	3 feet.

No. 3. Heavy stone like that described at Austin, with clay filling the open planes and joints..10 to 12 feet.

No. 4. Rusty bituminous films..½ to 1 inch.

[On the authority of the owners of this quarry, to this section may be added the following:]

No. 5. Limestone, filled with shells, blue, contains flint, makes lime, penetrated.. 3 feet.

The bedding of No. 3 is here broken in a manner similar to that of Alderson's quarry at Austin. The corners and angles of the beds are replaced by clay and the color of the stone is changed from blue to buff or drab, to the depth of about two inches.

Some years ago the rock was worked by Dr. Barns, of Austin, about half a mile above Gregson's mill. This quarry is now almost entirely flooded by the dam. The abutments of the upper bridge at Austin came from this quarry, in part. Judge Ormanzo Allen owned a quarry still above Barns that was also considerably flooded by the same means. The quarry most worked was just above the mill, owned by M. J. Woodson. It is now entirely under water. Stone is still taken out, however, all along, both above and below Gregson's. The beds at Gregson's show very nearly the same characters as at Austin. The descent of the stream is over about fourteen feet of rock, the layers of which are sometimes two feet or more in thickness, or massive, much like an indurated shale. In weathering these thick beds are checked by planes running mainly horizontal, instead of perpendicular or diagonal. Although mainly horizontal, these planes are apt to unite after a few feet, splitting up the heaviest beds into wedging, lenticular masses. Some parts are here plainly calcareous, affording traces of fossil remains that have the appearance of brachiopods. These portions are porous as if by the absorption of fossils.

At the mouth of Rose creek about the same thickness of the same kind of stone can be seen in the bed and banks of the creek. A fine exposure is owned by J. D. Woodard in the right bank of Rose creek near the crossing of the road from Austin to Officer's mill, perhaps a mile above its union with the Cedar. It is again seen above Officer's on the land of Col. Lewis, on the east bank.

At W. H. Officer's mill the left bank of the river shows about twenty feet of bedding. This is one mile below Rose creek. South of this mill rock of the same kind is seen at a number of places before reaching the state line. At two miles below Officer's it is quarried on R. B. Foster's land, and on Mrs. John Niles's, sec. 4, Lyle. At the last place it verges more toward a sandstone. It has been put into the foundation of a proposed mill by Alderson and company.

Two miles east of Officer's mill a farmer struck the same rock in two separate wells on his farm, in one at the depth of three feet and in the other at eleven.

Dobbin's creek, which joins the Cedar at Austin from the northeast, furnishes a water-power of fourteen feet by dam, where a mill is erected. A quarry in the left bank of this creek shows the same rock. The bluffs of the creek just below the mill rise about thirty feet, and show about twenty feet of rock. The beds are in every place greatly broken, and in some cases displaced. The rock is parted into blocks of varying size, according to the thickness of the layers, the uppermost being finest. Throughout, the partings and all the interstices are closely filled with Cretaceous clay, making the whole a close and almost impervious mass. It has very much the aspect of the Cretaceous on the Cambrian, as seen at Mankato,* except that the small cracks and openings are here all filled densely with the clay.

On the S. E. ¼ sec. 12, Windom, Mr. Thomas Smith struck the Austin rock in making explorations for coal, at a depth of about 34 feet. In the extreme northwestern corner of Mower county it was struck by a farmer in digging a well. It there has the form of the fine-grained sandstone seen at Austin. The surface features that prevail at that point pass into the northwestern corner of Fillmore county, and cover the most of Sumner township. Southward, at Spring Valley, a similar stone appears in the north side of the creek, where it has been opened for building purposes by Mr. James Wilder and Henry Thayer. This stone is, however, more dolomitic, and contains large *Strophomenæ*, and is thought to be allied to the Lower Silurian, though its palæontology has not been learned yet sufficiently to warrant any positive sentiments concerning its age.

Hudson River rocks? At two points within the county has been seen

*See the second annual report; also the report on Blue Earth county.

a light-colored, crumbling calcareous shale or clay which may belong to the Hudson River epoch. No fossils have been found in it. It has more resemblance, lithologically, to some Cretaceous beds,* but it holds, geographically, the right position to fall within the shale seen at High Forest in Olmsted county. This differs from that, however, in not being so coarse, nor in any degree arenaceous. The points referred to are both in the northeastern corner of the county. Along the road a mile and a half north of Grand Meadow it appears in a weathered and washed sloping exposure, near the crossing of the north fork of Bear creek. No other rock is to be seen in the vicinity, and nothing indicates its stratigraphic relation to other strata except that it occupies a position somewhat more elevated than the rock quarried by Mr. Bush, about a mile east of Grand Meadow. An exposure of similar shale is visible in the N. E. $\frac{1}{4}$ sec. 11, Racine, by the highway, east of the easterly crossing of Bear creek. This outcrop is topographically lower than the Cretaceous conglomerate seen in the immediate vicinity in the highest land.

The Galena and Upper Trenton. This limestone strikes across the northeastern corner of the county, and doubtless there are some exposures of it in the banks of the streams in Pleasant Valley and Racine, but none of them have been seen.

THE DRIFT.

It is only in the eastern portion of the county, and mainly in the northeastern, that there is any noticeable deposit of the loess loam. The soil here is somewhat different from that of the rest of the county, being rather lighter, both in color and composition. In general, throughout the county the drift consists of a stony clay, or till. The surface is smooth, or gently undulating. This clay has a light color for the first ten or fifteen feet, and below that depth it is apt to be blue. Stones of all kinds are disseminated through it. Some of the boulders are very large, and consist of granite. Sometimes very large boulders lie on the surface. Several such may be seen near Rose Creek village, and near Adams, and between Adams and Le Roy. At Austin a granite boulder was broken for building stone. It was at least sixteen feet long by twelve feet wide. Others were

*See the reports on Goodhue and Wabasha counties.

seen equally large in various parts of the county, and particularly on the high praries north of Brownsdale, near the county line.* Probably the average thickness of the drift for the county would be between fifty and seventy-five feet.

Ancient peat. The most interesting development in respect to the drift, in Mower county, is the existence of a bed of peat at various depths below the surface in the eastern and central portions of the county. The discovery of "coal" by Mr. Thomas Smith, S. E. ¼ sec. 12, Windom, led to some exploration of this peat bed. Mr. Smith followed it into the bank of Rose creek a distance of about seventy feet. Its greatest thickness was found to be eighteen inches. It lies at a depth of about fifty feet below the surface, having been met with in different places in that immediate vicinity. Above it is a gravelly clay, of a blue color, and the same is below it. On the top of the bed of peat were found pieces of wood, thought to be pine and cedar; but by far the most of the peaty substance consists of comminuted vegetable fiber.

This peat was met again in a shaft twenty rods further southwest, and was there about a foot thick, and about the same depth below the surface. It was met in wells two and a half or three miles northwest, at thirty-five feet below the surface. This bed of peat seems to be of considerable extent superficially. A similar deposit is struck in wells at Le Roy. Mr. J. D. Wilsey, on sec. 31, met it at twenty feet. Mr. Porter, who dug his well, describes the deposit there as largely made up of woody fiber, among which he thought he recognized hemlock bark. Several other instances of striking this buried vegetation are reported in the neighborhood of Le Roy. The clay overlying the peat bed is described as a gravelly yellow clay. Six miles northwest of Le Roy it is fifty feet under the surface, and from six to eight feet thick. It is here brownish black, and burns readily. At A. D. Parker's, near Le Roy, wood was found in digging a well. It appeared to be of cedar. At Grand Meadow wells strike black clay and muck, containing wood, at twenty-four or twenty-six feet, spoiling the water. Those that only go to the depth of twenty-two or twenty-three feet get good water. One that was fifty feet deep was so permanently bad from this cause that it was filled again. This peat has been met with at a number of places in Bennington township, and in the neighboring towns of Fillmore county. Much wood is found also in the vicinity of Lyle, at a few feet beneath the surface, in digging wells. A peat bed six feet thick was encountered on sec. 13, Pleasant Valley, at a depth of forty-five feet, underlying a compact layer of blue clay, situated in elevated land. Peat moss and sticks two inches in diameter were taken from a well at Austin, twenty feet below the surface.†

In the state of Iowa an ancient peat has slso been met with at a number of places. Dr. White describes it at Davenport, at Iowa City and in Adair county,‡ and refers its origin there to marshes that accompanied the valleys of the rivers near which the peats occur, when those rivers

*One boulder in this region was measured with the following result: North and south over the top, thirty-six feet; east and west over the top, thirty-two and a half feet; hight above the ground, eight and a half feet; with a form indicating that the major part of the stone was below the surface. A small part had been separated from the remainder, causing a fissure through the mass about ten inches in width.

†See a summary of facts respecting vegetation in the drift deposits of the Northwest in the *Proceedings of the American Association.* 1875. B., p. 43.

‡Geology of Iowa, 1870, Vol. I., p. 119.

spread wider, and flowed at higher levels. But in Mower county the peaty deposit is not confined to the valleys of streams, nor to the proximity of streams. Mower county is on one of the highest divides in the state of Minnesota, and from it flow the sources of streams toward the north, south and east. Those streams are small and never could have flooded the extent of country in which this peat is found. From all accounts it appears to be embraced between glacial deposits of gravelly clay, and it seems to mark a period of interglacial conditions when coniferous trees and peat mosses spread over the country. Peat mosses are not necessarily restricted to low, wet places. If the atmosphere be moist they will flourish on any surface, and an accumulation of good peat may take place on a bare, rocky mountain side. There are extensive marshes now existing in northern Minnesota, mainly covered with ericaceous plants, with some cedars and tamaracks, that are forming immense peat deposits. With an increase in the amount of moisture of the air such peaty accumulations would spread over much higher levels. A return of glacial conditions would bury such marshes below the deposits that are known as drift.

But little modified drift has been seen in Mower county. This, perhaps, is partly due to the fact that but little opportunity is afforded in the form of natural or artificial excavations for inspecting its actual composition. The plate of the county is wholly colored as if only the till characters of the drift exist, but a few exceptions should be mentioned. There is considerable gravel in the valley of the Upper Iowa river in Le Roy township, and in that of the Cedar in Austin and Lyle. From the south boundary of the county in sec. 33, Lyle, a flat tract consisting of gravel and sand accompanies the Cedar river northward, sometimes being about two miles wide. This plain rises from twelve to eighteen feet above the Cedar river along the north part of Lyle, and to Austin city. In the north part of Lyle a distinct terrace is seen running along the Cedar, one-half or three-fourths of a mile distant, limiting this belt of gravel and sand, and rising gradually about twenty feet above the gravel flat. This terrace gradually approaches the river toward the south, but is cut and disturbed by the entrance of Woodbury creek. The real cause of it is shown by the strike of the Devonian limestones where they appear in the banks of Cedar river, near the mouth of Woodbury creek, below which the general elevation of the country is increased, and the contour is much more rough. North of Austin this belt of gravel and sand extends to Madison, and is sometimes partly composed of stratified clay, as shown by wells in secs. 20 and 9 in Udolpho. At Dexter the surface consists of a loamy till, and at one mile east of Dexter there is a cut by the railroad in loam showing a thickness of five or six feet, while in the adjoining low land lies a large granite boulder. In general throughout the northern part of the county the till is found from six to twelve inches beneath the surface. In the valleys of Deer and Bear creeks is found more or less stratified clay, and this has been employed, formerly, in the manufacture of red brick, on secs. 15 and 16, Frankford.

Mounds. There is a multitude of mounds on the high prairies between Grand Meadow and Le Roy, which, were it not for their great number, would be unhesitatingly pronounced artificial. They are first seen surrounding a marsh about a quarter of a mile across, about two miles and a quarter south of Grand Meadow. About twenty are here visible, rising each about two feet above the surface. Farther south they increase in number, extending three or more miles toward the south and southwest. Probably five hundred could be counted, some being five feet high. They are scattered promiscuously over the upper prairie. The surface has the appearance of having been poorly drained formerly, and was perhaps covered with shallow water till late into the summer season. These mounds have the popular reputation of being "gopher knolls." It is thought that they occur where the ground is wet and the clay near the surface. Yet, south of the region designated they do not exist, though there is no apparent difference in the prairie. The material of which they consist is the ordinary loam of the surface soil. Several of them have been removed, when near the highway, and the material hauled into the street for grading. There is no record or knowledge of any human bones or other relics having been found in them.

MATERIAL RESOURCES.

With the exception of the central high prairie portion of Mower county, it is tolerably well supplied with wood for common fuel. On the prairies referred to wood is costly. That portion of the county is thinly settled with farmers. Along the valleys of the streams in the eastern and western portions of the county, the first settlements took place, and in those valleys are found the most of the population at this time. The principal natural wealth of the county lies in its soil and its agricultural adaptations. The people are generally farmers. The growth of the county in all respects will be primarily dependant on, and co-ordinate with, the settlement of the farming lands, and their profitable tillage. There is some water-power in the county, as at Austin, and below Austin to the county line, and at Le Roy and Ramsey, and it is well improved in the erection of flouring mills. Mower county contains no peat, and cannot hope for coal. The rocks that underlie the county cannot be depended on for producing anything but building stone and quicklime. Of the former some of the limestone would produce a good marble, if properly handled. That is the case particularly at Le Roy. For making quicklime there is ample opportunity. The only difficulty will be a competition with other localities from which transportation is light, that possess cheaper fuel for calcination. Red brick can be made at almost any place in the county. This has been demonstrated at Austin, Lansing, Le Roy and Frankford. At present there is no great demand for brick, and several establishments that were started have suspended operations.

The Mower county court house, just finished, is one of the finest in the state. It is built of red pressed-brick from St. Louis, but red brick from Austin were used in the inner walls. The outside basement walls are of dimension rock from Mankato, but the inner walls and general foundation are of the stone quarried at Austin. The steps leading to the front entrance are of the pinkish Kasota stone. The porch, with its carved capitals and columns, is of gray sandstone from Berea, Ohio. All the window tops and and the cap and sill courses are also of the Berea sandrock. The cornice and frieze, and the brackets, are of galvanized iron. The Masonic block, at Austin, is also trimmed with the Ohio stone.

Mr. L. G. Basford's residence has window-caps cut from the Austin stone, now standing fourteen years (1883). They are in good preservation, but are covered with paint. In other places in the city this rock is breaking up under the weather, especially in exposed steps and sills.

CHAPTER IX.

THE GEOLOGY OF DODGE COUNTY.

BY M. W. HARRINGTON.

Situation and area. This county occupies the angle formed by the boundaries of the two last described, being west of Olmsted and north of Mower. Its form is that of a rectangle, being four towns long north and south, and three in width east and west. Its total area is 438.65 square miles, or 280,738.90 acres, of which 279,956.47 are land, and 782.43 are water, according to the measurements of the original survey by the United States surveyors, on record in the office of the State Auditor at St. Paul.

SURFACE FEATURES.

Natural drainage. The surface waters leave the county for the most part toward the east and northeast by means of the branches of the Zumbro river. The largest of these is the south branch of the middle fork of the Zumbro, which rises in Rice lake, on the western border of the connty, and flows eastward through nearly the central portion of the county. The north branch of the same stream has its source in the wet prairies in the northwest corner of the county, and flows nearly eastward also. The south branch of the Zumbro reaches this county by two small streams which have their sources in the southeastern part. The upper tributaries of the Cedar river, known as the west, middle and east forks, rise in Westfield and Hayfield townships, in the southwestern corner of the county. These sources of the Cedar consist of a series of shallow lagoons which during the summer and autumn are not connected visibly by water currents. Lying in the broad depressions of the high prairies, they act as basins to receive the drainage from a large tract of country, and when they become full discharge successively into each other until their volume is sufficient to maintain a continuous stream. The water-shed between the sources of the Zumbro and the Cedar is very broad and flat, and from its summit the horizon fades out before the beholder in the dim, blue distance so gradually, that unless the air be clear it is difficult to distinguish it either to the north, south or west. This divide consists immediately of drift, as indicated by large boulders along the shallow drainage lines, and by the excavations for wells.

The fall of all the streams is inconsiderable in all parts of the county, but greater in the northern part than in the southern.

Water-power. The only improved water-power in the county is found on the middle and north forks of the Zumbro river. The following list shows the location and manner of improvement of these powers:

Mills.	Owner.	Location.	Stream.	Feet of head.	Run of stone.	Kind of mill.
Wasioja......	A. Mason & Son...	Wasioja village....	Middle fork....	9	4	Custom and flour.
Blake's.....	J. D. Blake........	Sec. 13, Wasioja...	Middle fork.....	12	4	Flouring.
Mantorville.	Adams & Kneeland	Mantorville village	Middle fork ...	{ 10 7	3	Custom.
Rockton....	John Bradford....	22, Mantorville....	Middle fork...	8	2	Custom and flour.
Agawam....	Chase & Swaringan	13, Mantorville....	Middle fork....	12	2	Flouring.
Eagle Valley	J. Gordon..	15, Concord.......	North fork.....	12	2	Custom.
Buchanan...	Widow Irish.......	Buchanan village .	North fork.....	10	....	Saw mill.
Milton....	James Elias..	9, Milton.....	North fork. ...	8	2	Custom.

Of the above mills that at Mantorville has two powers, one being about a hundred and ten rods above the other. There is an unimproved mill privilege at Concord.

The south middle branch of the Zumbro rises in Rice lake, which also has a natural outlet toward the west into Straight river, through Maple creek. In order that the mills on the eastward-flowing stream should have as much water as possible, the western outlet was cut off. Still the supply is so uncertain that the mills are compelled to stop some years during several months in the winter season. The water in the north middle branch is still more unreliable.

Topography. The surface is but little diversified. The southern and southwestern portions of the county are an undulating prairie, with no visible rock exposure, sometimes marshy, and but thinly settled. On some of these high prairies are frequently seen large quantities of boulders. They seem to prevail in the lower spots, and especially in boggy surfaces, yet are not wanting on the upland prairies. Some are twenty-five or thirty feet long, with corresponding width and hight. They are found all the way from a few miles south of Kasson to the Mower county line.* They constitute the most marked natural exception to the monotonous features

*See the Mower county report.

of the prairies. The valleys in the northeastern part of the county are from one to two hundred feet below the average level. They are sometimes precipitous and rocky, but not generally. About in the center of the county these streams pass from the drift deposits onto the rocky structure. Above this point their valleys are shallow and broad, and below it they change rather rapidly to the features that prevail, but more characteristically, in the "driftless area", and become narrow and rock-bound.

Elevations. The townships of Hayfield, Ripley and Ashland rise over thirteen hundred feet above the ocean. The valley of the north middle branch of the Zumbro descends from twelve hundred feet to slightly less than one thousand feet above the sea in crossing the county. The south middle branch descends from about twelve hundred feet to ten hundred and fifty feet in crossing the county. From the contour-lines of the map (plate 13) the townships have the following estimated average elevation, viz: Westfield, 1300 feet above the sea; Hayfield, 1340; Vernon, 1300; Ripley, 1310; Ashland, 1310; Canisteo, 1260; Claremont, 1250; Wasioja, 1225; Mantorville, 1190; Ellington, 1200; Concord, 1175, and Milton, 1140. This gives an average for the county of about 1250 feet above the sea.

According to the engineers of the Winona and St. Peter division of the Chicago and Northwestern railway, the elevation of Byron, in Olmsted county, is 1250 feet above the ocean, Kasson 1252 ft., Dodge Center 1288 ft., Claremont 1280 ft., and Havana, in Steele county, 1246 ft.

Timber, trees and shrubs. Along the streams in the eastern portion of the county is found considerable heavy timber, but the most of the county is natural grassland or prairie. In addition to the woody species named in the Olmsted county report, the following, not observed there, occur in Dodge county, and probably also others:

Menispermum Canadense, *L.* Moonseed.
Ceanothus Americanus, *L.* New Jersey tea.
Cratægus coccinea, *L.* Scarlet-fruited thorn.
Cr. Crus-galli, *L.* Cockspur thorn.
Ribes Cynosbati, *L.* Wild gooseberry.
Cornus circinata. *L'Her.* Large-leaved dogwood. Found in cold woods and on bluffs.
Fraxinus viridis, *Michx.* Green ash.
Celtis occidentalis, *L.* Sugarberry.
Ostrya Virginica, *Willd.* Hop-hornbeam.
Betula lutea, *Michx. f.* Yellow birch.
Pinus Strobus. *L.* White pine. A few straggling specimens were seen in Olmsted county There is a grove of the trees near Mantorville.
Abies balsamea, *Marshall.* Balsam fir. With the preceding.
Juniperus communis, *L.* Common juniper.
J. Virginiana, *L.* Red cedar.

THE GEOLOGICAL STRUCTURE OF DODGE COUNTY.

The underlying rocks can only be seen in the valleys of the streams in the northeastern portion of the county. Canisteo, Mantorville, Milton, Concord and Wasioja townships include all the rocky outcrops. Over the remaining seven townships the drift conceals every feature of the rock below. All the evidence that there is indicates that to some extent, at least, the rock so covered is Cretaceous, but no facts of observation can be cited to demonstrate this.

The Shakopee limestone is found in the bottom of the valley of the north branch of the Zumbro but a short distance east of the county line, and the characteristic arrangement of the bluffs, indicating that formation, enters the county about two miles and a half. The rock has not actually been seen in Dodge county, although the overlying St. Peter sandstone appears in several places. It is on the strength of this evidence that the Shakopee limestone is shown on the accompanying map as forming the floor of the valley in Milton township.

St. Peter sandstone. Surrounding this valley is the bluffy outcrop of this sandstone. It is sometimes seen in digging wells or is cut by the grading for the highway. It preserves its characters as a white, friable sandstone, growing reddish and attaining more firmness when exposed to the air.

The Trenton limestone comprises the remaining exposures along this stream. In descending the stream everything is covered by drift until reaching the vicinity of the Eagle Valley mills, sec. 15, Concord. Here a rock in rather thin layers is quarried, but without affording any good exposure of the strata. Two miles farther down the stream is a quarry at Concord, in the south bank N. W. ¼ sec. 23, with the following

Descending section at Concord.

1.	Black loam and reddish clay	4 ft.
2.	Rubble stone	2½ ft.
3.	Dolomitic rock, yellow, with fine reddish lines; layers two to eight inches thick	3 ft.
4.	Bluish stone, less dolomitic, in even beds from one to two feet thick	3 ft.
5.	Bluish stone, not dolomitic, in thin layers	1 ft.
6.	Heavy layers of bluish stone	3½ ft.
	Total	17 ft.

Below this is a compact limestone, not well exposed. It is not dolomitic and is good for burning.

At the saw-mill near the middle of sec. 17, Milton, the road passes around an exposure of rock. Here are about ten feet of shaly limestone and blue clay. A fine specimen of *Receptaculites* lay in the wheel-track of the road, and had been considerably marred. Many other incomplete specimens were found.

An eighth of a mile below this saw-mill (still in sec. 17, Milton), is an irregular bluff on the south side of the stream. It is concealed by debris, bushes, etc., and not very accessible. The following measurements and observations were obtained with as much accuracy as circumstances would admit. They are taken from above:

Section on sec. 17, Milton.

1.	Yellowish limestone in thin layers	10 ft.
2.	Compact aluminous layers, 4 to 6 inches	1 ft.
3.	Shale, limestone, and blue clay in alternate layers, usually thin	15 ft.

Below, passing under the debris and probably occupying the present river bed is a thick stratum of compact limestone, with a depth of upwards of twenty feet. *Receptaculites* is abundant in the rock.

As might be anticipated from the structure of the rock, living springs are abundant along these bluffs. One very fine one, the size of one's arm pours out from the rock just above the saw-mill, at a distance of twenty feet above the water of the stream. Here these springs are almost equal in number in bluffs facing north or south, betraying the absence of dip at this point in either of those directions.

Other small exposures of Trenton rock were seen in the road in several places within the Trenton area as marked on the accompanying map, as at sections 19 and 30 of Milton township, and in sections 12, 13 and 14 of Mantorville. The lower parts of the exposures at Mantorville and Wasioja are, in all probability, Trenton; but as it is impracticable to tell where this rock begins and the rock above ceases, these exposures will be described under the Galena. The Trenton can also be traced into this county from Olmsted, in sec. 14, Canisteo, and from Goodhue along the north fork of the middle branch of the Zumbro, near the north county line.

The Galena limestone is found cropping out along the south middle branch of the Zumbro. In descending this stream no rock is found until reaching sec. 14, Wasioja. The first important quarry is that of Thomas Arnold, on the north bank of the stream, in sec. 13. At the top of the exposed wall is a layer of five feet of rubble stone. Below this are thirty feet of dolomitic, sparry stone, yellow when weathered, but blue within. It is in evenly bedded layers from six inches to three feet thick. It works smoothly and is soft, without flint. Near the bottom the rock is gray when weathered.

A few rods below this, on the same side of the stream, are the lime-kilns of James Paul, two in number. This is in the village of Wasioja, in sec. 13. The rock, of which he has eight or ten feet exposed close by, is yellow and in thin, rather irregular, fragments. It is in all probability Galena. Mr. Paul obtains from this a lime of a light yellow color. He burns about 840 barrels per year, for which he obtains $1.00 per barrel. He uses for this eighty-six cords of wood, for which he pays $4.00 per cord. Mr. Paul praises his lime highly, and it is acknowledged by all to be good for laying stone. It is, however, generally said to be slow in slacking, and not strong. At Blake's mill, on the eastern edge of sec. 13, of Wasioja is an exposure of about thirty feet of rock where materials have been obtained for the mill and dam. The upper five feet are of broken rubble stone. The remainder is in solid, even beds, six inches to three feet thick. The stone is a limestone, yellow, dolomitic, compact, coarse-grained.

About half a mile above Mantorville, in section 17, of Mantorville township, is a natural exposure of about forty feet of rock, on the north bank. The upper twenty feet are composed of a compact rock in thick beds, yellow in color, wearing away very evenly by weathering, in a castellated manner. Below it the rock wears much more unevenly and is grayish. Between the two lies a thin soft layer which was not accessible. It wears out much more rapidly than the other rocks. It is probably a clay-shale. About twenty yards from this place is a fine spring, always flowing. It is caused by a layer of green shale lying just below it.

In the bed of the stream, just below the first dam at Mantorville, sec. 20, is a compact, dark limestone, in thin beds and not dolomitic. Just below the village of Mantorville are the quarries owned by H. Hook, P. Mantor, A. Doig and others.

Section at Hook's quarry, Mantorville.

1. Loose fragments,	4 ft.	
2. Beds from six to twenty inches each, of vesicular magnesian limestone, almost free from iron, very much used formerly for all kinds of construction,	30 ft.	10 in.
3. Thin, slaty, argillo-magnesian beds,	1 ft.	6 in.
4. Good heavy beds of magnesian limestone, same as No. 2.	11 ft.	6 in
5. Shaly and thinner beds, seen.	5 ft,	
NOTE—Where these beds are weathered out, a white deposit is accumulated on the slope below, having much the taste of lime, yet it may consist of alumina and lime. On the face of the rocks the coating is bitter and sour, tasting somewhat like Epsom salt.		
6. Heavy magnesian layers, of a buff color, with considerable shale	20 ft.	
Total	63 ft.	10 in.

The stone taken from the quarries at Mantorville is highly prized, and has been placed in some important buildings.* It is evenly bedded and can be got out in good shape. It has but little grit or flint to take off the edge of tools, working easily and cheaply. It hardens after exposure, and has a pleasant, light yellow color, or when from deep within the quarry shows a light blue color. It is rarely affected by spots of iron pyrites.

Section at Mantor's quarry.

1. Loose material, with broken rubble stone	2 ft.	
2. Light yellow rock, in layers three inches thick	1 ft.	
3. Yellow dolomitic rock, in thick beds	4 ft.	6 in
4. Shaly, yellowish rock, including a layer of two inches of an uncemented, rather fine gravel containing numerous black quartzyte pebbles		6 in.
5. Yellow, dolomitic rock, in thick beds	4 ft.	
Total	12 ft.	

In the bed of the race at the second dam at Mantorville, a hundred and ten rods below the mill, is a fossiliferous green shale. These sections, and that which follows, show that the transition from the Trenton to the Galena was gradual, the occurrence of the buff and magnesian layers marking those changes favorable for the deposition of the Galena limestone which preceded the full introduction of that epoch.

Section at Rockton mills, sec. 22, Mantorville.

1. Slope from the summit of the bluff (bid) estimated	40 ft.	
2. Magnesian layers, buff, much shattered	4 ft.	6 in.
3. Shale	2 ft.	6 in.
4. Good layers of vesicular, buff, magnesian stone, with some argillaceous patches	11 ft.	
5. Argillo-magnesian limestone, weathering into rather thin beds	3 ft.	
6. Vesicular, buff, magnesian limestone. In one bed		10 in.
7. Shale and shaly limestone	2 ft.	2 in.

*Compare the chapter on building stones, p. 167.

8.	Beds of argillaceous limestone, each of about eight inches and separated by shale beds, each of the latter being about two inches, containing *Receptaculites*	5 ft. 2 in.
9.	Shale	4 in.
10.	Vesicular limestone, argillo-magnesian, in one bed	9 in.
11.	Shaly and calcareous beds (thin)	8 in.
12.	Crystalline beds of a gray color, weathering buff, one bed	1 ft. 7 in.
13.	Shale and shaly limestone	1 ft. 4 in.
14.	Shale	8 in.
15.	Argillo-magnesian limestone, some parts crystalline and calcareous only; in three beds	6 ft. 4 in.
16.	Shale	4 in
17.	Argillo-magnesian; one bed	10 in.
18.	Shale	1 ft. 2 in.
19.	Hard crystalline limestone of a gray color with some cavities and specimens of *Rcceptaculites*	2 ft. 2 in.
20.	Shale	6 in.
21.	Argillo-magnesian, one bed; showing *Chætetes* and fucoids of the Trenton epoch	1 ft. 6 in.
22.	An interval, not well seen, of beds of greenish-blue shale and argillaceous limestone, each varying from eight to twelve inches, showing abundant fossils of the Trenton	16 ft.
23.	Blue, earthy limestone; under water and not well seen	6 in
	Total	103 ft. 10 in.

In Canisteo township, due south from Kasson, is an exposure of the Galena limestone at the crossing of one of the branches of the Zumbro, and along the stream for some distance below. It appears in heavy, coarse, cavernous layers eight to sixteen inches thick, of a buff color, and without apparent fossils, and has been slightly opened by quarrying.

Rock that resembles the Galena is used at Concord for building stone, and by the farmers for foundations between Concord and Mantorville.

THE DRIFT.

This covers nearly the whole county. Boulders are abundant and sometimes very large, as has been stated under the head of *topography*. A stony blue clay underlies the southern and western portions of the county, and its tenacious and impervious character is the cause of numerous marshes in that part of the county. This clay is uniformly met in digging wells, at the depth of from ten to thirty feet, and sometimes it contains logs and other vegetation. While it is essentially a drift-clay, probably, in nearly all cases it is augmented by the disrupted and disseminated shaly beds of the Cretaceous, which has added largely to the thickness of the drift-clay in other counties. These characters fade out toward the northeast, in Dodge county, so that the drift-clay loses its blue color, and all the materials of the drift are affected by yellow loam that there takes the place of the drift-clay.

On the railroad between secs. 32 and 33, of Wasioja, the water washed out a ditch to a considerable depth so that the following section could be seen:

Black loam	2 ft.
Yellow, sandy clay, with some small pebbles below	6 ft.
Alternations of thin, ferruginous, sandy films and black, or yellowish, sandy clay	4 ft.
Total	12 ft.

In the bottom of the ditch was a bluish quartzyte boulder, fifteen inches across, and six inches thick, worn off smoothly on one side by glacial action. The smooth side was polished, but scratched.

At the crossing of the railroad over a stream a similar section amounting to fifteen feet was seen, except that the bottom clay was dark blue and without the ferruginous films, and contained numerous drift-pebbles, and a piece of Galena limestone.

In some of the railroad cuttings in Wasioja, some ferruginous concretions of small size and much decayed were seen, with numerous fragments of Galena limestone, and a solitary piece of argillyte.

Two miles east of Kasson Mr. Watson Houston found a stick twenty-five feet beneath the surface, two feet long and three and a half inches in diameter. It was like Norway pine or tamarack, with loose texture and coarse annual growths.

Brick are made from the surface loam at Dodge Center, and three miles east of Dodge Center. At Kasson are made brick and drain tiles, for which, however, the clay is obtained at Mantorville.

Lime is burnt in sec. 17, Milton, from the strata of the Trenton, and on sec. 10, Milton, from a surface deposit of travertine.

CHAPTER X.

THE GEOLOGY OF FREEBORN COUNTY.

BY N. H. WINCHELL.

Situation and area. This is one of the southern border counties, and lies very near the center of the southern boundary of the state. It embraces five government towns east and west and four north and south in the form of a rectangle, making an area of 701.94 square miles, or 449,242.53 acres, after deducting the areas covered by water, the latter being 13,271.87.

SURFACE FEATURES.

Natural drainage. With the exception of Freeborn, Hartland and Carlston townships, the surface drainage is toward the south and south-east. The county embraces the headwaters of the Shell Rock and Cedar rivers of Iowa, and those of the Cobb river which joins the Minnesota toward the north. Hence it lies on the watershed between two great drainage slopes. For the same reason none of its streams are large, the Shell Rock, where it leaves the state being its largest. The streams have not much fall, but afford some water-power, which has been improved in the construction of flouring mills. Such are found at Albert Lea and Twin Lakes. In these cases the body of water confined in the upper lake serves as the water-head and reservoir, the mills being constructed near their outlets. There is also an available water-power near Shell Rock village, but its use would cause the flooding of a large body of land adjoining the river.

Topography. The surface of the county,* although having no remarkable changes of general contour, yet is marked by two belts or areas of rolling prairie which cross it from north to south, and is more or less covered with sparse oaks and oak bushes. The rolling tracts mentioned differ

*Some notes on the topography and on wells in this county are derived from Mr. Upham.

considerably in area but are alike in all essential features. The eastern belt of rolling land passes through sections 5, 9, 16, 21, 28, 33, in Newry township; through sections 4, 9, 16, 20, 30 and 31 of Moscow; through sections 6, 7, 18, part of 17, 19 and 30, of Oakland; section 36 of Hayward, and diagonally southwestward through Shell Rock, leaving the state east of Shell Rock river. In Shell Rock it is less marked, but a rolling surface is found along the valley of the Shell Rock river, accompanied by timber, and through sections 2, 10, 15, 16, 21, 22, 27, 28, and 33. This belt varies from one to three miles in width, and the short ridges and conical hills of which it consists rise from twenty-five to sixty feet above the smooth prairies adjoining on either side, their most characteristic development being in Newry, in section 16.

The other area of rolling surface occupies much of the central portion of the county, and varies from four to twelve miles in width, its most marked development being in secs. 1 and 2 in Pickerel Lake township. It covers nearly all of Bath, Bancroft and Albert Lea, and the northwestern third of Freeman. It also embraces the southeastern third of Hartland, the eastern three-quarters of Manchester, nearly all of Pickerel Lake and Nunda, the southeastern corner of Alden and a belt about two miles wide through the west part of Mansfield. It extends westward and northwestward in Faribault county nearly to Lura. The hills that diversify the surface in this part of Freeborn county are generally formed by smooth swells and gentle depressions in the gravelly clay, or hardpan of that part of the state, but sometimes they are abrupt and and stony, rising from seventy-five to one hundred feet. The valleys between are frequently wet, and contain much peat. The material of which the hills consist is the drift-sheet of the Northwest, mainly a gravelly clay, but sometimes gravel and sand in oblique stratification. The rest of the county is either flat or moderately undulating. The smoothest portions are the eastern two-thirds of Oakland, the greater part of London and the western half or two-thirds of Freeborn and Carlston. The marsh occupying sec. 12, Hayward, and parts of the adjoining sections, is commonly called the "big slough." The maximum depth of Freeborn lake is reported to be twenty-five feet, and of Geneva lake fifteen to twenty feet. The town of Albert Lea is forty-two feet above lake Albert Lea. The stream flowing from Fountain lake into lake Albert Lea falls eight and a half feet, and is the site of a dam and mills.

The plats of the United States surveyors, on file in the Register's office at Albert Lea, indicate considerably more area covered with timber, or as "oak openings," when the county was surveyed by them, than is now the case. The following minutes are based on an examination of their plats, and will give a pretty correct idea of the distribution of the oak openings and the prairie tracts throughout the county.

London. The most of this township is prairie, a belt of oak openings and timber entering it from the north about three miles wide, and extending to the center, bearing off to the southeast and terminating in section 24. The magnetic variation throughout the town was, when surveyed (1854), from 8° 20′ to 10° 42′, the greatest being in secs. 33 and 34.

Oakland. A little more than a half of this township consists of oak openings, an area in the easterr half only being prairie, with a small patch also in sec. 31. Two large sloughs cross the town, one through sections 30, 31 and 32, and the other through sections 4, 5, 8, 7 and 18. Magnetic variation about 9°, varying from 8° 12′ to 10° 8′, in 1854.

Moscow. Nearly the whole of this township is taken up with oak openings and marshes. Turtle creek crosses it from N. W. to S. E. A large portion of the northern half of the town is a floating marsh, containing a great quantity of peat. Magnetic variation from 9° 20′ to 10° 20′ in 1854.

Newry. There is a small patch of prairie in the northeast part of this town, secs. 1, 12, 13 and 24, and a small area in secs. 20 and 21. There is another in the N. W. corner, embracing sections 6 and 7, and parts of 5, 8 and 18. The rest is openings and marsh, particularly marsh in the S. W. corner. Magnetic variation 8° 20′ to 9° 40′, in 1854.

Shell Rock. A belt about 1½ miles wide along the west side of this town, accompanying the Shell Rock river, constitutes the only openings or timbered portion, the rest being prairie. This district also comprises some marsh, viz.: secs. 19 and 31. The first house in the county was built in sec 33 in this town, in the S. W. quarter. Magnetic variation 8° 45′ to 10° 15′, in 1854.

Hayward. A wide belt of prairie occupies about two-thirds of this town, running north and south through the center. On the west of this is a rolling tract embracing a portion of lake Albert Lea and some tributary marshes, while on the east a large marsh covers sections 12 and 14, and portions of 13, 11, 15, 22 and 23. There is also a prairie tract in sec. 1.

Riceland. This township is about equally divided between prairie, openings and marsh the first being in the south central portion, the second in the northwest and central, bordering on Rice lake, and the marsh in the northeastern part of the town. Magnetic variation from 8° 45′ to 10° 30′.

Geneva. There is but little prairie in this town, the southern portion being comprised in a large marsh which is crossed by Turtle creek, the outlet of Walnut (or Geneva) lake. The central portion is occupied by oak openings which also extend to the N. W. and W. boundaries. The prairie is in the northern and eastern portions. Magnetic variation 9° 10′ to 10° 23′, in 1854.

Freeman. This township comprises no prairie. It is mostly devoted to oak openings, but a series of marshes, drained by the tributaries of the Shell Rock, that cross it toward the S. E. take up a considerable area in the central and eastern portions. Mag. var. 9° to 10° 40′, in 1854, the greatest being in sec. 31.

Albert Lea. This township is nearly all taken up with oak openings, but a few small marshes, trending N. W. and S. E. are found in different portions. There is also a small patch of prairie in sec. 6, and another in the S. E. corner of the county. The western arm of Albert Lea lake, through which the Shell Rock river runs, is in the central and eastern part of this town and adds greatly to the variety and beauty of its natural scenery. Pickerel lake is also partly in this township. Mag. var. 8° 46′ to 10° 8′.

Bancroft. A little more than one-fourth of this township is prairie, situated in the central and southwestern portions. The rest of the town is covered with oak openings. The source of Shell Rock river is in the N. W. part of this town. Mag. var. 8° 50′ to 10° 15′, in 1854.

Bath. An area of openings comprising about half of this town in the central and eastern portions is nearly surrounded by a belt of prairie. Small marshes are scattered through the town. Mag. var. 8° 45′ to 10° 35′, in 1854.

Nunda. This town is also mostly openings, but an area of prairie occurs on sections 4, 5, 9 and 3; another lies southwest of Bear lake. Considerable marsh land is embraced within the area of openings. Mag. var. in 1854 10° 5′ to 12° 15′, the latter in section 31.

Pickerel Lake. The west half of this township is prairie, and the eastern is devoted to openings with lakes and marshes. Mag. var. 9° 45′ to 11° 50′ in 1854.

Manchester. About one-half of this town is prairie, the remainder being oak-openings. The prairie lies in the northwestern and southern portions. Small marshes occur both in the prairies and openings. Mag. var. 10° to 12° 15′ in 1854.

Hartland. This town is almost entirely composed of prairie, the only timber being about Mule or Le Sueur lake, and in the southern portions of sections 34, 35 and 36. There is not much marsh in the town. Mag. var. 9° 45′ to 12° 25′ (1854).

Mansfield. This town is nearly all prairie, a small patch of oak openings occurring in sections 3, 10 and 15. The northwest part of the township is rolling and the southeast is level and wet with marshes. Mag. var. 11° 30′ to 13° 40′ (1858).

Alden. This town is all prairie, with scattered small marshes. Mag. var. 11° 27′ to 13° 15′ (1854).

Carlston. This town is all prairie except a narrow belt of sparse timber about Freeborn lake. Long narrow marshes spread irregularly over the central and eastern portions of the town. In the southeast quarter of section 36 there is also a small area of sparse timber. Mag. var. 11° 13′ to 13° (1854).

Freeborn. In this town there is a little sparse timber about the north ends of Freeborn and Spicer lakes, and a little adjoining Spicer lake on the east. There are also some openings in section 26, where the arms of the marsh protect the timber from the prairie fires. The rest is of prairie, with spreading marshes. Mag. var. (1854) 11° 55′ to 12° 50′.

North and west of Albert Lea is a very broken and rolling surface of sparse timber. This tract consists of bold hills and deep valleys wrought in the common drift of the country. On some of these hills are granitic boulders, but the country generally does not show many boulders. The drift is usually in this broken tract, a gravelly clay. In some of the road cuts for grading a gravel is found containing a good deal of limestone.

A great many of the marshes of the county are surrounded with tracts of oak openings, a fact which indicates that the marshes serve as barriers to the prairie fires. Such marshes are really filled with water and quake with a heavy peat deposit on being trod on. They are very different from those of counties farther west, as in Nobles county, which in the summer are apt to become dried, and are annually clothed with a growth of coarse grass which feeds the fires that pass over the country in the fall. As a general rule but little or no grass grows on a good peat marsh.

The contour of the county is further exemplified by the following elevations obtained from lines run for railroad surveys:

Elevations taken from a preliminary survey made in July, 1870, *through Freeborn county, Minnesota, by* WM. MORIN.

Commencing on the state line (south) 930 feet east of the quarter stake on the south side of sec. 32, T. **101**, R. **20**; thence north to Glenville on sec 6, T. **101**, R. **20**; thence north 40° west to Albert Lea on sec. 8, T. **102**, R. **21**; thence north 40° east to Geneva on sec. 8, T. **104**, R. **20**, and thence north to the Steele county line.

	Above ocean. Feet.
Station No. 1, at point 930 ft. east of quarter stake on sec. 32, T. **101**, R. **20**,	1212
Station No. 100,	1221
Station No. 190,	1199
Station No. 199+10. Water in Shell Rock river, east bank,	1197
Station No. 200+80. Water in Shell Rock River, west bank,	1197
Station No. 202,	1212
Station No. 300. Glenville (town plat)	1221

Station No. 494. Summit between Glenville and Albert Lea,	11 miles.	1313
Station No. 654. Albert Lea (town plat),		1243
Lake Albert Lea,		1201
Station 1064. Summit at Clark's Grove,		1314
Geneva lake (or Walnut lake)		1214
Station No. 1330, at Steele county line, sec. 5, T. **104**, R. **20**,		1206

Elevations obtained of George B. Woodworth, assistant engineer of the Southern Minnesota railroad, La Crosse.

	Miles from La Crosse.	Feet above the sea.
Ramsey, crossing Iowa and Minn. div. of Chicago, Milwaukee and St. Paul railway,	103.1	1214
Depression, grade,	107.7	1197
Oakland,	109.9	1265
Summit, grade,	113.8	1270
Depression, grade,	117.6	1241
Hayward,	118.0	1248
Summit, grade,	121.5	1263
Depression, grade,	124.2	1206
Albert Lea,	124.6	1221
Burlington, Cedar Rapids and Northern crossing,	124.7	1220
Summit, grade,	128.9	1323
Armstrong,	129.8	1270
Summit, grade,	133.5	1317
Alden,	135.2	1261
Dood's switch,	139.7	1189
Wells,	144.4	1153

Elevations on the Minneapolis and St. Louis railway, from Robert Angst, assistant engineer.

	Miles from Minneapolis.	Feet above the sea.
Hartland,	94.9	1247
Manchester,	100.9	1258
Albert Lea,	108.0	1224
Twin Lakes,	115.0	1255
Norman,	121.4	1279

Average elevation of the county. The most of the county is more than 1,200 feet above the sea, the range being between 1,100 and 1,400, the average elevation for the county being about 1,250 feet. The average elevation of the different townships is about as follows, estimated from the contour lines: Newry, 1,275 feet above the sea; Moscow, 1,250; Oakland, 1,260; London, 1,225; Geneva, 1,240; Riceland, 1,240; Hayward, 1,240; Shell Rock, 1,260; Bath, 1,280; Bancroft, 1,290; Albert Lea, 1,250; Freeman, 1,250; Hartland, 1,225; Manchester, 1,275; Pickerel Lake, 1,290; Nunda, 1,275; Freeborn, 1,175; Carlston, 1,210; Alden, 1,260; Mansfield, 1,275. The mean elevation of Freeborn county, derived from these figures, is approximately 1,250 feet above the sea.

Soil. Throughout the county the soil depends on the nature of the drift combined with the various modifying local circumstances. There is nothing in the county that can properly be designated a *limestone soil*, or a *sandstone soil*. The materials of which it is composed have been transported perhaps several hundred miles, and are so abundantly and universally spread over the underlying rock that they receive no influence from it. The sub-soil is a gravelly clay, and in much of the county that also constitutes the surface soil. In low ground this of course is disguised by a wash from the higher ground, causing, sometimes, a loam and, sometimes, a tough, fine clay, the latter particularly in those tracts that are subject to inundation by standing water. On an undulating prairie, with a close clay, or clayey subsoil, such low spots are apt to have a black, rich loam or clayey loam, the color being derived from the annual prairie fires that leave charred grass and other vegetation to mingle with the soil. The same takes place on wide tracts of flat prairie. In these there may be but rarely a stone of any kind—indeed that is usually the case—but below the immediate surface, a foot or eighteen inches, a gravelly clay is always met with. This at first doubtless formed the soil, the disintegrating forces of frost, rain and wind, combined with the calcining effects of the prairie fires, having reduced the stones and gravel to powder, leaving a finely pulverized substance for a surface soil. In a rolling tract of country, while the low ground is being filled slowly with the wash from the hills, and furnished with a fine surface soil, the hills are left covered with a coarse and stony surface soil. For that reason a great many boulders are sometimes seen on the tops of drift knolls. Along streams, and about the shores of lakes, the action of the water has carried away the clay of the soil and often eaten into the original drift, letting the stones and boulders tumble down to the bottom of the bank, where they are often very numerous. Along streams they are sometimes again covered with alluvium—indeed are apt to be—but along the shores of lakes they are kept near the beach line by the action of winter ice. After a lapse of time sufficient, the banks themselves become rounded off, and finally turfed over or covered with trees. Thus lakes sometimes extend their limits laterally, but slowly become shallower.

This county is furnished with a number of very beautiful lakes. These are generally in the midst of a rolling country, and some of their banks are high.

Timber. In the survey of the county the following species of trees and shrubs were noticed growing native:

Quercus macrocarpa, *Michx.* Bur oak.
Populus tremuloides, *Michx.* Aspen.
Ulmus Americana, *L.* (pl. Clayt.), *Willd.* White elm.
Pirus coronaria, *L.* American crab-apple.
Juglans nigra, *L.* Black walnut.
Vitis cordifolia, *Michx.* Frost grape.
Prunus Americana, *Marshall.* Wild plum.
Quercus coccinea, *Wang.*, var. tinctoria, *Gray.* Black oak.
Prunus serotina, *Ehr.* Black cherry.
Carya amara, *Nutt.* Bitternut.
Corylus Americana, *Walt.* Hazelnut.
Celastrus scandens, *L.* Climbing bitter-sweet.
Fraxinus Americana, *L.* White ash.

Juglans cinerea, *L.* Butternut.	Rhus glabra, *L.* Smooth sumach.
Rubus strigosus, *Michx.* Red raspberry.	Rosa blanda, *Ait.* Rose.
Symphoricarpus occidentalis, *R. Br.* Wolfberry.	Tilia Americana, *L.* Bass.
Xanthoxylum Americanum, *Mill.* Prickly ash.	Cornus. Different species.
Salix. Different species.	Ribes Cynosbati, *L.* Prickly gooseberry.
Cratægus coccinea, *L.* Thorn.	Celtis occidentalis, *L.* Hackberry.
Acer saccharinum, *Wang.* Sugar maple.	Populus monilifera, *Ait.* Cottonwood.
Acer dasycarpum, *Ehr.* Soft maple.	Cratægus Crus-galli, *L.* Cockspur thorn.
Ulmus fulva, *Mich.* Slippery elm.	Fraxinus sambucifolia, *Lam.* Black ash.
Viburnum Opulus, *L.* High-bush cranberry.	Prunus Virginiana, *L.* Choke cherry.

Carya alba, *Nutt.* Shagbark hickory.

The last is seen on land of M. B. Bullis, in Moscow township, near the county line.—A. A. Harwood.

Besides the foregoing, the following list embraces trees that are frequently seen in cultivation in Freeborn county.

Juniperus Virginiana, *L.* Red cedar.	Pirus Americana, *DC.* Mountain ash.
Populus balsamifera, *L.* var. candicans, *Gray.* Balm of Gilead.	Populus dilatata, *Ait.* Lombardy poplar.
	Robinia Pseudacacia, *L.* Locust.
Larix Americana, *Michx.* Hackmatack.	Thuja occidentalis, *L.* Arbor vitæ.

THE GEOLOGICAL STRUCTURE.

There is not a natural exposure of the underlying rock in Freeborn county. Hence the details of its geological structure are wholly unknown. It is only by an examination of outcrops in Mower county and in the adjoining counties of Iowa, together with a knowledge of the general geology of that portion of the state, that anything can be known of the bed-rock of Freeborn county. In the absence of actual outcrops of rock within the county there are still some evidences of the character of the rock that underlies the county, in the nature and position of the drift materials. There is, besides, a shaft that has struck the Cretaceous in the northwestern portion of the county, in exploration for coal.

Although the drift is heavy it lies in such positions that it shows some changes in the surface of the bed-rock. It is a principle pretty well established that any sudden great alteration in the rock from hardness to softness, as from a heavy limestone layer to a layer of erosible shales, or from shales to more enduring sandstone, each stratum having a considerable thickness, is expressed in the drift by changes from a rough and rolling, more or less stony surface to a flat and nearly smooth surface, or *vice versa.* It sometimes happens that the non-outcropping line of superposition of one important formation with another, either above or below, can be traced across a wide tract of drift-covered country by following up a series of gravel knolls or ridges that accompany it, or by some similar feature of the topography. Again the unusual frequency of any kind of rock in the drift at a certain place, especially if it be one not capable of bearing long transportation, is pretty good evidence of the proximity of the parent rock to that locality.

Applying these principles to Freeborn county, we find throughout the county a great many boulders of a hard, white, compact, magnesian limestone, many others of which have been burned for quicklime. These attracted the attention of the early settlers, and before the construction of the Southern Minnesota railroad supplied all the lime in the county. Although these boulders are capable of being transported a great distance, their great abundance points to the existence of the source of supply in the underlying bed-rock. In the drift also are frequently found pieces of lignite, or Cretaceous coal, which cannot be far transported by glacier agencies. This also indicates the existence of the Cretaceous lignites in Freeborn county. In regard to changes in the contour of the natural surface, we see an evenly flat and prairie surface in the western tier of towns, and in the southeastern part of the county, and a hilly and gravelly tract of irregular shape in the central portion. There are two ridges or divides, formed superficially of drift, that occur in the central part of the county, one north of Albert Lea, and the other south of it, separated about eleven miles, as shown by a series of elevations for a preliminary railroad survey by Wm. Morin, already mentioned. What may be their direction at points farther removed from Albert Lea it is not possible to state with certainty, but on one side they seem to trend toward the northwest. Indeed there seems to be a northwest and southeast trend to some of the surface features. Such rough surfaces, and especially the ridges of drift are more stony and gravelly than the flat portions of the county. They mark the location of great inequalities in the upper surface of the underlying rock, the exact nature of which cannot be known.

In addition to these general indications of the character of the rock of the county, the shaft sunk for coal at Freeborn reveals the presence of the Cretaceous in that portion of the county, and examinations of the nearest exposures in the neighboring county of Iowa disclose the Hamilton limestone of the Devonian age. This limestone is exactly like that found so abundantly in the form of boulders in Freeborn county. As the general direction of the drift forces was toward the south, and as the strike of the Hamilton in Iowa is toward the northwest, there is abundant reason for concluding that that formation also extends under Freeborn county. The great distance toward the northwest through which these limestone boulders can be traced with equal abundance, is an evidence of the former extent of the Devonian rocks in that direction. The Devonian does not certainly cross the Minnesota river. Yet in McLeod county, which lies in the line of strike of the Devonian of Iowa and Freeborn county, toward the northwest, on the opposite side of the Minnesota river, the same limestone boulders are very abundant, some being so large as to have been reputed rock *in situ*, and quarried as such till exhausted. There is, in the neighborhood of Freeborn, an area of the Cretaceous, which must overlie the Silurian limestones. This Cretaceous area is believed to extend north and south across the west end of the county and to be roughly coincident with the flat and prairie portion in the western part of the county, in which case it also overlaps the Devonian.

Explorations for coal.

In common with many other places in southern Minnesota, Freeborn township, in the northwestern corner of this county, has furnished from the drift, pieces of Cretaceous lignite that resemble coal. These have, in a number of instances, incited ardent expectations of coal, and led to the outlay of money in explorations. Such pieces are taken out in digging wells. The opinion seems to grow, in a community where such fragments are found, that coal of the Carboniferous age exists in the rocks below. In sinking a drill for an artesian well at Freeborn village, very general attention was directed to the reported occurrence of this coal in a regular bed in connection with a "slate rock". This locality was carefully examined, and all the information was gathered bearing on the subject that could be found. The record of the first well drilled is given below, as reported by the gentleman who did the work.

1.	Soil and subsoil. clay	15 feet.
2.	Blue clay	35 feet.
3.	"Conglomerated rock" (Had to drill)	2 in.
4.	Sand with water	5 feet.
5.	Fine clay, tough, and hard to drill, with gravel, and limestone pebbles	60 feet.
6.	Sand with water	4 in.
7.	"Slate rock" } Probably Cretaceous	7 feet.
8.	"Coal" } Probably Cretaceous	5 feet 4 in.
	Total depth	127 ft. 10 in.

This indication of coal induced the drilling of another well situated one hundred feet distant, toward the northeast. In this the record was as follows, given by the same authority.

1.	Soil and subsoil, clay	15 feet.
2.	Blue clay	33 feet.
3.	"Conglomerated rock"	2 in.
4.	Sand with water and pieces of coal	12 feet.
	Total depth	60 feet 2 in.

When the drill here reached the "conglomerated rock", it was supposed to have reached the "slate rock", No. 7, of the previous section. The amount of coal in the sand of No. 4 was also enough to cause it to be taken for No. 8 of the previous section. Hence the boring was stopped; and having thus demonstrated the existence of a coal-bed, to the satisfaction of the proprietors, the enterprise was pushed further in the sinking of a shaft. In sinking this shaft water troubled the workmen so that at thirty-five feet it had to be abandoned.

Three-quarters of a mile north of these drills a shaft was sunk fifty-seven feet, but not finding the coal as expected, according to the developments of the last section above given, this exploration ceased. In this shaft the overseer reports the same strata passed through in the drift as met with in the first well drilled, but the so-called "conglomerated rock" was met at a depth of forty-five feet. The sand below the "conglomerated rock" here held no water, but was full of fine pieces of coal. Before sinking the shaft at this place a drill was made to test the strata. These being found "all right" the shaft was begun. In that drill gas was first met. It rose up in in the drill-hole, and being ignited it flamed up eight or ten feet with a roaring sound. The shaft was so near the drill-hole that it drew off the gas gradually, allowing the intermixture of more air, thus preventing rapid burning. From this place the exploration was re-directed to the first situation, where another shaft was begun. This was in search for the "lower rock", so called, or the "slate rock" supposed to overlie the "coal". Here they went through the same materials, shutting off the water in the five-foot sand bed, and sixty feet of fine clay, when water rose so copiously from the second sand bed (No. 6 of the first section given) as to compel a cessation of the work. In this shaft were found small pieces of the same coal, all the way. These pieces had sharp corners and fresh surfaces. The total depth here was 106 feet, and the water seems to have been impregnated with the same gas as that which rose in the drill at the point three-fourths of a mile distant. Such water is also found in the well at the ho'el at Freeborn. With sugar of lead it does not present the reactions for sulphuretted hydrogen, and the gas is presumed to be carburetted hydrogen.

Further exploration was undertaken in 1880. This was done by Mr. E. B. Clark, the shaft going to the depth of 144 feet. The section as reported by Mr. Clark, was found to be soil, 2 feet; yellow till, 14 feet; softer blue till, 29 feet; sand, 1 foot; gray till, harder than the yellow till, 47 feet; sand, 1 foot; gray till, 2 feet; quicksand, 44 feet, "containing at 124 feet from the surface a stratum of slate two inches thick, underlain by six inches of coal". Small fragments of lignite were found in the blue and gray till. but apparently not larger nor more numerous than are often found in this formation in wells throughout southern and western Minnesota. The remaining four feet were said to have been drilled in "slate"; but nearly all the detritus brought up was gray sand, with which was intermingled a small proportion of black slaty particles, perhaps making up a quarter of one per cent. This boring is eight rods farther east, and at a site three feet lower, than the first of those above mentioned.

This account of explorations for coal is but a repetition of what has taken place in numerous instances in Minnesota. The Cretaceous lignites have deceived a great many, and considerable expense has been needlessly incurred in fruitless search for good coal. In the early discovery of these lignites some exploration and experimentation within the limits of the state were justifiable, but after the tests that have already been made it can pretty confidently be stated that *these lignites are at present of no known economical value.* This, not in ignorance of the fact that they will burn, or that they contain, in some proportion, all the valuable ingredients that characterize coal and carbonaceous shales, but in the light of the competing prices of other fuels, the cost of mining them, and the comparative inferiority of the lignites themselves.

The drift. Till. This deposit covers the entire county and conceals the rock from sight. It consists of the usual ingredients, but varies with the general character of the surface. In rolling tracts it is very stony and has much more gravel. In flat tracts it is clayey. It everywhere contains a great many boulders, and these are shown abundantly along the beaches of the numerous lakes of the county. The frequency of limestone boulders, and their significance, have already been mentioned. Thousands of bushels of lime have been made from such loose boulder masses, mainly gathered about the shores of the lakes. The two belts of prominently rolling till described on page 377 are parts of a series of terminal moraines that mark the boundary of the ice-sheet in the last glacial epoch.* The average thickness of the drift in Freeborn county does not vary much probably from one hundred feet.

Gravel and sand. In general the drift of Freeborn county is glacier hardpan or till. Yet in some places the upper portion is gravel and sand, showing all the effects of running water in violent currents, such as oblique bedding and sudden transitions from one material to another.

*For a description of the mode of formation of the moraines, see the report of Waseca county.

In a gravel bank at Albert Lea, according to Mr. Wm. Morin, the jaw bone of a mastodon was found a number of years ago. It was sent to St. Paul, but was lost in the capitol fire in 1881.

From Albert Lea to a distance of four miles northward, the valley of the Shell Rock river is occupied by modified drift, consisting of stratified fine gravel, sand and silt, or clayey sand. This deposit has an area from one and a half to two miles wide, about two-thirds of its width being on the west side of the stream. Originally this nearly flat plain was continous from the east to the west side of the valley, through which the Shell Rock river has since cut its channel about forty feet in depth. A portion fully a mile wide remaining on the west side of the river in sections 29, 31 and 32, Bancroft, is known as "Itasca prairie",* a little collection of houses in the southeast quarter of section 31 being called "Itasca". The level site of the town of Albert Lea, consisting of stratified fine gravel and sand, is part of the same formation, which here is underlain by a mud or fine sand of dark color, sometimes yielding branches or twigs of wood. Besides the extension of this deposit upon both sides of the Shell Rock river and Fountain lake to the west end of lake Albert Lea, it also reaches from Itasca prairie two miles southwestward, by White lake to Pickerel lake, its width for this distance being from one to two miles. It is here nearly level, with its surface about forty feet above Pickerel and White lakes; against which, as also at the end of lake Albert Lea, it is terminated by steeply sloping escarpments. The origin of these beds of stratified drift is believed to have been from the floods formed by glacial melting, chiefly during the final recession and departure of the ice-sheet. It has evidently been in some places excavated by streams since the ice age. Yet it can scarcely be supposed that the hollows of all these lakes have been formed by such erosion; in some instances they must apparently be attributed to the presence of masses of ice remaining where the lakes now are, causing their basins to be left empty when the adjacent plains of modified drift were deposited.

Another remarkable area of modified drift known by the name of "Bear lake prairie," is found in Mansfield and the west end of Nunda, reaching six miles from north to south and the same distance from east to west in this county, while its southern portion continues two miles or more into

*This was named Paradise prairie by Lieut. Albert Lea. See page 67.

Iowa. This is a flat plain, consisting, beneath its fertile soil, of stratified sand and gravel. It is bounded on the east and southeast by Bear lake and Lime creek. Rolling areas of till jut up, island-like, twenty to forty feet above this plain in the three miles next southwest from Bear lake. The highest part of this expanse is its northwest and west border, which rests, along most of its extent, on the flanks of morainic hills. From this side a scarcely perceptible slope descends eastward thirty or forty feet in a distance varying from three to six miles, and terminates by descending beneath the water-level of Bear lake, which this modified drift bounds with a very low and flat, marshy shore. It is evident that the waters from which this plain of sand and gravel was deposited flowed in the direction of its slope, from west to east; and it is demonstrable that they were poured down upon this area, loaded with detritus, from the melting surface of ice that covered the country adjacent westward.

Bear lake prairie is surrounded by knolly and hilly accumulations of till, with an abundance of boulders and stones enclosed and strewn upon its surface, belonging to the inner or western belt of the terminal moraine. At the east these scattered and irregularly grouped hills rise twenty-five to fifty feet above Bear lake and Lime creek. At the west, in sections 31 and 32, Mansfield, they rise fifty to one hundred feet above this plain of modified drift; and three to five miles farther northwest in Kiester, Faribault county, they attain a hight fully 150 feet above the upper west edge of this plain, or about 200 feet above Bear lake. From the Kiester hills a series of morainic accumulations extends twenty-five miles or more northwestward, crossing Faribault county. At two places on the west border of Bear lake prairie, head-streams of the East fork of the Blue Earth river have their sources and thence descend westward and northward. One of these is Brush creek, which begins upon an area of low, moderately undulating till in sections 29 and 30, Mansfield, and flows south of the Kiester hills. The other is Jones' or Dunnell's creek, which rises in springs in the northeast quarter of section 17, Mansfield, issuing at the base of a bluff or bank of gravel and sand about twenty-five feet in hight, from whose top the broad Bear lake prairie stretches eastward. For a considerable distance thence northward, in section 8, this stream flows in a ravine forty to sixty feet deep, enclosed by rough knolls of morainic till. Along its next mile, in section 5, Mansfield, the morainic accumulations are less prominent and give place to smoother, undulating or moderately rolling till; except that here the stream is bordered by well-marked kames, or hillocks and ridges of water-deposited gravel and sand. One ridge, or kame, twenty to forty feet high, extends nearly a mile along the east side of the creek, separating it all this distance from a slough, to which two gaps supply outlets. Before these gaps were cut through, the slough was probably a lake. These kames are in large part gravel, very full of pebbles up to three or four inches in diameter, fully half of them being well water-worn. They also contain rarely boulders up to two or three feet in diameter. These rock-fragments, like those contained in the till of this region, are mostly granite, syenite, schists, and limestone. Though these kames are lower than the Bear lake prairie, they are believed to have been formed at a higher level, in the ice-walled channels of the glacial streams which carried forward their finer gravel, sand and silt to that plain. When the ice had wholly melted, these ridges of coarse gravel fell upon the till, which gradually descends northwestward from the moraine in a smoothly undulating surface, with no noteworthy accumulations of modified drift beyond these kames.

The plate (No. 14) which illustrates the geology of this county is designed only to show the features and distribution of the drift. In the areas represented as till-covered will be found numerous patches of modified drift which were too small to be noted. Of these, two areas of gravel and sand, which are more important than others, should be mentioned. One is along the Shell Rock river, particularly along the east side of the river, and the other extends northward from Geneva lake. Throughout the very rough portions of the morainic till there is also a frequent occurrence of large knolls and of flat tracts of modified drift, the morainic accumulation itself often consisting largely of this.

Wells. In the survey of the county considerable attention was paid to the phenomena of common wells with a view to learn the nature and thickness of the drift, and the following list is the result of notes made.

Good water is generally found throughout the county, in the drift, at depths less than eighty feet; but some deep wells that occur within the Cretaceous belt, in the western part of the county, are spoiled by the carburetted hydrogen. This must arise from carbonaceous shales in the Cretaceous, and indicates the extent of that formation.

The only well in the county that is known to have struck bed-rock is that of the Minneapolis and St. Louis railway at Albert Lea. It is near the station, on a flat which is about twenty feet below the main streets of Albert Lea and twenty feet above Albert Lea lake.

Deep well at Albert Lea.

1.	Clay, said to be free from gravel	34 ft.
2.	Quicksand	4 ft.
3.	Clay	32 ft.
4.	"Dark gray limestone," thought to be the same as that at Northwood	32 ft.
5.	White sandrock, giving a little water, which rose to within twenty feet of	

the surface ... 4 ft.

6. "Dark limestone," same as No. 4, with more water which rose to within six feet of the surface ... 41 ft.

Total depth ... 147 ft.

Notes of wells in Freeborn county.

Owner's name.	Location.	Depth in feet.	Kind of water.	Remarks.
W. P. Sargent	Sec. 29, Albert Lea	28	Good	½ bushel of coal at 26 feet.
Geo. Stevens	Freeborn	47	Carburetted	Pieces of coal in the blue clay; 26 feet of water.
T. A. Southwick	Freeborn	46	Soft	44 feet of water.
Ezra Stearns	½ mile west of Freeborn	30	Good	Found pieces of coal.
Ezra Stearns	½ mile west of Freeborn	42	Good	Found pieces of coal.
James Hanson	1 mile N W of Freeborn.	50	Carburetted	Found pieces of coal.
F. D Drake	Sec. 13, Freeborn	90	Carburetted	Water stands 5 feet from the top.
O. U. Wescott	Byron, Waseca county	94	Soft	
L. C. Taylor	6 miles N. W. of Freeborn	96	Good	Artesian; at first bringing stones and gravel.
Geo Snyder, Jr	2 miles N. W of Freeborn	61	Carburetted	
A. M. Trigg	Alden	37	Carburetted	Found pieces of coal in clay.
H M. Foot	Alden	50	Good	Found pieces of coal in clay.
John Melender	Alden	50	Good	Found pieces of coal in clay.
L. C. Taylor	6 miles N W. of Freeborn	96	Carburetted	Artesian
Wm. Comstock	3 miles N. E. of Alden	48	Carburetted	Nearly artesian.
Charles Ayers	N. W. corner of Freeborn	125	...	Bore for coal.
John Ayers	Trenton	142	...	Bore for coal; lost tools.
T. A. Southwick	Freeborn	35	Carburetted	Blue clay; water in sand and gravel.
J. F. Jones	Geneva	20	Good	Water in quicksand.
Nelson Kingsley	Geneva	12	Soft	Water in quicksand.
John Farrell	Geneva	12	Soft	Water in quicksand.
A. Chamberlain	Geneva	12	Soft	Water in quicksand.
D G. Parker	Albert Lea	72	Good	Struck gravel below the blue clay.
Dr. C. W. Ballard	Albert Lea	38	Good	In gravel
James Barker	Albert Lea	52	Good	Small bed of gravel in blue clay.
C. W. Levins	Albert Lea	25	Good	In gravel.
H Rowe l	Albert Lea	72	Good	In gravel below the blue clay.
W. W. Cargill	Albert Lea	85	Not good	Struck black clay, no sticks nor grit.
Charles Ostrom	Albert Lea	30	Good	In very fine blue sandy clay.
Lewis Gaul	Albert Lea	28	Good	"Yellow clay" all the way.
H. Rowell	Albert Lea	72	Good	Yellow and blue clay; then gravel.
Col S. A. Hatch	Sec. 4, Albert Lea	42	Good	Gravel and sand; water in quicksand.
Ole Knutson	Albert Lea	34	Good	Gravel and sand; water in quicksand.
W. W Cargill	Sec 28, Albert Lea	28	Good	Water in gravel.
Geo Topon	Sec. 29, Albert Lea	65	No water	Gravelly clay; fine sandy clay; on rock.
And. Palmer	Sec. 29, Albert Lea	28	Good	Water in green sand.
Dr A. C. Wedge	Sec 8, Albert Lea	28	Good	Water in green sand.
W. C. Lincoln	Albert Lea	32	Good	Gravel and sand, then quicksand.
Frank Hall	Albert Lea	65	Good	Gravel and sand, then quicksand.
Town well	Alden	44	Good	In gravel.
A. W. Johnson	Albert Lea	80	Not good	Drift clay; water in gravel.
Rev. G W. Prescott.	...	80	Not good	"Tastes like kerosene."
Town well	Twin Lakes	75	Not good	Clay only.
...	Alden	40	Not good	
A. Palmer, Jr	Sec 29, Albert Lea	30	Not good	Lump of coal at 27 feet.
Wm. Bell	Sec. 21, Newry	70	Good	Mainly in hard stony clay.
Jos. H. Butler	Sec. 28, Newry	75	Good	Mainly hard stony clay; water from gravel at 67ft.
James Bush	Sec 27, Moscow	32	Good	Water in sand and gravel below the blue clay.
Wm. Pace	S. E. ¼ sec. 34, Moscow	50	Good	Contains much wood; water seeps from blue clay.
S. G. Waters	Sec. 35, Hayward	40	Good	Inexhaustible water from quicksand
G. D. Barron	S. E. ¼ sec 2, Shell Rock	38	Good	Water in sand at the bottom
Ingebret Erickson	N. E ¼ sec 21, Bath	30	Good	Water from a thin bed of sand 10 ft. below suface.
Christ Lyngby	Sec. 25, Bath	18	...	Water seeps from the yellow till.
Mark A. Freeman	Sec. 14. Freeman	45	Good	Water from sand at the bottom, rising 20 feet.
John E. Hatle	N. W ¼ sec 1, Hartland	16	Good	Water at 14 ft. in sand and gravel below yellow and blue till.
Ole Peterson	S. W. ¼ sec. 15, Manchester	75	Poor	Muck at 70 ft injures the water.
Rolf Thykeson	N. E ¼ sec 16, Manchester	125	Poor	Water rises from 100 ft; stands 20 ft. below surface.
A. D. Le Fave	Sec. 2, Freeborn	70	No water	Passed through till, with some layers of sand.
Jason Goward	Freeborn village	95	Good	Water in gravel at 38 ft.
Asa Walker	Sec. 24. Carlston	100	No water	In till all the way.
James Fisk	Sec. 7, Alden	20	Good	Water from sand at the bottom.
J. A Burdick	S W. ¼ sec 24, Alden	15	Good	Water in sand at 12 ft.
Ole J Opbdal	Sec 11, Mansfield	10	Good	All fine gravel and sand.
Knut Oleson Saland	Sec. 14, Mansfield	20	Good	All fine gravel and sand.
John Cross	N. W. ¼ sec. 20, Mansfield	30	Good	Gravel and sand, 18 ft.; till, 10 ft.
Edward Emerson	Sec. 22, Mansfield	44	Good	Water rises 25 ft from sand at the bottom.
A. H Stewart	S. E. ¼ sec 18, Mansfield	50	Good	Mostly gravel and sand, underlain by till.
Several other wells	Sec. 27, Mansfield	15 to 20	Good	Only sand and gravel
John Niebuhr	N. W. ¼ sec. 17. Mansfield	96	...	Water seeps from till at 16 ft.; only till.
Wm. Emerson	N. W. ¼ sec. 18, Mansfield.	56	Scanty	Bored in clay
Wm Emerson	" (on lower land)	18	...	Water from gravel and sand at the bottom.
Several wells at.	Norman station, Iowa	15 to 30	Good	Yellow and blue till.
Several wells at	Northwood. Iowa	12 to 16	Good	In gravel and sand, underlain by fossiliferous clay.

In some wells at Albert Lea a muck is found, and such wells are unfit for use. This muck is reported to contain sticks, and is about thirty-eight or forty feet below the surface. It may indicate a former bed of the river, or an interglacial marsh.* It is by some called *slush*, and

*The Great Ice Age. James Geikie.

seems not to uniformly hold sticks and leaves, but to be rather a fine sand of a dark color. The well-diggers call it quicksand. Dr. Wedge, of Albert Lea, thinks the site of the city was once covered by a lake, and that this *slush* was its sediment; and that the overlying gravel, which is about thirty-eight feet thick, has since been thrown onto it by a later force, perhaps by currents. There is no doubt that the overlying gravel was thus deposited, those currents being derived from the ice of a retiring glacier.

Wells at Geneva are generally not over twenty feet in depth. They also pass through a gravel that overlies a quicksand. This village is situated with reference to Geneva lake as Albert Lea is with reference to Albert Lea lake, both being at the northern extremities of those lakes. The phenomena of wells at the two places are noticeably similar and in the same way different from the usual phenomena of wells throughout the county.

At Albert Lea.

Gravel, about thirty feet.
Quicksand, with water, sometimes black and mucky.

At Geneva.

Gravel, twelve to fifteen feet.
Quicksand with water.

It would seem that the history of the drift at Albert Lea was repeated at Geneva. These villages being both situated at the northern end of lake basins, are probably located where preglacial lakes existed. On all sides, both about Albert Lea and Geneva, the usual drift clay, hard and blue, is met in wells, and has a thickness of about one hundred feet.

Vegetation in the drift deposits of Freeborn county. On sec, 34, Moscow, sticks, which were apparently of tamarack, were found "in gravel and clay," from thirty-five to fifty feet beneath the surface. They were from three to eight inches in diameter, and were associated with remains of crawfish and gasteropod shells. Several other wells in this vicinity have also contained wood. On sec. 22, Moscow, Mr. D. M. Farr found a log of tamarack (?) a foot in diameter, at twenty feet below the surface, which was said to have had the appearance of having been *chopped off* at the ends [probably gnawed by beavers]. It was accompanied by peat-moss and sticks a few inches in diameter.

In Shell Rock, S. E. ¼ sec. 2, Mr. G. D. Barron's well contained a small stick of wood eighteen inches long at about thirty-five feet from the surface, and a single fragment of lignite. On sec. 28 the well of Mr. W. H. H. Gordon contained wood at about twenty-five feet beneath the surface, with fragments of bark; also that of E. Barber, on sec. 29, at about the same depth.

In Manchester, sec. 15, Ole Peterson encountered a bed of muck in his well at seventy feet below the surface. It was a foot thick and injured the water.

As already stated, considerable soft muck is found in many wells at Albert Lea.

Boulders. A few years ago a boulder was found on the border of a marsh about twelve miles south of Albert Lea, in Shell Rock, near the state line, which was supposed to be of meteoric origin, and was carried to Albert Lea for preservation. It was owned by Mr. G. D. Parker. Of this stone no further note would be made, were it not that it has been regarded by many who have seen it as a true meteorite, and that such opinion has been published. When found it was at first nearly covered by earth. On excavation it proved to be dark colored. It was among other drift boulders scattered promiscuously about. It is roughly pitted and has fragments and pebbles of quartzyte standing out all over it. It is rudely pyramidal in form and contains something more than three cubic feet, weighing about five hundred pounds. A couple of thin quartz veins cross it from one end to the other, one of them, however, running off the surface before reaching the end, being nearly parallel with the sides of the mass. It also contains hornblende, and perhaps other minerals. The quartzyte is pinkish and compact, grayish. The mass contain, no iron that can be seen. The regular quartz seams are evidence of its having been embraced once in the rocky crust of the earth. The rough exterior is due to the weathering out of some of the softer materials. It seems to have come from the great Ogishke Muncie conglomerate; but it is a rare thing to see a fragment from that formation in the drift in the central and southern parts of the state.

A large boulder exactly like the above, but one-third larger, was found about the same time in Murray county, and was offered for sale in St. Paul, with the belief that it was a meteorite.

MATERIAL RESOURCES.

In addition to the soil Freeborn county has very little to depend on as a source of material prosperity. As already stated there is not a single exposure of the bed-rock in the county. All building stone and quicklime have to be imported. The former comes by the Southern Minnesota R. R. from Lanesboro in Fillmore county, or Stockton in Winona county, though it is very likely that the Shakopee stone from Mankato will also soon be introduced. The latter comes from Iowa, largely, (Mason City and Mitchell) and from the kilns at Mankato and Shakopee. Some building stone is also introduced into the eastern part of the county from the quarries at Austin.

Lime. At Twin Lakes three or four thousand bushels of quicklime have been burned by Mr. Carter from boulders picked up round the lake shores. This lime sold for seventy-five cents per bushel. It was very fine lime, and purely white. The construction of the railroad put a stop to his profits, as the Shakopee lime could then be introduced and sold cheaper. The boulders burned were almost entirely of the same kind as those that are so numerous in McLeod county. They are fine, close-grained, nearly white on old weathered surfaces, and of a dirty cream color on the fractured surfaces. They very rarely show a little granular or rougher texture, like a magnesian limestone, though this grain is intermixed with the closer grain. They hold but few fossils. There are a few impressions of shells, and by some effort a globular mass of coarse favositoid coral was obtained.

Besides the above, which are distinguished as "white limestone", there are also a few bluish-green limestone boulders. One of these, which now lies near Twin Lakes, is about seven feet long by five or six feet broad, its thickness being at least two and a half feet. It has been blasted into smaller pieces for making quicklime, but nearly all of it yet lies in its old bed, the fragments being too large to be moved. This stone is also very close-grained. It is heavier than the other and more evidently crystalline. It holds small particles of pyrites. It is not porous, nor apparently bedded. On its outer surface it looks like a weathered diorite, and it would be taken, at a glance, for a boulder of that kind. It is said to make very fine lime. Several hundred bushels of lime were formerly burned also at Geneva.

Brick. At Albert Lea the following persons have made brick:

George Broughton, Wm. Cook, G. C. Dillingham, and Rusfeldt and

Kleven. These all make what is known as "slop brick", i. e. they handle and dry them after mixing in water, without the use of sand. The latter method (with sand) is much quicker and pleasanter, but in the use of the brick there is not much choice between the methods. At Broughton's the brick are red. The clay used, which is about five feet below the surface, is fine and of a yellowish ashy color. It is underlain by gravel. The clay itself locally passes into a sand that looks like "the bluff". At other places it is a common, fine clay-loam, with a few gravel-stones. There is but little deleterious to the brick, in the clay, although some of the brick are, on fractured surfaces, somewhat spotted with poor mixing, and with masses of what appear like concretions. The clay itself is apparently massive, but it is really indistinctly bedded, rarely showing a horizontal or oblique, thin layer of yellow sand. Oak wood costs from five to six dollars per cord.

The yard of Mr. Cook also furnishes red brick. He uses the same stratum of fine clay overlain by the same yellowish sandy clay or loam. The clay here shows to better advantage and is plainly bedded. It contains sticks, the largest observed being a little over half an inch in diameter. These sticks are plainly endogenous in cellular structure, but have a bark. They are not oxidized so as to be brittle, but are flexible still, with small branches like rootlets hanging to them. It is uncertain whether they belong to the deposit, or are the roots of vegetation that grew on the surface since the drift. There are no boulders of any size in the drift just here; but a few granitoid gravel stones. The aspect generally indicates that this clay has a local character largely, but no outcropping beds can be found in the neighborhood. Mr. Cook has made in one year 250,000 brick. The yard has been running twelve years. Brick here sell for $1.30 per hundred, as they come from the kiln, or $10.25 per thousand. Hard brick from the arch sell at $1.50 per hundred. The brick here seem to show a little more lime, but they are well made and well burned.

About a quarter of a mile south of Albert Lea, in the west edge of sec. 16 of that township, bricks have been made by Rusfeldt and Kleven since 1873. For several years previous to 1880, they made 500,000 to 700,000 yearly, selling at $7.00 per M. In the spring of 1880 they were putting in brick-making machinery, and expected to produce 1,500,000 bricks that year. The clay forms a ridge fifty or sixty rods long from northwest to southeast and about twenty feet high; it is yellowish in its upper ten feet and gray below. This clay when excavated and mixed from the upper and lower portions of the bank, contains the right proportion of sand, and none is used except for making the bricks slip from the mould. No fossils, as shells or wood, have been found in this deposit.

Bricks were formerly made at Geneva, and at a point about two and a half miles east of that place. At Geneva the clay was taken from the bank of Allen creek, about eighteen inches below the surface. It was a drift clay, with small pebbles. That used two and a half miles east of Geneva was of the same kind. In both places sand had to be mixed with the clay. About Geneva sand is abundant, taken from the gravel and sand knolls, and from the banks of the creek.

Peat. In Freeborn county there is an abundance of peat. The most of the marshes, of which some are large, are peat-bearing. In this respect the county differs very remarkably from those in the western portion of the same tier of counties, which, being entirely destitute of native trees, are most in need of peat for domestic fuel.

The peat of the county is generally formed entirely of herbaceous plants, though the marshes are often in the midst of oak openings. The peat-moss constitutes by far the larger portion. There is no observed difference in the peat-producing qualities between the marshes of the prairie districts and those of the more rolling woodland tracts of the county.

At Freeborn peat has been taken out on John Scovill's land. Here it is eight feet thick, two rods from the edge, and it is probably much thicker toward the center of the marsh. That below the surface of the water now standing in the drain is too pulpy to shovel out; and after being dipped out and dried on boards, it is cut into blocks and hauled to town. That above the water is more fibrous, and can be taken out with a spade in convenient blocks. Yet the level of the water varies, and that datum is not constant. It appears as if there were here a stratum of more fibrous peat, about twenty inches thick, that separates from the lower, and floats above it at certain times. In the peat at this place a sound elk-horn was taken out, at the depth of six feet.

There is a large peat marsh in sec. 11, Hayward, which extends also on much of secs. 12, 13, and 14.

CHAPTER XI.

THE GEOLOGY OF STEELE COUNTY.

BY M. W. HARRINGTON.

Situation and area. Steele county* (plate 15) lies in the second tier of counties from the Iowa line. It lies next west of Dodge county, being the fourth in number west of the Mississippi river. It has the form of a rectangle, and is bounded on the south by Freeborn, on the west by Waseca, and on the north by Rice county. The area of Steele county, compiled from the plats of the United States surveyors, is 430.59 square miles, or 275,579.16 acres, of which 2,817.69 acres are covered by water.

SURFACE FEATURES.

Natural drainage. This county is well provided with lakes, as may be seen in the following notes. Marshes also are numerous. These are due to the nearly level character of the county, and to the very slight elevation of one part above another. The small amount of slope in the surface is further shown by the sluggishness of the currents in the various streams. The course of the Straight river shows that some increase in hight occurs as we travel southward. But, although the county is very nearly level and has little change of elevation within itself, its elevation with reference to the rest of the state is considerable. This is shown by the fact that two streams originate here, viz: the Straight river in the southern part of the county, and a branch of the Zumbro.

Water-power in Steele county.

The small amount of fall of the streams limits the mill privileges in this county. The mills are found only on the Straight river, at Owatonna, and north.

The *City mills* at Owatonna, Drought and Whitson, owners. They have seven feet head of water, and three run of stone. It is a custom mill, but does a little export business.

*This county was examined in 1875, and was described in the annual report for that year. In the present report additional details are derived from Mr. Upham, respecting the drilling for an artesian well, the glacial drift, and sections of the drift shown by common wells.

Clinton mills are at Clinton Falls, Sherman and Winship, owners. They have ten feet head of water, and three run of stone. It is a custom and export mill.

Medford mills are at Medford, White, Beynon and company, owners. They have ten feet head of water and four run of stone. They do only an export business.

There is said to be an available water-power, unimproved, at Lindersmith's, between Owatonna and Clinton Falls.

Topography. This county is for the most part moderately undulating or nearly level, and is covered heavily by drift. As will be seen the rock appears at the surface only along the Straight river, near its exit from the county. Grassy swales are common and characteristic of the swamps, especially in Lemond township. Gravelly knolls are quite common in much of the county, especially in the southern part. They are short and steep in the southeast part of Somerset and the adjoining parts of Aurora, Summit and Blooming Prairie.

The following notes were taken from the field-notes and plats of the government survey in Steele county, access to which was obligingly given by the county register. The surveys were made in 1854.

Blooming Prairie was covered by thickets and low scrub for the most part. Marshes were numerous and there were two small lakes in the northern part of the township.

Aurora. This township much resembles the last; thickets and scrub over the most of it and numerous marshes, some of them quite large.

Havana. This township contains the major part of Rice lake. It is for the most part brushy or wooded, but the southwest part is prairie. Marshes are numerous but not large.

Merton. This township was found to be wooded on the south side and in the northwest corner. The remainder was prairie. A large marsh was located in sections 23 and 24, and many smaller ones were scattered over the country.

Summit was wooded in the eastern half, prairie in the western. A large branching marsh is located along the streams, and there are a few isolated marshes.

Somerset had several sections of prairie in the northeast corner, and the portion of the township lying west of the Straight river was prairie; otherwise it was wooded. The marshes platted are few and not large.

Owatonna. A band of woods, two or three miles wide, crosses the township, accompanying the Straight river and lying on its eastern bank. The remainder is prairie. The banks of the stream are bluffy. The site of the city of Owatonna was already in part claimed when the survey was made (1854).

Clinton Falls was mostly wooded, though a wedge of prairie lay between the Straight river and Crane creek. There was also a little prairie on the eastern border. There was a long marsh platted in sections 26 and 27.

Medford. This township is prairie, except for a wooded strip two to four miles wide, east of the river. The banks of the stream are rather bluffy.

Berlin was wooded through the center of the township; the remainder was for the most part prairie. The plats indicate marshes along the streams, and some other scattered marshy spots. Near the center lie Lonigan's and Beaver lakes, and in the southwestern part a pond. Beaver lake is said to be deep and clear, and to contain only soft water. This item, and much other valuable information concerning this county, the writer owes to Rev. G. C. Tanner, superintendent of schools for the county.

Lemond. The northwest part was woody and marshy, and there are besides two or three isolated groves of small extent. An extensive marsh crosses the north end of the township.

Meriden. This township was nearly all prairie, a little wood being found north of Crane creek and also a small amount in the southern part. The land along the creek was marshy. On the northern boundary a small lake was found.

Deerfield. A lake enters from the south. Another of about 220 acres is platted just north-east of this, and near it is a pond of about half the size. All the township was wooded except the northwest corner, which was prairie. Extensive marshes were platted in the southern and western part.

On comparing the magnetic variations given on these plats, as observed during the survey in 1854, it is found that the extremes are 7° 37′ in Morton, and 11° 40′ in Deerfield, eastward from the true north.

Elevations on the Winona & St. Peter division of the Chicago & Northwestern railway.
From John E. Blunt, engineer, Winona.

	Miles from Winona.	Feet above the sea
Claremont (Dodge county)	76.36	1280
Havana	83.90	1246
Owatonna	88.17	1144
Meriden	96.35	1149
Waseca (Waseca county)	102.63	1153

Elevations on the Iowa & Minnesota division of the Chicago, Milwaukee & St. Paul railway.
From profiles in the office of George H. White, engineer, Minneapolis.

	Miles from St Paul.	Feet above the sea.
Straight river, water, 1069; grade	60.2	1090
Medford,	60.4	1098
Clinton Falls,	62.5	1107
Maple creek, water, 1113; grade,	65.9	1128
Owatonna,	66.6	1144
Summit, grade,	70.3	1245
Somerset,	71.7	1222
Aurora,	75.2	1253
Turtle creek, water, 1238; grade,	75.7	1246
Road crossing in section 34, Aurora, -	78.5	1301
Summit, grade,	82.1	1313
Blooming Prairie,	84.6	1286

The hills of the terminal moraine in Blooming Prairie, Summit, Aurora and Somerset, are 1300 to 1350 feet above the sea, and are the highest land of this county. Its lowest land is where its northern boundary is crossed by Straight river, approximately 1060 feet above the sea. The extremes of elevation thus differ about three hundred feet.

Mean elevation of the county. Estimates of the average hight of the townships of this county are as follows: Blooming Prairie, 1300 feet above the sea; Aurora, 1280; Havana, 1240; Merton, 1240; Summit, 1250; Somerset, 1230; Owatonna, 1200; Clinton Falls, 1190; Medford, 1175; Berlin, 1250; Lemond, 1220; Meriden, 1175; Deerfield, 1160. The mean elevation of Steele county above the sea, derived from these figures, is approximately 1225 feet.

Soil and timber. This county has a fertile soil, and is wholly adapted for cultivation excepting a few unusually knolly tracts of small extent, and frequent sloughs which are valuable for their crop of marsh hay. Nearly all of the county is prairie, diversified here and there by tracts thinly wooded with bur oak. The only heavy timber of considerable area is found in a belt at the east side of Straight river, in Owatonna, Clinton Falls and Medford. The time spent in this county was not long enough to make out a complete list of its trees and shrubs. The following were noted.

Trees and shrubs of Steele county.

Tilia Americana, *L.* Basswood.
Rhus glabra, *L.* Smooth sumac.
Vitis Wild grape.
Ampelopsis quinquefolia, *Michx.* Virginia creeper.
Ceanothus Americana, *L.* New Jersey tea.
Acer saccharinum, *Wang.* Sugar maple.
Acer dasycarpum, *Ehr.* Silver maple.
Acer rubrum, *L.* Red or swamp maple.
Negundo aceroides, *Mœnch.* Box-elder.
Amorpha fruticosa, *L.* False indigo.
Prunus Americana, *Marshall.* Wild yellow or red plum.
Prunus. Cherry.
Rubus strigosus, *Michx.* Red raspberry.
Rubus villosus, *Ait.* Blackberry.
Pirus coronaria, *L.* American crab-apple.
Cornus paniculata, *L'Her.* Dogwood.
Symphoricarpus occidentalis, *R. Br.* Wolfberry.
Fraxinus. Ash.
Ulmus fulva, *Mich.* Slippery elm.
Ulmus Americana, *L.* White elm.
Juglans cinerea, *L.* Butternut.
Juglans nigra, *L.* Black walnut.
Carya. Hickory.
Quercus macrocarpa, *Michx.* Bur oak.
Quercus coccinea, *Wang.*, var. tinctoria, *Gray.* Black oak.
Corylus Americana, *Walt.* Hazelnut.
Ostrya Virginica, *Willd.*
Populus tremuloides, *Michx.* American aspen.
Populus grandidentata, *Michx.* Large-toothed aspen.
Populus monilifera, *Ait.* Cottonwood.

GEOLOGICAL STRUCTURE.

The glacial drift is so thick that it effectually conceals the underlying strata throughout this county, excepting slight exposures of the bed-rock in the valley of Straight river at and near Lindersmith's, two to three miles north of Owatonna. This rock has been referred, with some doubt, to the Hudson River epoch by Prof. Winchell. It certainly falls within the Trenton period, and may be lower than Hudson River.

The rock is an argillaceous and dolomitic limestone, and is first met at John Abbott's quarry, in section 33, Clinton Falls. It is in the bed and on the low banks of Straight river. The exposure at the time of examination extended only about four feet above the surface of the water. The rock is in horizontal layers, two to six inches thick. It is blue on fresh fracture, yellow when weathered, compact, sparry, and contains many minute fragments of blue shale. The loamy clay overlying was evidently not deposited by glacier ice, the rock *in situ* being rotted with age, like much of the rock in northeastern Iowa.

Just below, on section 28, is Lindersmith's quarry. The rock is in thicker layers than in Abbott's quarry. The following section was seen in one place, beginning above:

Loam	2 feet.
Black clay and limestone, in thin layers	2 feet.
Compact, blue limestone, in thin layers, to water's surface	4 feet.

The rock is like that in Abbott's quarry. Near by was another section as follows:

Black and red loam	2½ feet.
Hard, yellow clay	2 feet.
Blue stone, in layers two to five inches thick, extending to surface of water	7 feet.

Below this there is no more rock until the county line is passed. No fossils were found in the rock. This stone is used for flagging and other purposes at Owatonna, and is considered a good stone.*

Some evidence of the existence of Cretaceous beds was found. On the southeast quarter of section 26, of Deerfield, on the farm of Aug. Hoffmann, coal has been found in sinking a well. Dr. G. A. Rossbach states that they went through twenty-five feet of blue-black clay, in the under part of which were fragments of coal. After that they passed through gravel in which also were coal fragments. At the depth of sixty-three or sixty-four feet rock was struck; the drill showed it to be black shale with pieces of coal imbedded in it. Although no specimens of the coal were seen by the writer, the description given would answer for Cretaceous lignite. The evidence from the geology of adjoining counties, as well as the nature of the rock itself, justifies us in calling the rock Cretaceous. Just west of Owatonna another farmer is said to have struck coal also, though the writer was unable to get any further information on the matter.

Drilling for an artesian well. By a subscription of the citizens of Owatonna, a well was drilled in 1878, near the center of that city, to a depth of 387 feet. No artesian flow was obtained. Its site, a few feet higher than the depot, is approximately 1150 feet above the sea, being twenty-three feet above the top of the dam in Straight river, and some fifty or sixty feet below the average hight of the surrounding region. Mr. John Shea and Mr. Samuel H. Baker have furnished notes of the succession of beds penetrated by this well, as follows:

Section drilled for an artesian well at Owatonna.

		Thickness in feet.	Depth to top of strata.	Hight of top of strata above the sea.
1.	Gravel and sand	20	0	1150
2.	Blue, stony clay	14	20	1130
3.	Gravel and boulders, with much water	5	34	1116
4.	White quartz sand	21	39	1111
5.	Soft limestone, decayed	2	60	1090
6.	Yellow clay, making the water very yellow	1	62	1088
7.	White sandstone, quite hard	35	63	1087
8.	Blue, compact limestone	20	98	1052
9.	Blue sandstone, "like grindstone grit"	10	118	1032
10.	Blue shale	10	128	1022
11.	Light gray shale	10	138	1012
12.	Shale, "full of specks of iron pyrites, very hard to drill"	3	148	1002
13.	Blue shale	20	151	999
14.	Light gray shale	5	171	979
15.	Blue clay	12	176	974
16.	"Yellow, pyritous, very hard rock, appearing to contain scales of mica"	2	188	962
17.	Blue clay and shale	50	190	960
18.	Lead-colored clay, making the water dark-bluish	3	240	910

*See also the chapter on the building stones of Minnesota, pp. 176 and 200-203.

19.	Like No. 16	7	243	907
20.	Blue shale, arenaceous	3	250	900
21.	Blue shale	8	253	897
22.	A cherty layer	1	261	889
23.	Blue limestone	28	262	888
24.	White sandstone	80	290	860
25.	Similar to the last but very hard, thought to contain iron pyrites	8	370	780
26.	White sandstone	9	378	772
	Total		387	Bottom, 763

These notes are discussed as follows by Mr. Upham, in respect to the geological age of the several parts of the section.

The first thirty-nine feet are *drift*.

The next fifty-nine feet, to a total depth of ninety-eight feet, appear to be *Cretaceous* deposits. Formations of this age, including thick beds of sandstone. occur in Blue Earth county and farther west in this state, in northwestern Iowa, and in Dakota; but no massive sandstone, as found in this well from the depth of sixty-three to ninety-eight feet, is known in any of the older formations of this part of the continent till the horizon of the St. Peter sandstone is reached, which surely underlies these and the next lower strata of this section.

From 98 to 118 feet is undoubtedly the limestone before described, which outcrops beside the Straight river within a few miles northward. In this well its hight above the sea is approximately 1030 to 1050 feet, its top being thus fifty feet, very nearly, lower than the quarries three miles farther north, in Clinton Falls. This stratum thus dips to the south about sixteen feet per mile. If the same dip continues through the eight miles northward from the Clinton Falls quarries to the point near the center of Walcott township, in Rice county, where the Straight river cuts through the Trenton limestone into the St. Peter sandstone, it would carry the horizon of the limestone found at the depth 98 feet, or 1050 feet above the sea, in the Owatonna well, and at about 1100 feet in Clinton Falls, to a hight 175 to 200 feet above the top of the St. Peter sandstone, which is 1040 feet, very nearly, above the sea, in Walcott and at Faribault. This consideration. and the character of the beds penetrated in the next 144 feet at Owatonna, consisting mostly of shale and clay, lead to the conclusion that these strata from 118 to 262 feet in the Owatonna well, correspond to those which were penetrated, having a thickness of about 100 feet, above the Lower Trenton limestone in the well at the State reform school, near St. Paul, as described in the report of Ramsey county.

The blue limestone, twenty-eight feet thick, next in the descending order, between 262 and 290 feet in depth, is quite certainly the *Lower Trenton limestone;* being the same formation that occurs at Faribault, and at St. Paul, Fort Snelling and Minneapolis.

The remaining ninety-seven feet to the bottom of this section are the *St. Peter sandstone.*

Glacial drift. The drift in Steele county consists chiefly of till, or clay, sand, pebbles and boulders, mingled in an unstratified deposit, of which clay is the prevailing ingredient. It reaches from the surface to a depth that varies in this county from fifty feet to probably a hundred feet or more. The contour of this region is smoothly undulating and often nearly flat, excepting two belts of knolly and hilly till, from one to several miles in width, which extend from north to south, divided by a tract of gently undulating till, from six to fifteen miles wide. These are moraines heaped at the east border of the ice-sheet of the last glacial epoch, as terminal moraines are formed at the end of alpine glaciers. A considerable retreat of the ice, probably followed by a re-advance, took place between the time of accumulation of the eastern or outer belt of hills and hillocks and that of the inner, western member of this twofold formation.

In this county the eastern morainic belt extends through Merton, Havana, Aurora and Blooming Prairie, its eastern range of townships. It occupies the greater part of Merton, at the northeast corner of this county; but its hillocks, mounds or swells are only from twenty to thirty and rarely forty feet high. Most of them consist of till, or drift clay, enclosing boulders; but here and there are mounds of irregularly stratified fine gravel and sand. The east third of Havana has a similar rolling surface, bordering the west part of Rice lake. Through Aurora this moraine is well exhibited in scattered mounds and hillocks, fifteen to forty feet high. On the road from Owatonna to Blooming Prairie and Austin, it is crossed in sections 9, 15 and 22, being here about three miles wide. At Aurora station and for one and a half miles south, this formation is finely seen at the east side of the railroad, by which it is crossed in section 28. The boundaries of the moraine are very definite in this township. Its narrowest place in the county is found in section 28, north of which it is indented on the northwest side by a tract of lowland and marsh, which lies next west of the railroad, reducing the width of the hilly tract to one mile. At the west and southwest this quickly widens again to two or three miles, covering sections 29, 30, 31, and 32, of Aurora, and sections 25 and 36 of Somerset, with a profusion of knolls and hills, twenty to fifty feet high, sprinkled with boulders, principally granite and gneiss, mostly less than two feet in diameter, with occasional blocks or slabs of limestone, sometimes six or eight feet long. These elevations are seldom prolonged more than a few hundred feet. The trend of their longer axes is more frequently from east to west than otherwise, but this is not very noticeable. From the southeast corner of Somerset the moraine turns southward, and extends in typical hills and short ridges through the west two ranges of sections in Blooming Prairie. Here the trend of its separate elevations is most frequently from north to south, being parallel, as before in its east and west trends, with the course of the whole series. In the west part of sections 8 and 17, Blooming Prairie, these rough hillocks are well exhibited, being twenty to fifty feet above the depressions, and seventy-five or one hundred feet above the neighboring creek.

The largest boulders seen in this county are one about twelve feet in diameter at the Rock school-house in the southwest corner of section 8, Merton, and a second of about the same size beside the road in the northeast part of Summit.

The western or inner moraine lies in eastern Waseca county and in the southwest edge of Steele county, and extends from north to south in Freeborn county by Albert Lea, having a width that varies from three to ten or twelve miles. In Steele county this morainic belt occupies the southwest part of Meriden and the western two-thirds of Lemond and Berlin townships, being made up of massive swells of smooth contour, twenty to forty feet above the frequent depressions, many of which contain sloughs. The east portion of this prominently rolling land is three or four miles west of Straight river.

Wells in Steele county.

The records of the materials met in digging wells, examples of which are here given, further illustrate the character of the drift deposits.

Blooming Prairie. At the village the wells are 8 to 14 feet deep, averaging 10 feet. They go through till to the top of a stratum of quicksand, which has a considerable extent. The well at the south elevator was dark soil, 3 feet; hard, yellow till, 7 feet; and quicksand, 3 feet, penetrated with difficulty because of the large supply of water, which rises two to five feet above the top of this bed; to coarse gravel at 13 feet. This well and the similar railroad well, 14 feet deep, some twenty-five rods farther north, are the deepest here, no others having a depth of more than twelve feet. In wet seasons the cellars of this village are filled with water.

C. B. Pettie; sec. 24: well, 16 feet; soil, 2 feet; till, 14; quicksand at bottom. Wells in the vicinity are 15 to 25 feet deep, mostly less than 20; they obtain a large supply of excellent water.

C. J. King; N. E. ¼ of sec. 8: well, 15 feet; soil, 2 feet; clayey sand, 12; quicksand, 1 foot and extending below; water abundant.

Peter Thimson; also, N. E. ¼, sec. 8: well, 26 feet; soil, 2; sand to water at the bottom, 24 feet.

S. Peterson; N. W. ¼, sec. 9: well, 40 feet; soil, 2; gravel and sand, 8; yellow and blue till, 30; water rose 30 feet from sand and gravel at the bottom.

The three wells last described, and the next following, situated near the margin of the eastern terminal moraine, just outside the area that was overspread by ice, are in the modified drift which was deposited by water flowing from the wasting surface of the ice-sheet. These beds of stratified sand and gravel often reach a half mile to one mile away from the moraine upon its east side, varying in depth from 10 to 25 feet or more, with a smooth contour inclined slightly eastward

Aurora. John Bixby; N. E. ¼ of sec. 33, about thirty rods southeast from the boundary of the moraine: well, 29 feet deep; soil, 3 feet: coarse gravel, 2 feet; sand, 20 feet; blue till, 4 feet, and continuing lower; water comes in sandy veins in the till, not rising. Another well close southeast, and a third, one mile east, are likewise in gravel and sand, which here extend fully a mile from the edge of the morainic belt.

Havana. Wells at Havana station are shallow. J. S. Austin here went to a depth of 17 feet; the order being soil, 2 feet; sand, 4 feet; yellow till, 8 feet; and sand, 3 feet, not penetrated.

George L. Chambers; S. W. ¼ of sec. 20: well, 42 feet; soil, 2 feet; yellow till, 8; blue till, 32, water rose from quicksand at the bottom to a permanent level five feet below the surface in three hours. A few wells near the foregoing, about half a mile south of Havana station, find water at a depth of 40 feet that is offensive to smell and taste; but, excepting these, the water of wells and springs through all this region is good.

At the south side of the southwest quarter of section 29 are two flowing wells, the only ones learned of in this vicinity. The westmost, in the corner of this section, dug 16 feet and bored 18 feet lower, to a total of 34 feet, owned by Frank Truhlar, has been flowing twelve years. The other, about a third of a mile farther east, on John Chambers' farm, rented to L. L. Inman, is thought to be of nearly the same depth.

Merton. James Gibson; sec. 8: well 47 feet; soil, 2; yellow till, 10; blue till, spaded, 35; water stands 27 feet deep, rising from the bottom.

Somerset. G. Storer; sec. 33: well, 21 feet; soil, 2; yellow till, 8; harder blue till, 10; sand, 1 foot and extending lower, from which water rose 11 feet.

Lemond. C. G. Hersey; N. E. ¼ of sec. 21: well, 51 feet; soil, 2 feet; very hard yellow till, 10 feet; sand, 4 inches, containing water; blue till, picked, about equal in hardness with the yellow till, 39 feet, containing no layers of gravel or sand and no water.

Owatonna. In wells about Owatonna, sticks or fragments of wood are occasionally found in the till 30 to 50 feet below the surface; and a layer of peat is reported to occur under a considerable depth of drift, about three miles south of the city.

Mineral springs. The Owatonna mineral springs should be mentioned. They are nine in number, and are located about one and a half miles northeast of the city. They lie along Maple creek at the base of a low clayey bluff. Of the five seen by the writer, four deposited iron. The water of the fifth had a decidedly bluish tint. Fountain spring comes through a pipe that was put down twenty-two feet; the water flows out freely, rising about five feet above the surface. The others are natural springs. They are all undoubtedly due to the clay-floor underlying the loose material of the drift. The taste of the water in the five visited by me was slightly mineral. The analysis of the water, published by the Owatonna Mineral Springs company is appended. To which of the springs this analysis belonged could not be ascertained.

In one gallon, or 231 cubic inches, there are:

Chloride of sodium	.1680 grains.
Sulphate of sodium	.2856 grains.
Bicarbonate of sodium	1.8592 grains.
Bicarbonate of calcium	13.1992 grains.
Bicarbonate of magnesium	5.2920 grains.
Bicarbonate of protoxide of iron	.6160 grains.
Alumina	.2800 grains.
Silica	1. 1200 grains.
Organic matter	a trace.
Total	22.8200 grains.

Pottery and brick. Cornell Brothers, at Owatonna, manufacture stone ware. The clay employed is a fine, rich, plastic, blue clay, obtained from Eldora, Hardin county, Iowa. This bed of clay is being exhausted, and its quality is deteriorating. This has determined the firm to try a gray clay found about one mile east of Owatonna. This is the same layer of clay which crops out at the mineral springs near the city. It has been found to work well. Excellent fire-brick are also made from this clay. This firm manufactures about 1,000 gallons a week in jars, jugs, &c.

Dr. E. N. Morehouse makes common brick from a bluish, yellow washed clay, near Owatonna. He puts in the clay about one-third sand. He makes 225,000 bricks a year, using fifty cords of wood for every 100,000 of bricks. The bricks are, like all of those made from the washed clay, not first-class. Dr. Morehouse has experimented on making unglazed red ware from his clay, with fair results.

Odell and Cornell also make bricks near Owatonna. Bricks are also made on the farm of Mr. Skinner, near Blooming Prairie.

Mounds. A series of large mounds, which have much the appearance of being artificial, are situated on the east side of the slough at Aurora station; and several others lie near the railroad a few miles farther south.

CHAPTER XII.

THE GEOLOGY OF WASECA COUNTY.

BY WARREN UPHAM.

Situation and area. Waseca county (plate 15, page 395) lies in the south part of Minnesota, in the second tier of counties north of Iowa. Its largest town and county seat is Waseca, in Woodville township, about 65 miles distant, in a direction a little west of south, from Saint Paul and Minneapolis, 93 miles west of Winona, and 40 miles north of the Iowa line. This county is a rectangle, twenty-four miles long from north to south and eighteen miles wide from east to west, including twelve townships of the governmental surveys, each of which, six miles square, is an organized civil township. The area of Waseca county is 437.01 square miles, or 279,685.91 acres, of which 11,524.16 acres are covered by water.

SURFACE FEATURES.

Natural drainage. The Le Sueur river has its farthest sources in the southeast part of Waseca county and in the adjoining edges of Steele and Freeborn counties. This stream and its tributaries drain all of Waseca county excepting its northeast corner.

The main Le Sueur river runs from the southeast corner of this county northerly six miles through the east part of New Richland; then westerly through southern Otisco, into the southeast part of Wilton; then again northerly six miles to Carr's ford, in the southeast part of Saint Mary township; and thence westerly eleven miles through the north part of Saint Mary and Alton. On the right this stream receives small tributaries in sections 7 and 6, Otisco, the latter being named McDougal creek, and in sec. 34, Saint Mary. Its only considerable tributary on the left in this county is Boot creek, which comes from the south, approximately coinciding in its course with the boundary line between New Richland and Byron.

About a quarter of Waseca county, at the southwest, sends its surplus waters to the Le Sueur by the Big Cobb river, which flows through the south part of Vivian; while a branch of it, the Little Cobb river, and Bull run, tributary to the last and the outlet of Silver lake in Wilton, flow westerly across Freedom township, into Blue Earth county.

At the northwest, nearly all of Janesville, western Iosco, and the north part of Alton are drained by the way of lake Elysian and its outlet, which also passes into Blue Earth county and is there tributary to the Le Sueur river. Iosco creek, the largest stream that enters lake Elysian, receives a branch from the southwest named Silver creek.

The basin of the Cannon river extends into the northeast part of Waseca county, including northeastern Iosco, Blooming Grove, and the north part of Woodville, in all about sixty square miles. A considerable creek runs from Iosco northward to Waterville, and there empties into the west part of lake Sakata, through which the Cannon river flows; and Crane creek, tributary to the Straight river in Steele county, and by that to the Cannon river, has its source in Rice and Watkins lakes at the north line of Woodville.

Lakes. Lake Elysian, the largest body of water in this county, is five miles long and from a third of a mile to one mile in width. It has a north-northeast trend, and lies mainly in Janesville, but its north end is crossed by the county line. Rice lake, one and a third miles long from west to east, in sections 5, 6, 7 and 8, and Willis lake, in the southwest quarter of section 9, Janesville, lie west of lake Elysian; and lake Lily, and Reed's and Toner's lakes, each about a mile long, with east-southeast trends, extend in a series southeastward from Okaman at the head of lake Elysian, lying, except the northwest end of lake Lily, within the northwest quarter of Iosco. Helena lake, about three-quarters of a mile long from west to east, is crossed by the line between section 31, Iosco, and section 36, Janesville. Four small lakes, a quarter to a half mile in length, lie in Blooming Grove township. Rice lake, covering about a square mile, is crossed by the south line of Blooming Grove, its greater part being in Woodville; and close on its east side is Watkins lake, half as large, lying mainly in section 3, Woodville. Four other lakes lie in this township, within view from the Winona & St. Peter railroad. The first of these seen in proceeding westward is Goose lake, about one and a half miles long from northeast to southwest, lying at the north side of the railroad, three miles east of Waseca. Within a mile east of Waseca, this road goes between Clear lake, one and a half miles long from north to south and half as wide, lying on the north, and Gaiter lake, about a mile long from north to south and a quarter of a mile wide, on the south. Close west of Waseca, Loon lake, lying north of the railroad, has about the same extent as Gaiter lake, but with trend from east to west. Other noteworthy lakes in this county include lake Canfield, in the northeast part of Otisco; Thompson lake, two-thirds of a mile long from east to west, in the north half of section 13, New Richland; Silver lake, nearly two miles long from northeast to southwest and a half mile wide, in the west part of Wilton; Wheeler lake, a half mile long, in section 5, Vivian; another, of similar size with the last, in the north part of sec. 26, Freedom; Mud lake, also of small size, being about two-thirds of a mile long with trend from east to west, in section 11, Alton; and Buffalo lake, the largest, excepting lake Elysian, in this county, situated near the center of Alton, two miles long from northwest to south east, having an area of about a thousand acres.

Topography. The minor surface features of this county have been determined by the conditions attending the accumulation of the glacial drift or till. Its contour records the direction in which the ice-sheets moved, and their boundaries, the form given to the surface of this deposit being apparently quite independent of the small inequalities of the underlying rocks. Upon these the drift rests as a continuous mantle, filling up their depressions and making a more even expanse than those rocks probably exhibited before the glacial period, or would now show, were the covering of drift removed. The great slopes of the country, however, which shape its basins of drainage and determine the general course of its rivers, are due to the gradual changes in altitude of the older strata on which the drift lies. Thus the southeast part of Waseca county is more than a hundred feet higher than its west side because the bed-rocks underlying the till rise highest in that part of the county.

For a correct understanding of the origin of the topographic features of the drift-sheet, we need to review briefly the history of the glacial period. It is proved that this included several epochs of severe cold in which nearly all of the state was buried beneath a thick sheet of ice like that now spread upon the Antarctic continent and the interior of Greenland. Between these cold epochs were others when a milder climate reigned, and these accumulations of ice were partially or wholly melted away, giving place to animal and vegetable life upon the land, remains of which are preserved in fossiliferous beds enclosed between deposits of till. At least two glacial epochs have left very clear records of the extent reached by the ice-sheets. The earlier carried its drift as far south as Saint Louis, and nearly to the Ohio river on the east, even crossing this river at Cincinnati, as shown by Prof. Wright, and beyond the Missouri river on the west; but left a driftless area, which was surrounded by this ice-sheet, in southwestern Wisconsin and portions of the adjoining states, reaching from southeastern Minnesota eastward to the Wisconsin river and southward to the northwestern corner of Illinois. The later ice-sheet, which moulded the surface of this county, was of less extent. Its southern portion was divided into great lobes, somewhat as the earlier continental glacier had been parted at the driftless area, though again confluent farther south. The boundaries of this lobed ice-sheet of the last glacial epoch are marked by very distinct series of terminal moraines, or belts of hilly and knolly drift, which appear to have been deposited at the margin of the ice, corresponding to the drift heaped at the termination of alpine glaciers. These moraines have been traced, in a very irregular, looped course, through Wisconsin, Minnesota, Iowa, and Dakota. The glacial lobe whose eastern portion covered Waseca county stretched southeasterly from western Minnesota to central Iowa. Its eastern border, marked by moraine deposits, reaches from the Leaf hills in southern Otter Tail county southeasterly by Glenwood in Pope county to lake Minnetonka, and thence southerly, passing through Waseca, Steele and Freeborn counties, to the vicinity of Des Moines; whence its western border, shown by the continuation of this moraine, joined with the preceding by a U-shaped curve, extends northwesterly by Spirit lake and through southwestern Minnesota, to the Head of the Coteau des Prairies, in Dakota, twenty-five miles west of lake Traverse. The large area within this looped boundary was covered by ice so deeply that the pressure of its weight caused it to flow slowly outward from the center, where its thickness was greatest, toward each side, accumulating these hillocks of drift at its margin. At the same time a glacial current from the thicker northern ice was pushed southeasterly along the axis of this vast lobe and was deflected into its outward currents, as the trunk of a tree sends out divergent branches.

The moraines formed at the borders of this ice-lobe, both on its east and west sides, are mainly double, showing two well-marked belts of roughly knolly and rolling drift, each a few miles in width, divided by a tract of smoother surface, from two or three to twenty-five miles wide. As the course of this formation makes a loop like the letter U, having been accumulated by ice-fields covering the district enclosed, the outer moraine on each side is known to have been first made; and then, after a retreat of the ice-sheet, probably followed by a re-advance, the inner moraine was formed; for the latter would have had its very uneven surface planed off and mostly leveled, if it had been covered by a moving ice-sheet, forming terminal deposits beyond it.

South from Faribault to the Iowa line the moraine accumulated on the east side of this ice-lobe is twofold, and consists of approximately parallel belts of knolly and hilly till, from one to several miles in width, extending from north to south, between which intervenes a tract of gently undulating till, from six to fifteen miles wide. Of these the eastern or outer morainic belt extends through the eastern range of townships in Steele county. The western or inner moraine lies in eastern Waseca county and the southwest edge of Steele county, having a width that varies from three to ten miles. Its hills are almost universally till or unmodified glacial drift, rising in smooth but variable slopes, and exhibiting no parallelism or system in their trends. From Okaman, at the north line of Waseca county, and from Waterville, in Le Sueur county, southeastward through the northeast part of Iosco and the west half of Blooming Grove, to the southwest corner of this township, two miles north of Waseca, these elevations are 30 to 50 feet high. Through Woodville, within two to four miles east and southeast from Waseca, inconspicuous scattered drift hills and mounds, constituting a generally rolling surface, represent the morainic series. In Otisco, the next township south, it rises to its usual prominence in section 5, one and a half miles east of Wilton, where we find numerous steep ridges and round or irregular hills, more strown with boulders than the other portions of this township, which are moderately rolling and occasionally hilly. The east two ranges of sections in New Richland are included in this belt, being mainly covered by morainic mounds, swells and hills, 30 to 50 feet above the intervening hollows.

In the northeast corner of Waseca county, the east half of Blooming Grove and the northeast edge of Woodville are part of the gently undulating area between these morainic belts. The contour is approximately level, as seen in any extensive view, but it includes occasional broad hollows which are depressed 20 to 25 feet.

The northwest part of this county, west of its moraine, is also moderately undulating or rolling, in prolonged, smooth slopes, the highest swells being 10 to 30 or 40 feet above the neighboring sloughs and lakes. This description applies to Janesville, southwestern Iosco, Alton, and Saint Mary; and in the southeast part of this county the western two-thirds of New Richland have a similar surface.

About a third of Waseca county, including its southwestern townships of Freedom, Wilton, Vivian and Byron, is a very flat expanse of till, in some parts imperfectly stratified. The difference in elevation between the highest and lowest portions of the surface, connected by slopes from a quarter of a mile to one mile in length, is only five to ten feet. This is the eastern margin of the vast intra-morainic area of slightly or moderately undulating till which extends from here northwest to Big Stone and Traverse lakes and the Red river valley, its width being from the moraine of the Leaf hills and lake Minnetonka on the northeast to that of the Coteau des Prairies in southwestern Minnesota. The very smooth and often almost perfectly flat surface of these townships, and of a large part of Blue Earth and Faribault counties appears to have been due to the leveling action of a lake that covered this district during the departure of the last ice-sheet. In its recession northward the ice was a barrier which prevented the water of its melting from flowing away in its present course, following the northern slope of the land; so that a lake, similar in its origin to lake Agassiz in the Red river valley, extended over the greater part of the basin of the Blue Earth and Le Sueur rivers, its area being increased as fast as the border of this ice-lobe retreated to the north, till it was so far melted as to permit this glacial lake to be drained northward by the Minnesota river. Its outlet, while it remained a lake, is found in Iowa, and was tributary to the East fork of the Des Moines river, as described in the report of Faribault county.

Channels, ten to twenty-five feet in depth and five to ten rods or more in width, which may have been eroded by rills and streams under nearly the present conditions of climate, but have no water now running in them through the greater part of the year, cross the flat area of southwestern Waseca county in irregular courses. This area also contains here and there broad, bowl-like depressions of similar or somewhat greater depth, often with no outlet or depression continuing away on any side, and occupied by sloughs and lakes. These hollows sometimes have steep sides, which have been eroded and undermined by waves; but generally they are surrounded by slopes of 10° to 15°, about a third as steep as are produced by the falling down of a bluff of drift that has been undermined by water. In origin they seem to be like the basins of the ordinary small lakes that are scattered irregularly over the surface of the moderately undulating drift-sheet of this state. Variations in the direction or force of the glacial currents, and consequent irregularities in the amount of drift deposited or eroded by the ice-sheet, have commonly moulded this formation in swells and hollows, the latter being often without outlet. Here the surface has been smoothed by an extensive glacial lake, and the drift that would have formed swells has been swept into the adjoining hollows; but it appears that occasionally the supply of material thus carried into the depressions was insufficient to fill them, and their deep central portions remain empty, constituting very remarkable features in the topography because of the unusually flat tract in which they occur. These basins vary from 20 to 30 or 40 feet in depth, and in extent they are from thirty rods to one or two miles long, with perhaps half or two-thirds as great width, the largest area of this kind being that of Silver lake in Wilton. The shallowest hollows filled by sloughs are only two to five feet lower than the surrounding land, while the deepest are twenty feet below the general level.

Streams in this part of the county, as the Little Cobb river and Bull run, have cut valleys 20 to 30 feet deep. Boot creek, east of Byron, lies in a broad, shallow depression of slightly undulating till, two or three miles wide and 20 or 30 feet below the average surface on each side. The valley or channel eroded by the Le Sueur river in New Richland and southern Otisco is 20 to 30 feet deep; and in the remainder of its course through this county, passing by Wilton and Alma, its depth is about 40 feet.

Elevations on the Winona & Saint Peter division of the Chicago & Northwestern railway.
From John E. Blunt, engineer, Winona.

	Miles from Winona.	Feet above the sea.
Meriden (Steele county), -	96.35	1149
Waseca, -	102.63	1153
Janesville,	112.91	1063
Eagle Lake (Blue Earth county),	122.56	1012

Elevations on the Minneapolis & Saint Louis railway.
From Robert Angst, assistant engineer, Minneapolis.

	Miles from Minneapolis.	Feet above the sea.
At the north line of Waseca county,	67.0	1049
Iosco,	69.7	1146
Summit, natural surface, 1168; grade,	70.3	1154
Loon lake, water,	75.7	1134
Crossing Winona & Saint Peter railroad,	76.0	1154
Waseca,	76.2	1151
Creek in sec. 8, Otisco, water, 1071; grade on bridge,	81.2	1077
Le Sueur river, water, 1103; grade on bridge,	84.8	1116
New Richland,	88.7	1178

The highest portion of this county is the east half of New Richland and the southeast quarter of Otisco, which are about 1200 feet above the sea. Its lowest land is where the Le Sueur river and other streams cross its west line, at hights between 1000 and 1050 feet above the sea, the elevation of the Le Sueur river at this line being approximately 1010.

Mean elevation of the county. Estimates of the average hight of the townships of Waseca county are as follows: Blooming Grove, 1150 feet above the sea; Woodville, 1150; Otisco, 1160; New Richland, 1190; Iosco, 1100; Saint Mary, 1120; Wilton, 1110; Byron, 1150; Janesville, 1060; Alton, 1060; Freedom, 1070; and Vivian, 1100. The mean elevation of the county, derived from these figures, is approximately 1120 feet.

Soil and timber. The black soil varies in thickness from one to three feet, being least on swells and on the hillocks of the moraine, and greatest in depressions. It is a very fertile gravelly clay, with occasional boulders, and differs from the subsoil, both of which are till, in having been enriched and colored by the decay of vegetation through many centuries. This glacial drift includes a considerable proportion of limestone, both as boulders and pebbles, and also in a finely pulverized condition, which contributes in an important degree to the productiveness of the soil, and at the same time makes the water of wells hard. Wheat, oats, corn, potatoes, flax, sorghum, and all the crops that belong in this latitude, are successfully cultivated.

Timber covers the greater part of Janesville, the west half of Alton, and northwestern Iosco, this being the southeast edge of the Big Woods. About half of Blooming Grove is also wooded, and numerous large groves occur in the townships of Saint Mary, Woodville and Otisco, and in the northeast part of New Richland. The Le Sueur river is bordered by timber, which attains a width of one to one and a half miles at the east side of this stream in the southeast part of Wilton and the adjoining edge of Otisco. Southwest from the Le Sueur river, the flat expanse which reaches thence to the limits of the county is prairie, and its green mat of grass sometimes bears no tree nor bush within an area several miles in extent. The lakes, however, within this tract are usually bordered by wood, and belts of timber mark the course of its streams.

White and slippery elm, bass, sugar and red maple, box-elder, black and bur oak, butternut, white and black ash, ironwood, wild plum, Juneberry, American crab-apple, common poplar or aspen, cottonwood, and willows, are the principal species of trees in this county.

GEOLOGICAL STRUCTURE.

No outcrop of the strata underlying the drift occurs in Waseca county, but they have been reached by wells at three localities. One of these wells, reported by Prof. L. B. Sperry, "near Janesville, after passing through 200 feet of blue clay, reached a sandstone said to be identical with the St. Peter in appearance. An abundance of good water, which rose to within 30 feet of the surface, was found between the clay and the sandstone."

At the town of New Richland, a well at Dunwoody & Corson's mill reached a depth of 110 feet, finding the following section: soil, 2 feet; yellow till, with streaks of sand, yielding water, 30 feet; blue till, softer and sticky, 66 feet; sand, 2 feet; and hard, straw-colored sandstone, 10 feet. At this depth water was struck, and rose in two minutes to 30 feet below the surface. Another well at this mill, 149 feet deep, drilled by Mr. C. E. Whelpley, is reported by him to be drift, 107 feet; yellow calcareous sand-rock, 40 feet; and similar rock of blue color, 2 feet. A very large supply of water was obtained, rising to the same hight as the last. The well at the depot, about forty rods north of the foregoing and on land of the same hight, is 129 feet deep, and found the soil 2 feet thick; yellow till, spaded, 10 feet; blue till, mostly very hard, picked, 115 feet; and yellowish sandstone, similar to that of Dunwoody & Corson's well, 2 feet and extending lower. Water, found in this sandstone, rose 80 feet. It is noteworthy that the top of the bed-rock in these wells, only an eighth of a mile apart, differs about 25 feet in hight, probably on account of erosion in a formation horizontally stratified. About three miles northwest from New Richland, a well 110 feet deep on S. W. Franklin's dairy-farm, went 10 feet into this rock, after penetrating 100 feet of drift, obtaining water in the rock which rose to ten feet below the surface. At Owatonna on the northeast, and at Wells, in Faribault county, on the southwest, similar formations of sandstone, with associated layers of shale and limestone, encountered by deep wells, appear to be of Cretaceous age; and very probably these beds and the sandstone of New Richland belong to the same horizon. The evidence pointing to these conclusions is set forth in the report of Faribault county, to which the reader is referred.

Drift. Under the description of the surface features of this county, its glacial drift and terminal moraine have been already described in a general manner. The thickness of the drift varies from one hundred to two hundred feet over this county and a large adjoining region. This formation is principally the unstratified gravelly and stony clay called till, boulder-clay, or hardpan, with which are associated beds of modified drift, which were gathered from the melting ice, assorted and deposited by water. The following notes of wells exhibit in detail the character and order of the drift deposits.

Wells in Waseca county.

Blooming Grove. William Habine; sec. 3: a well 100 feet deep in till found no water; while another well only 16 feet deep, six rods farther east, on land of about the same hight, found plenty of water.

I. D. Beeman; sec. 10: well, 24 feet; soil, 2 feet; yellow till, 21 feet; blue till, soft and sticky, 1 foot and extending deeper; the water seeps.

P. Healy; sec. 15: well, 20; soil, 2; yellow till, 10 feet, containing veins of gravel, two to four inches thick; harder blue till, 8 feet; the only water obtained is from sandy and gravelly veins in the upper till.

Waseca, in Woodville. William Everett: well, 68 feet; soil, 3 feet; till, yellowish in its upper portion and bluish below, 47 feet; vein of sand, 6 inches; blue till, 15 feet; sand and gravel, 3 feet and reaching lower; from this bed, water rose to the vein of sand at 50 feet, there running off.

At McCutchins' elevator, on the Winona & St. Peter railroad, a well 140 feet deep is reported to have been all drift, but no particulars were learned. Water rises from the bottom to stand ten feet below the surface. No thick beds of sand are found here enclosed in the till, and no bed-rock is reached. Most of the wells of this town are only 15 to 20 feet in depth, and find water in the lower part of the yellow till.

Otisco. J. A. Canfield; sec. 3: well, 22 feet; soil, 2 feet; yellow till, 14 feet, shoveled, containing streaks of sand; blue till, harder and more gravelly, picked, 6 feet; water is found only in the yellow till.

Knut H. Esping; sec. 13: well, 24 feet; soil, 2; yellow till, shoveled, 12; sand, 3 feet; blue till, picked, much harder than the upper till, 7 feet; to sand at the bottom, from which water rose seven feet, flowing off in the upper sand.

New Richland. Wells in this town, penetrating to the bed-rock, are described on the preceding pages.

Iosco. N. N. Norcutt; S. E. ¼ of sec. 30: well, 30 feet; soil, 2 feet; yellow till, 18 feet; much harder blue till, 10 feet; the water seeps from the yellow till, and is excellent.

Saint Mary. E. Brossard; sec. 2: well, 16 feet; soil, 2; yellow till, 10; much harder blue till, 4; water seeps from the upper till.

Wilton. At the town, in sec. 1, a well for a steam saw-mill went 90 feet, its lower and greater part being in soft blue till, finding no water.

John McLin; sec. 20: well, 22 feet; soil, 2; yellow till, hard, but spaded, 18 feet; softer blue till, 2 feet and extending deeper; the water comes in seams of sand in the lower part of the yellow till.

Hans Krager; sec. 36: well, 30 feet; soil, 2; yellow till, shoveled, 6; blue till, harder, picked, 22 feet; no sand nor gravel was found in the blue till, and no water was obtained.

Byron. Garrett Hope; sec. 6: well, 38 feet deep, the only "fountain," or flowing well, in this township; soil, 2; yellow till, 10; blue till, 25; very hard, dark layer, 6 inches; gravel and sand, 1 foot, and extending lower, from which water rose instantly to the top, and has since flowed away from the mouth of this well during four years. This water threw up the auger and shafting, with which the well was being bored, weighing five hundred pounds or more, fourteen feet, and filled the boring with gravel to that hight. The site of this well is about fifteen feet below the general level of the country.

Janesville. The deepest wells learned of in this township are at the elevator beside the railroad near the depot, said to have been bored 150 feet, with loss of two sets of boring tools, but thought not to have reached the bed-rock; the well at the Taopi mills, 100 feet deep, in which the water rises to 60 feet below the surface; and the well at the railroad station, 76 feet in depth. The latter was dug twelve feet square for 56 feet, and then bored 20 feet more, finding a large supply of water, which, however, does not rise so as to fill the bottom of the portion dug. From all that could be gathered respecting these wells, they appear to have been till, with no notable layers of sand or gravel. The common wells of this town and its vicinity are 12 to 20, or sometimes 40 feet deep. Mostly they get water by its seeping from the yellow till. Wells that go lower sometimes find layers of dry quicksand in the blue till, ready to drink up the water derived from sandy streaks in the upper till.

Alton. E. F. Nettleton; S. W. ¼, sec. 32: well, 28 feet; soil, 2 feet; yellow till, 24; gravel, 1 foot; blue till, softer and more sticky than the upper till, 1 foot and extending lower; water rose five feet.

Alma. W. E. Lockwood: well, 46 feet; soil, 2½ feet; yellow till, 17 feet; harder blue till, 10 feet; sand, 6 inches; blue till, as before, 15 feet; gravel, 1 foot, from which water rose seventeen feet.

Alma City flour-mill: well, 63 feet, the deepest in this vicinity; soil, 3 feet; yellow till, 6 feet; harder blue till, 20 feet; gravel and sand, 5 feet; blue till, 25 feet; gravel and sand, 4 feet and reaching lower, from which the water rises thirty feet.

Freedom. Chris. Priem; sec. 23: well, 64 feet; soil, 3; yellow till, 14; soft blue till, 20; darker till, very hard, 13; soft blue till, 5 feet; dry sand and gravel, containing gas, which rose with such force as to throw up the gravel and sand three feet, and continued "blowing" three days; this stratified drift was penetrated to a thickness of 9 feet, and extended lower; water was found in the last four feet.

Henry Converse; S. W. ¼ of sec. 27: well, 107 feet, the deepest in this part of the county; soil, 3; yellow till, 16; soft, blue till, 88 feet, containing a layer of dry sand one foot thick at 70 feet below the surface; no water is found in this blue till; the well is used, but has only "surface water," which seeps from the upper till.

Vivian. Henry Laver; sec. 3: well, 95 feet; soil, 3; yellow till, 16; soft blue till, 30; dark till, very hard, 20; soft blue till, 25; black sand, 1 foot; water rose to five feet below the top in three hours.

John Bushou; sec. 12: well, 37 feet; soil, 3 feet; yellow till, 13; soft, blue till, 18; darker very hard till, 2 feet; gravel, 1 foot and extending lower, from which water rises and flows over the top of the well, making it a fountain.

Mr. Clarence W. Converse, well-maker, living on the S. W. ¼ of sec. 27, Freedom, thus sums up his experience in boring some two hundred wells in this and neighboring counties: The yellowish upper till is harder to bore than the blue till next below, which is moist and sticky, the auger going down five feet in the latter as easily as two feet in the former; but a third kind of till, called "hardpan," darker than the soft blue till, is generally as hard as the yellow till, and often, probably in half the instances of its occurrence, it is harder. The upper, yellow till is characterized by sandy streaks, and crevices which yield seep-water, found in half of all the wells. It is almost always directly underlain by the soft and moist blue till, which has no crevices with seeping water, but bears sand-veins from two or three inches to four feet thick, which contain water. The very hard, darker till is similar in yielding water with the last.

The maximum thickness of the yellow till found by Mr. Converse was 35 feet, in Spring Lake, Scott county. The greatest thickness of the soft blue till found is 88 feet, at his home in sec. 27, Freedom. The thickest bed of the very hard, darker till was 40 feet, occurring at French lake, in Rice county, six miles northwest from Faribault. An average of the thickness of this dark hardpan may be eight or ten feet; and about a quarter or a third of its beds are only from one to five feet thick. Fragments of lignite, up to four inches in diameter, are often met with in these drift deposits, most frequently in the dark hardpan. Pieces of wood, up to one foot long, are found rarely, but no shells nor other organic remains have been noticed.

MATERIAL RESOURCES.

The agricultural capabilities of Waseca county, its fertile soil, and its good supply of timber, have been spoken of on page 409.

No water-powers have been utilized in this county.

Drift boulders are the only stone found for the construction of foundations, walls of cellars and wells, culverts, etc. These boulders occur quite commonly upon the morainic belt, and are found sparingly in all parts of the county. They are mostly varieties of granite, syenite, and gneiss, with occasional blocks of limestone. In size they reach to five feet, and rarely to ten feet in diameter.

Lime has been burned from the boulders of magnesian limestone in the drift by E. R. Tuttle in Janesville, during the last twelve years, producing annually from 100 to 200 barrels, selling it at about $1.25 per barrel. The greater part of these boulders, estimated to be three-fourths or more, make white lime; while the remainder yield lime of yellowish or darkish gray color.

Brick have been made also by Mr. Tuttle about a third of a mile northwest from Janesville during the past twelve years, producing from 100,000 to 400,000 yearly, selling at about $7 per M. He uses stratified yellow and gray clay, which contains sandy layers so that it needs no intermixture of more sand. It is excavated to a depth of five feet. These bricks are red and of good quality.

In the northwest ¼ of sec. 2, Iosco, close to the north line of this county, and one and a half miles south of Waterville, red brick have been made during several years by Mr. David Wood, producing 200,000 to 300,000 annually, of excellent quality, bringing $7 to $8 per M. The clay used is stratified. It contains no sand in its upper four or five feet; but its layers below are separated by little seams of sand, occasionally with a thin film of iron-rust. This clay-bed extends to a depth of at least 13 feet, and is sufficient to make many millions of brick.

A kiln of red bricks, inferior in quality because cracked after burning by particles of limestone contained in the clay or sand used, was burned by I. C. Trowbridge several years ago in Woodville beside the railroad one and a half miles east of Waseca. No brick-making has since been undertaken in that vicinity. Clay suitable for this use, having no gravel, is said to occur on two or three acres of J. A. Canfield's land in section 3, Otisco, at about sixty rods northeast from his house.

Springs, chalybeate and also supposed to be salty because licked by cattle, occur in section 9, Otisco, south of the creek, being near the middle of the north side of the southwest quarter of this section. Another irony spring, somewhat resorted to by the people of its vicinity and from Waseca because of its medicinal properties, alterative and tonic, is situated northwest of the foregoing, in the southeast quarter of section 5, Otisco.

Aboriginal earthworks. The only mounds which seem to be perhaps artificial, observed or heard of in Waseca county, are two or three low, circular and dome-like heaps of earth 20 or 30 feet in diameter but only one to two feet in hight, seen in and beside the road that runs from Wilton southwest to Vivian, occurring nearly at the south line of section 10, and again in the northeast quarter of section 20, Wilton.

CHAPTER XIII.

THE GEOLOGY OF BLUE EARTH COUNTY.

BY WARREN UPHAM.

Situation and area. Blue Earth county (plate 16) lies in the central part of southern Minnesota, being in the second tier of counties north of Iowa. Mankato, its largest town and the first in size within the basin of the Minnesota river, is distant about 70 miles, measured in a straight line, southwesterly from Minneapolis and Saint Paul. The length of this county from east to west is five townships, or 30 miles, and its breadth from north to south varies from 21½ to 29 miles, being least through the center of the county, from South Bend, and greatest upon its western boundary line. The Minnesota river separates this from Nicollet county. After Mankato, the towns and villages of most considerable size are Lake Crystal, Garden City, Vernon Center, Good Thunder, Mapleton and Eagle Lake. The area of Blue Earth county is 776.88 square miles, or 497,201.73 acres, of which 21,619.39 acres are covered by water.

SURFACE FEATURES.

Natural drainage. This county lies wholly within the basin of the Minnesota river, which at South Bend and Mankato turns from its southeast course and thence flows northeastwardly almost at right angles with its upper portion. The drainage from the greater part of Blue Earth county, as also of Waseca, Faribault, Martin, and Watonwan counties, is discharged into the Minnesota by the Blue Earth river, which has its mouth about one mile west of Mankato. The slopes of this county and the courses of its drainage descend from three sides, east, south and west, toward the middle of its north side. In general the county is to be described as a nearly level, slightly undulating expanse, with mostly imperceptible slopes, which give direction to its streams. These at first flowed upon the general surface, 50 to 200 feet above the valleys, now enclosed by steep bluffs, which these streams by their long-continued wearing have excavated.

About three miles above its mouth the Blue Earth river receives from the east a tributary of nearly equal size with itself, namely, the Le Sueur river. This also has two large tributaries, the Maple and Big Cobb rivers, which unite with the Le Sueur from the south, respectively four and five miles above its junction with the Blue Earth. On its west side the only important tributary that the Blue Earth receives in this county, is the Watonwan river, which has its mouth about two miles above Rapidan Rapids, and includes within its basin of drainage all of Watonwan county and parts of the adjoining counties. Perch creek in Ceresco township, is a considerable tributary to the Watonwan from the south.

Above the mouth of Blue Earth river, the Minnesota in this county receives three other tributaries worthy of mention: Lyons or Minneopa creek, which forms the picturesque Minneopa falls; and Morgan creek and the Little Cottonwood river, which have their mouths about a half mile apart in section 16, Cambria, the most northwestern township of the county.

Lakes. Many lakes occur in this county, of which the largest are as follows: lake Wita, in the east part of Lime, having a length of one and a half miles and an area of about one square mile; lake Ballantyne, and Duck and Gilfillan lakes, in Jamestown, each about a mile long; lake Madison and Eagle lake, at the north side of Le Ray, each about three miles long and covering two square miles; lake Alice and Indian lake, each about a half mile long, in the southeast part of Le Ray; Rice lake, one and a half miles long, in southwestern McPherson; Perch lake at the west side of Medo, and Cottonwood lake in the southwest part of this township, each about two-thirds of a mile long; Rogers lake, of similar size, at the west side of Danville; Lura lake and lake Jackson, in Sterling, the former three and a half miles long, reaching south into the edge of Faribault county, and the latter about two miles long and from a half to one mile wide; a series of four lakes in the north part of Garden City township and the south edge of Judson, namely, in their order from southeast to northwest, Mills lake, Loon lake, Crystal lake, and lake Lily, of which the third is the largest, being one and a half miles long and from two-thirds to one mile wide; and Dackins, Stram, and Solberg lakes, the last, which is the largest, having an area of about a square mile, in Butternut Valley.

Nicollet named the area drained by the Blue Earth river (which he called the Mankato river) and its tributaries the *Undine region,* because of its great number of streams, "spreading themselves out in the shape of a fan," its numerous lakes surrounded by woods, and its wide, fertile prairies. The name was "derived from that of an interesting and romantic German tale, the heroine of which belonged to the extensive race of water-spirits living in the brooks and rivers and lakes, whose father was a mighty prince. She was, moreover, the niece of a great brook (the Mankato) who lived in the midst of forests, and was beloved by all the many great streams of the surrounding country."*

Topography. Nearly all of Blue Earth county has a smooth and flat or only slightly undulating surface; but this is deeply channeled along the river-courses. The south half of the county contains two small tracts of rolling land, in the northwest part of Sterling, and in the southeast of Pleasant Mound. In general, the northeast and northwest parts of the county are the most undulating. The Minnesota river at the north occupies a valley 200 to 225 feet below the general surface; and the Blue Earth

*For Nicollet's description of this region, see page 71.

river and its tributaries have cut channels that increase in depth from 50 to 100 feet along the upper portion to 150 and 200 feet near the Minnesota valley.

The central and southern portions of the county, embracing about three-quarters of its whole area, are a level, or only slightly undulating sheet of glacial drift, except that the rivers have cut deep valleys, which may be properly called channels, in the otherwise unbroken plain. This expanse includes the following townships in their order from the southeast: Danville, Medo, McPherson; Mapleton, Beauford, Decoria, Mankato; Sterling, Lyra, Rapidan, South Bend; Shelby, Vernon Center, Garden City; Pleasant Mound, Ceresco, and Lincoln.

Exceptions to the prevailing flatness of this area are the rolling tract mentioned in the northwest part of Sterling, reaching a mile or two north from the north end of lake Jackson, and rising 30 to 40 feet above the general level; the northwest part of Lyra westward from Good Thunder, and the most of Vernon Center and Garden City townships, undulating 10 to 20 feet in long slopes; and section 25, Pleasant Mound, where a group of kames, which suggests the name of the township, extends about a mile from north to south, with a width of one fourth to one third of a mile, consisting of many mounds, knolls, and short ridges, from 30 to 75 feet high, of no very notable parallelism in trend, but perhaps most frequently elongated from north to south. Their material is gravel, containing pebbles up to six inches in diameter, irregularly interstratified with sand. Boulders up to two or three feet in diameter occur rarely upon the surface of the mounds. In the south part of this section the contour changes to a more smoothed, rolling surface, with crests 20 to 30 feet high. The material here is the unmodified glacial drift or till, which also forms all the surrounding land, in prolonged low undulations. No other gravel deposits were observed in this vicinity.

Butternut Valley, Cambria, and Judson, including the part of Blue Earth county northwest from Lake Crystal, are gently undulating till, with the highest portions 10 or 20 feet above the lowest, the slopes occupying from one fourth of a mile to one mile. Isolated knolls of fine gravel and sand, 5 to 15 feet above the general level, occur rarely in these townships. Like the group of kames in Pleasant Mound, these accumulations of modified drift are believed to have been formed by streams that descended from melting ice-fields.

In the northeast part of this county, Mankato is nearly level from the top of the bluffs of the Minnesota river at the east side of the city through five miles east to Eagle Lake. To the east and north, nearly all of Le Ray, Jamestown, and the east part of Lime, are slightly or moderately undulating, with crests 10 to 25 feet above the hollows or 20 to 40 feet above the numerous lakes. Sections 19, 20, 29, and 30 of Le Ray are in massive swells 30 to 40 feet high. The northeast part of Jamestown, and the vicinity of Marysburg, are quite smooth, only undulating 5 to 15 feet in long distances.

Eroded valleys. The most notable topographic features of this county are the trough-like valleys that have been excavated by its rivers. The valley of the Blue Earth river through Shelby and Vernon Center is from 75 to 100 feet deep; in Rapidan and South Bend, before joining the Minnesota valley, its depth becomes 200 feet. Its exposures of rocks underlying the drift begin in section 13, Garden City, and extend interruptedly to its mouth. The width of this valley, between the tops of its bluffs, is mainly from a quarter to a half of a mile.

Watonwan river, tributary to this from the west, has a valley 60 to 75 feet deep through Ceresco, and from 100 to 150 feet deep through Garden City. Its only rock exposures are a few low outcrops of Shakopee limestone.

Maple river, tributary to the Le Sueur river, flows from south to north, being through the center of the county nearly parallel with the Blue Earth river and three miles east from it. In Mapleton and Sterling the valley of the Maple river is 40 feet below the general level; at Good Thunder, 75 feet; and near its mouth in Rapidan, 150 feet. The last two miles of this river, in sections 24, 13 and 12, Rapidan, have frequent exposures, and good quarries, of the Shakopee limestone.

The Big Cobb river empties into the Le Sueur about one and a half miles farther east. Its valley increases in depth from 40 feet in the southeast part of the county, to 100 feet at the quarries of Shakopee limestone in sections 19 and 18, Decoria, which are its only rock older than the drift. The Little Cobb river in Medo flows about 40 feet below the general level, The valley of the Le Sueur river in Blue Earth county is 50 feet below the average surface at Winnebago Agency, and 75 feet below the highest points; thence it rapidly deepens, and through Decoria, Rapidan and South Bend, is from 150 to 200 feet deep. Its last three miles, in the northeast part of Rapidan, and in South Bend, have numerous exposures of rock. Excepting these and the other outcrops of rock before mentioned, the material through which the valleys of the Blue Earth river and its tributaries are eroded, is till, which encloses only few and thin layers of gravel and sand. Their bluffs rise steeply from narrow bottom lands to the nearly flat expanse of the drift-sheet. The width of the valleys thus enclosed increases with their depth from an eighth of a mile near their sources to a third or half a mile where they approach the Minnesota river.

Indian lake, three miles southwest of Mankato and one mile east of the junction of the Le Sueur river with the Blue Earth, occupies an old valley cut by the Le Sueur river, but forsaken because in their long-continued erosion the barriers between these rivers was cut through. This former valley is from 100 to 175 feet below the general level, and is about three miles long, extending from the S. W. ¼ of section 35 northeast about one mile to Indian lake and thence two miles north to the west part of the city of Mankato. Its highest point, about 50 feet above the present Le Sueur river, is southwest of the lake, which outflows northward. West of this valley the remnant of the drift-sheet between it and the Blue Earth river has been divided by erosion into two plateaus, and the railroad from Mankato to Wells passes between them in the N. E. ¼ of section 26. A third and smaller plateau lies a half mile southwest from this gap, at the east side of the mouth of the Le Sueur. The diversified scenery here and the high and picturesque bluffs along the meandering courses of all the rivers of this region are due to erosion. Along the deeper valleys this erosion has usually cut through the thick sheet of drift and reaches a considerable depth into the underlying rocks.

The valley of the Minnesota river in Blue Earth county is bounded above Mankato by bluffs which are from a half mile to one mile distant from the river. Through Mankato this distance is about a mile, but below this city, in Lime township, it becomes fully two miles. The top of these bluffs is from 200 to 225 feet above the river. This deep valley has many exposures of the rocks that underlie the drift. About a third part of Mankato, including Front street, is on the bottomland, only 20 to 30 feet above the river, while the rest of the city occupies a gradual slope that rises 40 or 50 feet to the base of the bluffs which then ascend steeply 150 feet to the general level of the drift-sheet. These bluffs of boulder-clay nowhere present a smooth front like that which commonly bounds terraces of modified drift; but they are seamed and gullied into deep ravines by frequent rills and springs, many of which flow only at times of snow-melting or of large rains.

At the quarries and lime-kilns in the north part of Mankato the thickness of the limestone, varying in portions to calciferous sandstone and shale, all of light buff color, is about 65 feet, and this formation is underlain by white sandstone. A terrace of these strata, decreasing from two miles to one mile in width, and averaging 75 feet in hight above the river, extends thence eight miles north to Kasota; beyond which it continues at a less hight on the other side of the river through St. Peter. From Mankato to the north line of Blue Earth county this terrace is nearly two miles wide, and is bordered on the east by bluffs of till, about 150 feet high, their tops being approximately 225 feet above the Minnesota river.

It appears that the excavation in the old rocks along the Minnesota river was principally the work of pre-glacial streams; and that the erosion which has been effected here since the ice age has been mostly limited to clearing away a part of the drift with which the valley was then filled. The sheet of till appears to be spread with a somewhat uniform thickness, averaging about 150 feet, upon the bed-rocks, and doubtless at first presented a nearly level but slightly undulating, unchanneled expanse, whose lowest portions coincided approximately with the pre-glacial lines of drainage. The river, after excavating its valley through this sheet of glacial drift, found a channel in the underlying rocks which was eroded before the ice age. That it was not made in the recent epoch, seems to be proved by the fact that its bordering walls of rock, varying from one fourth of a mile to at least two miles apart, are through long distances concealed by drift, which alone forms one or both sides of the valley. The depth of the preglacial erosion was considerably below the present river, as is shown by the boring for an artesian well at the top of the river-bluff in Mankato, where the bed-rock was reached at 290 feet, or about 65 feet lower than the river.

Elevations. The following hights have been determined by railroad surveys within this county; the reference, unless otherwise stated, being to the track at depots.

St. Paul & Sioux City division of the Chicago, St. Paul, Minneapolis & Omaha railway.
Copied from profiles in the office of T. P. Gere, superintendent, Saint Paul.

	Miles from St. Paul.	Feet above the sea.
Mankato,	84.0	791
Blue Earth river, low and high water,	86.2	756–774
Blue Earth river, bridge,	86.2	795
South Bend,	87.6	808
Minneopa bridge, 68 feet above water,	89.2	863
Minneopa,	89.4	871
Summit, grade,	95.6	992
Lake Crystal,	97.3	994
Summit, grade,	102.2	1009
Iceland,	104.1	998

Winona & St. Peter division of the Chicago & Northwestern railway.
From John E. Blunt, engineer, Winona.

	Miles from Winona.	Feet above the sea.
Eagle Lake,	122.56	1012
Mankato Junction,	127.99	906
Mankato,	131.00	781

Mankato branch of the Southern Minnesota division, Chicago, Milwaukee & St. Paul railway.
From George B. Woodworth, assistant engineer, La Crosse.

	Miles from La Crosse.	Feet above the sea.
Mapleton,	161.4	1031
Maple river, water,	168.5	935
Good Thunder,	169.3	974
Rapidan,	175.6	979
Le Sueur river, water, 772; bridge,	177.9	825
Crossing St. Paul & Sioux City railroad,	181.3	795
Mankato,	182.5	770

The low-water slope of the Minnesota river descends 35 feet, approximately, along the north side of Blue Earth county, according to the following elevations from the United States engineer corps. Its highest floods rise about 25 feet above this line.

Minnesota river, low water.

	Feet above the sea.
At the northwest corner of Blue Earth county, about	778
At Judson	760
At South Bend and the mouth of the Blue Earth river	756
At Mankato	752
At the line between Blue Earth and Le Sueur counties, about	743

At the points of crossing the boundary of the county, the elevation of the Watonwan river is about 960 feet; of the Blue Earth and Maple rivers, about 990; and of the Le Sueur river, about 1010. The hights above the sea of the various townships of the county, excepting their portions which have been deeply excavated by rivers, are approximately as follows: Lime, the terrace of limestone in the west part of the township, reaching about two miles easterly from the Minnesota river, 820 to 840, and the remaining two-thirds, east from the top of the bluffs, 980 to 1020; Jamestown and Le Ray, 1000 to 1060; Mankato, 975 to 1020; South Bend, plateaus between the valleys, 960 to 990; Judson and Cambria, 975 to 1000; Butternut Valley, 980 to 1020; Lincoln and Garden City, 990 to 1020; Rapidan, 975 to 1000; Decoria, 990 to 1040; McPherson, Medo, and Danville, 1025 to 1075; Beauford and Mapleton, 1000 to 1040; Lyra, 975 to 1025; Vernon Center and Ceresco, 1000 to 1040; Sterling and Shelby, 1010 to 1060; and Pleasant Mound, 1025 to about 1100. The southwest part of the last named township, which is the most southwestern of this county, appears to be the highest portion of its entire area of flat or gently undulating drift; and the kames, or irregular hillocks and short ridges of gravel and sand, in section 25 of this township, rising 30 to 75 feet above the adjoining region, and approximately 1100 to 1150 feet above the sea, are the most elevated points of land in Blue Earth county. These hillocks are thus about 400 feet above the lowest land of the county, in the valley of the Minnesota river.

The mean elevation of Blue Earth county is 1,000 feet, very nearly, above the sea; but would be 1,025, without the reduction for its eroded valleys.

Soil and timber. The soil of this county is uniformly very productive, and is well adapted for all crops which can be cultivated in this latitude. Though the land is mostly level or only slightly undulating, it is yet so intersected with water-courses that nearly all portions are well drained, giving opportunity for early sowing and planting, and preventing damage to crops by heavy rains. At the surface is a stratum of black earth usually about two feet, but varying from one to four feet in depth. It is clay, with more or less intermixture of sand and gravel, and including occasionally a stone or boulder of considerable size. Its black color has been produced by the decay of vegetation through all the years since this deposit was spread here in the ice age. The subsoil is the same glacial clay or till, without this organic matter, and of light yellowish-gray color to a depth of ten or twenty feet, below which it is darker and bluish. This difference has been produced by water and air, which to these depths below the surface have changed the carbonate of iron in this formation to the hydrated sesquioxide. A considerable proportion of carbonate of lime is present in the soil of all this region, adding much to its fertility and making the water of wells hard; but no appreciable amount of the bitterly alkaline magnesic and sodic sulphates are found.

About five-sixths of this county was naturally prairie, and supplied magnificent pasturage for the herds of the first immigrants. This region is now entirely occupied by farms, and is mainly under cultivation. It generally has a good supply of timber, which fills its numerous river valleys with a stately growth, and forms frequent groves on the shores of its lakes, and occasionally upon the general surface of the country at some distance from lakes and streams. The northeast part of the county is covered by a heavy forest, which was originally continuous but has now many clearings and excellent farms. The soil has the same character and productiveness as upon the prairies. This timbered district includes the townships of Lime (excepting the terrace in its west part), Jamestown, Le Ray, Mankato, and portions of McPherson, Decoria and Rapidan, reaching south to the Le Sueur river. It is the southern end of the Big Woods, which thence extend north nearly a hundred miles.

The trees which make up the woods of Blue Earth county are mostly more valuable for fuel than for lumber for building purposes or wooden manufactures. The white pine, which supplies the greater part of the lumber used in this region, is not found in this county. The principal trees, according to Messrs. Ellison and Ford, owners of a saw-mill in sec. 29, Le Ray, arranged in their estimated order of abundance, are the white or American elm, bass, and ironwood, very plentiful; bur oak, slippery or red elm, black ash, box-elder and willows, common; sugar maple, white ash, black oak, wild plum, June-berry, American crab-apple, common poplar or aspen, and hackberry, somewhat common; butternut, and bitternut, soft or red maple, black cherry, large-toothed poplar, cottonwood, water beech, yellow or gray birch, paper or canoe birch, red cedar, black walnut and the Kentucky coffee-tree, rare; but no red nor white oak, nor tamarack. Among the shrubs of the county are the frost grape, Virginia creeper, climbing bitter-sweet, hazel, smooth sumach, prickly ash, choke cherry, nine-bark, meadow-sweet, thorn, rose, red and black raspberries, high blackberry, prickly and smooth wild gooseberries, black currant, wolfberry, common elder, high-bush cranberry, and species of honeysuckle and cornel.

GEOLOGICAL STRUCTURE.

In the valleys of the Minnesota river, and of the Blue Earth, Watonwan, Le Sueur, Maple and Big Cobb rivers, are numerous exposures of the middle members of the Lower Magnesian or Calciferous series, these being in ascending order the St. Lawrence limestone, the Jordan sandstone and the Shakopee limestone. These formations are nearly horizontal, and they probably underlie the drift or the Cretaceous throughout the whole county; but, because of the great depth of the till, they outcrop only in the bottomlands and lower half of the bluffs of these deep valleys. Under these strata, the deep well at Mankato penetrates the St. Croix shales and sandstone, which are the lowest members of the Lower Magnesian or Calciferous series, and a great thickness of the Potsdam sandstone and shales. Over the Lower Magnesian rocks, and often filling water-worn cavities in them, Cretaceous beds of clay, and sometimes of sand and gravel, are found at several places in the county. The various geological formations to be described in the order of their age, from the oldest to the newest, are: 1. Potsdam sandstone and shales; 2. St. Croix sandstone and shales; 3. St. Lawrence limestone; 4. Jordan sandstone; 5. Shakopee limestone; 6. Cretaceous beds; 7. Glacial and modified drift.

Potsdam sandstone and shales. One of the deepest drillings ever made in the United States or the world, is that done a few years ago at Mankato, in the hope of obtaining an artesian well. This was in the southeast edge of the city, at the top of a portion of the bluffs which is commonly called "Bunker hill". Its elevation above low water of the Minnesota river is about 225 feet, making its hight above the sea approximately 975 feet. The depth of this drilling is 2204 feet, of which the greater part, reaching from about 900 feet to the bottom, is in red sandstone and shales that are believed to belong to the later part of the Potsdam period, being intermediate in age between the St. Croix group and the Cupriferous or Keweenawan series, which Prof. Winchell and the writer refer to the earlier part of this Potsdam period.

No exact record can be found to show the character of all the strata passed through and the depths at which each began and ended; but two sets of specimens of the rock encountered at successive depths are preserved, one by Mr. W. Hodapp, druggist, showing the material at eighteen points in the section, and the other by the city council, representing twenty-nine depths. The second of these series of drillings was divided and supplied a complete duplicate set, which has been placed in the state museum. Descriptive notes were also taken of Mr. Hodapp's series, and the information gained from both is presented in the following table. Mr. G. C. Burt states that the thickness of the drift here was 290 feet, consisting mainly of the ordinary boulder-clay or till, excepting occasional layers of sand, varying from a few inches to five feet in thickness. He describes the first stratum of rock, reached at 290 feet, as a hard limestone, of light gray color.

Drillings from the deep well at Mankato.

At 310 feet, calcareous clay or shale, of greenish color.

At 330 feet, dolomite (magnesian limestone), reddish gray, somewhat siliceous.

At 380 feet, siliceous, reddish gray dolomite, containing green-sand.

At 390 feet, sandstone, with calcareous and greenish cement; containing much green-sand; the pulverized portions appearing like green shale.

At 450 feet, pinkish, somewhat siliceous dolomite.

At 453 feet, dull red quartzyte, or firmly cemented sandstone, finely granular, containing minute specks of green-sand.

At 495 feet, white, friable sandstone.

At 560 feet, fine shale, of dull pinkish color; not arenaceous, but the specimen of drillings includes intermixed sand, probably derived from a higher part of the well.

At 600 feet, like the last.

At 640 feet, yellowish, iron-rusted sandstone, with rounded, mainly siliceous grains; also including angular particles of dark red quartzyte, or hard, firmly cemented sandstone, similar to that at 453. Some of the quartz grains are covered with a thick scale, which on the outside is iridescent or sometimes black. These coated grains are occasionally aggregated into little lumps which seem to be the same with the dark red particles mentioned.

At 645 feet, similar to the last, but with less of the hard, dark red sandstone, and fewer coated grains.

At 650 feet, fine-grained sandstone.

At 660 feet, yellowish sandrock, consisting of white and yellowish siliceous grains, all rounded; and also containing occasional particles of red grit, and of greenish white, kaolin-like matter.

At 800 feet, coarse-grained, light gray sandstone.

At 850 feet, light gray sandstone, like the last, but less coarse.

At 915 feet, shale, slightly gritty, ocher-like, of dark, dull red color.

At 1010 feet, sandstone, composed mainly of grains of quartz, partly white, and partly stained with the dull red color of the last.

At 1060 feet, iron-rusted, somewhat pinkish, shaly sandstone.

At 1100, 1110, 1130, and 1140 feet, light red, medium-grained sandstone, consisting mostly of particles of white quartz, which are more or less covered with pinkish shale.

At 1150 feet, coarse gray sandstone, with mostly angular grains.

At 1240 feet, white sandstone, medium-grained, slightly red-stained.

At 1265 feet, fine, light pinkish sandstone.

At 1270 feet, coarser sandstone, reddish gray.

At 1280 feet, sandrock, having the quartz grains covered with films of red shale.

At 1320 feet, reddish, shaly sandrock.

At 1327 feet, very fine-grained, soft, pinkish gray sandstone.

At 1332 feet, sandstone like that at 1150.

At 1340 and 1342 feet, fine, reddish gray, soft sandstone, partly ochery or iron-rusted.

At 1450 feet, coarse, somewhat iron-rusted sandstone, made up largely of grains of white quartz, party water-worn, but often angular, of all sizes up to an eighth or sixth of an inch in diameter.

At 1500 feet, similar to the last.

At 1600 feet, medium-grained sandstone, reddish, in part ochery and shaly.

At 1650 feet, fine sandstone, whitish; including red and orange, apparently clayey, grains.

At 1700 feet, arenaceous, ochery shale, dull red in color.

At 1720 feet, red shale, without apparent sand-grains.

At 1810 feet, fine sandstone, with grains partly light gray, and partly dusky brown, the latter averaging slightly larger than the former. In the pulverized drillings these differently colored portions remain separate, though abundantly shaken; giving the powdered stone a mottled and streaked appearance.

At 1827 feet, medium grained, reddish, friable sandstone.

At 1860 feet, fine-grained, reddish gray, soft sandstone.

At 1872 feet, ochery and siliceous, very fine-grained, dull red shale.

At 2000 feet, red shale, with occasional grains of sand; resembling pipestone in color and fineness; but with scarcely more hardness than common clay.

At 2150 feet, similar red shale, slightly arenaceous.

At 2200 and at 2204 feet, was the same red shale, containing fine grains of white quartz.

From the depth of 915 feet in this well, to its bottom at 2204 feet, its section thus consists of sandstone and shale, mostly reddish in color, and not remarkably indurated. At 915 feet and again at 1700 and 1720 feet are beds of red shale; but from 1010 to 1650 feet, and from 1810 to 1860 feet, the specimens are siliceous, principally reddish and soft or friable, ordinary sandstone, with water-worn grains. At and below the depth of 1872 feet, the remaining 332 feet consist largely and perhaps wholly of dull red, slightly arenaceous shale, which extends below the bottom of the well. This formation of sandstone and shales, thus shown to have a thickness of about 1300 feet, appears to be, stratigraphically and lithologically, the same with the nearly horizontal red sandstone, including frequent beds of shale, which borders the south shore of lake Superior almost continuously from Fond du Lac to Grand island and again rises into view at the falls of St. Mary.

St. Croix sandstone and shales. The white sandstone in this well at 495 feet, the shale at 560 and 600 feet, and the light-colored sandstone from 640 to 850 feet, belong to the St. Croix formation, which is exposed in the bluffs of the St. Croix and Mississippi rivers. These beds, with the St. Lawrence, Jordan, Shakopee and St. Peter formations, are the western equivalents of the Calciferous, Quebec and Chazy rocks in the northeastern United States and Canada. The presence of the Potsdam sandstone and shales beneath the St. Croix in this and several other artesian wells in southeastern Minnesota, and the uniformity of the sections thus shown, demonstrate that these are two distinct formations, and make it almost certain that the St. Croix beds lie conformably upon the latest Potsdam deposits.

St. Lawrence limestone. This formation is the lowest of the three members of the Lower Magnesian series which are exposed in the valley of the Minnesota river and its tributaries in Blue Earth county. It was encountered in the Mankato well, according to Mr. G. C. Burt, at 290 feet, and extended 163 feet to the depth of 453 feet below the surface. Besides the magnesian limestone from which the formation takes its name, it includes beds of shale and sandstone, mostly calcareous; and in all these deposits it contains green-sand, sometimes in minute scattered grains, but often in considerable amount, forming so large a proportion of the rock as to make it appear like green shale, in the specimens pulverized by drilling.

The only outcrops of the St. Lawrence limestone in this county are in the valley of the Minnesota river in Judson; and, with the ledges of the same rock on the opposite side of the river, at Hebron, in Nicollet township and county, these are the first exposures of the Lower Magnesian series found in descending this valley. Along all the lower part of the Minnesota river, alternate strata of limestone and sandstone belonging to this series are frequently exposed in the bluffs and bottomland.

In Judson, at the middle part of the north side of the township, the St. Lawrence limestone is exposed along a distance of about one and a half miles, and has been considerably quarried at several places. It rises 30 to 35 feet above the river, and forms the border of a terrace covered by modified drift of the same hight and a half mile wide, which lies between it and the bluffs. Next southeast, at the east line of section 3, Judson, the road ascends to a terrace 60 feet above the river and a quarter of a mile wide, composed superficially of drift and abundantly strown with granitic and gneissic boulders of all sizes up to ten feet in diameter. Eastward this terrace sinks a little, to a hight about 45 feet above the river, and near the middle of the south part of section 2 it shows a bed of reddish arenaceous limestone, which does not, however, rise above the surface of the drift. It is believed to be the upper part of the St. Lawrence formation. Leaving this terrace at about a half mile farther southeast, the road next climbs about 125 feet in the N. W. ¼ of section 12, passing an unnamed waterfall in the Jordan sandstone, the brink of which is about 90 or 100 feet above the river.

At Mrs. G. W Wolf's house (Judson post-office), in the S. E. ¼ of section 33, this limestone has been quarried along an extent of about twenty rods, exposing a vertical thickness of four to eight feet, the top being 30 to 35 feet above low water of the river. Another quarry on the same farm, about sixty rods farther southeast, also shows a thickness of eight feet. The section here is at top 5 or 6 feet of a very hard and durable, flesh-colored or buff, magnesian limestone, somewhat striped or mottled with greenish tints, in layers from a few inches to one foot thick, having their planes of bedding and jointage often covered with green films; then a dark greenish, sandy shale, much of it finely laminated, crumbling under the influence of the weather, 1½ feet; changing below to a yellowish gray calcareous sandstone, about 4 feet thick; underlain by sandy shale, which is blue for its first foot, becoming yellowish gray below, excavated only 2 or 3 feet, but reaching deeper. All these beds, and their other exposures, both in Judson and Nicollet, are nearly level, but appear to have a slight general dip, in some portions amounting to two or three degrees, to the southeast.

About a third of a mile west of Mrs. Wolf's, a hard calciferous sandrock is exposed along a little creek for a distance of a quarter of a mile, sometimes showing a vertical thickness of six feet. It is green when first uncovered, but weathers to a mottled buff, of yellowish and reddish colors. It is probably the same with the third stratum of the foregoing section, and with the arenaceous limestone and crumbling sandstone seen in the race-way of the stone mill at Hebron.

Near the ferry, about a mile east from the first described outcrops, a thickness of eight feet of this limestone is seen at John Goodwin's quarry, lying 25 feet above the river. Professor

Winchell says of this: "The beds are four to eight inches, although the uppermost three or four feet of the quarry are very much weathered and in thinner beds. The bedding planes are usually entirely covered with a green coating, and the body of the whole is specked thickly, and sometimes largely made up of green particles."

The Jordan sandstone directly and conformably overlies the St. Lawrence formation, but their contact has not been observed in Blue Earth county. From the waterfall mentioned in section 12, Judson, this sandstone, gray or white, sometimes stained in small portions with iron-rust, soft and often friable, has many exposures eastward along the Minnesota valley, and also in the valleys of the Blue Earth and Le Sueur rivers.

In going southeast from this waterfall the road soon rises about 75 feet to a terrace of modified drift, upon which it runs one and one-fourth miles to a wind-mill in the N. E. ¼ of section 18, South Bend, where this terrace is called "Wind-mill bluff." Next the road descends to a terrace of the Jordan sandstone, which is frequently exposed upon a width that varies from an eighth to a fourth of a mile through a distance of two and a half miles east-southeast to South Bend, its hight above the river being about 100 feet. The beautiful Minneopa falls, in the N. W. ¼ of section 21, South Bend, four miles west of Mankato, have been produced by the excavation of Lyons creek in this sandstone which here contains hard layers near its top, but is soft below, being readily undermined by the waterfall and crumbled by weathering. The brink of this fall is about 95 feet, and the highest exposure of the rock here about 110 feet above the river, these hights being 850 and 865 feet above the sea.

Of Minneopa falls Prof. Winchell writes*: "The perpendicular fall of the water is about 30 feet, but 45 feet of the sandstone can be made out. Before reaching the point where the water leaps over, the stream works its way through a perpendicular thickness of 15 feet of sandstone beds. It then comes in contact with a harder portion of the sandstone, which has a thickness of about six feet. This resists the water longer than the underlying layers, and maintains a projecting shelf. The mist that rises keeps the walls wet, and the freezing of winter crumbles away the soft sandstone, so as to form about the pool where the water strikes, a walled amphitheater rising about 40 feet on each side. This glen is more or less shaded with elms, cedars, birches, butternuts and oaks. It is prolonged in the form of a rough and shaded gorge, worn in the solid rock, of about the same depth, down to the point of issue of the stream upon the Minnesota bottoms, the distance of about half a mile. The gorge below the fall is darkened by the dense foliage, the stream in its course being much of the time hid from sight but for a few rods. This gorge is crossed, about a quarter of a mile below the falls, by the St. Paul and Sioux City railroad. At the foot of the falls a little lake of water is confined by the upheaved pebbles in front of the cascade. The gravel of the surrounding beach is hard enough to admit of a passage on all sides. There are also several narrow paths along the walls of the amphitheater, where the fallen fragments are sufficiently turfed and overgrown to permit a passage up or down the stream. An elm tree which is nearly three feet in diameter grows near the foot of the cascade, and on the right bank. Its annual rings of growth would indicate at least some part of the time elapsed since the retreat of the fall from the place where it stands. Within six feet of it the perpendicular sandstone wall rises to the hight of over forty feet. The stream is subject to great fluctuations of volume, sometimes becoming quite dry. In passing down the Minneopa gorge to its union with the Minnesota river, the bluffs become more and more wooded, the stone only showing alternately in patches on opposite sides, and no lower view of the Jordan sandstone can be had, at least none that can be proved to be lower."

The unnamed waterfall in the N. W. ¼ of section 12, Judson, three and a half miles northwest from Minneopa, has also been described by Prof. Winchell.† "A little creek, which is dry in summer time, exposes first about two feet of coarse sandstone in its bed. Following the creek

*Second annual report, p. 150. †Same, p. 152.

down a few rods, there is a perpendicular fall of about fourteen feet, which in time of high water must make a handsome cascade, similar to the Minneopa waterfall. The immediate cause of the fall is the occurrence of a layer of about a foot with a harder or more enduring cement, underlain by crumbling sandstone. . . . . . The alternation of layers here is as follows:

No. 1.	Closely cemented sandstone, projecting beyond the next	5 inches.
No. 2.	Coarse white sand, in water-worn grains, crumbling out easily	6 inches.
No. 3.	Same as No. 1	6 inches.
No. 4.	Same as No. 2	1 foot.
No. 5.	Brink of falls. Same as No. 1	1 foot.
No. 6.	Same as No. 2, seen	30 feet.

"This horizon is undoubtedly the same as that at Minneopa falls. The appearance of the gorge below the falls, and the occurrence of a cemented part giving rise to the perpendicular fall of the water, are very much the same. The beds lie here, as there, nearly horizontal. The grains of sand are, perhaps, somewhat coarser here than at Minneopa.

"This sandstone can be seen in the bluffs on the opposite side of the Minnesota river, surmounted by a great thickness of drift. The bluffs are mainly wooded, but some smooth buttresses and slopes, wrought apparently in the drift, and covered with grass, yet reveal the stone, large slabs and blocks from which lie on the hillside."

The top of this sandstone in the foregoing section is approximately 100 feet above the river and 860 feet above the sea. About 50 feet below this is the highest outcrop of the St. Lawrence limestone, and this is probably very near the hight of the line of junction of these formations. East from Minneopa falls the Jordan sandstone has a slight dip eastward, and in one and a half miles sinks to a hight only 65 feet above the river, or 820 feet above the sea, at David P. Davis' quarry in South Bend, where the southeast end of its terrace before described (page 426) shows a vertical exposure of 20 feet, from 65 to 85 feet above the river, of the overlying Shakopee limestone. Only the upper one or two feet of the sandstone is exposed, seen at nearly the same hight with the railroad track and on each side of it, at this quarry. At the former South Bend station, a quarter of a mile farther east, the top of the Jordan sandstone and its junction with this limestone is three feet above the railroad, 55 feet above low water in the river, and 811 feet above the sea.

A mile farther east, at the highway bridge crossing Blue Earth river, the line of junction of these formations is 40 feet, very nearly, above low water of the Minnesota river. At the quarries and lime-kilns in the north part of Mankato, this line is about 10 feet above low water, the river at this stage being there 750 feet above the sea. About a mile and three-quarters below Mankato, at a point on the river sometimes known as "Hurricane bend," in section 36 of Lime township, the Jordan sandstone reaches 45 feet above the river, being overlain by the Shakopee limestone.

The thickness of the Jordan sandstone in Blue Earth county appears to be about 75 feet In the section of the deep well at Mankato, this formation was absent, having been wholly removed, with perhaps some of the underlying St. Lawrence limestone, by pre-glacial erosion. The top of this sandstone at its most western outcrops, in Judson and at Minneopa, has a hight above the sea of 860 or 865 feet, while a half dozen miles eastward in Mankato and Lime, its top is at 760 to 790 feet. The dip eastward thus averages twelve or fifteen feet per mile, but in some portions, as from Minneopa to South Bend, it is as much as thirty feet to the mile, or about a third of a degree.

Along the Blue Earth river the Jordan sandstone and the overlying Shakopee limestone are seen at many places in the two and a half miles below the mouth of the Le Sueur river; and above this point these strata are frequently seen in the bluffs of the Blue Earth river along a distance of two miles from the new bridge in section 27, South Bend, westward to the N. W. ¼ of section 29. The course of the river in this distance passes about one mile south of Minneopa falls. Farther up the Blue Earth river no outcrops of the Shakopee limestone are found, but this sandstone continues in exposures in the lower part of the bluffs. being in sight and forming vertical banks on one side or the other along nearly the entire extent of four and a half miles, measured in a straight line, to the N. E. ¼ of section 13, Garden City, ending near the former site of Cappel's mill, half a mile below the mouth of the Watonwan river. In the two miles above the new bridge, in South Bend, which show both the sandstone and limestone, the former reaches about 50 feet above the river, being capped by 20 to 25 feet of the latter. In sections 29 and 31, South Bend, this Jordan sandstone declines in hight from 50 to 40 feet; at Rapidan Rapids its hight is 30 feet; and beyond this its elevation above the river is diminished to only a few feet at its last outcrops, in the east edge of Garden City township. By comparison with the descent of the river, it appears that the top of the sandstone is nearly level in these exposures, having about the same hight as at Minneopa falls and in Judson. All these outcrops have the ordinary characters of the Jordan sandstone, being white or gray, soft and mostly friable, in horizontal beds from a few inches to one or two feet thick. At the bend of this river, in the south edge of section 21, South Bend, where this formation rises on the north side to a hight of about 50 feet and is overlain by 20 feet of Shakopee limestone, the upper part of the Jordan sandstone contains occasional flattened masses, two or three inches long and an eighth to a fourth of an inch thick, of a white powder, which when wet becomes a sticky paste.

In the north bluff of the Blue Earth river, within a short distance above the bridge in section 27, South Bend, and about three-quarters of a mile above the mouth of the Le Sueur river, is the place where the Sisseton Indians, as stated by Featherstonhaugh, obtained a bluish green pigment which was held in high esteem. Nicollet says: "It is massive, somewhat plastic, emits an argillaceous odor when breathed upon; color bluish green; easily scratched with the nail, when formed into hardened balls. The acids have no action upon it; it is infusible before the blowpipe, but loses its color and becomes brown. This color is due to the peroxide of iron" [otherwise combined chemically until changed by the blowpipe flame], "which it contains in the proportion of ten per cent. at least. It contains no potash, and but a small proportion of lime." This was found in a shaly layer at the line of junction of the sandstone and limestone; but it occurred here only in small amount, and had been nearly exhausted before the time of Featherstonhaugh and Nicollet.* In our exploration it was carefully looked for, but nothing of this kind worthy of note was seen. Somewhere in this neighborhood, either in the bluffs of the Blue Earth or Le Sueur river, as much as four thousand pounds of a similar green or blue earth, perhaps from this horizon of the Lower Magnesian, but more probably from the Cretaceous shales or clay common in this region, being supposed to be an ore of copper, was gathered and shipped to France by Le Sueur, in the years 1700 and 1701. Further reference to this subject will be found on a following page, in the description of the Cretaceous deposits. From this earth, the location and nature of which remain in some uncertainty, the name of the river and thence of the county is derived.

On the Le Sueur river the Jordan sandstone is frequently exposed along a distance of one and a half miles next above the bridge of the railroad from Mankato to Wells, in section 35, of South Bend and Mankato, and section 2, Rapidan. In ascending the river the first of these outcrops is found four miles southwest from Mankato, and about a half mile south from the site of Red Jacket mill, which was recently burned. Here this sandstone forms a perpendicular bank 20 to 30 feet high and an eighth of a mile long, lying at the northeast side of the river next above the railroad bridge. It is a levelly stratified, but often obliquely bedded, friable, white sandstone. Its top here is 800 feet above the sea. Overlying it is a thickness of about 60 feet of irregularly interbedded clay and sand, with ochery and iron-rusted layers, probably Cretaceous deposits, and above these glacial drift forms the upper part of the bluff. The Jordan sandstone here presents a notable peculiarity which has not been observed in its outcrops elsewhere, excepting at the point before mentioned on the Blue Earth river. This is the existence of frequent cavities in the sandstone, filled with masses of white friable clay, as described by Prof. Winchell, "about an inch in diameter, usually flattened, or pointed, or edged, which if dry crumble to powder in the fingers, revealing little or no grit, but which when wet are sticky and plastic." At the iron bridge near the south line of section 35, South Bend, about half a mile southeast from the last, this sandstone rises vertically to a hight of about 20 feet in the bank on the west side of the river, and is overlain by 20 feet of Cretaceous clay and sand, succeeded by 10 feet of somewhat ferruginous drift. About a half mile farther southeast, on land of O. Halberg, near the center of the east half of section 2, Rapidan, a short ledge of Jordan sandstone rises 15 feet or more above the river in its southwest bank; and the opposite bank, at 20 to 40 rods up stream from the last, shows this rock to a hight of 6 or 8 feet, overlain by 20 to 25 feet of Cretaceous clays, and capped by drift, the

*See historical notes respecting this locality, pp. 69 and 72; and of Le Sueur's copper mine, pp. 16, 59, and 71.

whole bluff being 50 to 75 feet high. The Shakopee limestone, next in geological order above this sandstone, was not found in place on this part of the river, but about six rods northwest from the sandstone outcrop on O. Halberg's land, large blocks of this limestone lie at the base of the bluff beside the river, and have probably fallen from a ledge above; yet the steep, wooded face of the bluff now exhibits only drift.

No fossils have been detected in the St. Lawrence limestone or Jordan sandstone in Blue Earth county.

Shakopee limestone. This member of the Lower Magnesian series, and the sandstone just described, which it conformably overlies, both having a very nearly level stratification, together make the rock-bluffs of the Minnesota and Blue Earth rivers in the townships of South Bend, Mankato, and Lime. Other outcrops of the Shakopee limestone, without exposures of the underlying formation, occur on the Watonwan river at and close below Garden City, and on the Maple and Big Cobb rivers within their last two miles. This limestone has been quarried at many places, and has a high value for building purposes and for the manufacture of lime and hydraulic cement.* It is mainly a compact and hard, thick-bedded, somewhat siliceous dolomite or magnesian limestone, of light buff color, often mottled with slightly contrasted reddish and yellowish tints. The layer which is burnt for lime at Mankato, situated in the upper part of this formation, is sparingly fossiliferous.† Professor Winchell, from an examination of the Mankato quarries and of the river bluffs for several miles below, gives the following general section, in descending order:‡

Section of the Shakopee limestone in Mankato and Lime.

1.	Porous magnesian limestone, not used	4–6 ft.
2.	Loose, friable sandstone	2–4 ft.
3.	Magnesian limestone burned for lime	2 ft.
4.	Calciferous sandstone, in heavy beds, of various grain and texture, sometimes mottled, quarried for building	30 ft.
5.	Upper shale bed, arenaceous and mottled with red	2–3 ft.
6.	Calciferous sandstone, generally used as a cut stone, compact and even grained,	4 ft.
7.	Rough and irregular magnesisn limestone, somewhat arenaceous, but unfit for cutting	10 ft.
8.	Lower shale bed; very much the same as the upper	2 ft.
9.	One heavy bed, generally good for cut-stone, becoming light blue on deep quarrying	3 ft.
10.	Irregular and sandy bed; more or less cavernous and porous, with lenticular stratification, its lower three or four inches apparently broken; fine-grained, and stained with iron	3 ft.
11.	Jordan sandstone, seen about	45 ft.
	Total of the Shakopee limestone, about	65 ft.

*See the chapter on building stones, p. 166. The quarries of this stone, and analyses of it, are noted in a later part of the present chapter.

†In the quarries at Mankato, and especially in that of the Standard Cement company, which is in the lower part of the formation, a handsome *Lingula* is occasionally found. This shell is about half an inch long, of acuminate-obovate outline, with concentric striæ.

‡Second annual report, p. 145.

This is approximately the thickness of this formation exposed to view in its outcrops through its whole extent of sixty miles along the Minnesota river. The quarries at the north end of Front street in Mankato exhibit the first nine numbers of the foregoing section, with a very slight dip northeast. The terrace, 75 feet above the river, one to two miles wide and ten miles long, made by the Shakopee limestone, underlain by the Jordan sandstone, extending from Mankato north through Lime and Kasota to St. Peter, has been described in speaking of the surface features of this county.

Opposite to Mankato this limestone and the underlying sandstone form the lower half of the river-bluff in Belgrade, Nicollet county. A mile west of Mankato, the Shakopee limestone makes the small plateau called Sibley mound, which lies at the east side of the Blue Earth river close to its mouth; and the similar plateau just opposite, on the west side of this river, to which the name L'Huillier mound has been given, consists of the same limestone with a considerable thickness of Jordan sandstone at the base. These mounds together reach about a third of a mile from east to west. The hight of the former is approximately 50 feet, and of the latter 75 feet, above the bottomland, which is five to ten feet above the Minnesota and Blue Earth rivers. Channels cut here by these streams, perhaps since the ice age, have separated these mounds from the Belgrade bluffs and from each other.*

Professor Winchell reports the following

Section of L'Huillier mound.

1. Pebbles and soil at the brink of the bluff	2 ft.
2. Dislodged, broken layers of Shakopee limestone	35 ft.
3. Crust of iron and manganese	2–4 in.
4. Green clay, or shale, becoming white toward the top and on the outer surface; evenly laminated, the laminæ passing up into the white color. This is unconformably overlain by masses of dislodged Shakopee limestone, the under surface of which is crusted and rounded by water action. It also ascends between openings in these masses	3 ft.
5. Perpendicular cliff of Jordan sandstone, showing irregular seams and laminæ of green shale, also small balls and bunches of curious shapes, sometimes conforming to the general sedimentation, and somewhat also to the false bedding, so called. These thin deposits of green clay are fourteen feet below the general bed of green clay (No. 4) above	10–15 ft.
6. Talus, covering the Jordan sandstone, and reaching to the alluvial flood-plain	25 ft.

The same strata outcrop in many places through a distance of six miles west-southwest from Mankato, occurring in the bluffs of the old channel of the Le Sueur river between three-fourths of a mile and one and a half miles north of Indian lake, in the bluffs of Blue Earth river a half mile farther west, in the terrace at South Bend, as before mentioned, thinly covered by modified drift, and again in the bluffs of the Blue Earth river a mile south of South Bend and Minneopa. The top of the Shakopee limestone in these exposures has a hight 75 to 100 feet above the Minnesota river, or about 825 to 850 above the sea; and the glacial drift, lying on this limestone and forming the higher part of the bluffs, has its top 200 to 225 feet above the river, at which elevation its slightly undulating expanse forms table-lands on each side of the valleys and thence reaches with imperceptibly ascending slopes to the east, south and west, beyond the boundaries of the county.

Like this sheet of drift, the underlying rocks appear to have a nearly level but slightly sloping top, which may have been the surface of this region before the ice age, but more probably was planed and brought to its comparative uniformity in hight by glacial erosion. In Blue Earth county the rock-surface, uncovered along the Minnesota valley, makes the terrace of Jordan sandstone in Judson and thence to Minneopa falls, and its continuation capped by Shakopee limestone at South Bend; is exposed, overlain by drift, in the bluffs of the Blue Earth and Le Sueur rivers, and of the Minnesota river in Belgrade; forms the L'Huillier and Sibley mounds; and, below Mankato, reaches in a broad terrace to Saint Peter. The Minnesota river, after cutting through the overlying 125 to 150 feet of till, found here an old valley which had been channeled in these rocks by pre-glacial streams.

*The east mound derives its name from the encampment near it of the troops under the command of Gen. H. H. Sibley, on their return from suppressing the Indian outbreak in 1862. L'Huillier was the assayer who examined Le Sueur's copper ore, and from whom his fort was named (see page 17).

At Garden City the Shakopee limestone is exposed on a small island and in the left bank of the Watonwan river, close below the dam and mill. The area of these exposures is about four rods square, and their hight three to five feet above the water. Professor Winchell records the occurrence of a species of *Euomphalus* in this stone, apparently the same fossil that was described and named *Straparollus Minnesotensis* by Owen. This rock has nearly the same aspect as at Shakopee, having frequent cavities, and being sometimes a breccia. It lies in thick beds which are irregularly tilted and dip synclinally 10° to 20° from both north and south into the river. The probable explanation of this is that this limestone, at first horizontally stratified, has been fractured by the removal of a part of the underlying friable Jordan sandstone, through pre-glacial drainage into a river lower than that of the present time. Another outcrop of this limestone is found a third of a mile northeast from Garden City, on land of the S. M. Folsom estate. It is at the northwest side of the Watonwan river, and is principally covered with drift, being seen at only a few small excavations upon an area fifty feet long and fifteen to thirty feet wide, adjoining the river and gradually rising about five feet above it. It has layers one foot or more in thickness, and has been somewhat quarried.

The valley of the Le Sueur river has an outcrop of this limestone on land of Andrew Algren, in the N. E. ¼ of section 11, Rapidan, being on the southwest side of the Le Sueur about two-thirds of a mile below the mouth of Maple river. The ledge seen here reaches five feet vertically, and is in level beds six inches to one foot or more in thickness. It is about twenty rods from the river and fifteen to twenty feet above it.

On the Maple river the Shakopee limestone is quarried at many places within a mile above its mouth, and occasional low outcrops of it are found along the next mile, to the south part of the N. W. ¼ of section 24, Rapidan. At these quarries the stone is a compact, light-buff dolomite, of nearly uniform texture and color, in horizontal layers one to three feet thick, reaching from the level of the river to hights twenty to thirty feet above it.

On the Big Cobb river this formation outcrops and is slightly quarried three-fourths of a mile and one and one-fourth miles above its mouth. The first of these localities is on land of Matthew Ryan, in the S. E. ¼ of section 18, Decoria, where this stone makes a terrace which extends about a quarter of a mile in the bottom land, being twenty to twenty-five feet above the river and seventy-five feet below the top of its bluffs and the general surface of the drift. The highest points of the limestone here are fully thirty feet above the river, and have the form of isolated mounds of horizontal strata, which have been spared, while the continuation of the same beds has been removed, by the agencies of weathering and erosion. These mounds rise ten to fifteen feet perpendicularly or often with overhanging sides. A similar picturesque weathering of this limestone, forming many such mounds five to ten feet high, was also seen four miles north of Mankato, on land of Joseph Kunz, in the S. E. ¼ of section 19, Lime. At Mr. Ryan's quarries, near the south end of the exposures of rock on his land, its hight at the east side of the river is about twenty feet and at the west side ten feet, their distance apart being ten or twelve rods. This stone has the same characters as in the quarries of Mankato and Maple river. It lies in beds which are from one to four feet thick, their stratification on the east side of the river being nearly level, but on the west side dipping 5° to 10° west. About a half mile farther south, on land of A. W. White, in the N. E. ¼ of section 19, Decoria, the Shakopee limestone is again exposed, forming a vertical cliff which rises from the level of the river to about thirty-five feet above it, in its left (here the northern) bank. It holds this hight for an extent of about ten rods, and continues with decreasing hight as much farther westward. At its west extremity this limestone is overlain by Cretaceous beds; but mainly this ledge is covered by till, which reaches seventy-five feet above the river.

The elevation above the sea of the outcrops of Shakopee limestone on the Watonwan river at Garden City and on the Maple and Big Cobb rivers is 875 to 900 feet, being about fifty feet higher than the top of this formation in Mankato and Lime, eight to twelve miles farther north.

Cretaceous beds. The only deposits found in Blue Earth county above the foregoing Lower Magnesian strata and below the drift are beds of clay, sand and sandstone, and rarely gravel, which are believed to have been formed in the Cretaceous age. Similar formations, containing characteristic Cretaceous fossils, occur in other portions of this state, toward the east, north and west, and have a great development farther west in the region drained by the upper Missouri river. No fossils have been found, however, in any of these deposits in this county, though they are exposed in many localities and present much diversity in material. They often occur in the ordinary manner of stratified sediments, unconformably overlying eroded surfaces of the Jordan and Shakopee formations; but another frequent mode of occurrence is in large water-worn cavities and fissures of these rocks, principally of the Shakopee limestone. Before the deposition of the beds here called Cretaceous, these Cambrian rocks at many places in the Minnesota valley had become channeled by rivers and sculptured into irregular basins, pot-holes, and hollows, from five to twenty-five feet in depth, often partly covered by overhanging walls. These pocket-like cavities are smoothly water-worn, and their surface is often thinly coated with iron ore. Within them clay has been sifted and packed so as to fill their irregular spaces, frequently covered in part by the limestone. The crust of iron ore (limonite with a little manganese oxide) was probably formed, however, since the clay was deposited. It should be added that the clay was doubtless of greater depth and extent at some former time; so that all the ore-covered surfaces observed may have become thus encrusted while enveloped in the clay. This deposit is, more strictly speaking, a very fine sandy and clayey silt, greenish or bluish, weathering white, horizontally bedded, or conforming somewhat to the shape of the hollow that holds it.

The following descriptions of these Cretaceous beds are given in geographic order, as they are found in descending the Minnesota valley, and afterward their exposures on the Blue Earth, Watonwan, Le Sueur, Maple and Big Cobb rivers are successively noted.

Within the Minnesota valley, in this county, the first occurrence of deposits probably of Cretaceous age is on land of Edward Rowe, in the west part of section 23, Cambria, where a conglomeritic sandstone, much broken into masses of various sizes up to eight or twelve feet long and five or six feet thick, covers a small area beside the river, having about the same hight with the flood-plain. It is underlain by a fine blue clay, without gravel or pebbles. Comparing these with the other beds of similar character in this region, we find outcrops of the sandstone on the opposite side of the river, in Nicollet county, one mile below and about two miles above this point. At the second of these localities some of its layers contain fragments of wood, or lignite, and angiospermous leaves. The underlying clay appears to be the same with that which elsewhere fills cavities in the Shakopee limestone. This order of deposition, first, clay, and later, sand and sandstone, is also found in these beds on the Maple river.

In South Bend, at David P. Davis' quarry, the section on the north side of the railroad is, at the top, fifteen to twenty feet of Shakopee limestone, in layers only a few inches thick, because of weathering, for its upper three to five feet, but below forming beds from one to three or four feet in thickness; containing many crevices and hollows up to twenty feet in diameter and ten to twenty feet deep, filled with a compact clay, mainly white or gray, but in a few places of a brick-red and elsewhere bluish green color (Fig. 23). Next below, this limestone appears, deceptively, to

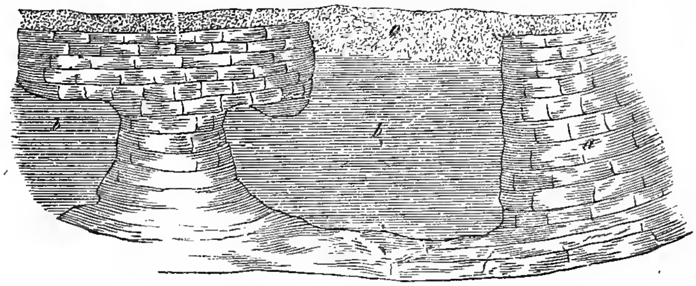


FIG. 23. CRETACEOUS CLAY IN HOLLOWS OF THE SHAKOPEE LIMESTONE, SOUTH BEND.
a. Shakopee limestone. *b.* Cretaceous clay. *c.* Drift.

be underlain by a nearly levelly stratified bed of this clay, four to five feet thick, lying on the Jordan sandstone, which forms the lowest one to two feet of the section. The horizontal bed of clay here is probably of small extent, filling a space from which the upper part of the friable sandstone had been excavated by running water. South of the railroad track, this stratum of gray and green clay, two feet thick, becoming gray sand below, also two feet thick, is seen along a distance of fifteen rods, overlain by limestone debris, and underlain by the Jordan sandstone.

Professor Winchell has described* an instructive section of the Shakopee limestone and its associated deposits of this clay, as observed in a cut near the railroad bridge which crosses the Blue Earth river about a mile above its mouth. "This cut is perhaps 70 feet above the river, the

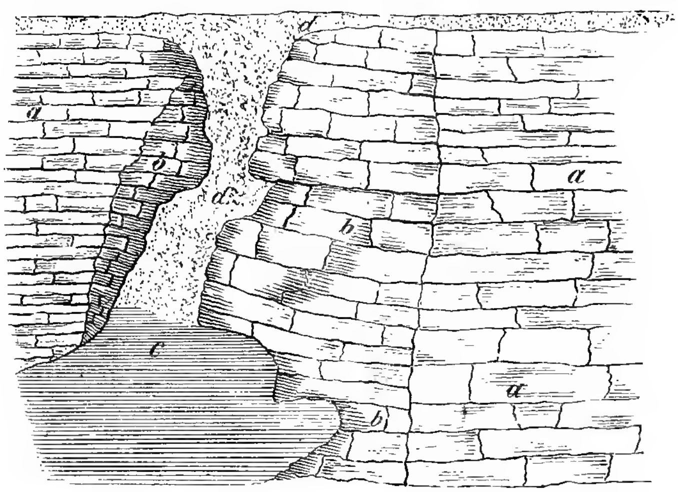


FIG. 24. SECTION NEAR THE RAILROAD BRIDGE, MANKATO.
a. Shakopee limestone, cut by the grading of the railroad. *b.* Weathered surface of same.
c. Cretaceous clay, greenish blue, bedded. *d.* Drift.

bank of which is composed entirely of rock, the lower portion of which is the Jordan sandstone, and the upper the Shakopee limestone, the latter comprising about 20 feet. In general this rail-

*Second annual report, p. 178.

road cut shows a mixture of Cretaceous clay with the Cambrian, the top of the whole being thinly and irregularly covered over and chinked up with coarse drift. The Cambrian is more or less broken and tilted, at least the bedding seems to have been cut out into huge blocks by divisional planes, which, either by weathering or water-wearing, were widened, the blocks themselves being subsequently thrown to some extent from their horizontality, tipping in all directions. The opened cracks and seams were then filled with the Cretaceous clay, which is deposited between these loosened masses, and sometimes even to the depth of twenty feet below the general surface of the top of the rock. The clay sometimes occupies nooks and rounded angles, sometimes sheltered *below* heavy masses of the Cambrian beds. The clay is uniformly bedded, about horizontally, with some slope in accordance with the surface on which the sedimentation took place. But the most interesting and important feature is *the condition of these old Cambrian surfaces.* They are rounded by the action of water, evidently waves. The cavities and porous spots are more deeply eroded, making little pits on the face of the rock; or along the lines of section of the sedimentation planes with the eroded surface, there are furrows due to the greater effect of water. The rounded surface of these huge masses of limestone is coated with a thickness of about a half inch, or an inch and a half, of iron ore, which scales off easily, and is easily broken by the hammer. While this scale of iron ore is thicker near the top and on the upper surface of the blocks, yet it runs down between the Cretaceous clay and the body of the rock."

Another deposit of greenish clay (Fig. 25) similar to the two last described, enclosed in a cavity of the Shakopee limestone and in part appearing to be a stratum overlain by it, was noted beside the carriage road from South Bend to Mankato close east of its bridge over the Blue Earth river.

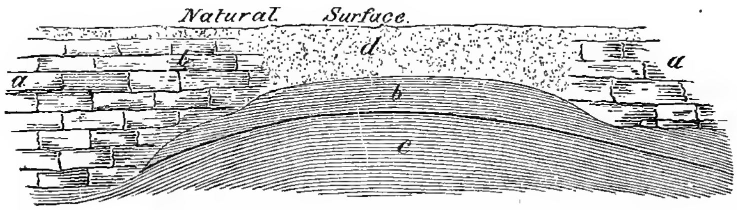


FIG. 25. CRETACEOUS CLAY BENEATH THE SHAKOPEE LIMESTONE, MANKATO.
a. Shakopee limestone. *b.* Bedded greenish clay, weathering white, but little sandy. *c.* Sandy, bedded greenish clay. *d.* Drift, mostly coarse fragments of Shakopee limestone.

In the S. W. ¼ of section 20, Lime, the quarry of J. R. Beatty & Co, exhibits a thickness of twenty to twenty-five feet of the Shakopee limestone. The top of this ledge is waterworn and hollowed in shallow pot-holes. Near the middle of the quarry face, as it was at the time of examination, these waterworn cavities reach to a depth of fifteen feet. their sides being in part encrusted with an iron-rusty scale, an eighth to a half of an inch thick. They are filled with very coarse ferruginous gravel, much waterworn, so that sometimes its pebbles up to three or four inches in diameter are almost perfectly spherical. In some of these crevices scanty traces of white clay occur with the gravel, the former being probably Cretaceous, while the latter seems to be older than the glacial drift, and may be Cretaceous or of earlier date. possibly representing the period in which these hollows were eroded. Close west of this quarry is found a thick bed of whitish, very fine earth (analysis 2, page 438), containing too little clay for brick-making.

Professor Winchell writes as follows respecting these probably Cretaceous deposits at localities recently examined by him near Mankato. "At the quarry of the Standard Cement company, lately opened in the east bank of the Blue Earth river about a third of a mile south of the railroad bridge, the Shakopee limestone is separated from the Jordan sandstone by a course of light green or often nearly white shale or clay, highly siliceous and aluminous, having a thickness of about three feet. The hydraulic qualities of the Shakopee limestone seem to be associated with the occurrence of this bed of shale, and to be altogether an accidental and local character. The formation has before been known to be somewhat hydraulic, but here this quality is so far extended as to make a valuable source of hydraulic lime. In the Shakopee limestone here are also numerous pits and gorges, rounded off with age and crusted over with a ferruginous scale that is sometimes as much as three inches thick. These old crevices cut across the strata and pass from top to bottom of the formation. They are filled with the same, or a very similar, light-colored clay, the same being continuous from the clay between the Shakopee and Jordan upward through the openings to the top of the limestone strata, and there spreading out, in imperfectly laminated beds, *over the similarly rusted upper surface* of the Shakopee. The bed of clay under this limestone is known to extend back from the bluff of the river about eighty feet, and seems to be *in situ* and of Cambrian age. Yet it seems not to be confined to this place between the Jordan and Shakopee formations, where the most of it is seen; and as it occupies eroded cavities and all seams and small openings within the Shakopee, and also overlies that formation, apparently unconformably, it has been considered of Cretaceous age.* Prof. A. F. Bechdolt, of Mankato, regards it as a result of chemical change in the overlying St. Peter sandstone and the underlying Jordan sandstone; but it more probably resulted from a local degradation of the hydraulic Shakopee limestone, through long sub-aerial exposure, if its origin be at all attributable to such agents."

"This white clay appears frequently at the same horizon, overlying the Jordan sandstone, at points in the Le Sueur valley. It was examined on the land of S. F. Alberger, along the banks of the Le Sueur in section 35, Mankato, where it lies about twenty feet above the river at the railroad crossing, and is overlain by a series of confused, concretionary and lenticular beds of sandstone, with alternations of clay, passing upward into a rusty conglomerate and crag-like rock, and into a sandstone containing traces of wood, similar to that seen in Fillmore and Mower counties, and at Fritz' quarry in Nicollet county, evidently of Cretaceous age. In ascending the river from the railroad crossing, the water line rises over the underlying sandstone, and reaches this clay bed. It is seen to become red in some places, and often somewhat gritty. The valley of the Le Sueur in this vicinity, and its tributary valleys, also the deserted channel through Indian lake, to which Prof. Bechdolt has called attention, are wrought principally in Cretaceous strata, overlain by a deposit of drift clay which shows, in numerous instances, the effect of water in its deposition."

Professor Winchell summarizes, in descending order, the following

General section of the Cretaceous in the Le Sueur valley, sec. 35, Mankato.

1. Conglomerate and sandstone; with traces of woody fiber; in oblique and lenticular stratification; the probable equivalent of fossiliferous strata at Fritz' quarry in Nicollet county, and of the sandstone a few miles southwest of New Ulm......20-30 ft.
2. Potter's clays and fine sand, irregularly and lenticularly interbedded...... ......20-30 ft.
3. Rusty and confused, concretionary sandrock..................................20-30 ft.
4. White (kaolinic?) clay; within of a light greenish color; becoming red and arenaceous in some places.. 6-8 ft.
5. Jordan sandstone, seen .... 20 ft.

Professor Bechdolt states that a slab of rusty sandstone was found some years ago on the bluff back of Mankato, containing fossil leaves resembling *Salix*; also, that a small shark's tooth was picked up in the alluvium at the mouth of the Blue Earth river; and that at any time small pieces of lignite coal may be found in the alluvium at the mouth of the Blue Earth, brought down by the latest freshet from the valley. All these were doubtless derived from Cretaceous formations.

On the Blue Earth river above the localities already mentioned, Cretaceous beds are reported by Mr. John Leiberg in the left (north) bank of the river about twenty rods below the new bridge in section 27, South Bend, being a somewhat sandy, deep green shale, exposed along an extent of about a hundred and fifty feet, rising in a flattened anticlinal about five feet above the line of low water; overlain by a bed of dark, ferruginous gravel, about ten feet thick, containing concretionary iron ore (limonite); above which is light gray or white, friable sand or sandstone, about thirty feet thick; succeeded by till, which forms the upper part of the bluff.†

At the east end of the Rapidan Rapids bridge, the cliff of Jordan sandstone, thirty feet high, is overlain by ten feet or more of interstratified clay, sand and fine gravel, referred to the Creta-

*See the second annual report. pp. 176—181; also the eighth annual report, p. 109

†It seems quite likely that this is the site of Le Sueur's copper mine, as it agrees well with Penicaut's description (See pages 17 and 428).

ceous age. The layers of clay are mostly white, but sometimes red; and the sand and gravel are occasionally cemented with iron ore. Above these the bluff consists of till, and rises to a hight about 150 feet above the river.

A sandstone, which may belong to either the Jordan or St. Peter formations of the Lower Magnesian group, but seems quite likely to be Cretaceous, and other beds more certainly referred to this later age, occur in the banks of the Watonwan river at Garden City, southwest and north of the fair-ground, rising fifteen to thirty feet above the river. Of these deposits Prof. Winchell writes*: "It [the sandstone] is here associated with more or less clay, crag, and iron and lime cement. A heavy deposit of drift crag [cemented gravel, probably Cretaceous] may be seen on E. T. Norton's place, and also . . . . . opposite Mr. Norton's. Under the crag is clean white sand. A little further up in the bluff is red and blue clay, belonging, undoubtedly, to the Cretaceous. This crag is sometimes made up of this white sand cemented, with little gravel. . . . . . It lies in a continuous layer along the bluff, and projects like a bed of rock, the incoherency of the underlying white sand causing it to crumble out. This is also shown on the north side [of the fair-ground], along the bluff where the current of the river has kept the surface fresh. This sandstone is again exposed in the banks of the river about two miles above Garden City."

On the Le Sueur river close above the railroad bridge the Jordan sandstone, described on page 428, is overlain by about sixty feet of clay and sand or sandrock layers, irregularly interstratified. In the lower portion the clay is mostly white, but at one place is red and by being washed down paints a portion of the bluff a few feet in width. This is about a hundred feet southeast of "chalk run," a gap in the bluff which has its name in allusion to these white and red clays. The sand is mostly ferruginous, and is cemented by iron-rust. These beds rise from thirty to forty feet above the railroad bridge, which is 825 feet above the sea. The clay which is used at Mankato for the manufacture of pottery is obtained at this place, southeast of the railroad and about fifteen feet above the level of the railroad grade. In the bank four rods east of the railroad bridge, the following descending section was noted. It is embraced in No. 2 of Prof. Winchell's general section already given.

Section of Cretaceous beds near the Le Sueur river railroad bridge, sec. 35, Mankato.

1.	Coarsely rocky drift	4–10 ft.
2.	Stratified gravel and sand, ferruginous, farther eastward iron-cemented	3–5 ft.
3.	Dull gray, horizonally stratified clay	1–2 ft.
4.	Dull gray, horizontally stratified sand	4 ft.
5.	Second layer of clay, like No. 3	1½–2 ft.
6.	Second layer of sand, like No. 4	4 ft.
7.	Third layer of clay, like No. 3	1½–2 ft.
8.	Third layer of sand, like No. 4, seen	1 ft.

The top of the last of these layers is six feet above the railroad, and is higher than the white and red strata which overlie the Jordan sandstone in the adjacent river-bluff. At the iron bridge, about a half mile farther up this river, the Jordan sandstone is overlain by twenty feet of clayey and sandy, nearly levelly stratified Cretaceous strata, of gray and whitish color, in many portions containing small lumps of white clay. In the east part of section 2, Rapidan, the northeast bank of the Le Sueur river shows a few feet of Jordan sandstone at the base, on which rest white and gray Cretaceous clays, closely like the deposits which fill cavities of the Shakopee limestone in South Bend and Mankato, nearly horizontal in stratification, having a thickness of twenty to twenty-five feet and exposed along a distance of about twenty-five rods. These strata are reddish in a few small and inconspicuous portions. Above them the upper part of the bluff is drift. Again, an eighth of a mile farther south, Cretaceous strata of similar character form the bank on the southwest side of this river along a distance of nearly twenty rods, but at the time of observation were much obscured by falling down. This bluff is 40 to 75 feet high, with ascent toward the south, all above 30 to 40 feet being drift.

On the Maple river are numerous exposures of sand or sandstone and clay, which closely

*Second annual report, p. 131.

resemble the beds described in Garden City. At Columbus Ballard's quarry, on the west side of the river near its mouth, in the N. E. $\frac{1}{4}$ of the S. W. $\frac{1}{4}$ of section 12, Rapidan, the west part of the ledge of Shakopee limestone which is worked, is overlain by twenty feet of Cretaceous clays, mostly whitish, in some parts irony, and rarely reddish. Here the limestone has a hight of only ten feet, but it rises twenty feet above the river a hundred feet farther east. Along the last two miles of this river, in the northeast part of Rapidan township, Prof. Winchell describes* "a friable, white sandstone. . . . . underlain by about two feet of a greenish blue clay, and associated with concretionary and irregular sheets of brown hæmatite. In the banks of the Maple, where the Shakopee limestone is exposed and somewhat quarried, there are occasional missing places in the beds of that formation. If by the action of the river the section is kept clear, so as to remove the drift, this bed of clay can be seen lying with distorted and dishing strata in these intervals. The strata are sometimes not preserved, but the masses appear as if thrust into the excavation in the Shakopee limestone, and are very sandy. In other cases the clay seems to have been shaped in layers conformable to the surface of the limestone, but unconformable with its bedding. At one place the following section can be made out:

1. Alluvium .... 15 feet.
2. Irony crag and impure iron ore .... 2 feet.
3. Greenish bedded clay .... 2 feet.
4. Strata of Shakopee limestone, more or less stained and encrusted with iron 4 feet.

"These parts are arranged, relatively to each other, as shown in Fig. 26.

FIG. 26. SECTION IN THE BANK OF MAPLE RIVER, RAPIDAN.

"The white sand . . . is in some way associated with the iron ore. It seems to lie in patches, sometimes just below the iron, and in other places where the iron is wanting. It seems to lie above the clay or shale. . . . At other places, a little above the point of the foregoing section, the iron and sand are found irregularly mingled, the iron occurring in the form of concretionary sheets, at least in sheets that enclose cavities. As much as four feet of this sand can here be made out, but the clay layer cannot be seen.

"At a point a few rods farther up, the white sand can be seen in a bluff on the left bank of the river (probably on sec. 13), rising 40 or 50 feet, its exact upward limit being hid by the drift. At the bottom of this bluff the Shakopee limestone is exposed in the form of a rounded water-worn buttress, rising in a solid mass about twelve feet above the river. About this bare rock, which exposes not more than a square rod of surface, or 200 square feet, are fallen pieces of the iron ore mentioned. The rock itself seems coated with thin layers of the irony stone, which yet appear calcareous. No clay or shale, the equivalent of No. 3, of the last section, can be seen. Overlying this iron and mingled with it, is a deposit of white sand, rising, as already stated, about fifty feet. This sand is so incoherent that one cannot ascend it. It slides like drift sand, yet is perfectly homogeneous *as sand*, without any resemblence to any drift sand. It is purely white. It is mainly massive; yet irregular lines of sedimentation can be seen in it. Also variously arranged in it are little, thin deposits of shale which probably were green till faded and oxydized. These are sometimes an inch thick, but usually not more than one-fourth of an inch. They are in detached, lenticular patches, and not now plastic, but soapy. No fossils can be seen. It seems to lie *unconformably on the Shakopee limestone*, separated only by a thin bed of greenish blue shale. . . . At a point a little further along, this sand is more persistent, and shows horizontal bedding, by reason of the manner of its falling down from the bluff. Beds, 3-8 inches."

At the quarries of Shakopee limestone on the Big Cobb river in sections 18 and 19, Decoria, about one and a half miles east from the last, are other Cretaceous beds. In two hollows of this

*Second annual report, p. 132.

limestone on the west side of the river at Ryan's quarry are deposits, one of white, and the other of red clay, each two to three feet thick. The west end of White & Curtis' quarry is covered by Cretaceous accumulations which are in turn overlain by drift. The section from top to base of the bluff here is as follows:

Section in the bank of the Big Cobb river, N. E. ¼ of sec. 19, Decoria.

1.	Yellowish sandy till	10-15 ft.
2.	Dark bluish till	30 ft.
3.	Red and yellow clay, seen at two places, each having an extent of only a few feet	2 ft.
4.	Ferruginous, sandy shale, with much interstratified loose sand, some of these beds being mainly white, others dark, while the greater part have an iron-rusted color, and are more or less cemented by limonite; visible along a distance of 25 rods, from the extremity of the Shakopee limestone southwesterly to the ford and foot-bridge; in thickness, about	10 ft.
5.	Incoherent, irregularly stratified sandstone, straw-colored or nearly white, containing infrequent specks of a snowy white powder; exposed at 12 to 18 feet above the river, for a distance of only 25 feet, being obscured below and elsewhere by the fallen talus	6 ft.
6.	Shakopee limestone, farther east rising 35 feet in a perpendicular cliff from the river, here	10-15 ft.

Numbers 3, 4 and 5 are believed to be Cretaceous, but no fossils were seen in any of these strata.

Analyses of Cretaceous clays from the vicinity of Mankato.

Five analyses, shown in the table below, have been made for this survey, of samples of the very fine, more or less clayey silt which has been described in the foregoing pages in respect to its manner of occurrence.

The first of these analyses (No. 67, eighth annual report) was made by Prof. S. F. Peckham, and is the clay or shale filling hollows of the Shakopee limestone in the west part of Mankato. Prof. Peckham remarks: "Its composition places it with orthoclase, although it has the physical properties of kaolin. It is chemically a slightly decomposed feldspar, while it has the appearance and some of the properties of clay. It, however, appears to contain too much iron to admit of its being used for white ware, although a practical test is often required to definitely settle the value of clays for such purposes."

The second analysis (No. 75, tenth annual report) was by Prof. J. A. Dodge, and is from a nearly white clayey bed of considerable extent, which has been tried unsuccessfully for brick-making, near the quarry of J. R. Beatty & Co., in section 20, Lime. "This was pulverized, without grinding up the particles of gritty matter that were to some extent intermixed with it; the powder was then mixed with distilled water, the suspended portion poured off and allowed to settle for a day or two; the settled portion was then collected, dried at 212°, and submitted to analysis by the common methods for silicates."

The third (No. 138, twelfth annual report) was by Mr. C. F. Sidener, and is a nearly white, very fine-grained, somewhat friable earth, in the lower part of the succession of Cretaceous strata in section 35, Mankato (from the east bluff of the Le Sueur river close above the railroad bridge, in No. 4 of page 435).

The fourth (No. 139, twelfth annual report), by Mr. Sidener, is from the same locality with the last, and is the red ochery clay which was mentioned on page 436.

The fifth analysis (No. 146, twelfth annual report), also by Mr. Sidener, is the clay or shale observed between the Shakopee limestone and the Jordan sandstone in the L'Huillier mound (No. 4, page 430). Like No. 1 of this table, but in less degree, "it is rather remarkable for containing so much potash, which probably exists in it in the form of finely divided potash feldspar."

	1.	2.	3.	4.	5.
Silica, $Si\,O_2$	70.10	87 70	93.65	73.34	68.70
Alumina, $Al_2\,O_3$	16.99	7.24	2.15	14.75	18.04
Lime, Ca O	.....	0.67	0.20	0.28	1.24
Magnesia, Mg O	.....	0.07	0.12	0.05	0.56
Potassa, $K_2\,O$	10.69	0.49	traces	traces	5.28

Soda, Na_2O	.....	3.17	traces	traces	0.24
Ferric oxide, Fe_2O_3	traces	traces	0.25	5.45	1.53
Sulphuric oxide, SO_3	0.23	....	.....	.....	.....
Phosphoric oxide, P_2O_5	.....	.....	.....	.....	0.09
Organic matter	.....	traces	.....	.....	traces
Water, H_2O	1.98	traces	2.25	4.71	1.40
	99.99	99.34	98.62	98.58	97.08

In the absence of palæontological evidence, it is impossible to determine to which part of the Cretaceous series these beds in Blue Earth county should be referred; but there can be little doubt that they belong somewhere in this age. Scanty exposures of Cretaceous strata are found in many parts of the western two thirds of Minnesota, enclosing sometimes marine fossils, sometimes impressions of leaves, and at a few places thin layers of lignite.

Before the Cretaceous age, during which western Minnesota and the region of the upper Missouri were depressed and covered by the sea, deep channels had been cut by rivers in the Lower Magnesian strata of this county; and the slopes and course of drainage seem then to have been partly like those of the present day. At least we find where the Minnesota river now flows a remarkably water-worn and deeply excavated valley, in which these Cretaceous beds of clay and sand were deposited.

Glacial drift. The drift in Blue Earth county has the same characters in its composition and sources of material, manner of formation, diverse deposits, and topography, as are found generally, except in its belts of terminal and medial moraines, throughout a very large area of southern and western Minnesota and upon much of Iowa and Dakota. In describing the surface features of the county, the topography of the drift-sheet, in its gently rolling or undulating and partly quite flat expanse, and the deep, trough-like valleys which intersect it, have been already sufficiently noticed. The thickness of this sheet of glacial drift is principally from 100 to 200 feet, but in the Mankato well it was found to be 290 feet. Its average upon the whole county is probably 150 feet. Before its erosion by rivers, this was a mantle entirely concealing the bed-rocks, which had no exposure in this region.

The formation of the drift, including removal, intermixture and deposition, took place in the last completed period of geological history, and is found to have been accomplished by the agency of a vast ice-sheet that rested upon the land and moved slowly forward because of the pressure of its own weight, covering the northern half of North America, as now the Antarctic continent and the interior of Greenland are buried beneath ice thousands of feet deep. In Blue Earth county and generally through the greater part of Minnesota, the material of the drift is principally the unmodified deposit of the ice-sheet, composed of clay, sand and boulders, mixed indiscriminately in an unstratified mass. Very finely pulverized rock, forming a stiff, compact, unctuous clay, is its principal ingredient, whether at great depths or at the surface. This formation is denominated till, boulder-clay, or hardpan. Layers of stratified gravel and sand are enclosed in this deposit, and are the source of the sudden inflow and rise of water frequently found in digging wells.

In this county and upon the western two-thirds of this state, the till has a dark bluish color, except in its upper portion, which is yellowish to a depth that varies from five to fifty feet, but is most commonly between fifteen and thirty feet. This difference in color is due to the influence of air and water upon the iron contained in this deposit, changing it in the upper part of the till from protoxide combinations to hydrous sesquioxide. Another important difference in the till is that its upper portion is commonly softer and easily dug, while below there is a sudden change to a hard and compact deposit, which must be picked and is far more expensive in excavating. There is frequently a thin layer of sand or gravel between these kinds of till, which have their division line at a depth that varies from five to thirty or very rarely forty feet. Owing to the more compact and impervious character of the lower till, the change to a yellow color is usually limited to the upper till. The probable cause of this difference in hardness was the pressure of the vast weight of the ice-sheet upon the lower and older till, while the upper till was contained in the ice and dropped loosely at its melting.

Again, in numerous places the upper till as here described is directly underlain by a softer till, moist and sticky, and dark bluish in color. This is usually of considerable thickness, or between twenty and fifty feet. It often encloses or is underlain by beds of water-bearing sand; but occasionally it has been penetrated and is found to lie directly upon a bed of very compact till, such as usually comes next below the upper till. In some cases this soft and moist deposit is evidently stratified clay, free from gravel or only holding here and there a stone, and all varieties appear to be found between this and an unstratified and very pebbly till; as indeed it may be that the latter in different localities shows all gradations from its occasionally very soft character, where a shovel can be easily thrust into it to the depth of a foot or more, to the hardest deposits of the lower till in which a pick can be driven only an inch or two at one blow.

The few beds found in this district which contain shells or trees that flourished in interglacial epochs, lie beneath two distinct beds of till, the lower sometimes showing its usual hard and compact character, but elsewhere being even softer than the upper till.

Excepting the division into beds as before described, the till is an entirely unstratified deposit. There has been no assortment of its materials by water, and the coarsest and finest are mingled confusedly in the same mass. Often a thickness of fifty feet or more exhibits no evidence of stratification.

The motion of the ice-sheet upon this part of the state was from northwest to southeast, as is shown by the direction in which the boulders of the drift in this region have been carried, and by the courses of the glacial striæ, or the scratches and grooves worn on the surface of the bed-rock by stones and boulders carried along in the ice. Small rock fragments, varying in size up to the dimension of six inches, are usually numerous and scattered through all parts of the till; they are, however, seldom abundant, and are sometimes so few that in well-boring none might be encountered. Boulders of large size are less frequent, and often a well or even a railroad cut in till fails to display any of greater dimension than two or three feet. Again, several may be found of various sizes up to five or perhaps seven or eight feet. They appear to be usually more numerous on the surface of the till than below. The number of boulders over one foot in size to be found generally upon the surface of moderately undulating tracts of till is estimated to vary from one or two to ten on an acre; but often, and especially on smooth or flat areas, they are more scarce, so that perhaps a dozen could not be gathered on a square mile.

The very smooth, and in many portions flat, surface of the southern two-thirds of Blue Earth county, and of the township of Mankato east from the top of the river bluff, indicates the extent of a lake which covered this area during the departure of the ice-sheet. In its recession from south to north the ice became a barrier here, as with lake Agassiz* in the Red river valley, preventing free drainage northward, and forming a lake which found its outlet southward in Iowa to the East fork of the Des Moines river, until the ice-sheet was melted upon the region covered by the Minnesota river from Mankato to its mouth. Besides its smooth or flat contour, the till upon the area occupied by this lake is distinguished by slight differences of its material from that of the more undulating districts surrounding it, in having a somewhat scantier intermixture of boulders and gravel, and occasionally in its imperfect stratification. Yet even where it shows distinct lamination, it usually is more like till than like ordinary modified drift, and contains stones and gravel through its entire mass. Rarely may be seen small areas of true laminated clay destitute of gravel. In the report of Faribault county, the outlet, boundaries, area and depth of this lake are treated of more fully.

Near Mankato Junction on the Winona & St. Peter division of the Chicago & Northwestern railway, in section 32, Lime, a cut eighty feet deep (figures 27 and 28) is made in till at the edge of the valley-bluff. The upper forty feet here is yellowish, and the lower forty feet dark bluish. Their line of contact forms a narrow shelf or bench in the cut, six to eight feet wide, apparently due to the greater hardness of the lower till; but their outlines and position make it probable that here their differences both in color and hardness have resulted from weathering. At the southeast end of this cut the yellow till for an extent of two or three rods and a hight of thirty feet is intersected by many nearly vertical banded veins which form an intricate network (figure 29, representing a space ten feet square) upon the steeply sloping face of the excavation. These veins or seams (figure 30) are two or three inches wide, and consist of films of ferric oxide, parted by laminæ of clay, often including near the middle a white or gray calcareous band from an eighth to a third of an inch wide. They appear to be veins of segregation, of somewhat similar origin with the tubular irony concretions which are often met in stratified clay and sand, and more rarely in till. Nowhere else have such vertical veins been found during all my exploration of the glacial drift.

FIG. 27.

FIG. 28.


FIG. 29.


FIG. 30.

ILLUSTRATIONS OF THE GLACIAL DRIFT, SEC. 32, LIME.

Wells in Blue Earth county.

The material and general character of the drift are illustrated by the following records of wells, including examples in most of the townships of this county. For the better exhibition of the succession of glacial deposits, this list is principally selected from the deeper wells of the county. Commonly an ample supply of excellent water, hard because of the presence of dissolved carbonate of lime, but not alkaline, is obtained from fifteen to forty feet below the sur-

*Compare the eighth, tenth and eleventh annual reports.

face, seeping into the well from the lower part of the yellow till, or furnished by springs from thin seams of sand or gravel next below this or within fifteen or twenty feet in the blue till.

Jamestown. Volk & Co.; Volksville, on the shore of Lake Washington, sec. 20: well, 120 feet deep; yellow till, 25 feet; blue till, 30; gravel and yellow sand, 15; ash-colored fetid clay, stratified, 10; sand, 40; no water. Another well, twenty rods from this, is 59 feet deep, being yellow till, 25; blue till, 33; a dark, cemented gravel, mainly composed of waterworn pebbles up to four inches in diameter, 6 inches; and common gravel, 6 inches, with water rising from it four feet.

William H. Rapley; sec. 30: well, 100 feet deep; yellow till, 45 feet, containing veins of gravel from six inches to two feet wide and from four to twelve inches thick; yellow sand, 55 feet; no water.

Le Ray. At Eagle Lake the wells are 16 to 25 feet deep, the deeper going through the yellow till and far enough into the blue till for a reservoir.

Mr. A. W. Redner, of Eagle Lake, a well-maker, states from an experience of about fifty wells in this and adjoining townships, that the yellow till is usually more filled with rock-fragments than the blue till, and is harder to bore or to dig with a spade. The blue till is more sticky. Lignite is frequently found, in pieces up to four inches long, mostly shaly and only half an inch or less in thickness.

Charles & William Macbeth; sec. 20: well, 55 feet deep; yellow till, 20; blue till, 30; quicksand, 1 foot; gravel, 1 foot; blue clay, containing small gasteropod shells, 3 feet.

McPherson. Charles Dittman; S. W. ¼, sec. 5, one mile north of Winnebago Agency (Hilton): well, 75 feet deep; yellow till, 15; at its base a gravel vein, nearly round and about a foot in diameter, was found running across the well; blue till, 55; quicksand, 5 feet and extending below; a small amount of water came in the gravel at fifteen feet, but this was lost in the quicksand at the bottom.

Mankato. Michael Rienbold; sec. 30: well, 30 feet; soil, 2; yellow till, all below; water seeps, being six feet deep in dry seasons.

Mrs. Mary Stuck; also sec. 30: well, 80 feet; yellow till, about 35; sand, 2 feet; blue till, softer than the yellow, 43; water rose forty feet from sand at the bottom.

Decoria. Henry Lortz; sec. 20: well, 33; yellow till, 14; sand, 1½ feet; yellow till again, 17; water rose three feet from sand at the bottom.

Adam Lortz; sec. 21: well, 90; yellow till, about 20; blue till, about 25; light-colored sticky clay, 10 feet; with probably stratified sand and gravel below. This well has only surface water; none in a dry season.

Rapidan. Fred Griffith; sec. 22: well, 24 feet; soil, 2; yellow till, spaded, 15; blue till, harder, but yet spaded, 7 feet; water seeps at the top of the blue till.

Lyra. Graham House; Good Thunder: well, 48 feet; soil, 2; yellow till, 16; soft blue till, 26; gravel and sand, 4 feet, with water issuing in this stratum but not rising above it.

R. L. Potter; sec. 33: well, 70; soil, 2; yellow till, 15; blue till, 53; water rises from gravel at the bottom to a hight six feet below the surface. This is the deepest well of its vicinity; it is at the general level of the country, about fifty feet above the Maple river. Nine rods farther east, a well 14 feet deep found a good supply of water, rising four feet from the bottom.

Sterling. W. Wells; sec. 4: well, 16½ feet deep, being all yellow till; water rose ten feet in four hours from sandy streaks at the bottom.

Garden City. At Lake Crystal, in the north edge of this township, the common wells are 15 to 30 feet deep. The well for the railroad and elevator here has a depth of 110 feet, of which the last 50 feet were bored. Its section is soil, 2 feet; yellow till, spaded, 15; softer and moister blue till, becoming more gravelly in the last 6 or 8 feet, 90; gravel, 3 feet; water rose from the bottom only twenty-five feet, but the well, when not pumped from, becomes filled with surface water.

Vernon Center. C. C. Washburn; N. W. ¼ sec. 26, close east of Edgewood station: well, 22 feet; soil, 2; yellow till, spaded, 20 feet; water seeps. At his barn, twelve rods to the south, is another well, 34 feet deep, having soil, 2 feet; yellow till, 18; harder blue till, 10; sand and gravel, 4 feet, from which water rose twenty-four feet in a half day, and stands permanently at this hight. The wells of this region average 20 to 30, and are occasionally 40 to 50 feet in depth. Lignite, in fragments up to four inches long, is found sparingly in the till in nearly all these wells.

Pleasant Mound. F. O. Marks; S. E. ¼, sec. 25: well, 55 feet; soil, 2; gravel, 6; light-gray "hardpan," very hard, 18; blue till, soft and moist, 29; water rose thirty-five feet in a few hours from a dark mud at the bottom.

William Robinson; sec. 26: well, 64; soil, 2; yellow till, spaded, 18; sand and gravel, 1 foot; soft and moist blue till, 43; with quicksand at the bottom, from which water rose thirty feet in six hours.

Ceresco. L. A. Pratt; sec. 24: well, 48; soil, 3; yellow till, spaded, 15; softer and moister blue till, 28; sand and gravel, 2 feet, reaching deeper; water rose four feet from this sand. Small fragments of lignite occur frequently in the wells of this region.

Lincoln. W. G. Bundy; sec. 30: well, 30 feet; soil, 2; yellow till, spaded, 24; harder blue till, 4 feet, and reaching deeper; water comes in sandy and gravelly veins in this blue till, becoming four or five feet deep.

Butternut Valley. Thomas Wilson; sec. 28: well, 58 feet; soil, 3; yellow till, spaded, 15; blue till, soft and moist for the first five feet, then mostly very hard and compact, requiring to be picked, in all, 40 feet, containing a piece of lignite, nearly a cubic foot in size, at a depth of about thirty feet from the surface; no sand nor gravel, and no good supply of water; this well has therefore been filled up.

Martin Osten; sec. 21: well, 28 feet; soil, 2; yellow and blue till, 26; with gravel and sand at the bottom, from which water rose to six feet below the surface.

Cambria. David T. Davis; sec. 26: well, 40; soil, 2; yellow till, spaded, 18 feet, containing gravelly streaks in its lower part, with a little water; much harder blue till, picked, 20; enclosing a vein of gravel and sand at the bottom, from which water rose two feet.

William E. Jenkins; sec. 34: well, 24 feet; soil, 2; yellow till, 18; harder blue till, 4 feet and extending lower; water seeps. Several small pieces of lignite were found in each of these wells.

Modified drift. In addition to the beds of modified drift enclosed in the till or lying below it, other accumulations of this kind of drift, derived directly from the ice-sheet but deposited by water, occur on the surface of areas which are mainly till. They consist of interstratified gravel and sand in knolls or mounds that rise ten to twenty feet, and rarely fifty to seventy-five feet, above the general level. These are seldom very numerous in western Minnesota, and are rarely extended in ridges or in any notable series. Their origin, however, was probably similar to that of the gravel ridges or kames which often form long series in other drift regions, being the deposits formed between walls of ice by glacial rivers that were poured down from the surface of the melting ice-fields. The only notable accumulations of this class in Blue Earth county are the group of hillocks before described in section 25, Pleasant Mound, and occasional knolls of fine gravel and sand, ten to fifteen feet in hight, in Butternut Valley and Cambria townships.

The valley of the Minnesota river at the north side of the county has been filled with modified drift to a depth of about one hundred and fifty feet, but it has since been nearly all excavated and carried away by the river.

At and opposite New Ulm, and four to eight miles farther down the valley, in Courtland, which adjoins Cambria, are conspicuous terraces of sand and gravel belonging to this formation, having hights from 100 to 150 feet above the river. Opposite to the southeast end of the Courtland terrace, a remnant of the same deposit lies in section 22 and the N. E. ¼ of section 21, Cambria, between the Minnesota river and the lower part of Morgan creek, having a hight of 100 feet or more and a length of about a mile.

Between Judson and Mankato, close southeast from the unnamed waterfall formed by the Jordan sandstone in section 12, Judson, the road rises about 75 feet higher, to a terrace composed mainly at its surface of coarse gravel and sand, irregularly and obliquely interstratified, upon which the road runs one and one-fourth miles southeast to the wind-mill in the N. E. ¼ of section 18, South Bend, where it is called the "Wind-mill bluff." This terrace of modified drift is two and a half miles long, reaching from the N. W. ¼ of section 12, Judson, to the S. E. ¼ of section 17, South Bend; its greatest width is about a third of a mile; its hight is estimated at from 170 to 150 feet above the river, declining toward the southeast, the bluffs of till at its southwest side being 30 to 50 feet higher, or 200 feet above the river.

In the farther descent of the valley, no other remains of this great deposit of stratified drift are found in the next ten miles; but, beginning again one mile beyond the north line of Blue Earth county, they are found thence commonly on one or the other side of the valley through its lower sixty miles, from Kasota and Saint Peter to its mouth. The depth of this valley drift, consisting of horizontally stratified gravel and sand, sometimes with thick beds of clay, is found by wells to be from 50 to 100 feet. This is at the side of the valley, in which this formation appears to have been a continuous flood-plain, gradually raised by the deposition of sediment, till its thickness along the middle of the valley, from which it has now been eroded, was from 75 to 150 or 175 feet, having a slope down-stream of about two feet per mile. The floods which brought this deposit and flowed over its broad plain were supplied from glacial melting.

The comparatively thin deposits of similar stratified gravel and sand, which cover the terraces of the Shakopee limestone and Jordan sandstone within the Minnesota valley, in this county and below, and the alluvium of the bottomlands, which are composed of fine silt, sand and occasional beds of gravel, have been worn and assorted by water nearly like the modified drift; but their origin seems attributable to the ordinary action of the river in the processes of excavation and sedimentation, and may be accounted for without reference to glacial conditions.

MATERIAL RESOURCES.

The principal resources of Blue Earth county are the products of its invariably fertile soil, and the water-powers afforded by many of its streams, which, by using their lakes for reservoirs, may be made nearly uniform in flow throughout the year. The valuable areas of timber and the prairies of natural grassland in this county both possess rich, deep, and well drained soil, bountiful and never-failing in its productiveness. Besides the agricultural capabilities of Blue Earth county, which have been before noticed, we have to enumerate here its water-powers, its quarries of building stone, the manufacture of lime, hydraulic cement, bricks, drain tiles and pottery, and artesian wells and fountains.

Water-powers in Blue Earth county.

The following water-powers are utilized in this county, all being employed for the manufacture of flour, excepting two saw-mills, of which one is situated on the Le Sueur river, in the southeast part of Mankato township, and the other in Le Ray on the outlet of Eagle lake.

Blue Earth river. Champion mills; V. H. Thompson; in the north part of sec. 16, Shelby; fall or head, seven feet; three run of stone.

Standard mills; Berry & Crow; Vernon Center, west of road, and north of river; head, seven feet; three run of stone.

Cable mills; Turner & Redfern; at middle of east half of sec. 18, Lyra; head, about seven feet.

Union mill; N. E. ¼ of sec. 31, Rapidan; head, about six feet; grist-mill.

Rapidan mills; Rapidan Mill Co.; at Rapidan Rapids; head, ten feet; mostly a custom mill.

Watonwan river. C. F. Butterfield's mill; in S. W. ¼ of sec. 32, Garden City; head, eight feet, as now located; owner expects to remove mill to a point about an eighth of a mile northeast, there to have a head of nineteen feet, four of it being gained by raising the present dam.

Watonwan mills; F. T. Enfield; upper mill in Garden City; head, seven feet; three run of stone.

Northwestern mills; Andrew Friend; lower mill at Garden City; head, seven feet; three run of stone; custom (exchange) and merchant mill.

Moore & Richardson's mill (formerly Folsom's); in S. E. ¼ of sec. 23, one mile below Garden City; head, about nine feet; two run of stone.

Maple river. Sterling mill; Mrs. M. Furman; just below mouth of Jackson creek, in the S. E. ¼ of sec. 9, Sterling; head, six feet; obtains water for dry season by raising and drawing four feet from lake Jackson at the west side of this township, and the same from Rice lake in Delavan, Faribault county.

Good Thunder mills; Palmer & Miller; two-thirds of a mile southeast from Good Thunder, beside the Mankato branch of the Southern Minnesota railroad; head, seven feet.

H. B. Doty's mill; in (or near) the N. E. ¼ of sec. 3, Lyra, one and a half miles north of Good Thunder; head, ten feet.

Maple River mills; George Gerlich; in the southeast part of Rapidan, four miles north of Good Thunder; head, twelve feet. All these are small custom flouring mills.

Outlet of Eagle lake and lake Madison. On this tributary of the Le Sueur river mills are owned by

Cate & Zimmerman; N. W. ¼ of sec. 20, Le Ray; one and a half miles southeast from Eagle lake; flour and grist mill; head, twenty-one feet.

Ellison & Ford; one mile south of the last, in sec. 29, Le Ray; saw-mill; head, fourteen feet.

Le Sueur river. Harvey & Bennett; Tivoli post-office, in sec. 25, southeast part of Mankato township; saw-mill; head, about nine feet.

Red Jacket mills*; Hillyer & Bingham; S. W. ¼ of sec. 26, Mankato, three and a half miles southwest from the city; head, twelve feet; canal, a third of a mile long; four run of stone; wholly a merchant mill.

Quarried stone. The St. Lawrence limestone in Judson has been worked at several places. On land of Mrs. G. W. Wolf it is quarried both at the south and north sides of a small lake which is close northeast of her house (Judson post-office); and also about sixty rods farther southeast. Work was begun here fifteen years ago; and sales have averaged about a hundred cords yearly. Only rough stone of small dimension is obtained, bringing from \$2 to \$4 per cord. At C. G. Swanson's quarry, a half mile southeast from the foregoing, the excavation is twenty rods long and exposes a vertical thickness of four or five feet. The sales at present are about twenty-five cords annually, at \$2.50 to \$3 per cord. John Goodwin's quarry, about a half mile farther southeast, has not been worked during the last five years.

The Shakopee limestone is much quarried in Blue Earth county. It

*Burned since this report was written.

is strong and durable, of attractive buff color, easily wrought to any desired form, and usually thickly bedded, supplying the largest sizes of dimension stone.* Its quarries here noted lie within the Minnesota valley in South Bend, Mankato and Lime townships, and in Belgrade, opposite Mankato; on the Blue Earth river, near the west part of the city of Mankato, and in the N. W. $\frac{1}{4}$ of section 27, South Bend; on the Watonwan river close below Garden City; within the valley of the Le Sueur river in sections 2 and 11, Rapidan; along the last mile of Maple river; and on the Big Cobb river in the west part of Decoria. The character of the formation at these localities has been already stated, and the ownership, situation, and extent of business of its quarries remain to be briefly mentioned.

At South Bend, beside the railroad, this limestone has been considerably quarried by David P. Davis, but little has been done here within the last few years.

In the north part of Mankato quarries are owned by J. R. Beatty, George Maxfield, the Chicago & Northwestern railway company, Adam Jefferson, and others. J. R. Beatty's east quarry reaches about thirty rods west from the north end of Front street. It has been operated about fifteen years, formerly supplying some eight hundred cords yearly at $3 per cord; but was not worked in 1879 and 1880. At present (1883) it supplies a large amount of stone both for building and for quicklime. In the bottom of the quarry the stone is blue.

George Maxfield's quarry, extending thence a quarter of a mile west, was leased from 1878 to 1880 to O. R. Mather, whose annual sales amounted to about $8000. This quarry supplied the masonry of the bridge at Shakopee, and the trimmings of the high school building at Le Mars, Iowa. The section here is given on page 429, the bluff of these quarries reaching from the top of the formation as there described to No. 9. Some portions of No. 3 are fossiliferous. In No. 4, a layer three feet thick, twelve to fifteen feet above No. 5, is reddish, having about the same tint as in the Kasota quarries, and is a good stone for cutting. Next above this is a thickness of eight feet used for common masonry. Another layer in No. 4, which is somewhat used for cut-stone, lies about six feet above No. 5; it is light straw-colored, and is finely laminated with curving concretionary films of ferric oxide. No. 6, called the best cutting stone, has a brownish buff color.

Adjoining the last and continuing northwesterly is another quarry owned by J. R. Beatty, from which the sales up to 1880 were about $1000 yearly. A third of a mile farther north, in the S. W. $\frac{1}{4}$ of section 6, this bluff has been quarried by Stephen Lamm & Co., who, jointly with Sullivan and Duffee, quarrying in Belgrade, supplied the stone for the Mankato bridge. These quarries, or others recently opened near them, are at present extensively worked by the Chicago & Northwestern railway company†, and for supplying the stone of the arched railroad bridge built in 1882 and 1883 at Minneapolis.

Half a mile farther north, in the N. W. $\frac{1}{4}$ of section 6, Adam Jefferson has quarried since 1877, selling about $1000 worth of stone yearly, at $3.50 per cord, and from fifteen to fifty cents per foot for cut stone, as window caps and sills. He supplied the masonry of the Le Sueur bridge. This quarry and that of Lamm & Co. expose a vertical thickness of fifteen to twenty feet, being in No. 4 of Prof. Winchell's section.

About a quarter of a mile farther north, yet in Mankato, a small quarry has been worked by Nathan Brooks.

In Lime township J. R. Beatty & Co. quarry extensively at the south side of a little creek in the S. W. $\frac{1}{4}$ of section 20. The working extends about fifteen rods on the face of a bluff which

*Consult the chapter on building stones, p. 166.

†At this quarry the workmen have the following designations for the different parts of the quarry, adopted for their own convenience. They are in descending order. 1. White ledge (very fine-grained stone). 2. Red ledge (harder and pinkish). 3. Gray ledge (coarse-grained). 4. Soft ledge (crumbled by freezing). 5. Bridge stone (coarse).

exposes twenty to twenty-five feet of this limestone, vertically, in beds from one to three or four feet thick. Quarrying was begun here in 1878, and in 1879 furnished the stone used for the Belle Plaine bridge, the sales of that year being $2500. Within a third of a mile southwestward, Joseph Kunz has quarried considerably at several places on his farm in the S. E. ¼ of section 19.

Valuable quarries of this limestone are worked upon the west bluff of the Minnesota river in Belgrade, Nicollet county, opposite to Mankato.

The St. Paul & Sioux City railroad company have quarried upon both sides of the Blue Earth river near their railroad bridge. The stone for the new bridge crossing this river in section 27, South Bend, was being quarried in 1880, about a sixth of a mile above it, from the Shakopee limestone which forms the upper part of the bluff north of the river.

The quarrying mentioned beside the Watonwan river, close below Garden City, on land of the S. M. Folsom estate, has been of small amount, perhaps supplying in all fifty cords of stone.

In the valley of the Le Sueur river, the fallen blocks of Shakopee limestone before spoken of on land of O. Halberg, in the east half of section 2, Rapidan, have been somewhat used for masonry; but this rock was not seen in place in the bluff above, which rises to a hight of seventy-five feet. Andrew Algren quarries this limestone slightly at its outcrop on his farm, less than a mile above the last, in the N. E. ¼ of section 11, Rapidan, getting out ten to twenty cords yearly.

Quarries on the Maple river within a mile above its mouth, in sections 12 and 13, Rapidan, are owned as follows: by Columbus Ballard, at the west side of the river, in the N. E. ¼ of the S. W. ¼ of section 12, leased to John C. Roland through several years past, considerably used for bridges, house-building, &c.; by Swan Larson, west of the river, in the S. W. ¼ of the S. W. ¼ of section 12, selling ten to twenty cords yearly at $3 per cord; by A. C. Wood, east of the river, in the S. E. ¼ of the S.W. ¼ of section 12, yielding excellent stone and considerably quarried; and by P. H. Kelly, in the N. ½ of the N. W. ¼ of section 13, also good, but not recently worked. The west pier of the bridge at Garden City was from Ballard's, and the east pier from Kelly's quarry.

In Decoria the Shakopee limestone on the lower part of the Big Cobb river has been quarried since 1875 by Matthew Ryan, in section 18, selling some seventy-five cords yearly, at $3 per cord; and since 1877 by A. W. White and Samuel Curtis, in section 19, selling annually ten or twenty cords. These quarries only supply the demands of their vicinity, and are scantily worked because they lack a sufficient market; but the stone here and on Maple river seems to be equal in quality to that of Mankato.

Lime. The St. Lawrence limestone in Judson appears never to have been used for lime-burning. From the Shakopee limestone on the Maple river lime was manufactured about fifteen years ago, but not since, because its cheapness at the Mankato kilns prevents competition.

At Mankato lime is burned by J. R. Beatty and O. R. Mather, from the layer No. 3 of Prof. Winchell's section of the Shakopee formation here. This buff dolomite produces a dark lime which slacks to a brown or cream color. It is magnesian, with a little admixture of sand, and is burned more easily, slacks with less heat, and sets more slowly, than pure lime. It is preferred by masons for brick and stone work, and for plastering except the finishing coat.

J. R. Beatty's kiln, at the west side of the north end of Front street, has been in operation ten years, averaging 7,000 barrels of lime yearly. It is a continual burner, with annual capacity of 12,000 barrels. O. R. Mather since 1878 has leased George Maxfield's kiln at the east side of the street, opposite to the foregoing, and burns about 6,000 barrels per year. This lime varies in price from fifty to seventy-five cents per barrel of about 225 pounds.

One and a third miles northwest from these kilns, in the N. W. ¼ of section 6, Mankato,

Adam Jefferson has burned two thousand to three thousand barrels of lime yearly since 1868.
The upper five to eight feet of the quarry worked by J. R. Beatty & Co., in Lime township, are excellent for lime, of which they here burned 2,000 barrels yearly in 1878 and 1879. Joseph Kunz, in the adjoining section 19, has also burned lime.

Hydraulic cement is manufactured by the Standard Cement company, on the east bank of the Blue Earth river about a mile southwest from the west part of the city of Mankato. The discovery of the hydraulic quality of the Shakopee limestone at this place is to be accredited to Mr. J. R. Beatty. The cement is made from the regular layers of the Shakopee, the whole exposed thickness of the strata, amounting to about twenty-two feet, being involved in the process. The rock varies somewhat from top to bottom, being too siliceous in one part and too calcareous in another, but when mingled in the process of manufacture makes a good hydraulic cement. Samples of the strata, selected for their excellence, have been analyzed by Mr. C. F. Sidener under the direction of Prof. Dodge, with the following result:*

No. 144. The powdered rock was digested in hydrochloric acid, whereby the greater part of it was dissolved with effervescence due to the escape of carbonic acid gas. The composition of the soluble and the insoluble portions is as follows:

Soluble in hydrochloric acid.		
Calcium carbonate, $CaO\ CO_2$	40.00	
Magnesium carbonate, $MgO\ CO_2$	31.50	
Ferric oxide, Fe_2O_3	2.73	
Silica, SiO_2	traces	
Alumina, Al_2O_3	0.85	
Potassa, K_2O	0.22	
Soda, Na_2O	0.54	
		75.84
Insoluble in hydrochloric acid.		
Silica	16.00	
Alumina	5.00	
Potassa	traces	
Soda	traces	
		21.00
Water		0.43
		97.27

The soluble portion is seen to be mainly carbonate of lime and carbonate of magnesia, with some oxide of iron, while the insoluble portion is silicate of alumina.

The chemical characters of the manufactured cement have been determined by Mr. Sidener as follows:*

No. 145. This material was found to effervesce very little with hydrochloric acid. It was accordingly analyzed as a silicate, by fusion in the usual manner. The result of the analysis is as follows:

*Twelfth annual report.

Lime, CaO	38.53
Magnesia, MgO	22.73
Ferric oxide, Fe_2O_3	4.71
Silica, SiO_2	16.24
Alumina, Al_2O_3	5.35
Potassa, K_2O	1.81
Soda, Na_2O	0.57
Water, H_2O	0.51
Carbonic acid, CO_2	9.26
	99.71

This company, beginning operations here in 1882 and 1883, have erected extensive buildings for carrying on the business, using the same rock in their construction. The Shakopee formation at this place has a different grain and texture from the strata seen at the quarries in the north part of Mankato and elsewhere.*

It seems to have more nearly the characters of the lower part of the Shakopee limestone quarried by J. R. Beatty & Co. in section 20, Lime, which on analysis showed a similar composition, being reported by Prof. Dodge as follows:†

No. 74. Rock a siliceous limestone. Digested with hydrochloric acid, a residue was left, amounting to 19.67 per cent. The dissolved portion was therefore 80.33 per cent.

Analysis of portion dissolved by hydrochloric acid:—

SiO_2	.27 per cent., being	.21 per cent. of whole rock.
Al_2O_3	.15 " " "	.11 " " " " "
Fe_2O_3	3.03 " " "	2.43 " " " " "
$CaO\ CO_2$	55.62 " " "	44.68 " " " " "
$MgO\ CO_2$	39.13 " " "	31.59 " " " " "
	98.20	79.02

Analysis of portion not dissolved by hydrochloric acid:—

SiO_2	78.27 per cent., being	15.29 per cent. of whole rock.
Al_2O_3	18.33 " " "	3.61 " " " " "
CaO	.48 " " "	.09 " " " " "
MgO	.23 " " "	.04 " " " " "
Alkalies	traces.	
Organic matter	traces.	
	97.31	19.03

A determination of water in the dried powder gave 4 per cent. (of whole rock.)

This is therefore a magnesian limestone, containing about 15 per cent. of silica, and but a moderate quantity of oxide of iron. It would appear likely to make a good hydraulic lime. No. 71 might also serve that use.

No. 71 is described by Prof. Winchell as "light blue calciferous sandrock, from the lower part of the quarry of Maxfield and Mather, Mankato, showing non-hydrated (un-oxidized) natural condition of the deeper beds of the Shakopee formation." Prof. Dodge says of this rock:‡

Ten grammes of the powdered and dried mineral were digested with hydrochloric acid; a residue was left which weighed 1.552 gms., making 15.52 per cent. of the rock; the portion dissolved was therefore 84.48 per cent.

*A bed of clay or shale underlying the Shakopee limestone at the Standard Cement company's quarry, and apparently associated with the qualities in the limestone which adapt it for the manufacture of hydraulic cement, is described on page 444.

†Tenth annual report, p. 204.

‡Same, p. 203.

Analysis of portion dissolved by hydrochloric acid:—

Fe_2O_3 with small amount of Al_2O_3 and SiO_2	3.14	per cent., being	2.65	per cent. of whole rock.
$CaO\ CO_2$	55.47	" " "	46.86	" " " " "
$MgO\ CO_2$	39.73	" " "	33.56	" " " " "
	98.34		83.07	

Analysis of portion left undissolved by hydrochloric acid:—

SiO_2	77.90	per cent., being	12.10	per cent. of whole rock.
Al_2O_3	19.24	" " "	2.99	" " " " "
CaO	.34	" " "	.05	" " " " "
MgO	.12	" " "	.02	" " " " "
Alkalies	traces.			
Organic matter	traces.			
	97.60		15.16	

It appears, therefore, that the rock is a magnesian limestone, with about 12 per cent. of silica and somewhat over 2½ per cent. of oxide of iron.

Bricks. The principal brick-making in this county is at Mankato.

The Mankato Brick company, O. R. Mather, superintendent, has three yards, two of which, making cream-colored bricks, are situated in the north part of the city, about fifty rods southwest from the lime-kilns, while the third, making red bricks, is a mile distant to the southwest. They all are on the bottomland, and the material used is the recent alluvium of the Minnesota river, the excavations reaching from the level of low water to fifteen feet above it. No sand is needed for tempering at these or the following yards. The difference in color of these bricks seems to be due to the mode of burning. With a rapid, hot fire, they take a light buff or cream color through the whole kiln; but when more slowly burnt they are red, except near the fire, where they become brownish or whitish gray. This business was begun ten years ago, and the annual product has averaged about 4,000,000. In 1880 it was 6,000,000, about two-thirds being cream-colored and one-third red. The bricks are sold at $5 to $7 per thousand, loaded upon the cars. Many of them go to distant points, as Saint Paul, Minneapolis, and Duluth, and to southwestern Minnesota and northern Iowa. About a sixth of a mile southwest from the third of the foregoing yards, in the west part of Mankato, F. Polchow & Co. have made red bricks eight years, averaging 4,000,000 yearly, and selling at about $6 per M. The material used is the same fine alluvial silt of the river. All these bricks are of excellent and durable quality.

In 1879 Willimes & Grothe began making bricks about one and one-fourth miles north of Mankato, being at the south side of a creek close southwest of Jefferson's quarry. They also use alluvium, producing red bricks excepting near the fire, where they are light gray. About 150,000 were made in 1879, and 3,000,000 in 1880, bringing $5 to $5.50 per M.

Red bricks have also been made since 1878, by Gekeler brothers, in the N. W. ¼ of section 8, McPherson, using the alluvium of the Le Sueur river. Their annual product is about 50,000, selling at $5 per M.

Brick-making was formerly done, but is discontinued, at five places in the west part of the county, as follows: by O. R. Mather, from 1867 to 1871, on the southeast side of Willow creek, in the S. W. ¼ of section 6, Shelby, producing red bricks of fair quality; also by Mr. Mather, during the next two years, in the southwest edge of the town of Lake Crystal; in 1869, south of the Garden City fair-ground, on the north bank of the Watonwan river, red bricks, cracked by particles of limestone contained in the sand which was employed for tempering, while the clay used is free from gravel and is said to have been tested in the Mankato pottery and found suitable for making stone-ware; in the N. W. ¼ of section 8, Shelby, on the east side of the Blue Earth river, about eight years ago; and, at nearly the same date, in the S. W. ¼ of section 32, Ceresco, west of Perch creek.

Fire-bricks. Mr. David P. Davis states that the Cretaceous clay in the lower part of his quarry at South Bend has been tested, and found to be of superior quality, for the manufacture of fire-bricks. From the pottery clay and sand of this age close east of the railroad bridge over the LeSueur river, fire-bricks are successfully made by Andrew Gapter, whose price for them is $40 per thousand at wholesale, and ten cents apiece in small lots.

Drain-tiles. S. F. Alberger, of Mankato, has recently begun the manufacture of drain-tiles. The clay used is obtained in the bluffs of the Le Sueur river and its tributary from the east known as Chalk run, in the S. W. ¼ of section 35, Mankato, being from No. 2 of the Cretaceous section recorded on page 435. The tiles made are firm and compact, and of a light red or pinkish color, varying to yellowish.

Pottery. Andrew Gapter has made pottery in the northeast part of Mankato since 1877; obtaining the clay used during the first two years from the bluffs of the Cottonwood river in section 3, Sigel, near New Ulm; but since then getting all the kinds of clay and sand required from the Cretaceous strata just mentioned on the Le Sueur river. He sells yearly about $3,000 worth of ware, the price being eight to nine cents per gallon. It is strong and durable, having, when not glazed, a reddish brown color.

Artesian wells and fountains. Some notice of the common wells of Blue Earth county, and of the ample quantity and good quality of their supply of water, was given in treating of the glacial drift.

The well at Mankato, 2,204 feet deep, the section of which has been presented on page 423, found no artesian flow of water, and is not used. It was drilled for the city, in the winter of 1874–5, at a cost of $12,000. About half its depth is six inches in diameter; and the portion below, three and five-eighths inches. Water was found in one of the layers of sand in the till at 85 feet. Within the rock it was first found at 540 feet, from which depth it rose to 90 feet below the top of the well. At 1,160 feet the drill fell a little, and from this new source the water rose ten feet higher. At 1,975 feet the drill again dropped, and the water rose ten feet higher still, to 70 feet below the surface. The supply appears, as tested by pumping, to be enough for the city's needs; and as the well is at the top, and near the edge, of the bluff, 200 feet above the greater part of the city, the water may be obtained and the well utilized by tunneling to it at a depth of eighty or ninety feet below its top.

Many flowing or artesian wells, called fountains, probably more than one hundred in number, have been obtained by boring to slight depths, from 25 to 75 feet, in the till, upon the area drained by the head-streams of Maple river, from Sterling Center fifteen miles southeastward, including Sterling and Mapleton townships in Blue Earth county, and reaching into Faribault county. It may be that this artesian water is continuous a half dozen miles still farther southeast to Wells, where the most remarkable flowing wells, or fountains, in Minnesota have been found. Though the water at Wells is obtained 110 to 120 feet below the surface, it is yet at a greater hight above the sea than in the shallower fountains on the Maple river.

These fountains are mostly bored in the valley of this stream, forty feet below the general level of the adjoining country, or in the similar valleys of its tributaries, which are depressed fifteen to forty feet. Near the Maple river they are commonly about thirty feet deep, being pipe from a half inch to one and a half inches in diameter, and the water rises from them five to ten feet above the surface. The sand and gravel which yield this water are not encountered everywhere upon this area, so that many borings in favorable situations get no artesian flow. It also seems likely that some localities have more than one stratum from which water may rise above the surface. For example, three fountains bored by William Randall in the southwest part of section 14, Sterling, in the valley of a small creek tributary to the Maple river which flows through the north part of this section, are 30, 50, and 60 feet deep, in their order as one follows down the creek. From the first to the third is about a third of a mile, in which distance the creek probably falls fifteen feet, making the difference in hight of the water-bearing sand at these points forty-five feet; suggesting, as the surface of the drift-sheet upon this region is nearly level, that these layers of sand, instead of being parts of any continuous stratum, may be distinct and independent of each other. The section of the lowest fountain here, 60 feet deep, was soil, 2 feet; soft and sticky blue till. 38 feet; sandy clay, thought to be free from gravel, 20 feet; with sand at the bottom from which the water rose in one minute to the surface.

The owners of the four mills on Maple river, and of the Red Jacket mill on the Le Sueur river, having been often hindered by scarcity of water, offered to pay $50 from each mill. if a hundred cubic feet of water per minute should be added to the Maple river by fountains. Well-makers accordingly obtained the right to bore on two farms and six fountains were obtained on each. One of the farms is now owned by E. W. Hicks, living close east of the northwest corner of section 14, Sterling. The largest of the fountains bored here forms a stream two feet wide and six inches deep. The other six fountains are on Mr. Cornell's farm, in the west edge of Mapleton, three miles farther southeast. Together the twelve fountains yield 135 cubic feet of water per minute; for which these mill-owners paid $325. This was done in 1877, and is regarded as a good investment, for this additional flow is constant through the year and enables the mills to work in the driest seasons.

CHAPTER XIV.

THE GEOLOGY OF FARIBAULT COUNTY.

BY WARREN UPHAM.

Situation and area. Faribault county (plate 17) is the central one in the tier of nine counties on the south side of the state, bordering Iowa. The distance from its north line north-northeast to Saint Paul and Minneapolis is about 90 miles; and from its east line to the Mississippi river at La Crosse is 120 miles. This county is a rectangle, its length from east to west being five townships, or thirty miles, and its width from north to south four townships, or twenty-four miles. Its area is 723.72 square miles, or 463.184.53 acres, of which 9,151.21 acres are covered by water. The largest towns and villages are Blue Earth City, Winnebago City, Delavan, Easton, Wells, and Minnesota Lake.

SURFACE FEATURES.

Natural drainage. The whole of Faribault county lies within the basin of the Blue Earth river, which flows northerly through its two western ranges of townships; while the East fork of this river, formed by Jones and Brush creeks in the southeast part of the county, flows west through its southern half and joins the main stream at Blue Earth City. The middle part of the northern third of the county is drained by the head-streams of Maple river, which is tributary to the Le Sueur and through that to the Blue Earth river. Dunbar, the most northeastern township, is drained principally by the Big Cobb river, also reaching the Blue Earth through Le Sueur river. The general slopes of the surface thus descend northward;

from the southeast part of the county westerly to Blue Earth City; and from its west boundary easterly to the Blue Earth river.

Lakes. Faribault county has frequent lakes, the largest of which is Minnesota lake, two and a quarter miles long from east to west and one to one and a half miles wide, lying in the northwest part of Minnesota Lake township, with its north edge reaching into Blue Earth county. Others deserving mention are Rice lake, in Delavan, three and a half miles long from north to south, and averaging about a half mile in width; Bass lake, north of the last, and only divided from it by a low and narrow ridge; Swan lake, about two-thirds of a mile long, with two or three others of smaller size, forming a group near the center of Barber township; Ozahtanka lake, having an area of about two square miles, in Barber and Emerald; Walnut lake, also covering about two square miles, in the south part of Walnut Lake township, and extending south into Brush Creek and Foster; Goose and Swan lakes, within a mile farther south in Brush Creek; and five lakes, from a half mile to one and one-fourth miles in length, lying in the southwest part of the county, in Jo Daviess and Pilot Grove townships.

Topography. The greater part of this county has a slightly undulating or often nearly flat surface, with slopes of very gentle and commonly imperceptible descent toward the water-courses. The streams have channeled from thirty to one hundred feet into the drift, which forms the surface and everywhere covers the county so deeply that the bed-rocks have no exposure within its limits. The East branch of the Blue Earth river at Clayton, in the north edge of Seely township, flows 30 feet below the general level; at Blue Earth City the valley is 50 feet deep; and northward through Verona and Winnebago City, its depth increases from 50 to 90 or 100 feet. Its bottomland, five to twenty feet above the stream, is mainly from a quarter to a half of a mile wide, bordered by steep bluffs that rise to the almost flat expanse of till upon which Blue Earth City and Winnebago City are built, and which covers the whole county excepting two belts of morainic hills. One of these extends from Kiester, in the southeast corner of the county, northwestward nearly to Delavan; and the other, which lies mostly in Iowa, includes the southern edge of Elmore and Pilot Grove. Many further details respecting the contour are stated in a later part of this chapter, in the description of the drift.

Elevations on the Southern Minnesota division of the Chicago, Milwaukee & St. Paul railway.
From George B. Woodworth, assistant engineer, La Crosse.

	Miles from La Crosse.	Feet above the sea.
Dood's switch, near the east line of the county	139.7	1189
Wells	144.4	1153
Junction of the Mankato branch	144.7	1145
Minnesota Lake station, on this branch	153.0	1038
Easton	153.3	1046
Summit, grade	157.1	1077
Delavan	159.2	1057
Depression, grade	159.5	1047

Crossing branch of C., St. P., M. & O. railway	166.1	1095
Winnebago City	166.3	1096
Blue Earth river, water	168.4	1014

The elevations above the sea of the Blue Earth river and its tributaries in Faribault county are approximately as follows: Blue Earth river at the south line of the county and state, 1125 feet; at the mouth of the East fork, in Blue Earth City, 1050; at the north line of the county, 990; Jones creek at the east line of the county, 1200; Walnut lake, 1125; Maple river at the north line of the county, 980; and the Big Cobb river in Dunbar, 1075 to 1100.

Mean elevation of the county. Estimates of the average hight of the townships of Faribault county are as follows: Dunbar, 1120 feet above the sea; Clark, 1170; Foster, 1200; Kiester, 1250; Seely, 1175; Brush Creek, 1125; Walnut Lake, 1125; Minnesota Lake, 1050; Lura, 1040; Barber, 1100; Emerald, 1125; Rome, 1160; Elmore, 1160; Blue Earth City, 1120; Prescott, 1100; Delavan, 1050; Winnebago City, 1080; Verona, 1100; Jo Daviess, 1150; and Pilot Grove, 1180. The mean elevation of the county is thus 1130 feet, very nearly, above the sea. Its highest points, the hills in section 3, Kiester, are about 1400 feet above the sea; and its lowest land, in the valleys of the Blue Earth and Maple rivers, slightly less than 1000.

Soil and timber. The soil of Faribault county has the usual character of the whole area of slightly undulating glacial drift which overspreads the basin of the Minnesota river. It is almost universally the unmodified drift, or till, consisting principally of clay, but enclosing a considerable proportion of sand and gravel and occasional stones and boulders. A thickness of about two feet of this deposit next to the surface has been made dark by decaying vegetation, and is the black soil. On the top of swells, and especially of the morainic hills and ridges, its depth is sometimes only about one foot, but is rarely much less; and in the depressions it is often three or four feet deep. This soil has a sufficient intermixture of sand to make it porous, easily allowing rains to soak into it and moisture to rise through it to the surface in a drought. It is therefore ready for early sowing and planting soon after the snow has melted in spring, and can well endure either very wet or unusually dry seasons. Besides wheat, which was formerly its leading crop, Faribault county is well adapted for raising oats, corn, hay, horses, pork, beef, butter, amber cane, flax, potatoes, and the ordinary vegetables and small fruits of the garden, all of which now receive due attention in the agriculture of this region.

Timber of large and dense growth usually occupies the bottomlands and bluffs of the Blue Earth river through this county, and of its East fork to a distance of fifteen miles above its mouth. It also forms groves or narrow belts on the borders of nearly all the lakes and creeks. With these exceptions the whole county, including both its smooth areas of nearly level till, and its rolling and prominently hilly tracts of the same glacial drift in moraines, is prairie, destitute of trees or shrubs, and bearing everywhere luxuriant grass.

The species of forest trees found in Faribault county, in the estimated order of their relative abundance, according to Mr. Alex. Halliday, proprietor of the Verona Star mills, are bur oak, slippery or red elm, soft maple, box-elder, wild crab-apple, black walnut, bitternut, common poplar, or American aspen, the large-toothed poplar, and cottonwood, common; black oak, white or American elm, sugar maple, and June-berry, less common; black cherry, white ash, hackberry, and butternut, scarce ; Kentucky coffee-tree, rare. The species of shrubs are stated by the same authority to be prickly ash, black currant, and hazel, abundant; frost grape, climbing bitter-sweet, smooth sumach, thorn, rose, wolfberry, and elder, common; choke-cherry, red raspberry, and prickly and smooth wild gooseberries, less common; the wild red cherry, and the black raspberry or thimbleberry, scarce. Mr. Halliday has seen cottonwoods and black walnut trees in this county five feet in diameter.

GEOLOGICAL STRUCTURE.

Faribault county has no outcrop of the bed-rocks that underlie the drift, but at five places wells have penetrated the drift and gone considerable depths into rock beneath. These are at Winnebago City, Easton, Minnesota Lake, Wells, and in Seely township. Their sections are as follows:

Winnebago City mills, a steam flouring mill; hight about 1,095 feet above the sea: well, 230 feet deep; soil, 2 feet; yellow till, 18 feet; blue till, 140, containing occasional beds of sand, from a few inches to five feet in thickness; stratified sand, probably modified drift filling a pre-glacial valley, 40 feet; yellowish and reddish magnesian limestone, 30 feet, the top of this rock being approximately 900 feet above the sea. Two other wells in Winnebago City go 150 and 160 feet in till, finding no bed-rock.

Terhurne & Scheid; Easton; hight about 1,050 feet: well, 205 feet deep; till, 101 feet, including layers of sand one to two feet thick, to rock at approximately 950 feet above the sea; consisting of whitish limestone, 8 inches; thin-layered, gray rock, probably also limestone, 2 feet; light gray sandstone, 101 feet, and extending below, coarsely granular, in some portions quite hard, quickly dulling the drill. This well was made with the expectation of obtaining an artesian flow.

Water was struck in the two feet of thinly bedded rock next above the sandstone, and rose to seven feet below the surface, but no considerable supply of water was found in the drift, and none additional in the sandstone.

Chauncy Barber; Minnesota Lake; at hight of about 1,040 feet: well, 140 feet deep; yellow till, 10; soft blue till, 80, to top of rock at approximately 950 feet above the sea; then, whitish limestone, 3 feet; thin-layered rock, probably limestone, 2 feet; soft, green shale, 2 feet; and gray sandstone, 43 feet, and extending lower. No water was found in the rocks below the drift.

C. W. Thompson; one mile west of Wells; about 1,140 feet above the sea: well, 153 feet deep; yellow and blue till, 117 feet; then, gray sandstone, 34 feet; softer, whitish shale, 2 feet; supply of water, insufficient. The top of this sandrock is approximately 1,025 feet above the sea. Another well, near by on the same farm, is 118 feet deep, and found soil, 2 feet; yellow till, 10; blue till, soft and sticky, 106 feet, excepting three feet of quicksand, with a little water, at about seventy-five feet from the surface; from sand or sandstone at the bottom water rose in this well to fifteen feet below its top.

In the twenty or more flowing wells, or fountains, at Wells, bed-rock is struck at 110 to 120 feet below the surface, or about 1,040 to 1,050 feet above the sea; and as soon as the thin stratum of the rock is pierced, water rises to the surface and five feet to fifteen feet above it. The section here is till, holding occasional layers of sand one to four feet thick, to a depth of 110 to 118 feet; then a stratum of yellowish or straw-colored rock is encountered, and after drilling into this a few inches or one or two feet, it appears that a vein of water one to six inches in thickness is found, not in gravel and sand but filling a cavity of the rock, from which the artesian flow comes. If the pipe is driven farther after reaching the water, it directly strikes upon rock below and the flow of water is shut off. No specimens of the stratum next above the water were obtained, but from the descriptions of well-makers and others it appears to be a limestone or a hard, sandy shale. It lies above the sandstone of Mr. Thompson's well, and the water probably lies at the junction of these beds, being held down by the impervious upper rock. The greatest thickness of the rock was at the vinegar factory, about one and a half miles south of Wells station, and probably ten feet higher, where a thickness of five feet of the yellowish limestone or shale were passed through at the depth of 110 to 115 feet. Water was found immediately under this, and rose to three feet below the surface. In rare cases this rock is not found before reaching the water supply, as in W. W. Woodard's well, in the south part of Wells, and on the highest land within the limits of this corporation, where the section was soil, 2 feet; yellow sand and clay, 6 feet; fine sand, 2 feet; yellow till, 10; blue till, 97, containing occasional beds of sand from two inches to two feet in thickness, yielding no water, till reaching the bottom at 117 feet, whence, without striking the usual layer of rock, an artesian flow of water rose to five feet above the surface. The beds of sand found in the till here are not persistent, as shown by two wells at A. L. Taylor's stable, one of which went through some four feet of sand at the depth of about sixty feet, while another boring twenty feet distant encountered only till or boulder-clay in this portion of its depth. In two instances, at Mr. Taylor's stable and at the Wells House, the bark of trees was found near the base of the drift deposits, 112 to 115 feet below the surface, but no shells nor other organic remains have been reported from these wells, which are usually bored two inches in diameter. Rarely these borings at Wells fail to secure an artesian flow, and in one of this kind Mr. P. Morse, well-maker, informs me that he went to a depth of 148 feet, the section being till 115 feet, and then sand, probably soft sandstone, for the remaining 33 feet, not passed through at this depth.

The only other point at which the bed-rock has been reached in this county is A. B. Brant's well, in the S. W. ¼ of section 4, Seely, close to Clayton post-office, which was bored 123 feet deep in hope of an artesian flow of water. This was soil, 2 feet; yellow till, 10; softer, moist, blue till, 80; harder blue till, 3 feet; bluish gray limestone, 28 feet, changing to lighter gray below, not penetrated. The top of this rock is estimated to be about 1025 feet above the sea. The only water obtained is from thin veins of sand which occur at various depths in the till, and it rises to four feet below the surface.

From the strike, dip, and hight of the rocky strata which outcrop in Blue Earth county and farther to the northeast and east, we may decide with much certainty that the rock of the Winnebago City well is the Shakopee limestone; and that the sandstone of the wells at Easton and Minnesota Lake belongs to the next higher formation, the St. Peter sandstone, still retaining in these wells a thin cap of the Trenton limestone, which directly overlies this sandrock at Minneapolis and throughout southeastern Minnesota.

The southeastward dip of these rocks, which carries them, with all the higher Silurian formations, beneath the Devonian limestone of Worth and Cerro Gordo counties in Iowa and of Mower and Fillmore counties in this state, makes it improbable that the limestone or shale and underlying sandstone encountered at Wells are the same with those of Easton and Minnesota Lake. But the Palæozoic series in this state and Iowa has no thick beds of sandstone above the St. Peter; and the next geological age which is represented in this region by such deposits is the Cretaceous. We seem obliged, therefore, to refer to this age a formation of white sandstone, about 60 feet in thickness, enclosing a layer three feet thick of limestone and yellow shale at 21 to 24 feet below its top, which is found in the deep well at Owatonna, succeeded below by the limestones and shales of the Trenton group and the St. Peter sandstone (page 398). The same Cretaceous sandstone appears to be the bed-rock struck by wells at New Richland in southeastern Waseca county (page 410), half-way from Owatonna to Wells; and at the latter place it seems probable that the layer penetrated by its artesian wells corresponds to the limestone and shale enclosed in the Cretaceous sandstone at Owatonna, while this sandstone lies next below and is found in C. W. Thompson's well to have a thickness of at least 34 feet. The top of the strata which thus appear to be a continuous Cretaceous formation has the following hights, approximately, above the sea: in the Owatonna well, 1111 feet, the included limestone and shale being found at 1090; at New Richland, 1070; and at Wells, 1040 to 1050. These places lie in a straight line, the distance southwest from Owatonna to New Richland being eighteen miles, and to Wells thirty-four miles.

Respecting the age of the limestone found in the well of section 4, Seely, we can only say that the known stratigraphy and topography of the region indicate that probably it belongs to either the Galena or Niagara formations, intermediate between the Lower Trenton and Devonian, while it may possibly represent either of the last. The nearest natural exposure of any rock older than the drift is thirty miles distant to the southeast, being on Lime creek in southwestern Worth county, Iowa. There the Hamilton limestone of Devonian age is found, and extends thence southeast to the Mississippi, having abundant outcrops along the Shell Rock and Cedar rivers.

Indications of the existence of Cretaceous beds containing lignite are reported to have been found in the S. W. ¼ of section 11, Verona. Mr. John Crapsey states that a great number of pieces of lignite, up to eight inches in diameter, were obtained by him there from the drift or talus forming the lower part of the east bluff of the Blue Earth river, a little above an island; and that near by the bed of the river seems to be a ferruginous sandstone or conglomerate. It is interesting to compare this with Prof. Bechdolt's observation (page 435) that fragments of lignite occur frequently in the alluvium of this river at its mouth. The layers of Cretaceous lignite in Minnesota, however, are too thin to be of value as a source of fuel; though they have supplied fragments found sparingly in the drift throughout the western two-thirds of the state.

Drift and contour.

The thickness of the drift upon this county probably varies from 75 to 200 feet, averaging 125 or perhaps 150 feet. It is composed mainly of till, which encloses occasional veins and beds of gravel and sand, and shows the same differences in color, hardness, and other characters, that have been mentioned more particularly in the report of Blue Earth county.

In northeastern Faribault county, the east half of Foster has a moderately undulating surface, composed of till, excepting occasional knolls or mounds of gravel and sand. From Freeborn lake to Wells, and thence north, northwest and west, to the north line of the county, to Minnesota and Lura lakes, and to Easton, the surface is very smooth and flat or more commonly somewhat unduting till, the descent of five to fifteen feet from the highest portions to the shallow depressions of sloughs being by long slopes. This area includes the west two-thirds of Freeborn and Carlston in Freeborn county; and, in Faribault county, all of Dunbar and Minnesota Lake, Clark, excepting its southwest corner, the northeast part of Walnut Lake, and nearly all of Lura, except part of its southwest quarter.

Again, on the other side of the moraine which extends northwestward from Kiester, flat or only slightly undulating till covers the southern and western parts of the county. Blue Earth river and its East fork have their course nearly along the center of this tract, from the west side of the Kiester hills westward to Blue Earth City, and then north by Winnebago City into Blue Earth county. The townships in this area are Seely, Brush Creek, Rome, Emerald, the southwestern half of Barber, Elmore, except a width of one to one and a half miles on its south side, Blue Earth City, Prescott, Delavan, Pilot Grove, except a width of one and a half miles on its south side, Jo Daviess, Verona, and Winnebago City.

*Glacial lake in the basin of the Blue Earth river.** The contour in these townships, as also in the northeast part of this county, in southwestern Waseca county, and through most of Blue Earth county, is generally quite flat, the drift being spread with an unusually smooth and even surface, nearly as in the Red river valley. The material of all these tracts is till,

*First described in the ninth annual report, page 341.

or a gravelly and stony clay. At many places, however, in western Faribault county and in Blue Earth county, its upper ten feet is found to be in part obscurely or sometimes quite plainly stratified. In this characteristic, also, it resembles the till which generally forms the surface of the south end and of the sides or outer portions of the flat Red river valley, which was covered by lake Agassiz during the recession of the ice-sheet.* Much of the basin that is now drained northward by the Blue Earth river, distinguished thus by its smoothed and sometimes partly stratified till, appears to have been occupied by a similar glacial lake, dammed by the barrier of the waning ice-sheet of the last glacial epoch during a considerable time in which this was retreating northward and northwestward from the south line of the state and from its eastern moraine, until its recession uncovered the present avenue of drainage to the northeast by the Minnesota river. The hight of this lake was approximately 1150 feet above the sea, making its depth in the north part of Faribault county 50 to 125 feet, on the west line of Waseca county about 75 feet, and in the north part of Blue Earth county about 200 feet. Its exact boundary can probably be traced, with the aid of leveling, along considerable portions of its eastern, southern and southwestern shores, by its beach deposits of gravel and sand. When this lake attained its maximum extent, it is believed to have spread far to the northwest beyond the limits of the basin of the Blue Earth river.†

The outlet of this glacial lake is found in Kossuth county, Iowa, at the head of the most southern branch of the Blue Earth river, where Union slough‡ occupies a continuous channel from the headwaters of the Blue Earth to Buffalo creek and the East fork of the Des Moines. It is stated that at the time of high water an uninterrupted canoe voyage has been made by this route from Algona on the East Des Moines river north to Blue Earth City. Union slough (also frequently called the "Big slough"

*Compare the eighth and eleventh annual reports.

†At time of formation of the moraine that reaches from Kiester northwestward (page 462), this lake probably bordered the ice-sheet from Faribault county to Yellow Medicine county, having a length of about one hundred and twenty-five miles with a width varying from five to fifteen miles, its area being thus about one thousand square miles. By the farther recession of the ice the size of the lake was greatly increased, so that it probably attained a length of one hundred and sixty miles, from Waseca to Big Stone lake, with a width of forty miles in Blue Earth and Faribault counties, but of only twenty miles or less in the upper part of the basin of the Minnesota river. Its area at this maximum stage appears to have exceeded three thousand square miles. The first outlet obtained at a lower level than Union slough in Iowa, and therefore reducing the depth and area of this lake, was doubtless in the vicinity of Elysian and Waterville in Le Sueur county, passing to the Cannon river, at a hight about 1075 feet above the sea, but afterward by a different avenue some fifty feet lower. A large area in Blue Earth, Brown, Nicollet, Sibley and Le Sueur counties, was probably covered by this lake while it outflowed to the Cannon river, until the retreat of the ice from the moraine at Elysian in Le Sueur county to that at Waconia in Carver county, uncovered the lower part of the Minnesota valley and permitted drainage to take its present course.

‡Compare Dr. C. A. White's *Report on the geological survey of Iowa*, 1870; vol. i, p. 57.

by settlers on its east side) lies in the east part of township **98**, and in sections 3, 4 and 9, of township **97**, range **28**, its length being about eight miles in a course first south and then south-southwest. Its width is from one-eighth to one-fourth of a mile, with enclosing bluffs which rise steeply twenty to thirty feet to the general surface of moderately undulating till on each side. The bottom of this glacial channel along the Union slough, where its descent was southward, is now mainly occupied by a marsh, because of the partial filling up of its continuation, since the ice age, by Buffalo creek. Along the head-stream of the Blue Earth river, from Union slough to the state line, this channel has a width of about an eighth of a mile, and is twenty-five to thirty feet below the average surface at each side, to which the ascent is by moderate slopes.

This valley, eroded by outflow from the glacial lake of Faribault and Blue Earth counties, soon changes upon the smoothed area covered by that lake to channels eroded since the glacial period by the present drainage. Thus the excavation by this branch of the Blue Earth river in Elmore is thirty to forty feet deep, and has steeper banks, but is narrower, than the valley in which it lies farther south. Northward, the lacustrine area, otherwise a vast plain, has become deeply eroded by the Blue Earth river and its tributaries.

Moraines. Exceptions to the generally smooth and nearly level contour of the drift are found in two rolling and hilly tracts, one in the eastern half of the county, the other on its southern edge. The most conspicuous elevations in this part of the state are the drift hills in Kiester township. This tract is closely joined with the inner or western of the two approximately parallel terminal moraines, which extend from north to south across Freeborn county, and which were accumulated at the east side of the vast lobe of the ice-sheet that in the last glacial epoch covered the basin of the Minnesota river and reached south to central Iowa. The drift upon this ice-covered area was left with a very smooth, slightly undulating surface, while its borders are marked by morainic belts of hilly and knolly drift. These hills in Kiester appear to indicate that the ice-margin here became indented by a re-entrant angle between two confluent ice-currents. Northwest from Kiester, a belt of hilly or more or less rolling drift reaches twenty miles, to the southwest part of Lura; and ten miles beyond appears to be represented by a hilly and rolling tract in the southwest part of Sterling, in Blue Earth county. The first opinion of the writer, stated in the ninth annual report, that this morainic belt was formed wholly as a medial moraine by converging ice-currents, seems questionable. Further exploration is needed to determine whether it is not instead a terminal moraine, accumulated on the southwest side of this ice-lobe, after three distinct times of recession from its outermost limit. This explanation is strongly confirmed by comparison with the three similar morainic belts beyond this toward the south and southwest, all of which are apparently terminal, as shown in the report of Watonwan and Martin counties.*

The most hilly portions of Kiester are its south side for a width of one mile, and a belt through its northeast part from section 13 to sections 3 and 4, in which are the most prominent of these hills, visible fifteen miles to the north and west. Their hight is from 100 to 200 feet above the lowland in these directions and above Bear lake in Freeborn county; the highest points, which are in the S. W. ¼ of section 3, being about 1400 feet above the sea. These are massive hills of till, of irregular outlines, but trending somewhat more from east to west than in other directions. Between the hill-ranges of the north and south parts of this township, its central portion for a width of two or three miles is only moderately undulating till, reaching east at the head of Brush creek to the west border of the plain of modified drift in Mansfield, Freeborn county. In sections 8, 17, 20 and 29, through the west part of Kiester, a series of hills of till, 60 to 75 feet high, connects the west ends of these ranges and forms the west border of the lower tract between them, except at the gap through which Brush creek flows.

In Foster, the township next north of Kiester, boldly rolling hills of till fifty to seventy-five feet high extend from section 28 to the north and northwest by Rice lake, where they occupy a width from one-half mile to one mile on each side of the lake. Still farther northwest the same contour and material border the east, north and west sides of Walnut lake, including the most of sections 25 to 28, and 33 to 36, of Walnut Lake township. The land south of Walnut lake is low and gently undulating till, with frequent marshes. In Barber, the township next west, a prominently rolling tract is found about the little lakes in sections 14, 15, 22 and 23. The material here is till, and its swells or hills are thirty to fifty feet above the hollows. Through six miles thence northwest a more or less rolling surface of the unmodified glacial drift continues in a belt about two miles wide, to the southwest part of Lura and the east edge of Delavan. On the railroad it is crossed in the first three or four miles east of Delavan, where its swells are twenty-five to forty feet high, not crowded and thickly set, but generally in long slopes, with no prevailing trend. This morainic belt divides two extensive areas of till, which are characterized by a very smooth and flat surface.

In the south edge of Elmore and Pilot Grove a width from one to one and a half miles is hilly or prominently rolling drift, and forms part of a

*In this connection it is important to note that Prof. N. H. Winchell in 1871 and 1872 observed four terminal moraines, which similarly appear to have been formed at the farthest limit and successive stages in the recession of a lobe of this ice-sheet covering the area of lake Erie and extending thence southwestward These moraines, explored in northwestern Ohio and adjacent parts of Indiana and Michigan, are named the St. John's, Wabash, St Mary's and Blanchard ridges (*Proceedings of the Am. Assoc. for Adv. of Science*. vol. xxi, 1872, pp. 160—177; also, *Report of the geological survey of Ohio*, vol. ii, 1874). Again, Prof. T. C. Chamberlin observed three distinct morainic belts belonging to this epoch, divided by smoother tracts, in a section between Black Brook (T. 32, R. 16) and St. Croix Falls, at the west side of Wisconsin (*Geology of Wisconsin*, vol iii, 1880, pp. 384 and 385).

If this be a fourth terminal moraine, its continuation northwestward is probably traceable to the vicinity of Big Stone lake. My observations of the area across which it would lie, make it certain that no very prominent accumulations of morainic drift occur there; but suggest that this formation should be searched for in a course extending by Madelia, near lake Hanska, Sleepy Eye creek, and the northwest corner of Redwood county, to the southwest part of Tyro in Yellow Medicine county, and thence to the eastern morainic belt in township 119, range 46, Lac qui Parle county. The glacial lake before mentioned would extend along this ice-border, through Watonwan, Brown and Redwood counties, covering an area several miles wide in the depression between the ice-sheet and the Coteau des Prairies. Its first interruption by land higher than 1150 feet above the sea would be in Yellow Medicine county, where a fourth morainic belt was observed, with a great water-course of some former time at its west side.

belt of similar contour, which seems to be a terminal moraine, reaching in Iowa through the north part of Hancock county, southwestern Winnebago, and northeastern Kossuth county, into Minnesota.

The most noteworthy hill of this area in Elmore is in the north part of section 32, rising 50 to 60 feet and about a sixth of a mile long, trending from east to west. In the south part of sections 25 and 26, Pilot Grove, hillocks and short ridges form a somewhat continuous east-to-west series, 40 to 50 feet high. These accumulations are chiefly till, differing from its level or moderately undulating tracts in a greater abundance of boulders; but occasional knolls, sometimes the highest of their vicinity, are composed of obliquely stratified gravel and sand. In sections 29 and 32, Pilot Grove, these morainic deposits are inconspicuous or wanting; next they rise to the hight of 30 to 40 feet in section 31 and the south half of section 30, at the southwest corner of Faribault county; and thence they occur scatteringly all the way northwest to East Chain, and less prominently to Fairmont. In this distance their material, and that of the whole region about them, is till. Their contour is seldom rough, but rises in swells, 25 to 50 feet above intervening depressions, with trends most frequently from northwest to southeast.

Modified drift. Kames occur three miles south of Walnut lake, in section 23, Brush Creek. They consist of short northwest to southeast ridges and round or conical knolls, steep-sided, about twenty feet high, composed of coarse gravel and sand, and form a series three-fourths of a mile long. The region surrounding them is slightly or moderately undulating till. A portion of the moraine, situated in sections 16 and 8, Walnut Lake township, two and a half to five miles northwest of the lake, is formed of kame-like deposits, accumulated in swells, knolls and northwest to southeast ridges, thirty to forty feet high, of very gentle slopes, composed mainly of stratified sand and fine gravel, as shown by wells, which do not reach the bottom of this modified drift at the depth of fifty feet.

Alluvium. The stratified clay and sand used for brick-making at Blue Earth City, and other similar beds of small extent, appear to be alluvium laid down along the avenues of drainage after the glacial lake that had covered this area was withdrawn by the departure of the ice-sheet which had been its northern barrier.

Pebbles and boulders. On the Kiester hills pebbles and boulders occur more plentifully than on the lowlands, but are not usually very abundant, and blocks more than five feet in diameter are rare. About one-twentieth part of the large boulders and probably one-fifth of all the pebbles are limestone, often obscurely fossiliferous. The greater part of the rock-fragments, especially the larger blocks, are granite, syenite, gneiss and crystalline schists. One boulder, ten feet long, of garnetiferous hornblende schist, was noted here. A greenish slaty rock is also sparingly represented. Only a few pieces of the red Potsdam quartzyte, which outcrops near New Ulm and southwestward, were seen, the largest being one foot long. No conglomerate was found. It is noticeable that a considerable proportion of the pebbles upon these hills of till are water-rounded, and that some have the flattened, discoid form which is characteristic of the stones of a shingle beach, worn by sliding with the rise and fall of the waves, rather than by being rolled in the channel of streams, which gives more commonly a somewhat spheroidal shape. These water-worn stones are evidence that the ice-sheet gathered much of its drift from pre-glacial valleys and lake shores, lifted these gravels of ancient rivers and beaches into its mass, and at its border and during its final melting deposited them as constituents of the till and modified drift.

Wells in Faribault county.

The following records of common wells afford further illustrations of the composition and order of the drift deposits.

Clark. The sections before described in Wells and its vicinity are in this township.

Foster. John Shequen; sec. 14: well, 18 feet; all sand; plenty of water.

M. Butler; S. E. ¼ of sec. 15: well, 30 feet; soil, 2; yellow till, 26; gravel and sand, with small amount of water, 2 feet; blue till below.

R. D. Taylor; N. E. ¼ of sec 21: well, 22; soil, 2; yellow till, 12; gravel and sand, 8.

Kiester. John Harvey; S. W. ¼ of sec. 31: well, 45; soil, 2; yellow till, with gravelly streaks, 12; gravel and sand, ½ foot; blue till, very hard at top for one foot, then moist and soft below, 31. This well has only seep water from the lower part of the yellow till.

A copious spring, much resorted to by cattle, slightly chalybeate, issues near the middle of sec. 14, upon land twenty-five feet higher than neighboring depressions and a hundred feet below the highest hills near at the northeast and northwest.

Mr. E. Porter, well-maker, of Lake Mills, Iowa, states that in the south part of Kiester the upper till, yellowish in color, is usually 8 to 10 feet thick; underlain by sand, 1 to 8 feet in thickness; succeeded by dark bluish till, called "hardpan", much harder than the upper till. Generally, however, it has been his experience that the yellow till is more stony and harder to bore or dig in than the underlying blue till, which is moist and sticky. The greatest thickness of yellow till found by him is twenty-five feet. He has frequently found fragments of lignite, but no unchanged wood nor shells.

Seely. I. M. Riker; N. E. ¼ of sec. 10: well, 30 feet; soil, 2; yellow till, 8; blue till, soft and sticky, 20; water rose ten feet from gravel and sand at the bottom.

A. B. Brant's well in sec. 4, reaching to the bed-rock, has been described on page 458. H. W. Everett, well-maker, states that the yellow upper till of this region almost always contains sandy streaks and seep water, while these occur less frequently in the blue till, which is moister and softer, and has fewer rock-fragments, than the till above. The greatest thickness of the yellow till, found in boring fifty wells, is 20 feet; and the greatest depth bored by him in the blue till is 70 feet. A dark "hardpan", much harder than either of these tills, is frequently found, varying from one to five feet in thickness, always lying under a considerable depth of the soft and moist blue till. Mr. P. Morse, of Wells, and W. Z. Haight, of Winnebago City, well-makers, agree with the foregoing as to the characters and order of the three distinct kinds of till generally met in deep wells throughout this county. Mr. Morse reports the maximum thickness of the dark hardpan, as found by him, to be 12 feet. Mr. Haight has found the yellow color of the till extending deepest on swells; while it is thin or wanting in depressions. Its maximum depth found by him is 50 feet; the greatest thickness of the soft, blue till, 50 or very rarely 75 feet; and of the darker till or hardpan, which almost invariably is overlain by a considerable thickness of the last, 10 feet. Small pieces of lignite, derived from Cretaceous strata mingled with the drift, are frequently found; but no shells, and no interglacial peat nor wood.

Brush Creek. Gustav Buscho; sec. 8; well, 20; soil, 2; yellow till, 4; quicksand, 1 foot; blue till, moist and sticky, yet harder than the upper till, 13 feet; water rose five feet from a vein of sand at the bottom.

Walnut Lake. C. F. Zimmerman; S. E. ¼ of sec. 4; well, 32 feet; soil, 2; yellow till, 15; harder blue till, 15; water rose in a half day twenty-five feet from sand at the bottom.

O. A. Odell, sec. 8: well, about 50 feet deep; all stratified gravel and sand.

C. S. Bates; S. W. ¼ of sec. 15: well, 30 feet; soil, 2; a marly layer, 1 foot; fine gravel, containing pebbles up to two or three inches in diameter, and sand, 27; water abundant, fifteen feet deep. The two last are upon the high rolling tract of modified drift, apparently of kame-like origin, which forms part of the moraine. Mr. Morse has bored to a depth of 166 feet in this township, about two miles north of Walnut lake, not reaching the bottom of the glacial drift.

Minnesota Lake. Chauncy Barber's well, near the depot, going through the drift into the bed-rocks, has been before described.

Lura. Also see a preceding page for Terhurne & Scheid's well, at Easton, in sec. 36. John E. James; Easton: well, 70; soil, 2; yellow till, 15; softer blue till, 53; water rose forty-five feet from sand at the bottom. Watson Cole, in the S. E. ¼ of sec. 32, has bored 160 feet, but the strata passed through were not learned.

Mr. Haight reports that in boring a well in this township, about two miles north of Easton, he met, at 60 feet below the surface, a layer of mixed sand and grass-leaves, appearing like drifted grass on a sandy beach. This was between beds of till, and marks an interglacial epoch; but no other testimony of this kind was obtained in Faribault county.

Barber. Andrew Wesner; sec. 22: well, 20; soil, 2; gray till, 5; blue till, 5; yellowish gravel and sand, 8 feet, with water in its lower portion.

Emerald. Fred Weber; sec. 10: well, 24 feet; soil, 2; yellow till, 4; blue till, soft and sticky, 18; no gravel nor sand layers; water seeps from the upper till, and is very scanty in a dry season.

F. Dreblow; Ewald post-office, sec. 30: well, 22; soil, 2; gray till, 2; blue till, 18; seep water only.

Elmore. Caleb McCarther; in southeast part of this township: well, 81 feet; soil, 2; yellow till, 18; harder blue till, 60; coarse gravel, 1 foot; from which water rose eighty feet, stopping at one foot below the surface.

Blue Earth City. George McCarther; in the city: well, 92 feet, being the deepest within the corporation; soil, 2; yellow till, 18; harder, dark till, 50; stratified gravel, sand and clay, 22; water rises, attaining a depth of fifty feet.

The railroad well here is 68 feet deep, finding soil and yellow till, 20 feet; blue till, 48 feet; with water rising from the bottom thirty-five feet. The elevator, close north of the last, has a well 36 feet deep, containing twenty feet of water.

Joseph Schimek, S. E. ¼, sec. 20; well, 44 feet; soil, 2; yellow and blue till, 42; only seep water. In another well, a quarter of a mile farther east, water rose forty feet from the bottom. G. B. Franklin, well-maker, states that the yellow till in this township is commonly 10 to 20 feet thick, its lowest foot being very hard, cemented by iron-rust. This is succeeded below by 15 to 20 feet of soft, bluish till, which in turn is underlain by a darker, harder, and more stony till, called "hardpan."

Delavan. H. E. Mayhew; at the village and depot, in sec. 36; well, 60 feet deep; yellow till, 15; soft blue till, 45; water rises from sand at the bottom to twenty feet below the surface.

Winnebago City. W. H. Holley; in the city: well, 96 feet; soil, 2; yellow till, 15; soft, blue till, 74; dark hardpan, with many limestone pebbles, 5 feet; water rose fifty feet from sand and, gravel at the bottom. The ten bushels of this sand and gravel which were drawn up contained about a peck of lignite in small fragments. Mr. W. Z. Haight supplied the record of this well; as also of the deep well at the Winnebago City mills, which reaches into the bed-rock, as before described. He states that in the vicinity of this city the order of the drift deposits is generally as follows: yellow till, about twenty feet; soft, blue till, 30 to 50 feet, becoming near its base a lighter bluish or brownish, soft mud, of fetid smell, 1 to 6 feet thick; and from this there is a change in two to five feet to the dark, very hard till called "hardpan," which is the hardest, most compact and most rocky of these tills.

Verona. John G. Pace; sec. 24: well, 44 feet; soil, 2; yellow till, 15; blue till, 16; gravel, sand and clay, 11; water rose ten feet.

Alex Halliday; at Verona Star mills; sec. 24: well, 45 feet; soil, 2; yellow till, 8; much harder dark till, 35; water rose nine feet from sand at the bottom.

Pilot Grove. Dr. G. D. Winch estate; sec. 8: well, 100 feet; soil, 2 feet; yellow till, about 5 feet; all below was blue till, about 93 feet, with few sand layers; at the bottom was sand, from which water rose ninety feet.

Pitt Wilson; S. W. ¼ of sec. 20: well, 70 feet; soil, 2; yellow till, 18; harder blue till, 50; water rose from quicksand at the bottom, and after one and a half hours flowed from the top of the well.

MATERIAL RESOURCES.

Agriculture must always continue the leading industry, as it unfolds the most valuable natural resources of this county. We have here to speak briefly of its water-powers, brick-making, peat, and artesian fountains.

Water-powers. Five water-powers are used in Faribault county, all situated on the Blue Earth river and employed by flouring mills, in descending order as follows:

Blue Earth City mills; N. Dustin & Co.; just below the junction of the east and west branches of the river, in the west part of sec. 8, Blue Earth City; head, about nine feet.

Verona Star mills; Alex Halliday; at the west line of sec. 24, Verona; head, eight feet.

Rising Sun mills; at the bridge in the S. W. ¼ of sec. 11, Verona; head, eight feet.

Banner mills; C. H. Payne & Son; at the bridge in sec. 33, Winnebago City, one and a half miles west from the town; head, nine feet.

Woodland mills; Dorsey Brothers; sec. 3, Winnebago City; head, about eight feet.

Bricks. Brick-making was begun at Blue Earth City in 1867, and was carried on nine years; but nothing was done in this work here in the years 1876 to 1879. This yard, owned by S. P. Childs, was leased in 1880 to Christian Severson, who expected that season to make 600,000 bricks, selling them at $8 per M. The mixed wood used for the kilns formerly cost $5 per cord, but is now furnished by the railroad at $3½ to $4. The bricks made here are red, of good quality, tempered by intermixture of one-sixth as much sand as clay. The excavation is in the south or right bank of the West branch of the Blue Earth river, about a quarter of a mile southwest from its junction with the East branch. The clay has a thickness of 25 to 35 feet, and at a few feet above the river is underlain by sand. The upper four to six feet of this clay are obscurely stratified. Its next ten feet are divided, similarly with the clay-beds at Carver and Jordan in the valley of the Minnesota river, into layers of light grayish color, composed of clayey and sandy fine silt, changing above and below to a nearly black, more unctuous and finer clay, which forms the partings between them. In the east part of this excavation the thickness of these layers is from a half inch to one inch, but within three rods to the west they are from one to six inches thick, being thinnest at the top. They are somewhat contorted or wavy, but in their whole extent are nearly level. The alternating conditions which produced these successive layers are believed to have been the yearly changes of the seasons, the principal mass of each layer being the deposition of the annually recurring periods of high water, and the darker partings being the sediment of a current of reduced volume and therefore slower and less turbid. The lower eight or ten feet of this clay are finely and obliquely laminated and very sandy. A well, 38 feet deep, at the top of this bank, even in hight with the brick-yard, finds the clay gradually become more sandy, and its last four feet are in clear sand, containing water at nearly the same level as the river.

In section 11, Verona, at the Rising Sun mills, a kiln of 130,000 red bricks was made by Westbrook & Ferguson in 1879, not with satisfactory success because of particles of limestone contained in the clay and sand, which after burning become slacked and crack the bricks. The clay used here is yellow, imperfectly stratified, apparently a part of the till, occurring in the northeast bluff at 15 to 30 feet above the river. The proportions of clay and sand mixed for these bricks was three and one. Bricks of the same color have been made also at several other places near the river in its next three or four miles below, with poor or sometimes fair results. The best have been from the recent alluvium of the bottomlands. Nothing has been done here in this business during the last few years, excepting the kiln just mentioned.

Red bricks of inferior quality, mostly somewhat cracked by particles of limestone, but otherwise durable, were made from 1870 to 1872, at the north line of section 8, Clark, about a quarter of a mile west of Wells, where they are seen in brick buildings. The material used was probably the obscurely stratified gravelly clay that often forms the upper part of the glacial drift upon this area which was covered by a lake while the ice-sheet was retreating across Faribault and Blue Earth counties.

Peat. In the second annual report of this survey, Prof. Winchell has treated of the peat of this state, the following details being given in respect to Faribault county.

Near Wells a slough on land of Clark W. Thompson was found to have from four to six feet of peat, in part watery and fibrous, but mostly of good quality, underlain by a bed, six inches to one foot thick, of peaty mud and clay with shells and some sand. An analysis, by Dr. P B. Rose, of Ann Arbor, Michigan, of this peat, after drying in the air, gave in 100 parts, 16 of hygroscopic water; 18 of ash; and 66 of organic matter. The ash, or inorganic matter, contained of silica 61.32 per cent.; lime, 12.44; carbonic acid, 10.69; iron and alumina, 9.71; magnesia, 2.43; sulphuric acid, 2.37; potassa, 0.55; soda, 0.23; and a trace of chlorine. The organic matter was made up of carbon, 51.94 per cent.; of hydrogen, 6.17; and of oxygen and nitrogen, 41.89. The heating power of a hundred pounds of this air-dried peat appears to be equal to that of ninety pounds of dry oak wood. The residue of ashes from peat is fifteen to twenty-five times greater than from an equal weight of wood.

Without some process of manufacture, or preparation for use by condensing its volume and forming it into blocks, peat is too soft and friable, and makes a slow, smoldering fire. In 1871 Mr. W. Z. Haight prepared peat for fuel at Wells, and it was considerably used by the locomotives of the Southern Minnesota railroad. This work was described by the Wells *Atlas*: "A bold bank is selected, in order to secure a good drying yard close to the bog, on which the engine and machinery are located, where a frame is erected 12x16 feet and eight feet high, from the top of which a wooden car-track, supported by a light trestle-work, descends to the surface of the bog, a distance of 150 feet, with a fall of 25 feet. From that point the track is made in sections of 14 feet each, which are portable, thrown down on the surface of the bog; and with the use of a few curved sections, the track can be shifted in any direction so as to excavate the entire bog that is in reach. This track can be extended many hundred feet out across the surface of the bog, if desired, giving access to several acres. On this track one car plies, which is loaded by three men who stand by the edge of the excavation (water being lowered about six inches from the surface to insure dry feet). The sod is cut up into chunks, with sharp, diamond-pointed, spade-like tools, from two to four feet deep, according to depth of the peat, and left submerged in the water until the car is at the proper place, when the chunks are pitched from the water into the car, with common four-tined forks, and when the regular amount, about two tons, is loaded into the car, it is hauled by the power of the engine up the incline, over the large platform under which the mill is situated; and by a simple contrivance the car is made to dump its load, also to unship the windlass from the power that hauled it up, being no trouble to the feeder, who at will starts the car back, which, in going down the inclined plane gains momentum that carries it out hundreds of feet along the level track. Meanwhile the men in the bog do the necessary work, cutting chunks for another load, so there is no time lost in the absence of the car. The feeder, who stands on the platform, then feeds the turfy mass into the mill, which is an ingeniously constructed machine, though simple, very durable, so arranged with knives cutting through grates, pickers, conveyers, &c., that it will treat the most fibrous mass or sod peat that can be produced and reduce it to a pulp or jelly at once, and that too without clogging or winding in the machine. Owing to its perfectness it renders it unnecessary to strip off the top sod from the bog, all that is necessary being to mow off the grass or other vegetation, if there is any growing thereon, thereby saving considerable expense in labor, also a good part of the fuel, when ground up with the lower or more decomposed peat. By the conveyers, the peat, as fast as pulped, is forced through a pipe into a vat with dump bottom, which holds one cart load. Here the cartman receives it by driving his cart under and dumping a load into it from the vat, adjusts the vat bottom, drives to the spreading ground, dumps his load from the cart and returns, during which time another load has accumulated in the vat. The pulp is dumped on a smooth plat of ground, where a man with a common shovel spreads it into beds four inches thick, nine feet wide, and as long as necessary, setting up boards at the sides to keep it from spreading, who is followed by another man with a tool similar to a rolling colter for a plow, fixed on a long handle, who cuts the beds of soft peat into blocks 8x13 inches, which commence to solidify at once by the ejection of the water; and in one or two days, by the use of a light tool made expressly for the purpose, these blocks are tipped up on edge or corners promiscuously, so the sun and wind can have a better chance at them. In two days more they are piled in open ricks, in which posture they remain on an average two weeks, when they are housed to finish drying.

"The cost, the past season [1871], of running this establishment, at a capacity of 60 tons of wet or 15 tons of dry peat per day (equal at least, when properly prepared and well seasoned, to 15 cords of good wood), is as follows:

Superintendent	$2.50
Engineer per day	2.75
Three men in bog to load car	6.00
Man to spread pulped peat into beds	1.50
Boy to turn blocks	1.00
Two boys to rick up blocks	2.00
Man to feed peat into mill	1.50
Boy to drive cart	1.00
Man to cut peat into blocks	1.50
Cart horse	1.00
One ton peat at cost price for engine	1.72
For oil, and wear and tear on engine	1.00
Add 22 cts. for housing 15 tons, one day's product	3.30
Total	$26.77

"All the peat is being sold at $4.00 a ton, except that to the railroad company, at which price the yield per day would be $60.00." The value of the manufactured peat is estimated equal to that of good wood per cord; and the cost of the plant, capable of manufacturing 100 tons of wet peat, or 25 tons when dry per day, including mill ($400), frame, trestle-work, car-track, car, dump cart, etc., is stated to have been about $700. The demand, however, was too small to lead to the continuation of this business. Two or three years later Mr. Haight again worked peat in this manner near Easton; but here, also, the enterprise was soon abandoned, though a good fuel could be made at small cost, if sufficient quantities could be sold to keep the machinery and workmen employed.

An analysis, by Dr. P. B. Rose, of the peat manufactured by Mr. Haight at Wells, gave of water, 14 per cent.; ash, 18; and organic matter, 68. The ash yielded silica, 58.31 per cent.; lime, 14.18; carbonic acid, 11.63; iron and alumina, 10.21; magnesia, 2.90; sulphuric acid, 2.11; potassa, 0.41; and soda, 0.18. Of its organic matter, carbon was 52.02 per cent.; hydrogen, 6.68; and oxygen and nitrogen, 41.30. A hundred pounds of this peat was found equal in heating power to ninety-eight pounds of dry oak wood.

A peat deposit, eighty or a hundred acres in extent and said to reach a depth of four feet, occurs on land of H. F. Quinby and J. Robinson, in section 30, Minnesota Lake.

Near Easton peat is found in considerable quantities on land of W. Z. Haight. Four specimens of this peat, air-dried, were submitted to chemical examination by Prof. S. F. Peckham, as to their "hygroscopic water, organic matter, and ash. They were all treated exactly alike. An average sample of each of the specimens was finely pulverized and thoroughly mixed. Of this one gramme was carefully weighed in a one-ounce platinum crucible. The covered crucible containing the assay was then placed in an air bath, and heated to 212—220 degs. Fahr., until it ceased to lose weight. The loss was estimated as hygroscopic water. The cover was then removed, the crucible inclined and heated to dull redness, finally to bright redness, until the combustible matter was entirely consumed. The loss was estimated as organic matter and the residue as ash. The following results were obtained:

	1.	2.	3.	4.
Hygroscopic water	13.04	10.99	20.64	16.75
Organic matter	48.64	44.56	53.60	47.03
Ash	38.32	44.45	25.76	36.28
Analyses of the ashes yielded:				
Silica (SiO_2)	83.13	83.35	72.79	80.55
Carbon (C)	.86	.03	.95	.75
Iron oxide(Fe_2O_3) and iron phosphate ($Fe_2P_2O_8$)	7.99	5.29	9.46	10.23
Lime (CaO)	5.44	7.39	5.92	5.61
Magnesia (MgO)	1.75	.97	6.13	.76
Sulphuric acid (SO_3)	.78	2.57	trace	1.34
Undetermined	.05	.40	6.25	.76"

Of these specimens the first was taken from a bog at eighteen inches below the surface; the second, from the same bog at three feet below the surface; while the third and fourth are from another bog near, respectively at the same depths of eighteen inches and three feet. Their values for heating, compared with that of an equal weight of dry oak wood, called 100, were found to be in the foregoing order, 64.0, 58.6, 70.5, and 61.7.

Artesian fountains. The remarkable flowing wells, or fountains, which are found at Wells, were discovered after the village had received this name in honor of a distinguished citizen. The section of the drift penetrated here, and the character of the bed-rock found at the bottom of these wells, from which their water rises immediately 110 to 120 feet to the surface and five to fifteen feet higher, have been sufficiently treated of under the head of the geological structure of the county. Most of these wells have been bored two inches in diameter, and reduced to a half inch or less at the top. The pipe is often prolonged above the surface, conveying the water into tanks. About twenty of these wells have been obtained within a radius of one mile. Their supply is large, but not inexhaustible; for, when Hon. M. S. Wilkinson's well was bored, a half mile north of the village and on land ten or fifteen feet lower, its two-inch stream, very copious, lowered the wells in the village so that their water no longer reached the surface. After this new well was reduced to a small flow, yet affording an abundance for all the requirements of house and farm, the water of all the other wells rose very nearly as high as before. If, therefore, the proposition which was once suggested, to tap this stratum of water by a large well for water-power to a grist-mill, had been adopted, the flow would have been found inadequate, while the water of the small wells would have failed to rise to the surface. This water is of excellent quality, very clear and cool; it is somewhat chalybeate, so that it gives a slight coating of iron-rust to wooden gutters and troughs.

The ground upon which these artesian waters are gathered and whence they receive the pressure that causes them to rise here above the surface, is probably Freeborn county, which begins four miles east of Wells, and extends thirty miles to the east, with an average elevation about a hundred feet higher above the sea. From this station the railroad rises 108 feet in going nine miles southeast to Alden; while its summit, six miles farther east, is 170 feet, and the depot at Albert Lea is 68 feet above Wells.

Other artesian fountains are obtained in this county from water-bearing beds of gravel and sand included in the glacial drift, at depths from thirty or forty to nearly a hundred feet. They are most frequent in Dunbar, Minnesota Lake and Lura, and especially near the Maple river through the second and third of these townships and through Mapleton and Sterling in Blue Earth county. Rarely artesian water is found farther to the south and southwest in Faribault county. The only instances learned of are Ole E. Johnson's well, about 90 feet deep, in the southeast part of Emerald, and two in Pilot Grove, one being on the farm that was owned by the late Dr. G. D. Winch, in section 8, about 60 feet in depth, which after overflowing four years ceased in the autumn of 1879, and the other being Mr. Wilson's, in the S. W. ¼ of section 20, which was sunk in 1880, 70 feet deep, and at the time of this examination had been running four months.

All these artesian wells, as also the common wells of the county, already described in treating of the glacial drift, invariably have good water, and nearly always in ample amount within twenty-five to fifty feet from the surface. It is, however, hard water, holding the carbonates of lime and magnesia in solution, and requires cleansing with ashes or otherwise before it can be satisfactorily used for washing with soap.

ABORIGINAL MOUNDS.

Numerous circular mounds, apparently artificial, one to one and a half feet high, and fifteen to twenty feet across, are seen near the road along a distance of three miles about half way between Freeborn and Wells; and a few similar mounds were seen in and beside the road two or three miles west of Wells.

Two mounds, twenty feet in diameter and one and a half feet high, occur at the south side of the S. W. ¼ of the S. W. ¼ of section 13, Brush Creek, about a third of a mile east of the bridge over the East branch of the Blue Earth river.

Again, in Kiester, two mounds of about the same size as the foregoing were noted near the middle of section 19.

In Mansfield, the most southwest township of Freeborn county, lying next east of Kiester, two or three such mounds were observed in the N. W. ¼ of section 13; also, at the south side of section 34 of this township, close to the state line, are two or more of these small mounds. Passing the last, a road extends south into Iowa, and about a mile beyond the state boundary a mound of this form but two feet high, being larger than any of the others here mentioned, was seen six rods east of this road, with a second of the smaller size near it.

CHAPTER XV.

THE GEOLOGY OF WATONWAN AND MARTIN COUNTIES.

BY WARREN UPHAM.

Situation and area. Watonwan and Martin counties lie in southern Minnesota, the former being directly north of the latter, which borders on Iowa. They are a little west of the central meridian of the state. The distance of Madelia in Watonwan county southwest from Minneapolis and St. Paul is 87 miles; and Fairmont in Martin county is 27½ miles south, and two miles west of Madelia. From the east line of Martin county to the Mississippi at La Crosse is 150 miles; and from the west line of these counties to the line between Minnesota and Dakota is 80 miles.

Both these counties are rectangles, the extent of Watonwan being twenty-four miles from east to west and eighteen from north to south; while Martin county reaches six miles farther east, and is thirty miles long from east to west, with a width of twenty-four miles. The area of Watonwan county is 435.45 square miles, or 278,689.92 acres, of which 1,638 acres are covered by water. The area of Martin county is 723.89 square miles, or 463,288.40 acres, of which 12,267.35 acres are covered by water.

SURFACE FEATURES.

Natural drainage. Watonwan county is wholly drained by the river of the same name, which empties into the Blue Earth river about three miles below Garden City in Blue Earth county. The North and South forks of the Watonwan river, having their sources in Cottonwood county, traverse respectively the northern and southwestern parts of Watonwan county, each receiving several tributary creeks, and are united in one stream two miles west of Madelia, and about twenty miles, following the course of the

river, above its mouth. Antrim, the most southeast township of this county, is drained by Perch creek, which has its source a few miles farther south in Martin county, and flows northeast to the Watonwan river.

Among the *lakes of Watonwan county* the following are worthy of mention: Emerson lake, at the north side of Madelia, two miles long from east to west and one and a half miles wide, with about half its area in Linden, Brown county; five or six smaller lakes in Madelia, within a few miles to the southeast from Emerson lake; a dozen smaller lakes, probably some of them dry in the summer, lying in Fielden and Antrim; three lakes in Saint James, the largest, a mile or more in length, close southwest of the town; Long lake, two and a half miles long from east to west and half a mile wide, and Kansas lake, of equal width and a mile in length, in Long Lake township; four unnamed lakes in Odin, the largest, in sections 5 and 6, being about a mile long and a half mile wide; and Wood lake in Adrian, two and a half miles long and from a quarter to a half of a mile wide.

The greater part of Martin county is also included within the basin of the Blue Earth river, to which its waters are carried by Elm, Center and South creeks, all of which join the Blue Earth in Verona, Faribault county. Elm creek, the largest of these, and the only one which rises beyond the west line of this county, has been sometimes called Chain river; deriving its name from the remarkable chains of lakes which find their outlets by these creeks. The southeast corner of Martin county is tributary to the Blue Earth river by smaller creeks above the foregoing; and the north edge of the county sends its streams to the Watonwan river.

An area of about a hundred and fifty square miles in the southwest part of Martin county lies in the basin of the Des Moines and is drained by the head-stream of the East fork of this river, which has its farthest source nearly at the middle of the line between this and Jackson county and thence flows southeastward, passing through Tuttle's lake upon the state line.

The *lakes* of this county, mostly lying in three distinct chains or series, present very interesting features, and seem to give important evidence respecting the history of the glacial period. On this account further notice of them is deferred to the later part of this chapter where the drift is described.

Topography. Watonwan county descends toward the east and northeast, but in a broad view its slightly undulating expanse seems nearly level. Generally its surface is in very gentle slopes which soon conduct the surplus waters of rains and snow-melting into depressions, which merge into ravines and lead to small water-courses, and by them to the larger permanent streams. Here and there, however, are depressions which have no such free drainage, and contain sloughs or lakes.

The general slope of Martin county sinks slightly toward the east, giving direction to its streams. To the traveler this descent is imperceptible, and it appears as a vast, moderately undulating, but approximately level prairie. Erosion by the present creeks of this county has depressed them from ten to thirty or forty feet below the average hight of the land on each side, forming along considerable portions of their course distinct valleys, with irregularly sloping, narrow bottomlands, bordered by low but steep bluffs. In Watonwan county the South fork of the Watonwan river lies in a valley which it has cut forty feet below the general level along all its course from Mountain Lake to Madelia; and the North fork and its tributaries have similarly channeled their part of the drift-sheet. Below the junction of these branches the Watonwan valley increases to fifty or sixty feet in depth before leaving the county at the southeast corner of Madelia. The only place at which these valleys have cut through the drift is in Martin county, on Elm creek in section 6, Rutland, where the bed-rock, probably sandstone, is found at a slight depth below the surface.

Adrian, the most northwest township of Watonwan county, has the only outcrop of the bed-rock in these counties, this being the eastern extremity of a prominent ridge of the red Potsdam quartzyte. It is seen at the surface in the N. W. ¼ of section 29, and gives to this and the contiguous sections 30 and 19 an elevation fifty to one hundred feet above the rest of this township; but this ridge here, and through its whole extent of nearly twenty-five miles westward, where it rises much higher, is mainly covered by a smooth sheet of till.

Elevations, St. Paul & Sioux City division, Chicago, St. Paul, Minneapolis & Omaha railway.
Copied from profiles in the office of T. P. Gere, superintendent, St. Paul.

	Miles from St. Paul.	Feet above the sea.
Madelia	109.0	1021
Watonwan river, water	110.5	979
Lincoln	116.4	1042
Saint James	121.6	1073
Butterfield	130.1	1184

Elevations, Southern Minnesota division, Chicago, Milwaukee & St. Paul railway.
From George B. Woodworth, assistant engineer, La Crosse.

	Miles from La Crosse.	Feet above the sea.
Winnebago City (Faribault county)	166.3	1096
Fairmont	183.0	1176
Sherburne	197.5	1273
Junction of branch to Jackson depot (Jackson county)	209.1	1446

The highest land of Watonwan county is either the east part of the quartzyte ridge in sections 19 and 30, Adrian, or the southwest corner of the county, both of which are nearly 1,300 feet above the sea. Its lowest land is where the Watonwan river passes out from this into Blue Earth county, at a hight of about 960 feet above the sea. The mean hights of the townships of this county are approximately as follows: Madelia, 1,025 feet above the sea; Fielden, 1,050; Antrim, 1,100; River Dale, 1,040; Rosendale, 1,060; South Branch, 1,120; Nelson, 1,075; Saint James, 1,120; Long Lake, 1,150; Adrian, 1,150; Butterfield, 1,200; and Odin, 1,240. From these estimates the mean elevation of Watonwan county is found to be 1,110 feet, very nearly, above the sea.

In Martin county the greatest altitude is attained at the west side of Lake Fremont township, about 1,400 feet above the sea; and the lowest points of this county are at its east line where Elm, Center and South creeks are 1,050 to 1,075 feet in elevation. The townships of this county, with their mean hights approximately estimated, are: Nashville, 1,125 feet above the sea; Center Creek, 1,140; Pleasant Prairie, 1,200; East Chain, 1,240; Westford, 1,150; Rutland, 1,175; Fairmont, 1,200; Silver Lake, 1,230; Waverly, 1,175; Frazer, 1,200; Rolling Green, 1,240; Tenhassen, 1,250; Galena, 1,200; Fox Lake, 1,240; Manyaska, 1,260; Lake Belt, 1,275; Cedar, 1,260; Elm Creek, 1,300; Jay, 1,325; and Lake Fremont, 1,350. The mean elevation of Martin county, deduced from these figures, is 1,225 feet.

Soil and timber. The soil of Watonwan and Martin counties, like that of a vast region extending from them on all sides, is very fertile, easily worked, and well adapted for the cultivation of all the staple agricultural products of this latitude. A black, clayey, and slightly sandy and gravelly loam, from one to three feet thick, forms the surface, which is nearly everywhere sufficiently undulating to carry away the waters of heavy rains and snow-melting. Boulders are scattered very sparingly over the entire area of these counties, but scarcely anywhere are objectionably numerous. This soil and the subsoil of yellowish gravelly clay are the till, or unmodified drift of the glacial period. They are somewhat porous on account of their considerable proportion of sand intermixed, causing them to absorb much moisture from rains and give it up readily to vegetation. The principal crop of Watonwan county, as generally northward through this state, is wheat; but in Martin county corn, stock, and dairying also hold a prominent place, as commonly southward through Iowa.

Both these counties are principally prairie, being natural grassland, without tree or shrub; excepting narrow skirts of timber, which generally surround the lakes and extend along the principal streams, sometimes widening to form groves. Probably the aggregate area of these belts of timber is less than one hundredth part of either Watonwan or Martin county. The following species of trees, arranged in their estimated order of abundance, were noted as occurring on the South fork of the Watonwan river: American or white elm, white ash, box-elder, ironwood, cottonwood, bur oak, slippery or red elm, hackberry, bass, soft maple, black walnut, willows, the American aspen or poplar, and the wild plum. Common species of trees about Silver and Iowa lakes, in Martin county, are bur oak, bass, white ash, white and red elm, and black walnut; bitternut is somewhat frequent; and cottonwood, soft maple and butternut occur rarely.

GEOLOGICAL STRUCTURE.

The only exposure of bed-rock in Watonwan county is found, as already stated, in the N. W. $\frac{1}{4}$ of section 29, Adrian. A smooth and flat surface of the very compact and hard, red Potsdam quartzyte is seen here along an extent of five rods from northwest to southeast, with a width varying from five to twenty feet. This is on an eastward slope, in a slight depression of drainage. The quartzyte does not project out of the drift, and cannot be seen at a distance. It is undoubtedly the bed-rock beneath all the southwest quarter of Adrian, but is elsewhere covered within the limits of this township and county by the smoothed sheet of glacial drift, which rises in a broadly rounded ridge because of the prominence of this underlying rock. Through the north half of section 30, Adrian, it lies at no great depth, and has been encountered in ploughing and digging at several places. This ridge, having here and there outcrops of the same red quartzyte, continues more than twenty miles to the west, in northern Cottonwood county.

In Martin county a large mass of compact, gray sandstone, contained in the till, has been quarried at the south side of Elm creek in the west part of section 6, Rutland, on land of G. S. Livermore of Fairmont, yielding about three cords of good building stone, besides one or two cords of inferior quality wasted. This lay at a hight of about five feet above the creek, being imbedded in the base of its bluff of till, which rises thirty feet. It was divided in beds one to two feet thick, with an inclination of about 30° eastward, and is said to have been entirely removed by quarrying. Some of these layers show oblique lamination. The color and texture of this stone, its rarely enclosing soft black particles, which are apparently lignite, and the oölitic structure that much of it exhibits, give it a very close resemblance to the sandstone, quite surely of Cretaceous age, found outcropping in Alta Vista, the most northeast township of Lincoln county, and in Eidsvold and Westerheim, lying next to the east in northwestern Lyon county. Mr. Livermore states that bed-rock exists near the surface, as learned by thrusting down an iron bar, along the marshy bottomland and beneath the channel of the creek, for a distance of six or eight rods from the point where this block occurred, being probably the same formation in place, but not rising into view. The only wells learned of in these counties that have gone through the drift are the following, situated in Fairmont and Jay townships in Martin county.

On land of A. L. Ward, in section 9, Fairmont, a well about 150 feet deep went through drift, 90 feet; hard rock, about 50 feet; and a softer layer 10 feet thick, from which water rose to sixty feet below the surface. On land of H. W. Sinclair, in section 29, Fairmont, rock was encountered at a considerable depth and the well was abandoned. No further details were ascertained respecting the bed-rocks in these wells; consequently no opinion of their geological age can be given. The strike of the limestone and sandstone formations of the Lower Magnesian series, in their exposures along the valley of the Minnesota river and in Blue Earth county, indicates that their continuation underlies the greater part of Watonwan and Martin counties; but here they are doubtless covered in part and perhaps mainly, by Cretaceous strata.

Deposits which seem referable to the Cretaceous age, were found in the lowest thirty feet or more of a well 180 feet deep, on the farm of Cargill. Van & Co., in the S. E. ¼ of section 14, Jay. This was dug a hundred feet and bored below. Its section in the portion dug was soil, 2 feet; yellow till, 18 feet; and very hard blue till, much of it about as hard to excavate as rock, 80 feet. Some ten barrels of water come in daily from the lower two feet of the yellow till, but none was found in the blue till. The portion bored consisted of yellowish gray sand with little gravel, dry, and yielding gas in which fire could not burn, 50 feet; then, shale, 10 feet; and gray sand or soft sandstone, bored into 20 feet, and continuing below the bottom of the well. The last thirty feet were bored during the rainy season, when so much water (a hundred barrels or more per day) came in from the yellow till that it was not evident whether the last stratum yielded any water. This well was made in 1879 and the spring of 1880, and supplies all the water that is wanted from it. The strata here encountered below 150 feet probably belong to the Cretaceous age, and perhaps also the fifty feet of sand between these and the till. This thick bed of gas-bearing sand and gravel was struck at the bottom of a well 113 feet deep at Sherburne station, two miles to the northeast, of which full notes are given in the list of wells illustrating the drift.

Drift and contour.

Glacial striæ are very distinct on the quartzyte ledge exposed in section 29, Adrian, mostly bearing S. 30° E., referred to the true meridian, but in one place, on its southeast portion, bearing S. 20° E.

The contour of Watonwan and Martin counties is like that which prevails generally in the basin of the Minnesota river, and is formed by a slightly undulating or in some portions moderately rolling sheet of till, with massive swells rising in long smooth slopes ten to twenty or thirty feet above the depressions. The gently undulating, smoothed surface of most of this region appears to mark areas over which the ice-sheet moved in a continuous current, and from which it disappeared by melting that was extended at the same time over a wide field. Compared with the thickness of the drift, its inequalities of contour in these counties are small, and in an extensive view it seems approximately flat. It is a part of the inclined plain which rises by an imperceptible slope from the Minnesota river to the Coteau des Prairies. Its rate of ascent toward the southwest, or increase in average hight, varies from five to fifteen or twenty feet per mile. This gradual change in altitude is doubtless produced by increase in hight of the bed-rocks upon which the drift lies as a sheet of somewhat uniform depth, probably varying in these counties from 50 to 150 feet; but the numerous small elevations and depressions of the surface appear to be due to the accumulation of different amounts of till by adjoining portions of the moving ice-sheet, without any corresponding unevenness of the underlying rocks.

Third terminal moraine. The most rolling portion of the drift-sheet in these counties is at the southeast, entering East Chain township from Iowa, and reaching northwestward to Fairmont. It is the continuation of a belt of hilly till, which is connected with the inner or western one of the two terminal moraines that extend from north to south through northern Iowa, passing near Clear Lake and Forest City. This belt, three to six miles or more in width, reaches from the vicinity of Pilot mound in northeastern Hancock county northwestward about forty miles, by Forest City, through western Winnebago county and northeastern Kossuth county in Iowa, and into southeastern Martin county. It attains its greatest hight in the north part of township **98**, range **25**, Winnebago county, where it is 100 feet above the general level. In northeastern Kossuth county this tract expands to a width of ten miles and reaches from Ramsey, at the east side of Union slough, north and northwest to the state line, lying on both sides of the head-stream of the Blue Earth river. Its northeast border is in the south edge of Elmore and Pilot Grove in southwestern Faribault county, where it consists of hillocks and short east-to-west ridges of till, 30 to 50 feet high. Thence these accumulations of till occur scatteringly in southeastern Martin county to East Chain and less prominently to Fairmont. In these townships the contour is seldom rough, but rises in swells 25 to 50 feet above intervening depressions, with trends more frequently from northwest to southeast than in other directions; while nearly all the remainder of this county is more smoothly undulating, in longer slopes, with the highest parts only 10 to 20 feet above the lowest near.

The belt of hilly and rolling glacial drift thus traced from Iowa into Minnesota was probably accumulated as a terminal moraine at the end of the ice-lobe which extended southeastward from the Leaf hills and the Head of the Coteau des Prairies, as more fully explained on page 406; but at a late part of the epoch, after two distinct recessions of the ice had taken place in southwestern Minnesota. When this lobe of the ice-sheet attained its greatest area it terminated on the south in the vicinity of Des Moines, and was bounded on its sides by the outermost belt of hilly and knolly drift deposits. On its east side only two morainic belts are found, but on its west side three are clearly distinguished in the west edge of this state and the east edge of Dakota.* At the time of accumulation of the second belt of morainic drift, the end of this ice-lobe had receded to Mineral ridge in the north part of Boone county, Iowa; and when the third belt was formed, its extremity appears to have been in Hancock county, Iowa. The length of this ice-lobe was thus diminished forty miles between the times of formation of its first or outer moraine and its second or inner moraine, and was still further shortened seventy-five miles before its third moraine was accumulated. Across the area from Fairmont northwest to Yellow Medicine county this third moraine was not noticed as a continuous formation. In the line where it would be looked for, we find the surface somewhat more prominently rolling than ordinary in Waverly, at the north side of Martin county; but only the usual low undulations were noted northwestward in Watonwan county. The nearest tract of typically morainic contour observed in this direction, which seems to be probably a part of this belt, is thirty miles from Waverly in the north part of Stately, the most southwestern township of Brown county.†

For one or two miles southeast and south of Madelia, and for one mile southeast of Saint James, the surface has frequent swells twenty to thirty feet above the depressions, being more rolliug than most other parts of Watonwan county, which is generally very gently undulating in smooth prolonged slopes, with occasional lakes and here and there sloughs ten to twenty feet below the highest portions of the adjoining country.

Chains of lakes. It has been frequently noted that the lakes which abound upon areas overspread by the glacial drift, have their prevailing trend, or average direction of their longer axes, parallel with the course

*See the ninth annual report.

†During the examination of these counties, and of others northwestward, where this moraine may very likely be found traceable continuously, though not conspicuous excepting a few portions described in the following chapters, to the third terminal moraine in Yellow Medicine and Lac qui Parle counties, this highly probable relationship was not recognized, and the writer owes the suggestion of it to Prof. T. C. Chamberlin. It seems desirable that this region be traversed again, with the special object of tracing this moraine. (Also see page 463.)

that was taken by the ice-sheet. The swells and undulations of the till have their greatest extent in this direction, and the lakes fill the hollows that are formed by its unequal accumulation. Among the hills of the terminal moraines, however, the longer axes of the lakes are apt to be transverse to the course in which the ice came, but parallel with its border. In each case, such lakes are due to variable glacial erosion and deposition; and the basins in which they lie are not more remarkable features of the contour than are its swells, hills, and areas of highland. The deepest lakes contained in depressions of the till in this state are from fifty to one hundred and fifty feet in depth, reaching as far below the average level of the drift-sheet as its most elevated portions rise higher; but a great majority of these lakes, especially upon regions of only slightly undulating surface without prominent elevations, are shallow, ranging from five to twenty-five feet in depth. They mainly have very gently ascending shores, but sometimes on one or more sides are partially bounded by steep banks five to twenty or thirty feet high, formed by the wear of waves which have eaten away projecting portions of their margin of till, leaving its boulders, but strowing its finer detritus over the lake-bed.

In regions of modified drift, consisting of stratified gravel and sand that were supplied from the dissolving ice-sheet, the lakes, from ten to fifty feet or more in depth, and often bordered by level or undulating tracts of modified drift, from twenty-five to one hundred feet or more above them, lie in depressions which at the time of the fluvial deposition of this drift were probably still occupied by unmelted masses of ice, preventing sedimentation where they lay and consequently leaving hollows enclosed by steep and high banks, whose top is the margin of plateaus or plains of gravel and sand. No examples of lake basins thus surrounded by modified drift were found in Watonwan and Martin counties, neither of which have any noteworthy deposits of this class, nor any such rough morainic areas as to influence the distribution and trend of their lakes.

Most of the lakes of Minnesota, and of all glaciated regions, present only such forms and arrangement as are readily explained thus by the modes of excavation and accumulation, and the diverse deposits of the ice-sheets. The first described and most common type of lakes found upon the surface of the drift, trending in parallelism with the course in which the ice moved, finds illustration in Watonwan county by the lakes of Madelia, Fielden, Long Lake and Adrian. Here the glacial current passed southeastward, this region being near the axis of the great lobe of the continental glacier which stretched from the Leaf hills and the Head of the Coteau des Prairies southeast and then south to the center of Iowa.

Martin county presents, however, in its three remarkable chains or series of lakes, a problem which the foregoing general explanations of the origin of lakes upon areas of glacial drift do not solve, though they are needed to prepare us for its consideration. These series are known as the East, Central and West chains of lakes.

South creek receives the outflow from the East chain of lakes, and connects them by a stream which descends toward the north. This chain extends from the Iowa line about twelve miles northerly in a somewhat irregular course, lying upon the line between East Chain and Silver Lake townships, and continuing northward through the east part of Fairmont and the northwest corner of Pleasant Prairie. It includes two lakes in section 36, Silver Lake; two lakes at the west side of sections 19 and 18, East Chain, now united under the name of East Chain lake by a dam which has a fall or head of eight feet; two unnamed lakes in sections 7 and 6, East Chain; another, about a mile long, lying principally in section 36, Fairmont; Rose lake, a mile and a half long from south to north, at the west side of sections 25 and 24, Fairmont; lake Imogene, on the township line, about one and a half miles northeast from the last; and Lone Tree lake, lying a mile farther northeast and reaching about a mile in length from south to north, at the east side of section 6, Pleasant Prairie, and of section 31, Center Creek. These lakes are bordered by rolling areas of till, thirty to forty feet above them, to which elevation their shores ascend mostly by quite steep slopes. The east bank of East Chain lake, two miles in length, has been recently undermined along the greater part of the first mile from its north end. In width the lakes of this chain vary from one-fourth to two-thirds of a mile. The spaces between them are sometimes marsh and as wide as the narrower parts of the lakes, but in some other portions is a contracted channel, such as might have been cut by the stream which outflows from them. Thus the series does not occupy depressions in any well-marked continuous valley. Another lake lies close beside this series in section 12, of Silver Lake township, but divided from it by a portion of the till thirty to forty feet high, through which it has no outlet. The fall of South creek through this chain of lakes in the distance of about nine miles from the Iowa line to the mouth of Rose lake, whence it turns northeastward, is about fifteen feet, half of this being at the East Chain dam.

The Central chain includes about twenty lakes, and extends twenty-two miles in almost perfectly straight due north course from Iowa lake, crossed by the state line, to Perch lake at the head of Perch creek, three miles south of the line of Watonwan county. This series of lakes lies three to six miles west of the East chain, being in the west part of Silver lake, Fairmont, Rutland and Westford, which form range **30** in this county. Their outlets are South, Center, Elm and Perch creeks. In their order from south to north, the lakes of this Central chain are Iowa lake, two and a half miles long from northwest to southeast, and from a quarter of a mile to one mile wide; Silver lake, close north of the last, one mile long and a half mile wide, lying at the east side of section 30 of the township to which it gives its name; Summit lake, beginning about an eighth of a mile north of the last, and extending a mile at the east side of section 19; Wilmont lake, a mile long and two-thirds of a mile wide, lying mostly in section 7; Bardwell lake, beginning about three-fourths of a mile north of the last and reaching thence a mile to the north with a width of about a quarter of a mile, mostly in section 31, Fairmont; Mud lake, of small size; Amber lake, shorter but wider than Bardwell lake, in the east part of section 30; Hall's lake, mostly in sections 19 and 20, one and a quarter miles long from south to north and from a half to three-fourths of a mile wide; Budd's lake, extending about a half mile in both length and width, crossed by the line between sections 17 and 18; lake Sisseton, nearly a mile long, at the west side of the town of Fairmont; Lake George, three-quarters of a mile long, at the east side of section 6; Buffalo lake, at the east side of sections 31 and 30, Rutland; the Twin lakes, about a mile farther north; lake Charlotte, in section 17, Rutland; High lake, at the southeast corner of section 7; Martin lake, a mile long from south to north and a third of a mile wide, lying on the line between sections 5 and 6, Rutland; a lake, nearly a mile long, at the east side of sections 31 and 30, Westford; and Perch lake, in sections 19 and 18 of this township.

The shores and the country on both sides of the Central chain of lakes, as of the East chain, consist of till, which soon rises to a moderately undulating expanse that has a hight thirty to forty or fifty feet above the lakes. Though forming a very distinct, straight series, they do not occupy a well-marked continuous valley; but its width varies from one mile or more to less than an eighth of a mile, and it is in three places interrupted by water-divides at whose lowest points the slopes of till reach ten to fifteen feet above the adjoining lakes. Silver and Iowa lakes are the headwaters of South creek, and have their outlet by a stream that runs east nearly along the state line to the south end of the East chain. The middle part of the Central chain, reaching twelve miles from Summit lake to the Twin lakes is tributary to Center creek; and its portion farther north, excepting Perch lake, is within the belt drained by Elm creek.

Iowa and Silver lakes have the same level, which is nearly that of Summit lake. Mr. William H. Budd, of Fairmont, states that the descent from Summit lake to Wilmont lake is three feet; thence to Bardwell lake, probably ten feet; thence to Mud and Amber lakes, still water; thence to Hall's lake, about two feet; to Budd's lake, again about two feet; to lake Sisseton, one foot; and to lake George, one and a half feet. Buffalo lake and the Twin lakes, lying north of Center creek, and lake Charlotte, tributary to Elm creek, are reported by Mr. Budd to be at about the same level with lake George, being some six feet higher than Center creek at a half mile farther east, and about twenty feet below Summit, Silver, and Iowa lakes at the southern end of this chain. From lake Charlotte to Martin lake, the fall is about two feet, and the remaining lakes of the series, north of Elm creek, have approximately the same hight.

East Chain lake, though raised by its dam, has a depth of only fifteen feet, and probably none of the lakes of that chain are much deeper. The maximum depths of some of the lakes in the Central chain are reported as follows: Iowa lake, fifteen feet; Silver lake, about fifty feet, being the deepest of this series, as none of its other lakes, and perhaps no other in this county, exceeds half this depth; Hall's lake, twenty or twenty-five feet; Budd's lake, sixteen feet; and lake Sisseton, eight feet.

The West chain of lakes is less distinctly connected than the East and Central series, from which it also differs in having the longer axes of some of its lakes transverse to the course of the chain, and in having shorter series of lakes joined with it as branches. Its south end is Tuttle's lake, which is crossed by the state line, about four miles west of Iowa lake, the south end of the Central chain. Thence the West chain reaches northwesterly twenty miles, then northerly nine miles, and then northwest and west eight miles, to Mountain lake in Cottonwood county, its whole extent being thirty-seven miles. From the middle of the south line of Martin county, it extends through the townships of Tenhassen, Lake Belt, Manyaska, Fox Lake, Elm Creek and Cedar, in this county, crossing its north line five miles from its northwest corner; through Odin, the most southwest township of Watonwan county; and into Mountain Lake township in Cottonwood county. It is tributary, in its successive portions from south to north, to the East fork of the Des Moines river, to Center and Elm creeks, and to the South fork of Watonwan river. This West chain comprises about twenty-five lakes, in the following order from south to north: Tuttle's lake, on the state line, about four miles long from northeast to southwest and averaging a mile in width, reaching in Martin county from the south side of section 31 to the north side of section 28, Tenhassen; Alton lake, one and a half miles long and one-fourth to two-thirds of a mile wide, in sections 20, 19 and 18, of this township; Dutton or Swan lake, Clear, Fish and Buffalo lakes, each nearly a mile long, and together stretching west-northwest four miles, from near the northeast corner of section 25 to the northwest corner of section 21, Lake Belt, which takes its name from these four lakes; Holmes lake, at the north side of sections 2 and 3, and Goose lake, lying mostly in section 4 of the same township, each about one and a half miles long, trending from east to west and southwest; Prairie lake, in sections 15, 22 and 21, and Manyaska lake, in sections 20 and 19, Manyaska, similar to the last in their extent and trend; Munger lake, in sections 17 and 8, about a mile long from south to north; Temperance lake, close north of the last, of similar length, but trending from southwest to northeast; Fox lake, three and a half miles long from east to west, and from a fourth to a half of a mile in width, lying at the south side of sections 31, 32 and 33, of Fox Lake township; an unnamed lake, a mile long from east to west and half a mile wide, mostly in section 31, north of the west end of Fox lake; the Big Twin lakes, together extending two and a half miles from southeast to northwest, in sections 13, 12, 11 and 2, Elm Creek; Cedar lake, about three miles long from south to north, with an average width of a half mile, lying mainly in sections 36, 25 and 24, Cedar; three other lakes, each about a mile long, in sections 13, 12 and 1, Cedar; three unnamed lakes, varying from a half to three-fourths of a mile in length, and all trending from southeast to northwest, situated in Odin, Watonwan county, the first being mainly in the north half of section 26, the second in the west part of section 15, and the third extending through the northwest corner of section 10; a lake, one mile long from east to west and a half mile wide, in sections 5 and 6; a small lake at the northwest corner of section 6, Odin; and Mountain lake, two miles long from northeast to southwest and nearly a mile wide, situated two miles southeast from Mountain Lake depot and village.

The series of four lakes mentioned in Lake Belt township, lies somewhat west of the direct course of this chain of lakes, and may be regarded as a branch of it; and two miles east of this lake-belt, another series of lakes, very plainly a branch of the West chain, diverges from it, and reaches almost due north twelve miles from Tuttle's and Alton lakes. This series, connected at its south end with the West chain, includes in order from south to north, Clayton lake, a mile or more in extent, lying mostly in sections 21 and 16, Tenhassen; Babcock lake, about a mile long from southwest to northeast and more than half as wide, in sections 17, 8 and 9, and Rice lake, three-quarters of a mile long, at the west side of section 4 of the same township; Pierce lake, about a mile in diameter. in sections 27 and 28, and a long and narrow lake, reaching from section 10 to section 7, in Rolling Green; Swan lake, a half mile long, in section 31, Fraser; and Eagle lake, close northeast of the last, covering nearly all of section 29 and portions of the adjoining sections, two miles in length, with trend from northwest to southeast. To these, as a continuation of this branch, ought perhaps to be added four other lakes, which are situated four to nine miles farther north, varying from a half mile to one mile in length. and principally included in sections 36 and 25, Galena, and sections 18 and 7, Waverly.

Besides the lakes thus enumerated as constituting the three chains of lakes and this branch series, which lies midway between the Central and West chains and is connected with the latter, Martin county has only three other lakes of noteworthy size, namely, Ash and Calkins lakes, each about one and a quarter miles long, in the south part of East Chain township; and another of similar extent, in sections 16, 9 and 8, Elm Creek.

The West chain of lakes, like the East and Central chains, extends through a region of moderately undulating till, the direct deposit of the ice-sheet, with no noteworthy areas, nor unusually thick included layers, of water-deposited gravel and sand. The lakes of the south half of this western series, and of its branch from Tuttle's to Eagle lake, lie only ten to twenty feet below the average hight of the adjoining land, which rises in long, gentle slopes from their shores. Northward, in Cedar, Odin and Mountain Lake townships, the contour is nearly like that along the East and Central chains, the lakes being bordered by bluffs of till, of moderate or often steep ascent, thirty to forty feet high, whose crest is at the general level of the slightly undulating drift-sheet. In Mountain lake an island, which has given this name, rises with steep shores and table-like top, about forty feet above the lake, having similar outlines with the surrounding bluffs and upland. Much of this lake is now filled with grass and reeds.

It seems difficult to explain the origin of these remarkable lake-basins in the drift, for, so far as they extend, they have the aspect of eroded valleys, such as have been commonly formed by the rivers of this region, but they sometimes are separated by divides of till as high as the country around. Thus they no longer form continuous channels, which must have been their original condition, if they are parts, as thus indicated, of ancient water-courses. Nowhere else in my exploration of the glacial drift, have similar chains of lakes been found, bordered and occasionally divided by areas of till, without notable deposits of modified drift, and not occupying distinct valleys of former streams. Yet these plainly connected series of lakes, converging, and one of them receiving a tributary branch, in their course toward the south, are related to each other like confluent rivers. Their origin cannot be referred to the ordinary causes and conditions, already reviewed, which produced the irregularly scattered lakes of drift-covered areas; but, excepting this arrangement of its lakes, Martin county is not distinguishable from the surrounding region of drift.

The explanation of these series of lakes, which seems most probable, is that they mark interglacial avenues of drainage, occupying portions of valleys that were excavated in the till after ice had long covered this region and had deposited most of the drift-sheet, but before the last glacial epoch, which again enveloped this area beneath a lobe of the continental glacier, partially filling these valleys, and leaving along their courses the present chains of lakes. Fossiliferous beds are occasionally found in this and adjoining states, and, significantly, at a few places within the basin of lake Agassiz, intercalated between thick deposits of till. Some of these interglacial beds, doubtless including those in the Red river valley, since covered by lake Agassiz, were formed after an ice-sheet had extended to the extreme southern limit of the glacial drift. They prove that the long, very severely cold period in which ice-fields reached south to northeastern Kansas, St. Louis, and southern Illinois, was succeeded by a milder climate, under which the ice was melted from Minnesota and even as far northward as to Hudson bay, again permitting plants and animals to occupy the land. The terminal moraines of the Northwest, formed by a later ice-sheet, show that another great epoch of cold once more buried the north half of the continent under ice, which, however, did not extend so far south as before. This ice was divided at its border into vast lobes, one of which, about three hundred miles long and one hundred miles wide, and probably from a tenth to a half of a mile thick, was accumulated upon the area that stretches from the head of the Minnesota river southward to central Iowa, including Watonwan and Martin counties, its width at this latitude being from

Albert Lea on the east to Worthington on the west. Before the glacial epoch in which the ice had its greatest extent, and probably also between that time and the date of the terminal moraines that cross Wisconsin, Minnesota and Dakota, other glacial epochs spread ice-sheets upon this region; but their moraines have been leveled and covered with additional deposits of till, and the interglacial soil and fossiliferous sediments of sloughs and lakes have been mostly ploughed up and mixed in the drift, while their remnants have been similarly buried, by the more extended ice-sheets of these subsequent epochs. Such remnants of interglacial beds, containing leaves and shells, have been found in Center Creek and Silver Lake townships in Martin county, as stated in the notes of wells on page 487. The chains of lakes in this county appear to show that interglacial rivers, between the time of greatest extent of the ice and the date of the last glacial epoch, were here carried southward in four confluent valleys to the East fork of the Des Moines river. The present drainage of Martin county is mostly transverse to this course and tributary to the Blue Earth river; but the watershed and slopes that now turn it away from the Des Moines are so slight that if the streams of this area had channels from north to south, such as were probably eroded along the lines of these chains of lakes while the margin of the ice-sheet that had reached to the farthest limit of the glacial drift was receding across these counties, they would continue to flow southward to the Des Moines. Probably all of this county, excepting perhaps its most northeast township, was during a long interglacial epoch included within the Des Moines basin, which still embraces a part of it at the southwest. The last ice-sheet doubtless added considerably to the drift, but did not entirely remold its topographic features; so that here even the interglacial water-courses cut in the drift remain in some portions with little change, still having steep bluffs and holding these series of lakes. This interpretation of their meaning is strongly confirmed by features of the valley of the Minnesota river, which seem to be explicable only by referring them to similar causes.*

Boulders and gravel, though always present, are nowhere abundant in the till of Watonwan and Martin counties; and boulders larger than five feet in diameter are very rare. The frequency of limestone fragments is nearly the same as is usual through all western Minnesota. This rock often makes one-third or one-half of the gravel in the till and on the beaches of lakes; but it supplies a much less proportion, perhaps not exceeding one twentieth, of the boulders larger than

*Compare article on the Minnesota valley in the ice age, *Proc. of Amer. Assoc. for Adv. of Science*, 1883, and *Amer. Jour. Sci.* (3), vol. xxvii, 1884.

a foot in diameter. The other large boulders are granite, syenite, and crystalline schists. The red Potsdam quartzyte is scantily represented in the drift along the west border of these counties. Itis almost entirely wanting farther east; but west of the Des Moines river, in Jackson county, and through Dickinson county and southward in Iowa, this quartzyte is a principal ingredient of the drift, making from one tenth to one half of its rock-fragments. At Clear lake in Lake Belt township, thirty-five miles south-southeast from the east end of the ridge of Potsdam quartzyte in Adrian, scarcely one pebble in a thousand is from this source; while a quarter of the stones over three inches in diameter, and two-thirds of the smaller gravel, are limestone.

Wells in Watonwan county.

Madelia. H. B. Wadsworth; Madelia village: well, 50 feet deep; soil, 2 feet; yellow till, spaded, 28 feet; much harder blue till, 20 feet; water rose ten feet in two hours from gravel at the bottom. Most of the wells at Madelia are from 15 to 30 feet deep, having a good supply of water that seeps from the yellow till. Lignite, in fragments up to three or four inches long, and small pieces of wood, as of twigs or limbs, are occasionally found embedded in the till of these wells. Their water is invariably good, except in occasional instances where it has been spoiled by the decay of wooden curbing.

Fielden. H. W. Wadsworth; sec. 21: well, 70 feet; soil, 2; yellow till, spaded, 25, with water seeping sparingly in its last three or four feet; much harder blue till, picked, 43; water rose forty feet in three hours from whitish gravel at the bottom. Several pieces of lignite were found in the upper till. Wells in this township often find an ample supply of water at a depth of 25 feet or less. The only flowing well learned of in this county is William Sargent's, on section 20, about 25 feet deep.

Antrim. C. O. Martin; sec. 8: well, 29 feet; soil, 2; yellow till, 23; blue till, 4; water rose twelve feet in one day from gravel and sand at the bottom.

Robert Dewar; sec. 10: well, 70 feet; soil, 2; yellow till, spaded, 25; sand and gravel, with clay, interstratified, 4 feet; blue till, harder than the upper till, yet much of it spaded, 39 feet, the lowest two or three feet very hard; at the bottom, water rose from gravel and sand twenty-five feet in a half day.

South Branch. Benjamin A. Town; sec. 14: well, 23 feet; soil, 2; sandy yellow till, with water in its lower part, 5 feet; moist blue till, mostly spaded, 16 feet; water rose six feet in one day from a gravelly streak in the blue till.

Long Lake. William Evans; sec. 19: well, 21 feet; soil, 2; yellow till, picked, 19; water comes slowly from sandy streaks at the bottom.

Saint James. The railroad well here was dug 22 feet, and then bored about 10 feet more, through blue till, to white sand, from which 1500 barrels of water have been drawn in ten hours.

G. H. Reynolds; Saint James: well, 28 feet; all yellow and blue till; water came up unexpectedly at night, when the workmen had left the well dry the previous afternoon, filling the well to two feet below its top. The yellow till at this town is 10 to 20 feet deep, with blue till usually a little softer, below.

John Schutz; sec. 10: well, 28; soil, 2; yellow till, 10; blue till, 16; water rose ten feet in one hour.

James Curry; sec. 18: well, 25; soil, 2; yellow till, spaded, 20; sand and gravel, with water, 1 foot; blue till, softer than the yellow, 2 feet. It was estimated that a half bushel of fragments of lignite, up to six inches in length, was found in the till here; but none was contained in the sand and gravel.

Adrian. Joel Parker; sec. 26: well, 22; soil, 3; yellow till, spaded, 20; with softer and moister blue till below; water seeps in the lower part of the yellow till.

Frederick Klein; S. W. ¼ of sec. 30: well, 27; soil, 2; yellow till, 10; softer and moister blue till, 13; gravel and sand, 2 feet, and extending deeper; water rose two or three feet above the top of the gravel; lignite was found in fragments up to three inches long. The water in all the wells of this region is of excellent quality.

Wells in Martin county.

Nashville. Henry C. Henton; sec. 9: well, 24 feet deep; soil, 2 feet; yellow till, 19 feet; gravel, 3 feet, and reaching below; water rose fourteen feet in one hour.

J. A. Armstrong; S. E. ¼ of sec. 9: well, 81 feet; soil, 2; yellow till, 22; gravel and sand, 6 inches, yielding enough water for ordinary house use; blue till, very compact, but moist and soft to bore, 56½ feet; the auger then dropped, and within fifteen minutes the water rose through thirty-one feet of two-inch boring so fast as to fill in this time thirty feet of the larger boring above, three feet in diameter, rising thus sixty-one feet. Within a distance of six rods around this place, six wells have found quicksand at a depth varying from 12 to 16 feet, thence extending, at least in some of these wells, to a depth of five or six feet, but not passed through by any of them, because of its immense supply of water. These shallow wells, however, were unserviceable from becoming filled with quicksand.

J. H. Smith, in sec. 3 of this township, has a well about 75 feet deep, which has several times become filled nearly to the top with quicksand.

Most of the wells in northeastern Martin county are only 10 to 30 feet deep, finding plenty of water in the lower part of the yellow till, or in gravel and sand under this and overlying the blue till. Lignite is occasionally found, the largest fragments being three or four inches long.

Center Creek. Hosea True's well, in the north part of this township, is reported to have been till, 60 feet, yellowish near the surface and dark bluish below; then sand 8 feet, containing "elm leaves and clam shells in abundance, the latter three to four inches long." This is on the ordinary undulating surface of the drift-sheet, south of the valley of Elm creek. Mr. Alexander Douglas, who bored this well and reported it thus, states that in his work boring nearly forty other wells in this county, he nowhere else found leaves, but in several instances found similar shells in coarse dark sand, at depths varying from 20 to 60 feet below the surface, under yellow and then blue till.

Westford. E. Huber, sec. 34: well, 45 feet; soil, 2; yellow till, 10; blue till, softer, moist and tenaceous, most gravelly in its lower part, 33 feet; water, seeping from the lower part of the blue till, filled this well to a depth of ten feet in three days.

Rutland. R. J. McCadden; sec. 5: well, 32 feet; soil 2; sand and fine gravel, somewhat clayey, 6; yellow till, 5; blue till, about the same as the yellow till in respect to hardness, 16: sand and gravel, 2 feet; blue till, 1 foot and extending below; water rose ten feet in one day.

Fairmont (also see page 477). Occidental hotel: well, 85 feet; yellow till, 24; softer blue till, 60; water rose about forty feet from gravel and sand at the bottom.

R. M. Ward; Fairmont: well, 40; soil. 2; quite hard yellow till, 22; blue till, softer, but very tenaceous, 16 feet and lower; water seeps in a moderate supply from the lower part of the yellow till.

Silver Lake. A. W. Young; sec. 29: well, 30 feet; soil, 2; yellow till, picked, 8 feet; blue till, 20 feet, harder to excavate because more tenaceous, but not harder to drive a pick into; gravel, one inch; underlain by fetid clay, containing decaying vegetation; water rose six feet in a quarter of a day from the gravel. This blue till contained a few pieces of lignite, the largest being six inches in diameter. Pieces of wood are also found occasionally in the till by wells in this vicinity, and in one instance a log a foot in diameter was encountered thirty feet below the surface. In digging O. H. Roice's cellar on sec. 27 of this township, gasteropod shells were found at a depth of six feet below the surface, in a layer of sand and gravel two inches thick, overlain and underlain by yellow till. These organic remains, like the chains of lakes, are records of an interglacial epoch.

East Chain. W. H. Rich; at the village, sec. 7: well, 44; soil, 2; yellow till, 6; reddish gravel, 4 feet; light-colored till, 20 feet; dark, bluish "hardpan," six inches; gravel, 3 feet; blue till, 8 or 9 feet, and extending below; a running stream of water was found in the gravel at 32 to 35 feet, not rising; it was running toward springs that occur a little above the level of East Chain lake, which is a short distance west of the well.

Tenhassen. William Merry; sec. 29: well, 21 feet; soil, 2; yellow till, 19; water rises twelve feet from sand at the bottom. No wells in this region exceed 25 feet in depth, and the water is uniformly good.

Lake Belt. J. H. Headly; S. W. ¼ of sec. 18: well, 18 feet deep; soil, 2; light gray till, 16; water rose four feet from springs in the lower part of the till.

Manyaska. Henry Hulsemann; N. E. ¼, sec. 12: well, 26; soil, 2; yellow till, spaded, 24; water seeps; about a dozen small pieces of lignite were found.

Frederick Hulsemann; N. W. ¼. sec. 12: well dug 18 feet, and bored 25 feet; soil, 2; yellow till, spaded, 10; harder blue till, 31 feet; at 43 feet from the surface the auger suddenly fell six inches, and water rose to be eleven feet deep in the dug portion of the well in five minutes, and in two hours or less reached its permanent level, two feet below the top of the well. This water at first was dark, as if stained, and its taste and smell were offensive; but after a few months it became good water, and had continued so three years, being regarded at the time of this information, in 1880, as good as any in this region. Another well, fifteen rods northwest from the foregoing and on land ten feet higher, was yet only 18 feet deep, being soil, 2 feet; yellow till, 14 feet, with streaks of sand; and dark gray, very compact "hardpan," picked, and holding together in masses of a hundred pounds' weight, about 2 feet. During excavation the water broke through this hardpan, and rose to seven feet below the top very suddenly, bringing up large quantities of dark gray quicksand. This well caved in after two weeks. Numerous pieces of lignite were found in both these wells.

A large chalybeate spring, of reputed medicinal virtue, occurs in the N. E. ¼ of sec. 2, at the south side of Lily creek, which is the outlet of Fox lake at high water.

Railroad well at Sherburne, in the S. W. ¼ of sec. 7: 113 feet deep; dug seven feet square to a depth of 76 feet, and bored six inches in diameter below; soil, 3 feet; yellow till, 7 feet; from gravelly streaks in this till eight feet below the surface, water came in large amount, filling the well eight feet deep in twelve hours (probably at a wet season, not considered sufficient for the requirements of the railroad); blue till, much harder, 90 feet; gravel, 2 feet, with considerable water, which rose forty feet, or more, but was not supposed to be a large enough supply; blue till, still harder than before, 6 feet; gravel, also yielding water, 2 feet; dark bluish "hardpan," exceedingly hard, 2 feet; and gravel, 1 foot, reaching lower. The water that had come into the well from the gravel at 100 to 102 feet, was shut off by the tubing; and when the last stratum of gravel was struck, the water that came at the depth of eight feet from the yellow till was drained away into this lowest gravel, from which gas rose with a loud roaring and filled the well. This appears to have been choke-damp, or carbonic acid. At this juncture, some implement having been accidentally dropped into the well, the foreman of the work commanded one of his men to go down for it, and, being angry at his refusal, himself rashly descended and was immediately killed by this gas, after it had been ascertained that fire was extinguished by it. The water from the yellow till continued to sink into this gravel during several weeks, at the close of which the pipe became clogged and the well has since been full of water.

Jay. In the S. E. ¼ of sec. 12, a half mile west of Sherburne, a second railroad well, 90 feet deep, was soil and yellow till, 10 feet; and blue till, with occasional gravelly streaks, yielding some water but not enough, 80 feet, and extending below. The water-tank at this place draws from a lake.

Besides the well reported on page 477, another on Cargill, Van & Co.'s farm, in sec. 14, thirty rods south from that well, is till, to gravel and sand at 50 feet, from which water rose twenty-six feet in fifteen minutes. The water of this is a larger supply and better in quality than that of the deep well, which is much harder, having more of the carbonates of lime and magnesia in solution, and consequently objectionable for use in steam-boilers, because of its greater amount of mineral residue, forming scale.

Fox Lake. Henry Miller; S. E. ¼ of sec. 26: well, dug 24 feet and bored 15 feet; soil, 2 feet; yellow till, spaded, 12; sand, 3 feet; yellow sand and clay, with gravelly streaks, mainly very fine and dry, very hard, 3 feet; iron-rusted gravel, interbedded with white gravel, 4 feet, containing many fragments of lignite up to six or eight inches in length, mostly in the white layers; gravel, sand, and clay, interstratified, mostly gray or yellowish, mainly hard, but with some very soft layers, 15 feet, to the bottom of the boring, where the auger became immoveable, and was left, in either a log of wood or a mass or bed of lignite. This well is used, being supplied by seeping water, which, like nearly all the wells of this region, is of excellent quality.

MATERIAL RESOURCES.

The fitness of Watonwan and Martin counties for farming and herding is their chief source of wealth; and by this they are capable of supporting a large and prosperous population, mainly agricultural, with towns and villages as required for manufacturing and centers of trade.

Water-powers. The only water-power used in Watonwan county is that of the Madelia mills, owned by J. T. Fisher, on the Watonwan river about a mile west of the town; head, eleven feet; a flouring mill, doing custom grinding; three run of stone. Other water-powers may be utilized on the main stream and on both its north and south branches.

In Martin county, also, only one water-power is now employed, this being at the flour mill of East Chain, owned by Ruble & Murphy, of Albert Lea, but leased to S. Vermilya; the fall or head is eight feet.

A dam was once built at or near the outlet of lake George in the Central chain of lakes, raising lake George six feet, and flowing back to Hall's lake, in sections 19 and 20, Fairmont, this being raised about one foot. A grist-mill, said to have a head of six or eight feet, several years ago stood a little below the foot of Wilmont lake, one of the same chain of lakes, in the northwest part of Silver Lake township. Good water-powers are also available on Elm, Center, and South creeks.

Building stone. No stone-working has been done in these counties, except the use of boulders, chiefly granite, syenite, and gneiss, with occasional slabs of limestone, and in one instance a large mass of probably Cretaceous sandstone, found, as already stated, in section 6, Rutland. These erratics of the drift, though dissimilar, make substantial, rough foundations, cellar walls, and curbing in wells.

Brick-making is not carried on in either of these counties; but about ten years ago red bricks of good quality were made on the north side of Watonwan river, a little east of the bridge close southwest of Madelia; and again a year or two after this, light-reddish bricks were made at Saint James.

No lime-burning was learned of in these counties.

Peat occurs in numerous places, and near Fairmont has been prepared for use as fuel by Mr. A. L. Ward.

ABORIGINAL EARTHWORKS.

Two interesting artificial mounds, of the usual form like a low, round dome, are situated about forty rods east and southeast of the mill at the north end of East Chain lake, and about forty feet above the lake. These have been opened by Mr. S. Vermilya, who reports that the northern mound here, about sixteen feet across and two feet high, was found to contain much wood in poles four to six inches in diameter, suggesting that they might originally have served as a roof, covered by earth. Two skeletons, thought to have been male and female, were here entombed in a sitting posture, about three feet below the natural surface or five feet below the top of the mound. With these were found an iron spoon, wasted by rust; iron handles and fragments of leather, as of a valise; two pairs of scissors, and a thimble, made of a brass-like alloy; bracelets of similar metal. less corroded; and many beads of glass and other material, mostly, like the metallic articles, not of Indian manufacture, but made by white men.

About twenty rods south of this mound, a second, only elevated one foot above the ordinary surface, with its top apparently sunken in, also contained poles of wood. The only skeleton found here was apparently that of a woman, buried, unlike those of the first mound, in a reclining position, and enclosed in a rude coffin, which was a dug-out canoe, cut in two at the middle, one part being placed above and the other beneath the body. Among the articles found here were beads; one pair of scissors; two thimbles, in a wooden tray; and a kettle of sheet-iron. Mr. Vermilya reports, within a distance of a half mile from these, several other artificial mounds, one to three feet high.

In the northeast corner of section 6, Rutland, a group of eight mounds (Fig. 31), of the common round form and varying from one and a half to three feet in hight, lies between Elm creek and Martin lake, on land about thirty feet above them. Six of these are in a straight line, which bears S. 60° E., and reaches about thirty rods, or some three-quarters of the distance from the creek to the lake. Mr. R. J. McCadden and others opened four of these mounds in 1879, finding several skeletons in each, buried about one foot below the natural surface, in a sitting position, facing the east, of stature five and a half to six feet high. Implements and utensils found were twenty or thirty unfinished flint arrow-heads in one place, and with them a wedge-shaped stone, supposed to be for skinning, and a pipe, about five inches long, of the form and proportions shown by figures 32 and 33, cut out of some dark gray stone; a few flint arrow-heads here and there in the other mounds; and in the largest mound of the group (not that which contained the many arrow-heads and the pipe), a small, unbroken cup (fig. 34), three inches in diameter and two and one-third inches high, with an aperture of one and a half inches, having a nearly uniform thickness of an eighth of an inch, made of baked clay, gray in color, slightly mixed with gravel on the inner side. This cup is perforated just below its rim by four holes, in pairs close together on its opposite sides. No articles of metal were found.

These two localities are in Martin county; no mounds were observed, nor heard of by inquiry, in Watonwan county.

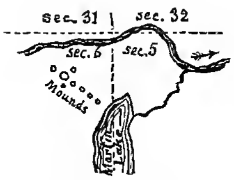


FIG. 31.
ABORIGINAL MOUNDS, SEC. 6, RUTLAND.

FIG. 32.
PIPE, VIEW FROM ABOVE.

FIG. 33.
PIPE, SIDE VIEW.

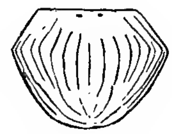


FIG. 34.
CUP.

ARTICLES FOUND IN MOUNDS, SEC. 6, RUTLAND.


JACKSON
MARTIN COUNTY
NOBLES COUNTY
STATE OF IOWA
T. 104 N
T. 103 N
T. 102 N
T. 101 N
R. XXXVIII W.
R. XXXVII W.
R. XXXVI W.
R. XXXV W.
R. XXXIV W.
LA CROSSE
WEIMER
DELAFIELD
CHRISTIANA
KIMBALL
ALBA
HERON LAKE
WEST HERON LAKE
BELMONT
ENTERPRISE
EWINGTON
RUST
HUNTER
DES MOINES
WISCONSIN
ROUND LAKE
SIOUX VALLEY
MINNEOTA
MIDDLETOWN
PETERSBURG
HERON LAKE
WILDER
OKABENA
LAKEFIELD
BROWNSBURG
JACKSON
Brickyard
L. Minneseka
L. Carroll
Summit L.
Fish Lake
Lower L.
L. Otto
Elm Creek
Independence L.
Flaherty's L.
Boot L.
Clear L.
Jack Creek
Okabena Creek
Little Sioux River
Des Moines River
Round Lake
Plum Island Lakes
State Line L.
Rush L.
Skunk L.
Little Clear Lakes
Little Spirit Lake
Loon L.
Pearl L.
SPIRIT LAKE
Woodstock Branch
Sioux City Div. of Chicago St. Paul
Southern Minnesota
Div. of C. M. & St. P.

CHAPTER XVI.

THE GEOLOGY OF COTTONWOOD AND JACKSON COUNTIES.

BY WARREN UPHAM.

Situation and area. The map of these counties forms plate-pages 19 and 20. Cottonwood is one of the second tier of counties north of the Iowa line, from which it is separated by Jackson county. From Saint Paul and Minneapolis southwest to Windom and Jackson is about 130 miles. From La Crosse and the Mississippi river west to the eastern boundary of these counties is 180 miles; they are 30 miles long from east to west; and from their west line onward to the east line of Dakota is 50 miles.

Cottonwood county has a length of five townships, and a width from north to south of four; except that on the northeast two of the townships that would be included in this county if it were a complete rectangle, belong to Brown county. With this reduction, Cottonwood county has eighteen townships, each six miles square. The only towns and villages of this county are in the southeast part, on the line of the Saint Paul & Sioux City railroad. These are Windom, the county seat, situated in Great Bend township, Bingham Lake, in Lakeside, and Mountain Lake. Cottonwood county has an area of 650.39 square miles, or 416,250 acres, of which 8,655.65 acres are covered by water.

Jackson county is a rectangle, five townships in length from east to west and four in width from north to south. The important towns are Jackson, the county seat, in Des Moines township, and Heron Lake, in Weimer township. This county has an area of 722.66 square miles, or 462,501.20 acres, of which 16,434.75 acres are covered by water.

SURFACE FEATURES.

Natural drainage. The northwest part of Cottonwood county, including Germantown, Highwater, Ann, Westbrook, Storden, northwestern Amboy, and most of Rose Hill, is drained to the Cottonwood river, which flows through southern Redwood county, only a few miles farther north, and enters this county for a short distance in the northeast corner of Germantown. Its tributaries from Cottonwood county, in their order from west to east, are Dutch Charley's, Highwater, Dry and Mound creeks. The largest of these is Highwater creek, whose sources are several lakes in Rose Hill township, only three to seven miles from the Des Moines river. Its course in this county is east-northeast, about eighteen miles.

The Little Cottonwood river, tributary to the Minnesota a few miles below the Cottonwood river, rises nearly at the center of Cottonwood county, and its first ten miles, flowing northeast, are in Amboy and Delton townships. Its farther extent of about thirty miles eastward through Brown county, is approximately parallel with the Big Cottonwood, and mainly three to six miles distant to the south from that river.

A tract in the east part of Cottonwood county, reaching west to its center, including Selma, Mountain Lake, Carson, the south half of Delton, and the northeast part of Dale, is drained by the head-streams of the Watonwan river, tributary to the Blue Earth and, by that, to the Minnesota. The area in Cottonwood county included within the basin of the Minnesota river is approximately 450 square miles.

The remainder of this county, including its southwestern townships, an area of about 200 square miles, is drained by the Des Moines river, which flows in a zigzag course, crossing South Brook, Springfield and Great Bend diagonally, having a general southeast direction in South Brook and Great Bend, but making an offset in Springfield by running eight miles northeasterly. Harvey creek, the outlet of lake Augusta in northeastern Amo, entering the Des Moines at its big bend in the southwest corner of Dale, is its largest tributary from the north in this county; from the south it receives the outlet of Spring lakes, which lie in the southwest part of Great Bend, and the outlet of Heron lake.

Among the *lakes of Cottonwood county* the following merit enumeration: Mountain lake, two miles long and from a half mile to one mile wide, two miles southeast from the depot and town of this name; Bingham lake, one mile long from northeast to southwest, close north of the town to which its name is given; Clear, Cottonwood, Wolf, Summit and Glen lakes, one-third to two-thirds of a mile long, in the west and southwest portions of Lakeside, one to three miles eastward from Windom, beautiful lakes of clear water, divided by irregular hilly or rolling areas of prairie, and skirted by narrow woods; Fish lake, nearly two miles long from northeast to southwest, and one-fourth to two-thirds of a mile wide, crossed by the south line of Lakeside and having about half its area in Jackson county; the Spring lakes, reaching two and a half miles from north to south, four miles west of Windom; the Three lakes, and Swan lake, each about one mile long, in Dale; Rat, Long, Eagle and Maiden lakes, from one-third to one mile long, in the south half of Carson; lake Augusta, about one and a half miles long and a half mile wide, in Amo; Hurricane lake, more than a mile long from north to south, lying in section 31, Highwater, and section 6, Storden; Double lake, of similar extent and trend, in sections 23 and 26, Westbrook; Berry and Twin lakes, with others, varying from a quarter of a mile to about one and a half miles in length, trending to the south or southeast, in Rose Hill; Oaks lake, one and a half miles long from north to south, but narrow, lying in section 32, Rose Hill, and sections 5 and 8, South Brook; and Talcott lake, in sections 19 and 30, South Brook, a mile long from north to south, with the Des Moines river flowing through its northern end.

Jackson county is partly drained by Elm creek to the Blue Earth and Minnesota rivers; partly by the Des Moines river, which crosses Iowa and enters the Mississippi at the southeast corner of that state; and partly by the Little Sioux river, which joins the Missouri thirty-eight miles north of Omaha.

About 90 square miles of northeastern Jackson county are tributary to the Minnesota river by Elm creek, which flows east through Martin county and enters the Blue Earth river after a course of forty miles. Its sources, in Belmont and Christiana, are only two to four miles east of the Des Moines river.

About 420 square miles of this county lie within the basin of the Des Moines, which flows, after leaving Cottonwood county, in a south-southeast course. Its only important affluent in these counties is the outlet of Heron lake, which comes into it nine miles west of Windom.

Some 210 square miles on the southwest are in the basin of the Missouri, being drained by the head-streams of the Little Sioux river.

Lakes in Jackson county. East of the Des Moines river the only notable lakes in Jackson county are Fish lake, about two miles in length, on the north line of Christiana, half of it being in Cottonwood county; lake Otto and Independence lake, each about a half mile long, respectively on the east and south boundaries of Christiana; and Lower's lake, of similar size, near the center of the township.

West of the Des Moines, the largest body of water in this county and in all southern Minnesota is Heron lake, eleven miles long, with a width of two and a half miles in its central part, diminished to a half or a fourth of a mile at each end, giving it an area of about fourteen square miles. This lake, reported to be only from five to fifteen feet deep, is mainly clear, but has some portions that are reedy, with marshy shores, affording a paradise to ducks, herons and blackbirds. Other noteworthy lakes in this part of Jackson county are lake Carroll, a half mile long from northeast to southwest, in northern Delafield; Minneseka lake, a mile long from east to west, crossed by the west line of this township; Flaherty's lake, a mile or more in length from north to south, and a half mile wide, in sections 6 and 7, Heron Lake; Boot lake, a mile long from north to south in sections 30 and 31, Belmont; Clear lake, exceeding a mile in length from east to west and about three-fourths of a mile wide, at the west side of Des Moines; Loon lake, nearly two miles long from north to south, crossed by the east line of Minneota; the Little Clear lakes, in sections 22 and 23 of this township; Little Spirit lake, about a mile in diameter, lying mainly in section 35, Minneota, divided from Spirit lake in Iowa by only a narrow low ridge of gravel and sand, pushed up by ice during the recent period; Skunk lake, a mile long from east to west, lying mostly in the south half of section 22, Sioux Valley; Rush lake, also a mile long, but trending from north to south, in the southwest part of the same township; Plum Island lakes, a half mile and one mile long, near the middle of Round Lake township; Round lake, a little more than a mile n diameter, in the northwest part of this township; and State Line lake. a mile long from north to south, situated at the southwest corner of the county.

Topography. In northern Cottonwood county a massive ridge of the red Potsdam quartzyte extends twenty-five miles from west to east through Storden, Amboy, Delton and Selma, terminating in the west edge of Adrian, the northwest township of Watonwan county. This highland is mostly covered by a smooth surface of till, but has frequent exposures of the rock. Its altitude increases from 100 feet at its east end to 300 feet westward, above the broad, slightly undulating sheet of till, which, excepting a morainic tract in Stately, covers the region toward the north. The hight reached at the top of this quartzyte ridge, 1300 to 1500 feet above the sea, is a permanent rise of the land, which to the south and southwest holds nearly this average elevation, with a general ascent westward.

This ridge was probably considered by the early French explorers as the northeast border of the *Coteau des Prairies*, which name, meaning the Highland of the Prairies, they gave to an elevated tract, extending about two hundred miles from north-northwest to south-southeast in eastern Dakota and southwestern Minnesota. Of this highland in Cottonwood and Murray counties, Nicollet says:* "Under the forty-fourth degree of latitude, the breadth of the Coteau is about forty miles, and its mean elevation is here reduced to 1,450 feet above the sea. Within this space its two slopes are rather abrupt, crowned with verdure and scolloped by deep ravines thickly shaded with bushes, forming the beds of rivulets that water the subjacent plains." It is not continuously recognizable as a great topographic feature south of this quartzyte ridge.

The Little Cottonwood river and the north branch of the North fork of Watonwan river flow northeasterly through gaps in the range of quartzyte, a hundred feet or more below its crest, the former finding its passage at the middle of the north half of Delton, and the latter about a mile west from the center of Selma. Excepting at these points, the ridge is unbroken and uplifts a broad, smoothly rounded top, covered with till through which the quartzyte has occasional outcrops. It extends in a course a little to the north of west twelve miles from the north part of section 25, Selma, to the north part of sections 9, 8 and 7, Delton; and thence a little to the south of west ten miles to Highwater creek at the middle of Storden township. In its east half, through Selma and Delton, this ridge has a width that increases toward the west from a half mile to one or two miles, elevated 50 to 100 feet above the average of the land for the next five or six miles to the south, and twice this hight above the country which it overlooks northward to the horizon. Both slopes of the range have a gentle descent, that to the north occupying a width of one to two miles, and reaching from section 7, Delton, to the falls formed by this quartzyte on the headstreams of Mound creek, in the southwest corner of Brown county, and in the N. E. ¼ of section

**Report on the upper Mississippi river*, 1843, p. 10; consult also plate 7 and page 68 of the present volume.

36, Germantown. In the central and southwest part of Amboy and the east half of Storden, this highland, besides slowly increasing in elevation westward, expands to a greater width, and forms an approximately level plateau of till, one to three miles wide, with outcrops of the quartzyte only upon the slopes which descend from it. The most southern exposures of this rock in Cottonwood county are in the west part of sections 6 and 7, Dale, and in section 12, Amo, on the western descent from the most southern part of this plateau, which here in northwestern Dale is 75 or 100 feet above the remainder of this township and its Three lakes, and about 150 feet above lake Augusta on the west.

This area of Potsdam quartzyte is the only part of Cottonwood county which has exposures of the bed-rocks, the remainder being moderately undulating or rolling and sometimes hilly glacial drift. The general slope, as already stated, rises from east to west, and at the west side of Amo and in Rose Hill this drift attains as great an altitude as the quartzyte range eight miles northeast in Amboy and Stordon.

The townships of Westbrook, Ann, Highwater and Germantown, lying north of this hight of land in Rose Hill, Amo and the ridge of quartzyte, have mostly a smoothly rolling contour, with the crests of swells fifteen to thirty feet above the depressions. The creeks which drain this district northward to the Cottonwood river flow in valleys that they have eroded 20 to 40 feet below the average surface.

The whole of Jackson county, like the northwest and south parts of Cottonwood county, is so deeply covered by the glacial drift that it has no outcrop of the underlying rocks. Southwest and south of the quartzyte ridge, these counties are crossed by a belt of knolly and hilly or prominently rolling morainic drift, two to seven miles wide, which reaches from Rose Hill southeast to the Blue mounds west of Windom, and thence south through the center of Jackson county to the west side of Spirit lake. From the vicinity of Windom a branch of this moraine extends ten miles north through the west part of Lakeside and Carson. The same knolly and broken contour of the drift is found also in the south part of Sioux Valley and in Round Lake township, on the southwest border of Jackson county. Excepting these morainic tracts and the ridge of quartzyte, these counties are a smoothly undulating, and in part almost flat, sheet of till, ascending with a very gentle slope from east to west, enclosing lakes here and there in its depressions, slightly channeled by creeks and deeply cut by the Des Moines river. Many further details respecting the contour of the drift are presented in a later part of this chapter.

The valley of the Des Moines river in South Brook, the most southwest township of Cottonwood county, is less distinct in its outlines, and its depth is less, than in any other part of its extent below lake Shetek. South Brook has mostly a rolling contour of massive swells, variable in their forms, trends, and extent, rising 20 to 50 feet above the Des Moines river, which flows among them in an irregular course, generally without any well-defined valley of bottomland and bluffs, but turned here and there by small undulations. In section 19 it passes through the north end of Talcott lake, which lies in a shallow basin of the drift-sheet, covering nearly a square mile, but only from five to eight feet deep.

In Springfield where the Des Moines flows northeast, at right angles to its course both above and below, it again occupies a definite valley, channeled 50 to 75 feet below the average hight of the rolling surface on either side. At the northeast corner of this township is the great bend of the Des Moines. Here it enters a valley transverse to its course through the last eight miles, and is carried in it thence to the southeast. This valley has a nearly flat alluvial bottomland, a third to a half of a mile wide, enclosed by bluffs 50 to 60 feet high. It continues two or three miles northerly from the great bend, with the same width and depth; and is less distinctly marked three or four miles farther, along the upper part of Harvey creek to lake Augusta. The excavation of this channel was probably effected by floods discharged from glacial melting, while the receding ice-sheet still covered these counties farther east. In the central part of Great Bend township the river is bordered on the west by morainic knolls and small ridges of rocky till, which rise successively one above another to the top of the Blue mounds, one to one and a half miles distant; and in the vicinity of Windom the ascent from the river eastward has a similar contour.

Through Jackson county the valley of the Des Moines is 100 to 150 feet below the average hight on each side, and is from one-third to two-thirds of a mile wide between the tops of its bluffs, which in the north part of the county rise in knolly and irregular slopes of morainic drift, but at Jackson and southward have generally the nearly straight course and steep ascent characteristic of ordinary fluvial erosion. At Jackson the immediate river-bluffs are about 100 feet high, but there is a further rise of the moderately undulating expanse of till on each side, amounting to 50 or 75 feet within a mile or less from the top of the bluffs. This town is built on four terraces of modified drift, successively about 20, 30, 40 and 50 feet above the river, together occupying a width of one-fourth to one-third of a mile. They are mostly composed of sand and gravel for several feet next below the soil; but in some places the underlying till reaches quite to the surface.

Distances along the Des Moines river, measured in direct lines between its principal bends, are as follows: from its source to the foot of lake Shetek (this portion being commonly called Beaver creek), 24 miles; to a point on the south line of Cottonwood county, two miles north of the north end of Heron lake, 48 miles; to its great bend, 56 miles; to Windom, 63 miles; to Jackson, 81 miles; to the state line, 91 miles; and to its mouth at Keokuk, about 385 miles. Thus a little less than one-fourth of its entire length lies in Minnesota.

Elevations, Saint Paul & Sioux City division, Chicago, Saint Paul, Minneapolis & Omaha railway.

From profiles in the office of T. P. Gere, superintendent, Saint Paul.

	Miles from St. Paul.	Feet above the sea.
Mountain Lake, depot	137.0	1300
Bingham Lake, depot	143.2	1420
Summit, grade	144.1	1437
Windom	147.8	1353
Des Moines river, water	148.1	1331
Bluff siding	149.7	1425
Wilder	154.0	1448
Heron lake, water	159.0–159.5	1403
Heron Lake, depot	160.3	1417

Elevations, Southern Minnesota division, Chicago, Milwaukee & Saint Paul railway.

From George B. Woodworth, assistant engineer, La Crosse.

	Miles from La Crosse.	Feet above the sea.
Top of bluff at junction of branch to Jackson depot	209.1	1446
Des Moines river, water	211.8	1288
Des Moines river, bridge	211.8	1353
Summit, grade	216.6	1517
Lakefield	220.6	1463
Okabena	229.1	1410
Crossing Saint Paul & Sioux City railroad	232.2	1414

The highest portions of Cottonwood county, about 1500 feet above the sea, are in Rose Hill township, in western Amo, and the plateau upon the west part of the quartzyte ridge in southeastern Storden and southwestern Amboy, and the tops of the Blue mounds, which are 1450 to 1525 feet above the sea. The lowest land of this county, nearly five hundred feet below these tracts, is where the Cottonwood river enters the northeast corner of Germantown, at a hight of about 1030 feet above the sea. The elevation of the Little Cottonwood river where it leaves the county is estimated to be 1150 feet; and of the most northern tributary to the Watonwan river, at the east line of Selma, 1100. The Des Moines river descends in this county approximately from 1400 to 1330 feet above the sea.

Estimates of the average hight of the townships of Cottonwood county are as follows: Selma, 1225 feet above the sea; Mountain Lake, including two governmental townships, 1300; Delton, 1325; Carson, 1375; Lakeside, 1410; Germantown, 1200; Amboy, 1400; Dale, 1450; Great Bend, 1410; Highwater, 1225; Storden, 1400; Amo, 1450; Springfield, 1430; Ann, 1300; Westbrook, 1420; Rose Hill, 1450; and South Brook, 1425. The mean elevation of Cottonwood county, derived from these figures, is 1360 feet.

In Jackson county the greatest altitudes are attained by the inner terminal moraine which extends from north to south through the center of the county, its crests being 1475 to 1550 feet above the sea; and by the outer terminal moraine, which has about the same elevation from Skunk and Rush lakes to Round and State Line lakes in the southwest corner of the county. The descent of the Des Moines river is estimated to be eighty feet, from 1330 at the north to 1250 feet, approximately, where it crosses the state line, at the lowest point in this county. Mean hights of the townships of Jackson county are estimated as follows: Kimball, 1350; Enterprise, 1375; Wisconsin, 1400; Petersburg, 1375; Christiana, 1400; Belmont, 1410; Des Moines, 1420; Middletown, 1425; Delafield, 1440; Heron Lake, 1460; Hunter, 1475; Minneota, 1460; Weimer, 1415; West Heron Lake, 1420; Rust, 1440; Sioux Valley, 1460; La Crosse, 1425; Alba, 1450; Ewington, 1500; and Round Lake, 1520. The mean elevation thus obtained for the whole county is 1430 feet.

Soil and timber. The soil of Cottonwood and Jackson counties has the same nearly uniform fertility that characterizes all southern and western Minnesota. A black, sandy clay, with some intermixture of gravel, and containing occasional boulders, forms the soil, which has been colored to a depth of about two feet below the surface by decaying vegetation. Unmodified glacial drift or till, the same as the soil, excepting that it is not enriched and blackened by organic decay, continues below, being yellowish gray to a depth of 10 or 20 feet, but darker and bluish beyond, as seen in wells. This deposit contains many fragments of magnesian limestone, red quartzyte, granites and crystalline schists; and its fine detritus is a mixture of these rocks pulverized, presenting in the most advantageous proportions the mineral elements needed by growing plants. Wheat has been the principal crop, but stock-raising has also received much attention in Jackson county during several years past. A large variety of crops is profitably cultivated throughout this region, including wheat, oats, corn, garden fruits and vegetables, potatoes, and hay. In general, Jackson and Martin counties have a somewhat more sandy soil than the districts adjoining them on the east, north and west, and appear to be therefore slightly less adapted for wheat-raising. Besides this staple product, horses and cattle, pork and beef, butter and cheese, have become considerable exports.

From 1873 to 1876 Cottonwood and Jackson counties, in company with all southwestern Minnesota, were distressed by the ravages of the Rocky Mountain locust. To many the work of plowing and sowing, and the wheat sown, were total losses during these years. In 1880 frequent groves were noticeable between Fairmont and Worthington, which had been set out to shield farm-houses from the wind, and still remained, though the buildings were gone and the farms deserted, telling where in this struggle the grasshoppers had conquered. Though the wheat was nearly everywhere eaten by them so that no harvest could be saved, the prairie grass suffered only slightly, and from this epoch herding has taken an important place in the agriculture of Jackson and Martin counties.

The opinion prevails, and seems to rest upon a correct knowledge of facts, that the yield of wheat generally in the southern tier of counties of Minnesota during the past fifteen years or so, averaging ten to fifteen bushels per acre, has been only half or two-thirds as great as during the preceding ten or fifteen years. Much land remains that was never broken with the plow, and this contrast in productiveness is exhibited by newly broken ground in all respects similar to adjacent tracts that were first cultivated twenty or thirty years ago. It appears also that the early immigrants found wetter seasons, the sloughs more frequently impassable, and the lakes mostly standing at somewhat higher levels, than during the fifteen years next before 1880. To differences in rain-fall thus indicated, and differences in temperature and winds, and in their distribution through the year, making up the climate as a whole, we must attribute the diminution in the wheat crop. Probably these general climatic changes will be found to be periodic; lessened precipitation of rain and snow, and reduced yields of wheat through several years, being succeeded by a term, perhaps of equal duration, bringing as great rainfall, and as plentiful harvests, as have ever been recorded. The more wet years from 1880 to 1882 may mark the beginning of a period especially favorable for wheat-raising in southern Minnesota.

These counties are natural prairie, affording rich pasturage, and ready for the plow. Less than a hundredth part of their area is wooded. This includes small groves and narrow skirts of timber and brushwood about the shores of lakes, along the large creeks, and especially along the whole extent of the Des Moines river. The following species of trees and shrubs are found at Talcott lake: American or white elm, bur oak, white ash, box-elder, black walnut, willows, prickly ash, smooth sumach, frost grape, Virginia creeper, climbing bitter-sweet, wild plum, choke-cherry, black raspberry, rose, thorn, smooth wild gooseberry, and wolfberry, common; red or slippery elm, cottonwood, hackberry, waahoo, and black currant, less frequent. Basswood grows at Oaks lake, a few miles farther north. About Spirit lake, which lies in the north edge of Iowa and extends into the south part of section 36, Minneota, the timber consists principally of bur oak, white and red elm, white ash, basswood, sugar maple, box-elder, black walnut and cottonwood.

GEOLOGICAL STRUCTURE.

Potsdam quartzyte. The only exposures of bed-rock in this district are the red quartzyte which forms a prominent ridge in the north part of Cottonwood county, reaching into the edge of Watonwan and Brown counties. From the most eastern to the most western outcrop of this rock is a length of twenty-three miles; and the width upon which it is occasionally exposed increases from a half mile or less at the east to six miles at the west. The contour of this area has already been described as rising in a massive highland of rock, mostly covered by a smooth sheet of till, with gracefully rounded top and moderate slopes. The general character of this formation, and the location, extent, and special features of its outcropping ledges are to be noted here.

In Courtland, two miles east of New Ulm and about thirty miles east-northeast from this ridge in northern Cottonwood county, and again in Pipestone and Rock counties, fifty miles west-southwest from this ridge, the same rock-formation has extensive exposures, and it continues westward in Dakota to Dell Rapids and Sioux Falls on the Big Sioux river, and to Rockport on the James river, seventy miles west of Minnesota, and about a hundred and eighty miles west-southwest from New Ulm. All these outcrops are mainly very hard, fine-grained quartzyte, differing in color from pinkish gray to dark dull red, always having some red tint; and varying in the thickness of its beds from a few inches, or sometimes only a half inch or less, to one or two feet. It is usually perceptibly tilted, with considerable variability in the direction of its dips, which vary in amount from one or two to fifteen or twenty degrees, and rarely attain an inclination of forty-five degrees. This quartzyte is a metamorphosed sandstone. At a few places it occurs in an imperfectly indurated condition, being a more or less crumbling sandrock, composed of water-rounded grains. Sometimes, too, it is a conglomerate, enclosing abundant water-worn pebbles up to an inch in diameter, what was originally an ordinary fine gravel having become so cemented as to form a very compact and hard, tough rock; and by diminution in the number of pebbles scattered through it, the formation exhibits all grades between this pudding-stone and its typical condition as a quartzyte. Again, it occasionally contains layers, from less than an inch to several feet thick, of argillaceous rock, so fine-grained and even in its texture as to appear macroscopically homogeneous, doubtless metamorphosed from deposits of fine silt or clay in the midst of beds of sand; commonly dull red, but often mottled with pale spots or striped by the same lighter tints in parallelism with its stratification; soft enough to be easily carved and polished, and in its best varieties entirely free from grit. This has been named *catlinite*, and its finest layer is that which has been worked by the Indians, to whom it is still reserved, at the celebrated Red Pipestone quarry.

The planes of bedding of this quartzyte frequently show very distinct and beautiful ripple marks, such as are made by waves upon the sandy shore and bottom of lakes or of the sea. No fossils have been detected in this formation, as here described in southwestern Minnesota and southeastern Dakota; and fucoid impressions, rarely observed, are the only remains of life yet found in the probably equivalent Cupriferous series of red quartzytes and sandstones interstratified with thick basaltic overflows and beds of tuff and tufaceous conglomerate, which is very extensively developed about lake Superior. The quartzyte from New Ulm to the James river is closely like the sandstone and quartzyte associated with trap rocks in northeastern Minnesota, in northern Wisconsin and northern Michigan; but its deposition was not similarly accompanied by outflows of igneous rock, nor has this formation in southern Minnesota been intersected by trap dikes. Foster and Whitney referred these rocks in the region of lake Superior to the Potsdam age, considering them the western equivalent and representative of the Potsdam sandstone in New York; and the explorations by this survey of their continuation into northeastern Minnesota sustain this conclusion,* while the observations of this quartzyte outcropping in the southwest part of the state and farther west indicate that it belongs to the same epoch. This formation underlies the Calciferous or Lower Magnesian series, which outcrops along the lower part of the Minnesota river from a point fourteen miles east-southeast of New Ulm, and along the Saint Croix and Mississippi rivers.

In the N. E. ¼ of section 25, Selma, this red quartzyte is exposed upon an eastward slope of till, with an area three rods long from northwest to southeast, and about a rod wide, rising some two feet above the general surface.

In the S. E. ¼ of section 23, Selma, this rock outcrops on a southward slope along a distance of about twenty-five rods from east to west, with a width of two or three rods and a hight of only one to two feet. It dips about ten degrees southward. Both these ledges have been slightly quarried. They are the ordinary, very hard quartzyte, intersected by systems of joints which give it a rhomboidal fracture. Other outcrops of the same stone, which have not been visited in this survey, occur northwestward at numerous places in this township and in the northeast part of Delton, upon the high ridge and in the hollow where the north branch of the North fork of Watonwan river crosses it.

The quartzyte also has frequent exposures in Delton along nearly the whole extent of the Little Cottonwood river through this township, and in its tributary ravines. In the east part of the S. E. ¼ of section 8, it has been much quarried in the banks and channel of this stream, supplying rough stone used for foundations, cellar walls, well curbing and culverts, or, by Russian immigrants, for chimneys, being sometimes teamed fifteen miles. It occurs in layers of all thicknesses up to two and a half feet, the thinly bedded portions, as usually, being much divided by joints into rhomboidal fragments a foot or less in length. The bedding planes are often ripple-marked over several square rods together, in parallel undulations about a quarter of an inch high and two to four inches apart from crest to crest. The dip is about 5° S. 20° W. This is some twenty rods east of the Little Cottonwood falls, where the same rock in its upper portion forms layers three to six feet thick, dipping about six degrees to the south, but only a few feet lower, near the level of the stream, is thin-bedded and somewhat contorted and irregular in stratification.

Quartzyte outcropping in the north part of the S. W. ¼ of section 18, Delton occurs in layers up to six inches thick, dipping about 3° S. 70° E. Twenty rods farther south it has a dip of the same amount but changed in direction to S. 40° E., all these bearings being referred to the true meridian. Its only exposures observed in the south half of this township are in the S. E. ¼ of section 30, where it is visible at numerous places along an extent of about an eighth of a mile in

*Consult Prof. Winchell's article on "The Potsdam sandstone," in the tenth annual report, pp. 123—136.

a ravine tributary to the Watonwan river. No other outcrops were learned of upon the head-streams of this river farther eastward in Delton.

A ledge of this rock, very remarkably striated, as described on a following page, and bearing rude Indian inscriptions, is found on the ridge about a mile north-northeast from the Little Cottonwood falls and quarry, being in the north part of the N. W. ¼ of section 9, Delton. It has an area about twenty rods long from east to west, and four to eight rods wide. The dip of its stratification was not distinctly seen, but is believed to be about five degrees southward, which is the slope of the surface. Numerous figures are pecked on this rock, representing animals, arrows, etc., similar to those inscribed by the Indians on the quartzyte beside the boulders called the Three Maidens, near the Pipestone quarry. From this ledge westward the same typical quartzyte frequently outcrops upon the higher part of this ridge and on its northern slope through the northwest part of Delton, northern Amboy and northeastern Storden.

In the S. W. ¼ of section 2, Amboy, a ravine ten to fifteen feet deep extends east-northeast in a straight course about forty rods, varying from two to three rods in width, bordered by vertical walls, ten to fifteen feet high, of rough, thick-bedded quartzyte, of red or reddish gray color, nearly level in stratification, mostly much divided by joints. The eastern half of this ravine holds a long pool, ten to twenty feet wide, and five to eight feet deep. At the top of the wall of rock south of the west part of this pool, the much jointed, deep red, striated surface is in many places soft and like pipestone to the depth of an eighth of an inch; but within, these small jointed masses are gritty and hard, the pipestone being only a thin coating at the bedding-planes. At the western end of this ravine, on its north side, eight feet above the rivulet that flows east into the pool, this rock encloses a layer, nearly level, varying from four inches to a foot in thickness, somewhat like the pipestone of the famous quarry in Pipestone county, having nearly the same very fine texture and dark red color, but not so hard, and at this place, through its extent of twenty feet exposed to view, easily divisible into small flakes and fragments because of joints, and therefore not seen in any solid mass. The edge of this layer has been mostly removed by weathering to a depth of two to six feet into the wall of tough, reddish gray quartzyte, which overhangs and underlies it. The divisions of this very fine-grained bed from the coarse quartzyte are not definite lines, but these unlike sediments are more or less blended and interstratified through one to six inches. Both above and below, the quartzyte in some portions contains pebbles up to a third or half of an inch in diameter, and is quite variable in texture, but is nowhere finely laminated. At a few places the pipestone also is found to contain these small gravel stones; and a few fragments of pipestone up to three inches in diameter are seen enclosed in the quartzyte within one to two feet above the pipestone layer.

Picturesque falls are produced by this formation in the N. E. ¼ of section 36, Germantown. The rock here is mostly a very coarse-grained, thick-bedded sandstone, slightly iron rusty or reddish in color. Nearly all of it is somewhat friable, being thus unlike the other exposures of this formation in this county. In some portions, however, it is here very hard and compact, and then usually has a deeper red hue. Its dip is about 5° S. 10° E. Besides this general dip, the beds often show oblique lamination. This rock is in some places slightly conglomerate, holding pebbles of white quartz, and less frequently of red felsyte, or possibly jasper, the largest seen being an inch long. These falls are about two miles northeast from the gorge last described, being on a lower part of the same stream, which is one of the sources of Mound creek. Along its intervening course and within short distances from it on each side this formation has frequent outcrops, notably for a quarter of a mile south and southwest from the falls. The stream descends thirty feet in a succession of little cascades, within a distance of twenty rods; next below which is a basin some six rods long and four rods wide, bordered by vertical or overhanging walls of rock, about thirty feet high. At its east end this basin is so contracted that for a distance of about twenty feet these walls of rock are only eight to fifteen feet apart. Below, for the next twenty-five rods, the gorge is four to six rods wide, bordered by vertical walls of reddish sandstone or quartzyte, which decline from thirty to twenty and ten feet in hight. The same rock is seen thence nearly all the way for a half mile east, mostly forming cliffs fifteen to twenty feet high at the south side of this creek, to the junction of another stream from the south in section 31, Stately, Brown county, which also has an interesting fall formed by the quartzyte.

The most western exposure of this rock learned of in Cottonwood county is in the N. W. ¼ of section 28, Storden, on land of C. P. Carlson. Typical quartzyte, very compact and tough, varying in color from dull red to slightly reddish gray, is here exposed in the bed of a stream tributary to Highwater creek, along a distance of fifteen rods or more from north to south, with a width of two to four rods. Its dip is about five degrees to the southeast or S. 60° E. It is much divided by joints and is thereby somewhat fractured into rhomboidal pieces. Ripple-marks were seen in several places, the undulations being two to three inches wide. Fragments of red pipestone up to two inches in diameter occur rarely in this rock.

Another outcrop is reported one mile northeast from the last, on the N. E. ¼ of section 21, Storden, in a ravine; and others occur a half mile southeast of Carlson's, near the center of section 27, in the bed of small ponds through which the brook flows.

The west part of the S.W.¼ of section 6, Dale, has considerable exposures of quartzyte, scarcely rising, however, above the general surface of the till, along a distance of twenty rods and more from north to south, on a westward slope, about a mile east from the east end of lake Augusta. These ledges are owned and have been slightly quarried by Peter Schmith. The stone varies in color from yellowish gray to a dull red, is much jointed, and has a dip at the quarry of about five degrees northeast. Laminæ of pipestone from a fourth to a third of an inch thick, deep red, traversed by whitish veins, in their predominant red color and soft slaty texture closely like the pipestone of Pipestone quarry, were noted here upon the surface about fifteen feet east of the quarried excavations, occurring at bedding planes along an extent of about two rods. Here, also, fragments of this deep red pipestone, up to one or two inches in diameter, are enclosed in the quartzyte, which is mostly of a more grayish red color.

Several other outcrops of this rock, similar in extent and character, occur within a distance of a mile to the south and southwest through section 7, Dale, and in the east edge of section 12, and perhaps also of section 1, Amo. These most southern exposures of this area of quartzyte were examined by Prof. Winchell in 1873, and have been described on pages 159 and 160 of the second annual report. The dip at one place near the east line of section 12, Amo, is recorded to be "4° or 5° N. 10° W. The stone is very hard, but banded with light and red beds, evident on the planed surface and on the fractured side."

The observations of dip recorded in the foregoing pages indicate that these Potsdam strata in Selma, Delton, Stately and Germantown are monoclinal, dipping generally about five degrees southward; and that probably farther west in Germantown, Amboy, Storden, Dale and Amo, where a greater width is exposed, they are synclinal, on the north dipping about five degrees toward the south, and on the southwest dipping an equal amount toward the northeast and north. From the Little Cottonwood falls in Delton along the distance of three miles northerly to the falls in section 36, Germantown, Prof. Winchell in a recent reconnoissance found numerous outcrops of the rock with a nearly uniform southward dip of about five degrees, from which he computes the thickness of the formation exposed between those points to be approximately 1380 feet. Stratigraphically, the lowest of the beds thus observed are at the falls on Mound creek in Germantown, where outcrops extending twelve hundred feet from north to south, with a dip of five degrees toward the south, give a thickness of 100 feet for the friable sandstone seen at that place. This forms the base of the strata measured, lying below beds of very hard and compact quartzyte, which are almost a quarter of a mile thick.*

*See an instructive paper, by Prof. R. D. Irving, on the nature of the induration of sandstones and quartzytes in Wisconsin, probably of the same kind with the induration of this quartzyte, *American Journal of Science*,(3), vol. xxv, pp. 401-411, June, 1883.

Fifteen miles south-southwest from the rock outcrops of Dale and Amo, this Potsdam formation is reached in the railroad well at Heron Lake at a depth of 186 feet, its first 34 feet, to a total depth of 220, being a reddish quartzyte or sandstone, underlain by a whitish gray quartzyte. This is the only well in Jackson county which goes through the drift, and no wells were learned of in southern or western Cottonwood county that penetrate to the bed-rock.

It does not seem certain that the Heron Lake well encounters anything but drift deposits above the Potsdam quartzyte; but its section from 115 to 186 feet may be through Cretaceous beds, which, however, were learned of in no other well in these counties. The order of deposits found was soil, 2 feet; yellow till, 13; blue till, 100; yellow clay, 10; dark, very hard and dry, fine silt, like dried mud, 16 feet; light gray clay, free from gravel, 24; and interstratified sand and fine gravel, 21 feet, being in total 186 feet, to the Potsdam rocks before described.

Drift and contour.

The surface of the Potsdam quartzyte in many places shows distinct glacial markings, notes of which are presented in the following table. These bearings are referred to the true meridian, from which the magnetic needle here has a variation of about ten degrees to the east.

Courses of glacial striæ in Cottonwood county.

Selma, N. E. ¼ of sec. 25	S. 20° E.
Selma, S. E. ¼ of sec. 23, and varying from this two or three degrees on each side.	S. 20° E.,
Delton, S. E. ¼ of sec. 30	S. 15° E.
Delton, S. W. ¼ of sec. 18	S. 15° E.
Delton, N. W. ¼ of sec. 18	S. 25° E.
Delton, N. W. ¼ of sec. 9; also all courses from S. to S. 80° E., intersecting upon the same surface.	mostly S. 25° to 40° E.;
Amboy, south part of sec. 2, near (north of) a school house..	mostly S. 40° E.;
and, within a distance of one rod from striæ of this course, also	S. 45° and 55° E.
Amboy, S. W. ¼ of sec. 2, at the pipestone locality, about a quarter of a mile northwest from the last, and rarely deflected to S. 70° E., all intersecting on the same surface.	S. 35° to 50° E.,
Germantown, N. E. ¼ of sec. 36, about thirty rods southwest from the falls	S. 30° E. and S. 70° E. (fig. 35)
Five rods east from the last, striæ were noted at different spots within a space of about one rod square of nearly level rock, bearing	S. 30°, 50° and 70° E.
Generally here these marks have been effaced, and none could be found on the ledge described in the N. W. ¼ of sec. 28, Storden.	
Dale, S. W. ¼ of sec. 6	S. 20° to 25° E.
Dale, south part of sec. 7	S. 34° E.
Amo, east part of sec. 12	S. 30° to 32° E.

Near the Little Cottonwood falls, in the S. E. ¼ of section 8, Delton, and at points on the north side of the quartzyte ridge in the northwest part of this township, the angles of projecting ledges of this rock were observed to be rounded off by glaciation.

The most remarkable deflections and intercrossing of glacial striæ ever seen by the writer, were found at the locality mentioned in the N. W. ¼ of section 9, Delton. It is on the southern slope of the ridge formed by this quartzyte, as already described. This ridge is elevated about 300 feet above the lowland, which, from its base two or three miles farther north, extends northward more than fifty miles, across the basin of the Minnesota river; but its hight above the average surface to the south and southwest is slight, probably not exceeding 50 feet. Its length is about twenty-five miles, extending from east to west; and this locality is near the middle of its extent. Very distinct glacial markings occur here promiscuously crossing each other in all directions between north to south and S. 60° E., and, very rarely, S. 80° E.; but a great majority are between S. 25° E. and S. 40° E. Many are from ten to thirty feet or more in length, and from an eighth to a half of an inch deep; others are very delicate lines. Curved striæ were observed at one place; two or three parallel furrows (fig. 36), covering a width of several inches and extending about ten feet to the southeast, were gradually deflected nine inches southerly from their direct course in the last four feet. All the other very abundant intercrossed striæ observed here are straight, or deviate only slightly from straight courses. The outcrop containing pipestone in section 2, Amboy, furnished the only similar instance seen in these counties. Here several parallel glacial scratches bend twenty or thirty degrees in a length of about eight inches (fig. 37). The curvature of these ice-marks, where no obstacle existed to cause deflection, indicate that they were engraved during the final melting and recession of the ice-sheet, when it had become thin, and that its margin at the date of this curved striation was near, perhaps within a few rods. In such a situation the unequal melting of the edge of the ice must produce changes, such as are thus recorded, in the direction of its motion.* The prominence of the quartzyte ridge doubtless gave unusual irregularity to the outlines of the retreating ice-border in northern Cottonwood county, which, by the resulting deflections of the glacial current, appears to have been the cause of the singularly varying and intercrossed striation of this region.

During the greater part of the last glacial epoch the ice-fields here appear to have flowed in a nearly south-southeast course; but when they were being melted away, the direction of movement close to the ice-border would be often deflected because it must flow toward the nearest part of this irregular and changing boundary, which here and there became indented by bays of small or large extent. The intersecting striæ on the ledge in section 9, Delton, record very changeable glacial currents, now deflected to a due south course, twenty degrees to the right from the direction which they had previously held through this glacial epoch, but presently diverging as much or twice or three times as much to the left, attaining a southeast or even a nearly east course. The medial moraine directly south of this locality, in Carson and Lakeside, suggests that, when the ice retreated, probably two glacial currents converged here, pushing against each other, and that the striæ bearing south were made by the current on the east, and those bearing S. 60° to 80° E. by the current on the west.

Divergences to the east from the prevailing direction of glaciation were noted also four miles farther northwest, in Amboy and Germantown, upon the northern slope and at the north base of this massive ridge. In Germantown a surface about a yard square was observed, on half of which the striæ bear uniformly S. 30° E., and on the other half S. 70° E., as shown in fig. 35, these portions meeting at a slightly beveled angle from which

*Similar curved striæ are recorded and figured by Desor (Foster and Whitney's *Report on the lake Superior land district*, part I., p. 206), and by Andrews (*Am. Jour. Sci.*(3), vol. xxvi, p. 100, Aug., 1883).

each side slopes down two or three degrees.* The former of these courses of striation is probably that which prevailed till the departure of the ice-sheet, when the great quartzyte ridge and the irregularity of the glacial melting caused a deflection of forty degrees toward the east. The later ice-current was steadily maintained during a considerable time, sufficient for planing off a part of this surface of very hard quartzyte, but not touching the adjoining part, which could only escape by having a thin covering of drift.

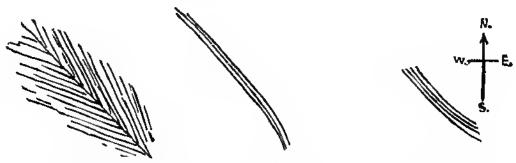


FIG. 35. IN THE N. E. ¼ OF SEC. 36, GERMANTOWN. FIG. 36. IN THE N. W. ¼ OF SEC. 9, DELTON. FIG. 37. IN THE S. W. ¼ OF SEC. 2, AMBOY.

SKETCHES OF GLACIAL STRIÆ ON THE QUARTZYTE IN COTTONWOOD COUNTY.

The drift spread over Cottonwood and Jackson counties is principally till, in part morainic, being accumulated in knolls and hills, or with a prominently rolling surface in massive, smoothly sloping swells, but for the greater part it is only gently undulating in contour. Its thickness on the quartzyte ridge varies from nothing to probably fifty feet or more, and in other portions of these counties it probably varies from one hundred to two hundred feet in depth. The moraines to be described were formed at the west border of the ice-sheet of the last glacial epoch, the first when this ice covered its maximum area, and the second after it had receded considerably from its farthest limits, when its retreat was interrupted by a halt and perhaps even by some re-advance.

First terminal moraine. The outer or western morainic belt of the Coteau des Prairies extends into the south edge of this state along its course of twenty miles next west of Spirit lake, where the greater part of its width lies in Iowa. From the Little Sioux river at the west side of Minneota, through Sioux Valley and Round Lake townships, to Indian lake in southeastern Nobles county, the part of this formation in Minnesota is characterized by numerous small ridges, hillocks, and swells of till, and is from one and a half to five miles wide, reaching north to Skunk lake, to a half mile beyond Rush lake, to Plum Island and Round lakes, and to the north end of Indian lake. Its greatest extent north in this distance is at the north side of Round lake; but south of this a tract about two miles wide and three miles long to the east from State Line lake, is smooth and only slightly undulating, though enclosed by rolling or knolly morainic areas.

Second terminal moraine. The inner or eastern of the two terminal moraines upon the Coteau des Prairies extends from the west side of Spirit lake north through the central range of townships in Jackson county. The width of this belt is from three to six miles. Its surface is

*Compare similar observations in Rock county, reported in chapter xviii.

prominently rolling, mostly in massive swells, 20 to 40 feet above the depressions, but at many places in small, steep knolls and hillocks of similar hight. The elevation of the range above the general level is from 40 to 75 feet. Its material is till, which here contains more gravel and boulders than on its smooth, slightly undulating areas which extend at each side beyond the limits of the county. In Minneota this morainic belt is about three miles wide, reaching from Little Spirit lake and Clear lakes west to the Little Sioux river. It here has many knolls and short ridges which continue into Hunter, and are crossed seven to ten miles west of Jackson by the road to Worthington. Farther to the north, the moraine forms a prominently rolling tract, about six miles wide, between the Des Moines and Heron lake, rising in smooth massive swells 50 to 75 feet above the general level at the top of the bluffs of the river, and 75 to 100 feet above the lake.

In the southwest part of Cottonwood county, this belt of notably rolling and hilly drift occupies the west half of Great Bend, the north part of Springfield, northeastern South Brook, southwestern Amo, and nearly all of Rose Hill. Its width in these townships varies from two to five miles. To the northwest from the offset of the Des Moines river which crosses this formation in Springfield, it lies a few miles northeast of this river and parallel with it, having within the limits of this county and especially in Rose Hill township a prominently rolling contour in smooth swells, 20 to 40 feet above the intervening hollows and frequent lakes. To the south from this offset and the great bend of the Des Moines, the second terminal moraine lies west of this river and approximately parallel with it, their distance apart being from one to ten or twelve miles, along an extent of a hundred and forty miles, through Jackson county and onward in a nearly south-southeast course to Pilot mound and Mineral ridge in northern Boone county near the center of Iowa.

The most conspicuous portion and most rougbly broken contour of this morainic belt in Cottonwood county are in the west part of Great Bend, where a group or range of hills, known as the Blue mounds, begins three miles west of Windom and thence extends three or four miles in a northwest course, with a width varying from a half mile to one and a half miles, lying between the Des Moines river on the northeast and Spring lakes on the southwest. These hills are composed of till with frequent boulders, and rise in very irregular slopes to hights 100 to 175 feet above the river and 25 to 75 feet above the general level at their west side. The most elevated of these mounds, in sections 17 and 20, are visible from the southeast part of Murray county, fifteen miles to the west; but from the east they can only be seen within a distance of six or eight miles.

Medial moraine. Across the Des Moines river, the land ascending from it east of Windom, opposite to the Blue mounds, has similar but less prominent morainic features. It consists of irregular knolls, hillocks, and low ridges of till, with enclosed hollows and lakes, occupying a width of two or three miles, and gradually rising in this distance about 100 feet above the Des Moines river. This tract seems to be part of a medial moraine (so called because formed between opposing ice-currents), connected with the second terminal moraine as a branch from its northeast side, and extending north through the two western ranges of sections in Lakeside and Carson. Its most broken portion is found in sections 17, 8 and 5, Carson, which have many small hills and ridges 40 to 75 feet high, mostly trending from north to south, composed of till with abundant boulders. Ten miles north from these hills in Carson is the morainic tract through which Mound creek flows in Stately, but the intervening area, across which the quartzyte ridge extends from east to west, is destitute of such knolly drift deposits.

East of the second moraine, the country extending from it to the Des Moines river in southern Jackson county is till, nearly flat through the central part of Middletown for five or six miles northeast from Spirit lake; moderately undulating in the eastern third of Minneota; and in the west part of Des Moines township massively rolling, in parallel swells that trend nearly from north to south, sloping gently down on their east and west sides to the intervening depressions which are 30 to 50 feet lower, the distance between the tops of these undulations being from a half mile to one or two miles.

The surface of the part of Jackson county east of the Des Moines river is a smooth, nearly flat, but everywhere more or less undulating sheet of till, sloping eastward ten to twenty feet per mile. Its descent on the line of the Southern Minnesota railroad is 173 feet in eleven and a half miles from the junction of the branch to Jackson, at the top of the eastern bluff of the Des Moines.

Beyond the knolly and broken ascent east from the Des Moines river in the vicinity of Windom, the contour changes to a smooth and nearly flat expanse of till, which thence extends seventy-five miles eastward, descending with an imperceptible slope to the Blue Earth river, and beyond this rising in the same manner to the belts of drift hills at the sources of the Le Sueur and Cannon rivers, well named by Nicollet "the N. E. prong of the Coteau des Prairies," since they are of the same age with the moraines of these counties and a curved continuation from them (see page 406). The eastern two-thirds of Lakeside and Carson, and all of Mountain Lake township, included in the vast area of intra-morainic till, are slightly undulating and differ only five to ten feet in broad swells and depressions from being a perfect plain. This expanse, stretching on all sides to the horizon, would be commonly called level, but the survey of the Saint Paul & Sioux City railroad shows that its descent eastward is uniformly about twenty feet per mile through these townships, or some 200 feet in the ten miles from the railroad summit a mile west of Bingham Lake to the east line of this county. If the same slope were continued westward it would pass over the summit of the Blue mounds; hence they cannot be seen east of Bingham Lake.

Mountain lake, which has given its name to a railroad station and township, is so called because it contains an island that rises about 35 or 40 feet in steep bluffs, attaining the same hight with the bluffs that surround the lake, even with the average surface of its vicinity. The probable origin of this depression and of its steep enclosing bluffs, has been pointed out in treating of the chains of lakes in Martin county, the most western of which appears to have its beginning in this lake.

West of the second moraine, the eastern shore of Heron lake mainly rises in gradual slopes of till, reaching the summits of the morainic belt at a distance of three or four miles; the south end of this lake, lying within the edge of the moraine, is enclosed by banks about forty feet high; but on the west and southwest is a very flat expanse of till, 10 to 20 feet above the lake, only undulating five to ten feet in slopes a mile long, stretching with slowly increasing hight as far as the view extends westward. On the Sioux City railroad in the ten miles southwest from Heron Lake to Hersey, the ascent is 68 feet; in eight miles on its branch from Heron Lake northwest to Dundee, 26 feet; and on the Southern Minnesota railroad in seven miles northwest from its intersection with the Sioux City line to De Forest, is 32 feet. Trains approaching De Forest from the southeast come into sight near the south end of Heron lake, and are visible during forty minutes before their arrival. This smooth plain of till continues south through Rust and Ewington townships, having the same slight ascent to the west, and crossed from north to south or southeast by occasional water-courses and sloughs ten to twenty feet below the general level.

Interglacial drainage. Heron lake lies in the continuation of the southeast course of the upper Des Moines river below lake Shetek. There seem to be good reasons for believing that lake Shetek, this part of the Des Moines, Heron lake, and Spirit and Okoboji lakes in Iowa, resemble the chains of lakes of Martin county, in occupying portions of what was originally a continuous valley excavated by interglacial drainage in the thick till of the earlier and severer glacial epoch, before the time of the last ice-sheet by which the terminal moraines in this and adjoining states were formed. It is probable that the Des Moines river then continued southeast where Heron lake is now, and onward in the same course through Hunter, where the rolling and hilly drift of the second terminal moraine now forms a watershed a hundred feet above Heron lake; thence southward at the east side of Minneota to Spirit lake and the Okoboji lakes; then, from West Okoboji lake south along the course of the Little Sioux river, which now receives the outflow of these lakes, to its bend three miles east of Spencer; and thence eastward about twenty miles, by Trumbull, Palo Alto and Lost Island lakes, re-entering the present valley of the Des Moines river at Emmettsburg. Hights along this distance are approximately as follows: lake Shetek, about 1,475 feet above the sea; the Des Moines river at its point nearest to Heron lake, about 1,375; Heron lake, 1,403; railroad summit between Heron lake and Jackson, 1,517; Spirit lake, about 1,400; the Okoboji lakes, about four feet lower than Spirit lake; Little Sioux river at Spencer, about 1,300; lakes and lowest part of the divide between Spencer and Emmettsburg, about 1,350; and the Des Moines river at Emmettsburg, about 1,125. The remarkable depth of the south part of West Okoboji lake, exceeding one hundred feet, is thus very probably in an unfilled portion of an interglacial valley, elsewhere choked up with the drift of the later ice-sheet by which the morainic hills and swells, partly rough and partly smooth, adjoining this lake and covering most of northern Dickinson county, in Iowa, were accumulated.

At Emmettsburg this interglacial Des Moines river was joined by a large tributary from the north, formed by the union of the streams whose courses are marked by the chains of lakes in

Martin county, and flowing southwestward across Emmett county at right angles to the present East fork of the Des Moines. Portions of its channel are preserved in Swan lake, six and a half miles long from northeast to southwest, and from one-fourth to two-thirds of a mile wide, only ten to fifteen feet deep, but occupying a hollow twenty-five to fifty feet below the gently undulating expanse of till on both sides; and in the High lakes, nearly three miles long, lying one to three miles south of the soutwest end of Swan lake. This river probably coincided in its course with the present Des Moines southward from the north line of Palo Alto county. Medium lake, which reaches four and a half miles northeast from Emmettsburg, varying from a quarter to a half of a mile in width, mostly ten to fifteen feet deep, with a bottom some forty feet below the average of this moderately undulating region, but at one point, a little north of its center, found to be more than fifty feet deep, its surface being about thirty feet above the Des Moines river, probably marks the position of another interglacial tributary of the Des Moines, joining it at nearly the same place with the branch from Martin county.

Drainage during the last glacial epoch. Very significant changes in the drainage of this region have been produced by the lobe of the ice-sheet which covered these counties and a width of about a hundred miles eastward during the last glacial epoch. From the south end of Heron lake to Okoboji township in southern Dickinson county, Iowa, the interglacial channel of the Des Moines has been principally lost by being filled with the drift of terminal moraines, accumulated at the west border of the ice. The outer belt of these deposits extends in Iowa from Storm Lake in Buena Vista county northward through eastern Clay county to the Okoboji lakes, and thence westward to Ocheyedan mound in Osceola county. Thence passing into Minnesota, it reaches northwesterly through the central part of Nobles county, western Murray county, and the most northeast township of Pipestone county, forming there and farther northwest the highest part of the Coteau des Prairies. The present basin of the Des Moines river from central Iowa northwestward was entirely covered by this ice-sheet; but a small part of its interglacial valley, in southern Dickinson and northern Clay county, Iowa, and most of the basin of Ocheyedan creek, here tributary from the northwest, were outside the ice-lobe, by which they were dammed and their drainage in the old course to the east and southeast was made impossible. A lake about a hundred and fifty feet deep and covering the greater part of Clay county, was thus formed at the west side of the ice-lobe, until its overflow cut the deep, trough-like valley or channel in which the Little Sioux river now flows along the south side of Clay county and in northeastern Cherokee county, 150 to 200 feet deep, and in some places only a quarter of a mile wide between the tops of its bluffs, which consist wholly of glacial drift.* This outlet was so deeply excavated while the ice-sheet lay as a barrier on the east that after its departure the stream continued to flow by this passage to the Missouri, through a broad area of till which has its surface 100 to 150 feet higher than the divide between the Little Sioux and Des Moines rivers east of Spencer.

In northern Clay county, where the Little Sioux river takes the place of the interglacial Des Moines, the broad and deep valley eroded by that stream before the last glacial epoch has become nearly filled with modified drift, which forms an extensive plain, ten miles long and two to four miles wide, bordering the Little Sioux river through Summit, Riverton and Spencer, reaching west to Stony and Ocheyedan creeks. These fluvial beds of gravel and sand were deposited after the excavation of the channel of the Little Sioux river, by which the lake that previously existed here had been drained into the Missouri; and they are thus shown to have been supplied during the latter part of this epoch, while the ice-sheet, in which they had been held, was being melted away.

The decline and departure of this ice was interrupted by a halt and probably by a re-advance, forming a second or inner line of terminal moraine, which reaches through Murray, Cottonwood and Jackson counties, from the east side of lake Shetek southeast to the Blue mounds west of Windom, and thence south to Spirit lake, and continues southeast in Iowa within a few miles west of the Des Moines river to Pilot mound and Mineral ridge. At this time the drainage from the head of the Des Moines basin, in Murray county, and the waters of Heron lake and its tributaries went southward through West Heron Lake, Rust and Sioux Valley townships, and were carried by the Little Sioux to the Missouri river, instead of going southeast as now to the Mississippi. Heron lake then stood about twenty feet higher than now, probably covering three times its present area. The shallow channel of its overflow has become partly filled by the silt of tribu-

*White's *Geology of Iowa,* vol. ii., p. 205.

taries, and contains a succession of sloughs and small reedy lakelets, connected at time of high water by a stream, which is the head and most northern source of the Little Sioux river.

Farther recession of the ice gave to the waters of Heron lake and the upper Des Moines river a lower outlet by the present course northeast across the second terminal moraine at the north side of the Blue mounds, and thence southeasterly along the east side of this moraine. This avenue of drainage became marked by a considerable valley eroded while the ice yet lay as a barrier upon the east part of Cottonwood and Jackson counties; for the top of the bluffs, and the general surface of the country, bordering the Des Moines in eastern Jackson county are slightly higher than the watershed between Heron lake and the Little Sioux river; and, furthermore, the natural slope in eastern Cottonwood and northeastern Jackson county is eastward, so that this river could not flow here to the south-southeast unless its valley had been thus formed before the ice-sheet was melted at its east side, being excavated sufficiently deep to hold the stream afterward in this course.

An exception to the generally smooth contour of the drift-sheet north of the quartzyte ridge is found in a quite roughly hilly morainic area, apparently isolated, which lies mainly in the north half of Stately, the most southwest township of Brown county, and extends into Germantown to the west side of section 12. Its abrupt mounds and ridges of stony till are 25 to 75 feet high, having their greatest prominence in Stately along the lower part of Mound creek. This tract appears to belong to a third terminal moraine.* Through the middle of Germantown a notable valley, having a flat bottom of stratified gravel and sand, enclosed by moderately steep slopes which rise about forty feet to the undulating surface of the till on each side, was observed, extending five or six miles in an east-southeast course from near Dry creek at the north side of section 17 in this township, to Mound creek at the east side of section 30, Stately. Another valley of similar character was noted three-fourths of a mile farther south, running parallel with the last through the north part of sections 25 and 26, Germantown. These deserted water-courses were probably formed during the departure of the last ice-sheet. Upon this region its border doubtless retreated to the north and northeast; and while it still lay as a barrier upon the north part of Germantown and was accumulating the morainic hills that lie a few miles to the northeast in Stately, the drainage from its melting was carried by these valleys southeasterly. Farther northwest, the land for a considerable distance along the probable course of the ice-margin in this stage of its retreat is lower than where these valleys occur, and therefore would be occupied by a lake; and again southeastward, from the south part of Stately to Silver Lake in Martin county, a narrow glacial lake probably extended along the border of the ice-sheet, having a hight about 1200 feet above the sea, and overflowing south of Iowa lake to the East fork of the Des Moines river.

Boulders and pebbles. The boulders of the drift in these counties are mainly granite and syenite, crystalline schists, quartzyte, and limestone. The quartzyte ridge in northern Cottonwood county has supplied from a tenth to a half of the large rock-fragments in the drift south of it. In traveling from Fairmont to Worthington, boulders and pebbles of quartzyte are first seen abundantly in the vicinity of Jackson, and are plentiful thence westward. At the northwest side of Spirit lake this formation has supplied a sixth part of the larger stones and boulders, but its proportion in the beach-gravel is only a fifteenth or twentieth. Of a hundred and fifty small pebbles counted on a space one foot square of the beach at the west side of Spirit lake, half were magnesian limestone, probably derived from the formation that outcrops near Winnipeg; and the other half were

*See page 479; also the report of Brown and Redwood counties.

granite and syenite, schists, white quartz, the red quartzyte, etc. One pebble, two inches long, of pipestone, one of conglomerate, and seven or eight of the ordinary quartzyte, doubtless all derived from the Potsdam formation in Cottonwood county, were included in this number. Among the large boulders, over one foot in diameter, in these counties, it may be that a twentieth part are limestone. At Windom limestone containing *Receptaculites* was found in the drift by Mr. Savidge, in digging his cellar.

Modified drift. The only noteworthy deposits of modified drift observed are the terraces in the Des Moines valley at Jackson, which have been already described on page 496.

Wells in Cottonwood county.

Records of the deposits of drift dug through for wells in Cottonwood county are as follows:

Selma. C. J. Gabrielson; sec. 10: well, 18 feet; soil, 2; yellow till, 14; blue till, harder, but spaded, 2 feet; water seeps.

Silas Blackmun; sec. 10: well, 22 feet; soil, 2; yellow till, 16; harder blue till, 4; water rose two and a half feet, in very large supply, from a compact and hard gravelly layer at the bottom.

Mountain Lake. Railroad well: dug 67 feet, and bored 5 feet more, stopped by a boulder; obtaining a fair supply of water, but probably all from the upper part of the well.

Lake hotel; Frank Shaubut, proprietor: well, 64 feet; soil, 2; yellow till, 24; blue till, very hard and compact, 38 feet; water rose from the bottom to stand eight feet below the top in twelve hours. This water was good the first year, but afterward gradually became very offensive to smell and taste, so that the well is no longer used. It has wooden curbing, the decay of which was probably the source of its contamination. Another well, four rods east from the last, found soil 2 feet, and yellow till, 24 feet, from which water seeps in good supply and of excellent quality.

Most of the wells at Mountain Lake village are 15 to 35 feet deep. The yellow till varies in thickness from 15 to 30 feet, succeeded by blue till.

A. L. Warren; sec. 34, about a mile east of the depot: well, 45 feet; soil 2; yellow till, 28; yellowish gray quicksand, 15 feet, not passed through; plenty of water. The only other well in this region that finds this quicksand is a neighbor's, some ten rods south.

Delton. S. M. Beaty; N. W. ¼ of sec. 18: well, 28 feet; soil, 2; yellow till, spaded, 18; Potsdam quartzyte, 8; water came in slowly, and holds through the year ten to fifteen feet deep.

This township has two flowing wells, the only ones learned of in Cottonwood county: Joseph S. Naramore's, in sec. 12, 38 feet deep, which has overflowed six years; and Richard Lahart's well, about 16 feet deep, in sec. 34.

Carson. Arthur Minion; sec. 4: well, 22 feet; soil, 2 feet; yellow till, shaded, 10; blue till, much harder, picked, 10; water rose from sand and gravel fifteen feet in as many minutes. Fragments of lignite are often found in the wells of this region.

Lakeside. Lakeside mill (steam flouring mill), at Bingham Lake: well, 100 feet deep; dug 50 feet and bored below, all in till; has forty feet of water. Other wells at Bingham Lake are 15 to 20 feet deep, with plenty of good water. Stoned wells in this township invariably have good water; but those curbed with wood all become poor because of its decay.

Germantown. Colin Buchanan; sec. 20: well, 23 feet; soil, 1 foot; yellow till, spaded, 20 feet, containing a sandy layer at ten feet, which was one and a half feet thick and dipped 45° to the north; gravel and sand, 2 feet, from which water rose six feet in three hours.

Amboy. Henry Stubb; sec. 24: well, 30 feet; soil, 2; yellow till, spaded, 13 feet, its last five feet being most sandy and gravelly, but also the hardest; blue till, likewise spaded, 15 feet; water rose ten feet in one day from gravel and sand. Several pieces of lignite, up to six inches in length, were found in this well. All the wells in Amboy and Delton have good water.

Dale. J. Q. Picket; sec. 2: well, 20 feet; soil, 2; yellow till, spaded, 18; water rose five feet in one day. The majority of the wells in Dale have excellent water; but some, because of wooden curbing, become too offensive to be used.

Windom. R. R. Jenness; well, 70 feet; soil, 2 feet; coarse gravel with many large boulders, 5 feet; till, yellow at top for a few feet, blue below, very hard, 62 feet; white sand, 1 foot, and extending deeper, from which water rose forty feet in a quarter of an hour.

S. S. Johnson; well, 60 feet; soil, 2; gravel, 4; till, as in Mr. Jenness' well, 54 feet; water rose from sand at the bottom fifty-seven feet in two hours, but afterward fell away by soaking into the ground, and now usually stands ten feet below the surface. At the top of the sand from which the water came, were branches of wood and gasteropod shells, probably interglacial, in a thin layer of muck. The water at first was very dark and disagreeable to the taste, like that of a peat swamp (perhaps because of the decay of wooden curbing); but since the first two years it has been of good quality. Within fifteen rods from this well are others that get a large supply of water in gravel at 12 or 15 feet.

Highwater. G. H. Beng; N. W. ¼ of sec. 28: well, 40; soil, 2; yellow till, becoming dark below, mostly picked, 38; water rose seven feet in a half day, from gravel and sand. This is on a rounded swell, twenty or thirty feet above the country all around for several miles.

R. Hogenson; sec. 30: well, 21 feet; soil, 2; yellow till, spaded, 9; much harder blue till, picked, 10 feet; the only water found seeps into the well at the base of the yellow till. This glacial drift at the depth of eighteen feet contained a piece of lignite, three feet long and nine inches thick, weighing about a hundred pounds. Another lump of lignite, nearly equal in size, has been found within about a mile to the southwest, in the bed of Dutch Charley's creek in section 36, Ann.

C. Peterson; sec. 30: well, 35 feet; soil, 3; yellow till, picked, 17; dark, bluish and brownish till, with irony seams and small pieces of lignite, 15 feet; water rose eight feet in one day from sand and gravel at the bottom, not dug through but found to be at least two feet thick.

Storden. Charles Swenson; sec. 22: well, 20; soil, 2; yellow till, 15; blue till, very hard, 3 feet; water rose five feet from gravel and sand at the bottom.

Charles H. Ripke; N. E. ¼ of sec. 26: well, 16 feet; all yellow till, partly hard and picked; to a layer of gravel, about one foot thick, from which water rose six feet in a half day. All the wells upon this highland, underlain by the red quartzyte, have excellent water.

Ann. Hogen Anderson; S. E. ¼ of sec. 24: well, 18 feet; soil, 2; yellow till, picked, 16 feet; the water seeps.

Rose Hill. Jacob Tabert; sec. 20: well, 42 feet; soil, 2; yellow till, spaded, 32; gravel and sand, 1 foot; blue till, harder than that above, 7 feet, and extending below; water comes sparingly from the gravel and sand, failing in very dry seasons.

Jacob Wall; S. W. ¼ of sec. 28: well, 20; soil, 2; yellow till, 18; water rose eight feet in two hours from sand at the bottom.

Wells in Jackson county.

Wisconsin. John M. Utter; N. W. ¼ of sec. 21: well, 72 feet, the deepest in this township; soil, 2 feet; yellow till, 15 feet; blue till, not harder than the yellow till, but worse to dig, because of its tenacity, 55 feet; water comes slowly from sandy streaks, a half inch to two inches thick, in the blue till, especially in the last twenty feet.

Des Moines. Joseph Thomas; S. E. ¼ of sec. 24, about a mile east of Jackson: well, 33 feet; soil, 2; yellow till, spaded, 10; harder blue till, picked, 21; water rose to ten feet below the top in one day. Wells in this vicinity, on the upland above the Des Moines valley, are 15 to 30, and rarely 50 feet deep, all in till.

Jackson. G. C. Chamberlin: well, 130 feet deep, situated about 30 feet above the Des Moines river, below which it thus goes 100 feet, this, added to the depth of this valley, being about 200 feet below the original surface of the drift-sheet; this well, below its 2 feet of soil, was all till, yellowish above, but mainly bluish, enclosing dark sandy streaks, but no considerable layers of sand or gravel and no water, and having throughout some intermixture of stones and gravel, one boulder weighing about fifty pounds being found at the depth of a hundred feet. Sticks of wood and small gasteropod shells were obtained at about the same depth. This well became filled with surface water, but was not used, and has been filled up. At a point twenty feet from the foregoing, another well has been dug 26 feet deep, in till, mostly yellow but blue below, yielding a plenty of water.

Most of the wells at Jackson find an ample supply of excellent water at depths from 20 to 30 feet.

Delafield. M. A. Foss; sec. 18: well, 22 feet; soil, 2; yellow till, 10; much harder blue till, 10; water rose six feet in three hours, from a vein of sand three inches thick.

Heron Lake. M. A. Foss; at Lakefield, in the S. W. ¼ of sec. 33: well, 21 feet; soil, 2 feet, yellow till, picked, 16; quicksand, 3 feet; water is five feet deep.

Hunter. Railroad well, 68 feet deep; in the N. W. ¼ of sec. 3, one mile east of Lakefield: soil, 2 feet; yellow till, about 20; harder blue till, 18; gray quicksand, 4 feet; blue till, 24 feet, and extending deeper; water came in sandy steaks in the last three feet, and rose in three days to be forty feet deep.

Minneota. William Austin; S. W. ¼ of sec. 25: well, 27 feet; soil, 3; yellow till, spaded, 24; water seeps, filling the well usually to a depth of nine feet.

Weimer. The deep railroad well at Heron Lake, penetrating to the Potsdam sandstone, has been described on page 503. The common wells of Heron Lake are 10 to 20 feet deep, finding 2 to 4 feet of soil, and yellow till, which is spaded, for all below. The water is naturally good, but by the decay of wooden curbing is often made objectionable to both taste and smell.

Sioux Valley. A. McCulla; sec. 34: well, 36 feet; soil, 3; yellow till, picked, 17; sand and gravel, 4 feet; blue till, much harder than the upper till, 12 feet; water rose ten feet in two days from springs in the blue till.

La Crosse. R. Nelson; sec. 13: well, 30 feet; soil, 2; yellow till, 11; yellow "hardpan, almost as hard as rock," 17 feet; water rose five feet from sand at the bottom, but the well is sometimes filled to the top with surface-water.

Ewington. Nelson Jordan; N. W. ¼ of sec. 30: well, 30 feet; soil, 3; yellow till, spaded, 12; darker and harder gray till, picked, 15; water seeps from the lower part of the yellow till, filling the well to a depth of fifteen feet.

Round Lake. J. Walker; sec. 14: well, 19 feet; soil, 2; sand, 4 feet; yellow till, spaded, 8 feet; blue till, very tenaceous, but not harder than the yellow till, 5 feet; water comes in the lower part of the yellow till, usually standing ten feet deep.

The drift contains a considerable proportion of the carbonates of lime and magnesia, giving a very productive soil, and making the water of springs and wells hard; but it supplies no noticeable admixture of the bitter and alkaline ingredients which are found abundantly in the water of some districts farther west.

Analysis of the water of Heron lake.

A sample of the water of Heron lake, collected in June, 1882, was analyzed by Mr. W. A. Noyes, with the following result:*

Chemical series, No. 128. Composition of residue from evaporation.

	Parts per 1,000,000.	Percentage.	Grains per gallon.
Silica	7.1	2.6	0.41414
Alumina and oxide of iron	1.7	0.6	0.09916
Carbonate of lime	102.7	37.7	5.99049
Sulphate of lime	47.9	17.6	2.79241
Nitrate of lime	5.0	1.8	0.29165
Carbonate of magnesia	76.3	28.0	4.45058
Carbonate of lithia	traces.		
Sulphate of potash	8.0	3.0	0.46664
Nitrite of potash	traces.		
Sulphate of soda	18.5	6.8	1.07911
Chloride of sodium	5.1	1.9	0.29748
Total	272.3	100.00	15.88166

*Eleventh annual report.

Iodine, bromine and phosphoric acid, absent. Test with potassium permanganate showed 2.6 parts oxygen consumed by organic matter per 1,000,000 water. Hardness, 22 degrees. The water is notable for excessive hardness, due to sulphate of lime and carbonates of lime and magnesia.

Travertine. Small deposits of travertine, or calcareous tufa, made by springs that issue from the drift, often called "petrified moss" from its having incrusted moss and leaves, thereby preserving their forms, occur in Jackson county on the east side of the ravine of a creek near the center of section 26, Petersburg; and on the southeast side of a creek near the center of section 15, Des Moines, about two miles northwest from Jackson and some 50 feet above the Des Moines river.

MATERIAL RESOURCES.

Agriculture must be the chief industry and source of wealth to Cottonwood and Jackson counties. Their soil, their narrow belts of timber beside rivers and lakes, the natural pasturage and plough-land of their broad expanse of prairie, have been treated of on a former page of this report. Items to be noticed here are water-powers, building stone, lime, bricks, and peat.

Water-powers. The only water-power used in Cottonwood county is that of the Windom mills, on the Des Moines river, owned by Collins & Drake; head, nine feet; three run of stone; a large flouring mill.

Another excellent water-power is available on this river a mile below Talcott lake, where a dam may be built which would make this lake a reservoir, raising it three or four feet.

In Jackson county the Des Moines river supplies three powers, all used by flouring mills. These are the Brown brothers' mill, in section 28, Belmont, having a head of about nine feet; the Des Moines Valley mills, owned by E. P. Skinner, in section 10, Des Moines, three miles northwest from Jackson, with a head of about eight feet; and the Jackson mills, at Jackson, owned by J. W. Hunter, with head of nine feet and three run of stone.

Building stone. The Potsdam quartzyte of northern Cottonwood county has been somewhat quarried, as already mentioned, in sections 23 and 25, Selma, in section 8, Delton, and in section 6, Dale. Owing to the very hard and gritty nature of this rock and its tendency to rhomboidal fracture, it supplies only rough blocks, seldom of large dimensions, yet quite suitable for common foundations and walls, and for the masonry of culverts and small bridges.

Lime. Boulders of magnesian limestone, gathered from the drift, are burned for lime by Lars Rasmusson, in section 11, Des Moines, about two miles north of Jackson. These yield white lime, of which he usually burns two kilns, each containing about a hundred bushels, yearly. It is sold at forty to fifty cents per bushel. Other lime-burners of Jackson county are Andrew Monson, in Belmont, and Ole Solem, in Christiana. No lime is made in other parts of this county nor in Cottonwood county, not because of scarcity of limestone boulders, which are plentiful, but because this region has little timber, fuel being consequently too expensive for this use.

On the southwest side of Spirit lake, white lime is burned from boulders by A. Kingman, who sells it at seventy-five cents per bushel, oak wood being worth $5 per cord.

Bricks. The only brick-making that has been done in these counties is by Major H. F. Bailey, at the west side of the Des Moines river about a quarter of a mile south of Jackson. A kiln of bricks was made here about ten years ago, but none afterward till 1879, when another kiln of 100,000 was burned. These are red bricks of good quality, and are sold for $8 per M. No sand is mixed with the clay, which is dug a few rods northeast from the kiln, at a hight of six to twelve feet above the river. The soil at the surface is removed to a depth of two or three feet, and the next five or six feet are yellow clay, free from gravel, and levelly stratified.

Peat. An exploration of the peat of southern Minnesota was made in 1873 by Prof. Winchell, whose descriptions, in the second annual report of this survey, embrace the following notes pertaining to Cottonwood county.

Mountain Lake. "Near Mountain Lake station, on land of A. A. Soule, a coarse turf-peat covers the surface of a dry slough to the depth of ten to eighteen inches. Near a spring, along the side of this slough, which is tributary to Mountain lake, the surface quakes and the peat is thickest."

"Around Mountain lake the land is low, and is flooded in the wet season. This low land contains considerable peat for some distance out toward the lake. The surface shakes under the tread. It is covered in the summer with a tall grass, which much resembles the wild rice, yet the softest places, where the peat occurs purest, are furnished with a short grass. Peat here is two or more feet thick. The land examined is owned by A. A. Soule." This peat, taken two feet below the surface, analyzed by Prof. S. F. Peckham, was found to contain, when air-dried, 8.69 per cent. of hygrometric water, 31.90 of organic matter, and 59.41 of ash (No. 1).*. He estimated a hundred pounds of it to be equivalent to forty-two pounds of oak wood.

Lakeside. "Sec. 24; land of S. O. Taggart. In a dry slough, covering many acres, the surface consists of a turf-peat, to the depth of about a foot, passing into black mud and sand. The very top is fibrous and even spongy." The analysis of this, by Prof. Peckham, gave 10.80 per cent. of hygrometric water, 16 33 of organic matter, and 72.87 of ash (No. 2); a hundred pounds being equivalent to twenty-one pounds of oak wood.

Peat is again found farther west in the same township, also on "land of S. O. Taggart, 5 miles east of Windom. In a narrow spring ravine, where water stands or slowly runs throughout

*Numbers refer to the table of analyses of these peat ashes, by Prof. Peckham, on page 516.

the year, and near its head, a thickness of a foot or more of turf-peat may be taken out over a space of a few rods square. It is thicker and better near the head of the ravine than at any other point, owing to the more constant protection of the grass and roots from the prairie fires."

"Other similar peaty ravines occur on land of Miss Ellen Imus, near that of Mr. Taggart."

Great Bend. "N. E. ¼ of sec. 38; land of A. J. Hall. In a turfed ravine, where water stands or slowly oozes through the turf, sloping gently toward the Des Moines river, a turf-peat may be taken out to the depth of a foot or twenty inches. The belt containing peat is from ten to twenty feet wide, and similar in its situation to that of Mr. S. O. Taggart, but more extensive. It shakes under the feet for three or four feet about, but a horse can walk safely over it in most places in the dry season. Indeed, it is mown for hay every year. An irony scum lies on the ground and on the grass stalks. The peat itself is a turf, but contains shells and some grit.

"Another similar ravine is on the same claim. Numerous others might be located along the ravines that cross the Des Moines bluffs."

"N. E. ¼ of sec. 30; land of Arthur Johnson. Turf-peat occurs in a ravine, twenty feet over, where fuel can be taken out."

Amo. "Sec. 13. A slough that shakes is in the valley that forms the prolongation of the Des Moines valley northwestward above the great bend a few miles above Windom, and has a spongy peat about two feet in thickness, with black mud below. It covers six or ten acres." This peat, taken two feet below the surface, was found by Prof. Peckham to contain, when air-dried, 9.85 per cent. of water, 42.63 of organic matter, and 47.52 of ash (No. 3); a hundred pounds of it being equivalent to fifty-six pounds of oak wood.

"In the same prolongation of the Des Moines valley, on K. K. Peck's land, two miles above the bend of the Des Moines, is a thickness of two or three feet of peat. This valley seems to hold about two feet of peat along a considerable area through the middle, and would supply a great quantity. It is not of a superior quality, but might be very useful to the settlers." Professor Peckham's analysis of peat taken here two feet below the surface gave 13.58 per cent. of hygrometric water, 53.28 of organic matter, and 33.14 of ash (No. 4); a hundred pounds of this air-dried peat being considered equal in value to seventy pounds of oak wood. Peat from this place three feet below the surface yielded 11.03 per cent. of water, 41.67 of organic matter, and 47.30 of ash (No. 5); a hundred pounds of it being about equivalent to fifty-five pounds of oak wood.

Springfield. "The land of George C. Bush, sec. 6, holds a peaty turf, in a dry slough near the mouth of a ravine, in considerable abundance."

South Brook. "Sec. 2. Side-hill peat occurs on a gentle slope over the space of a few rods, having a thickness of a foot and a half or two feet. Such peaty patches appear also on the opposite side of the main valley, arising from the issuing of springs that keep the surface moist, while the lower land in the same slough is dry and hard. This peat is not free from sand. It also smells strongly of sulphuretted hydrogen."

"Peat exists, according to Mr. John Crapsey, three miles north of Talcott lake."

Four localities of peat are reported by Prof. Winchell in Jackson county, as follows:

Delafield. "S. W. ¼ of sec. 4; land of Rev. Edward Savage. A good moss peat occurs here in a slough, having an average thickness of two feet, over an area of ten acres or more. The slough is confined between bluffs that appear to be entirely composed of drift, and has a feeble drainage into a small lake. The surface is mostly covered with a short grass, but also with chair-bottom rushes. Some patches also of *Typha latifolia* are seen. No horsetail rush appears. In passing over the surface of this marsh it quakes five or six feet around, and the auger hole is immediately filled with water to the top. Below eighteen inches (even sparingly in ten or twelve inches) shells begin to be rather common, and the auger next brings up a black mud with many shells. The most of this peat is made up of the peat moss, though at a depth of a foot or eighteen inches it contains grass roots and other fiber." This peat from eighteen inches below the surface, by Prof. Peckham's analysis, contains, when air-dried, 10.22 per cent. of hygrometric water, 64.48 of organic matter, and 25.30 of ash (No. 6); a hundred pounds of it being worth as much for heating as eighty-five pounds of oak wood.

Weimer. "Sec. 31. A thin deposit of about six inches of peat covers about half an acre, mostly under water. This is the only peat that can he found in the vicinity of Heron Lake."

Wisconsin. "On the S. E. ¼ of sec. 27, Mr. W. V. King correctly describes a peat marsh."

Round Lake. "Sec. 20; land of Everett W. Scovill. Peat here covers four or five acres, and is associated with a deposit of bog iron ore."

Analyses of peat ashes.

The ashes of the specimens of peat mentioned as analyzed by Prof. Peckham, were also subjected to analysis by him, and their composition was found to be as follows:

	1.	2.	3.	4.	5.	6.
Silica	64.27	88.28	81.99	72.64	64.37	68.06
Carbon	2.80	1.32	1.14	0.75	0.16	1.34
Iron oxide and iron phosphate	9.75	6.34	9.39	15.46	21.41	8.82
Lime	15.75	0.84	4.84	5.87	6.26	5.03
Magnesia	1.77	0.51	0.60	trace	1.54	4.81
Sulphuric acid	3.69	trace	1.12	5.73	7.58	6.53
Undetermined	1.97	2.71	0.92	....	....	5.41
	100.00	100.00	100.00	100.45	101.32	100.00

Traces of phosphoric acid were found in all; and of alkalies in Nos. 2 and 3. Carbonic acid was present in considerable amount in Nos. 1 and 6, and in very small amount in No. 2.

ABORIGINAL EARTHWORKS.

Though artificial mounds probably exist in these counties, none were observed during their examination.

In the north part of section 17, Spirit Lake, about a mile south of the state line, an interesting group of six or eight mounds, of the usual round form and two to four feet high, was seen beside the road, at the northwest side of Spirit lake and a short distance south of Little Spirit lake, on land fifteen to twenty-five feet above them.

GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA
MURRAY AND NOBLES
COUNTIES
BY WARREN UPHAM
Explanation
Modified Drift, Gravel and Sand
Till
Smoothly undulating or rolling
More prominently rolling
Knolly and hilly
Terminal Moraines
Contour Lines are shown approximately for each 50 feet above the sea
LYON COUNTY
REDWOOD CO.
PIPESTONE COUNTY
COTTONWOOD COUNTY
ELLSBOROUGH
SKANDIA
LAKE SARAH
SHETEK
HOLLY
CAMERON
LOWVILLE
MASON
MURRAY
DOVRAY
CHANARAMBIE
LEEDS
CENTER
LIME LAKE
DES MOINES RIVER
MOULTON
IONA
BONDIN
BELFAST
MURRAY
T.108
T.107
T.106
T.105
Redwood R.
Current Lake
Iron L.
Lake Iva Delle
Sources of Des Moines River
Bear Lakes
TIBBETTS LAKE
Long L.
L. Maria
Clear L.
James L.
L. Isabella or Round L.
L. Fremont
Lake Sarah
LAKE SHETEK
Plum Cr.
Buffalo L.
Long L.
CURRIE
Clear Lakes
Lake Beauty
Star L.
L. Eliza
Beaver Creek
HADLEY
Summit L.
LIMESTONE
Okseda
Sand L.
Buffalo Ridge
BLACK HILLS DIVISION OF C. ST. P. M. & O. RY.
Lime L.
AVOCA
DES MOINES RIVER
SOUTHERN MINNESOTA DIVISION
IONA
Badger L.
Center L.
Chanarambie Cr.
L. Cora Belle
Talcott L.

CHAPTER XVII.

THE GEOLOGY OF MURRAY AND NOBLES COUNTIES.

BY WARREN UPHAM.

Situation and area. Murray and Nobles counties (plate-pages 21 and 22) lie in the southwest part of Minnesota, the former being in the second tier of counties north of the Iowa line, from which it is separated by the latter. The east boundary of these counties is 210 miles west from the Mississippi river at La Crosse; their extent from east to west is 30 miles; and from their west boundary to the line between Minnesota and Dakota is 20 miles, this width being occupied by Pipestone and Rock counties. The distance from Minneapolis and Saint Paul southwest to Currie in Murray county, measured in a straight line, is about 140 miles; and to Worthington in Nobles county, about 155 miles.

The most important towns and villages of Murray county are Currie, on the Des Moines river near the foot of Lake Shetek, in Murray township; Avoca in Lime Lake township, and Hadley in Leeds township, on the Black Hills branch of the Chicago, St. Paul, Minneapolis & Omaha railway; and Fulda in Bondin township, on the Southern Minnesota division of the Chicago, Milwaukee & St. Paul railway. The county seat and largest town of Nobles county is Worthington, on the Saint Paul & Sioux City (C., St. P., M. & O.) railway. Hersey and Bigelow are small villages on this line of railroad; and Rushmore and Adrian are considerable towns on its Sioux Falls branch.

Each of these counties is a rectangle thirty miles long from east to west and twenty-four miles wide; so that together their extent from north to south is forty-eight miles. Murray county has an area of 721.56 square miles, or 461,801.20 acres, of which 16,909.93 acres are covered by water. The area of Nobles county is 727.66 square miles, or 465,704.16 acres, of which 10,827.04 acres are covered by water.

SURFACE FEATURES.

Natural drainage. The Des Moines river rises at the west side of Murray county, and flows east and southeast across this county. Springs and two or three lakelets on the east side of the highest ridge of the Coteau des Prairies, partly lying beyond the west line of Murray county in the east edge of Ætna and Rock townships in Pipestone county, are the heads of the Des Moines river. The greater part of Murray county is drained by this stream. Its most important tributary in this county is the outlet of lake Shetek, which unites with it about a mile west of Currie. The Des Moines river above this affluent is commonly known as Oksida or Beaver creek. About a mile east of Currie, nearly at the center of Murray township, the Des Moines turns southeast, and holds this course to the east line of the county. Its length in Murray county, not including small bends, is forty miles.

The portions of Murray county which lie outside the Des Moines basin, are in its northwest. northeast and southwest corners. At the northwest, the head-stream of Redwood river, rising in Ætna, the northeast township of Pipestone county, flows to the east and north through Ellsborough, receiving the drainage of some thirty square miles in this township. The northwest part of Skandia, the township next to the east, sends its waters into the head-stream of the Cottonwood river.

Holly. the most northeast township of this county, and the northeast half of Shetek township on the west, and of Dovray on the south, and the northeast corner of Des Moines River township, are tributary to the Cottonwood river by Plum creek, and in small part by Dutch Charley's and Highwater creeks.

Southwest of the Des Moines basin, Moulton, nearly all of Chanarambie, and portions of the townships east of these, are drained by the head-streams of Chanarambie and Champepadan creeks, sending their waters into the Rock river, and by that to the Big Sioux and Missouri.

The areas of Murray county thus belonging to four river basins are approximately as follows: within the basin of the Des Moines river, 520 square miles; of the Redwood river, 30 square miles; of the Cottonwood river, 80 square miles; and of the Rock river, 90 square miles.

The most noteworthy *lakes in Murray county* are the following: lake Shetek, the largest, about seven miles long from north to south, and varying from a quarter of a mile to one and a half miles in width, quite irregular in outline with numerous bays and headlands, and containing islands (accidentally omitted from plate 22), its northwestern part being an arm or bay nearly three miles long and an eighth to a third of a mile wide, known as the Inlet; lake Sarah, two miles long from northwest to southeast and about a mile wide, at the center of Lake Sarah township, about two miles west of the Inlet of lake Shetek; lake Maria, extending northwest from lake Sarah, two miles long and a half mile wide; the group of the Bear lakes, four in number, from one mile to two and a half miles in length, lying in the north part of Lowville and the south edge of Skandia, the most southern of the group being recently called Tibbett's lake; Lime lake, in the township of this name, extending two miles west from Avoca; and Buffalo, Duck and Star lakes and lake Eliza, which with others form a northwest to southeast series, three to four miles northeast from the Des Moines river and approximately parallel with it.

Nobles county is divided to the basins of the Des Moines, Little Sioux and Rock rivers. At the northeast an area of about 240 square miles is drained eastward by Jack and Okabena creeks into Heron lake and the Des Moines river. Elk creek, rising in Elk township, flows east across the south part of Hersey, and joins Okabena creek a short distance after crossing the east line of Nobles county.

The portion tributary to the Little Sioux river and thus to the Missouri, is principally drained by Ocheyedan or Ocheeda creek, and embraces about 90 square miles.

The remainder of this county, including about 390 square miles or slightly more than half its area, is tributary to the Rock river, by Champepadan, Elk and Kanaranzi creeks and the Little Rock river; making, with the tract in the Little Sioux basin, 480 square miles, approximately, drained to the Missouri river.

Lakes in Nobles county. In the western third of Nobles county and thence westward, there are no lakes, or they are very rare and of small area. This region lies on the southwest side of the outer moraine of the last glacial epoch, at which time it lay beyond the boundaries of the ice-fields, though in an earlier cold epoch it was deeply covered by ice and is overspread with its unmodified drift or till. Farther east, this county has frequent lakes. The West and East Graham lakes, respectively two and three miles long, both trending southwesterly, give name to Graham Lakes township; and another township is named from Indian lake, in its sections 27 and 34, about a mile long from north to south, with a maximum depth of fifteen feet. West Okabena lake, nearly two miles long and about a half mile wide, lies at the west side of the town of Worthington. This and the next are not tributary to Okabena creek, from which, however, the West Okabena lake is separated by only a low, marshy tract of small width, and an ice-heaped ridge of gravel and sand along which a road is built; but at its stage of high water in spring this lake has its outlet into the East Okabena lake, of nearly as great area, close east of Worthington, which at such time overflows southward into lake Ocheeda, and through this into Ocheyedan creek. Lake Ocheeda is about six miles long, trending from northeast to southwest, reaching from section 32, Lorain, to the center of Bigelow, with a width that varies from an eighth of a mile or less to a half or two-thirds of a mile. Mr. A. Miner, civil engineer, of Worthington, reports the maximum depth of West Okabena lake to be twenty-five feet; of the East Okabena lake, fifteen feet; and of Lake Ocheeda, in its northeast part, twenty feet. West Okabena lake is estimated to be twelve feet below the railroad at Worthington station, or 1,570 feet above the sea, and this is one foot above East Okabena lake. Lake Ocheeda is estimated by Mr. Miner to be four or five feet lower, being thus 1,565 feet, very nearly, above the sea.

Topography. The Coteau des Prairies in Murray and Nobles counties declines in hight from northwest to southeast. In Nobles county the most elevated portion of this highland reaches from the south and southwest part of Indian Lake township and the east part of Bigelow, north-northwesterly through the northeast edge of Ransom, southwestern Worthington, the northeast half of Dewald, the southwestern part of Summit Lake, the northeast part of township **103**, range **42**, and through the middle of Willmont.

This crest of the Coteau des Prairies is a belt from three to five miles in width, composed of massive swells and smoothly rounded, moderately sloping hills of till, 30 to 50 and rarely 75 to 100 feet above the intervening hollows. Their trends are more frequently from north to south or southeast than in other directions; but this approach to uniformity in trend is seldom very noticeable, and their order of arrangement and the form and connected outlines of this range of highland show much variety of contour. At a distance of several miles it generally presents the usual aspect of any moderately rolling prairie, appearing to be of about uniform hight; and upon nearer approach, and in crossing this belt, it is seen to consist only of broad and smooth undulations and swells, more or less sculptured, especially on the southwest side, by streams. A branch one to two miles in width, extends from this belt northward through the east part of Summit Lake township, including within its area the lake of this name. Here, and northerly into Murray county, this most prominently rolling and highest part of the Coteau des Prairies in this latitude forms the watershed between the basins of the Mississippi and Missouri rivers. Its connection with the roughly hilly and knolly outer terminal moraine, traced from central Iowa northward to Spirit Lake and thence westerly to Ocheyedan mound, south of this county, and still more prominently exhibited along the crest of the Coteau des Prairies in western Murray county and thence northwesterly to the Head of the Coteau, shows that the border of the ice in the last glacial epoch extended to this belt of massively rolling till; but though it thus represents the outer moraine of that epoch, it nowhere in Nobles county has such roughly broken knolls, and small, short and steep ridges, as are common along nearly all the rest of this morainic line.

Farther westward, the surface of Nobles county is in swells of till, which trend mostly from north to south, more massive and smoother than those which form the outer terminal moraine, and of about the same elevation; or in nearly level, equally high plateaus of till, as at Rushmore, ten miles west of Worthington, and in the southwest part of Little Rock. Northeast from the morainic belt, there is a descent of 50 to 75 feet within one or two miles, and thence a smooth, slightly undulating area of till extends with an imperceptibly descending slope northeastward twenty miles to the inner moraine beyond Heron lake and the upper part of the Des Moines river. The valleys cut by the creeks which cross this expanse are only 10 to 20 feet deep, and the lakes, sloughs and lowest depressions are about the same amount below the highest land of their vicinity to which the ascent from the lake-shores is usually in prolonged, gentle slopes. On the Saint Paul & Sioux City railroad the slope of this broad, approximately flat area of eastern Nobles county is about 100 feet in the eight miles between Worthington and Hersey, thus averaging a descent to the northeast of twelve feet per mile.

In western Murray county the outer or first terminal moraine rises in a conspicuous series of hills, knolls and ridges of till, roughly broken and irregularly grouped, separately of small size and hight, but together forming an elevated belt from 50 to 100 feet or more above the smooth area of till on each side. It includes the west edge of township **105**, range **42**, being here only from one-fourth of a mile to one mile wide; the south two-thirds of Leeds; the northeast two-thirds of Chanarambie, its most conspicuous portion in this county being Buffalo ridge, 100 to 150 feet high, trending from southeast to northwest, in sections 21 and 16 of this township; the west half of Cameron; and the southwest corner of Ellsborough. Its area in Leeds, extending six miles east from the main course of the series, and surrounded on the south, east and north by a lower expanse of smooth, slightly undulating till, may be a medial branch. The material of this roughly hilly belt is till, but it differs from that of the gently undulating region through which it lies in containing, and being overstrown with, abundant boulders and pebbles, principally of granite, syenite, gneiss and schists, but also including many of limestone. Many of the hollows enclosed among these knolls and ridges are bowl-shaped or of irregular form, without outlet, and occasionally contain sloughs and lakelets.

Moulton, the most southwest township of Murray county, and the west edge of Chanarambie, lie on the west side of this moraine, and have the smooth, massively rolling surface which prevails in the west part of Nobles county, the higher portions of this tract being 50 or 75 feet above the water-courses and twice this amount below Buffalo ridge.

Eight miles northeast from the outer morainic belt, in sections 8 and 5, Mason, is a remarkable plateau of till, with its top nearly level and covering one and a half square miles, from which there is a descent of about 200 feet in three miles east to Lake Shetek, and about 100 feet in the same distance west to Bear lakes. Smooth, prolonged slopes descend from this highland on all sides; and, with the exception of this area, a gently undulating and often nearly flat belt of till, increasing from ten to twenty miles in width, extends from northwest to southeast through the central part of Murray county. Beaver creek crosses this area in a channel usually 20 to 40 feet below the general surface, and the frequent lakes and sloughs lie 15 to 25 feet below the average hight of their vicinity. Avoca and Fulda are situated upon this slightly undulating, approximately flat expanse, with no hills or notable elevations within view, excepting the morainic hills in Leeds, distant ten to fifteen miles westward. Though this region appears to be level, its surface has a somewhat uniformly descending slope of eight or ten feet to the mile from west to east, as shown by railroad surveys. In the distance of about twelve miles from Avoca southeast to Dundee, the descent is 90 feet; and in nine and a half miles easterly from Iona to Fulda the descent is 100 feet. the latter town being 62 feet above De Forest, and 105 feet above the surface of Heron lake, situated respectively six and a half and fifteen miles farther southeast. The Des Moines river, flowing along the east side of this area, has excavated a valley about 75 feet deep, and from a quarter of a mile to one mile wide, to which the descent is mostly by moderate slopes.

In northeastern Murray county the second morainic belt, two to four miles wide, constituting the northeastern border of the Coteau des Prairies extends from lake Eliza northwest by Star, Duck and Buffalo lakes and the northeast side of lake Shetek, occupying the northeast part of Des Moines River township, southwestern Dovray, northeastern Murray, the southwest half of Shetek, and the northeast part of Lake Sarah. It is distinguished from the slightly undulating areas of till at each side by its more frequent boulders and its more rolling and occasionally hilly contour; but it scarcely anywhere exhibits the rough surface which characterizes the greater part of this series of drift accumulations. The summits of its swells are 30 to 40 feet above the intervening depressions, sloughs and lakes; nearly the same above the general level on each side; and from 75 to 100 feet above the Des Moines river, and 40 to 50 feet above lake Shetek.

The only part of the second moraine in this county which rises in mounds that are conspicuously seen at a distance of several miles, is in the northeast corner of Murray township, upon an area from a half mile to one mile wide, extending two miles northwesterly from Buffalo lake; but its hills here are only 30 to 50 feet above the average hight of the range. Along the northeast side of the northwest arm of lake Shetek, commonly called the Inlet, are frequent small patches where boulders nearly cover the ground, mostly forming knolls from three to five or ten feet high, and occurring from the lake shore to twenty-five feet above it.

The portion of Murray county northeast of this second moraine is drained into the Cottonwood river. It consists of till, with a smoothly undulating or moderately rolling surface, the highest parts being generally 10 to 30 feet above the lowest. The only considerable stream in this northeast corner of the county is Plum creek, which has eroded a remarkable valley, 40 to 50 feet deep, bordered by steep bluffs, sloping from 30° to 45°, along a distance of five miles, from the east side of section 18, Holly, to the black walnut grove which borders this stream in the south edge of Redwood county. This valley receives numerous short tributary ravines.

Elevations, St. Paul & Sioux City division, Chicago, St. Paul, Minneapolis & Omaha railway.
From profiles in the office of T. P. Gere, superintendent, St. Paul.

a. *Main line.*

	Miles from St. Paul.	Feet above the sea.
Hersey (Brewster)	170.0	1485
Elk creek, water	171.5	1473
Summit, grade	178.2	1588
Worthington	178.4	1582
East Okabena lake, water	178.5	1569
Junction of Sioux Falls branch	181.8	1633
Summit, grade	182.3	1654
Summit, grade, highest point on line from St. Paul to Sioux City	184.6	1656
Bigelow	187.8	1631
State line	188.3	1643

b. *Black Hills division (Woodstock branch).*

Dundee	168.4	1443
Avoca	180.1	1533
Summit, grade	201.1	1850
Summit, grade	201.9	1849
Murray and Pipestone county line, grade	202.5	1839

c. *Sioux Falls branch.*

Junction	181.8	1633
Summit, grade	184.5	1691
Little Rock river, water	187.4	1629
Little Rock river, bridge	187.4	1649
Rushmore	190.1	1665
Adrian	196.9	1538
Kanaranzi creek, water	198.0	1499
Kanaranzi creek, bridge	198.0	1511
Summit, grade	199.5	1569

Elevations, Southern Minnesota division, Chicago, Milwaukee & St. Paul railway.

	Miles from La Crosse.	Feet above the sea.
De Forest	239.5	1446
Fulda	246.1	1508
Iona	255.6	1608
Summit	259.4	1705
Entering Chanarambie valley	264.0	1634

The highest land in Murray county is Buffalo ridge, in Chanarambie township, the top of which is about 1950 feet above the sea. Other portions of the outer terminal moraine, in this and Cameron townships, are from 1800 to 1900 feet in altitude, and it is crossed by the railroad to Woodstock at a hight of 1850 feet. At the northeast corner of Moulton this range is intersected by Chanarambie creek, which is here more than 300 feet below Buffalo ridge. The next six miles of this moraine southward are a comparatively narrow and inconspicuous belt of gravelly and rocky knolls and small ridges of drift, 1700 to 1750 feet above the sea, or 75 to 125 feet above the Chanarambie valley.

Des Moines river has its sources at an elevation of 1800 to 1900 feet above the sea. Lake Shetek, and this river at its outlet, are about 1475; and its point of exit from Murray county is estimated to be about 1400 feet above the sea.

The lowest land of Murray county is the northeast part of Holly, 1250 to 1300 feet above the sea, making the extremes of hight in this county differ by seven hundred feet.

The highest portions of Nobles county, lying in Willmont, in township **103**, range **42**, and in Summit Lake and the north part of Dewald, are 1700 to 1725 feet above the sea. Champepadan and Kanaranzi creeks cross the west line of this county at about 1475 and 1450 feet above the sea. Little Rock river has an elevation of about 1475 feet, and Ocheyedan creek is about 1550 feet above the sea, at the Iowa line. The lowest land in Nobles county is where Jack creek crosses its eastern boundary, at a hight of about 1420 feet above the sea, some three hundred feet below the crests of the morainic belt.

Estimates of the average hights of the townships of Murray county are as follows: Holly, 1400 feet above the sea; Dovray, 1480; Des Moines River, also 1480; Belfast, 1460; Shetek, 1490; Murray, 1525; Lime, 1525; Bondin, 1530; Lake Sarah, 1540; Mason, 1575; Center, 1590; Iona, 1610; Skandia, 1600; Lowville, 1640; Leeds, 1700; T. **105**, R. **42**, 1700; Ellsborough, 1725; Cameron, 1775; Chanarambie, 1800; and Moulton, 1660. From these figures the mean elevation of this county is found to be 1590 feet, very nearly, above the sea.

The townships of Nobles county, with estimates of their average hight, are as follows: Graham Lakes, 1460; Hersey, 1500; Lorain, 1560; Indian Lake, 1580; Seward, 1530; Elk, 1575; Worthington, 1625; Bigelow, 1625; Bloom, 1625; Summit Lake, 1660; Dewald, 1660; Ransom, 1600; Willmont, 1700; T. **103**, R. **42**, 1650; Olney, 1580; Little Rock, 1540; Leota, 1640; Lismore, 1600; West Side, 1550; and Grand Prairie, 1500. The mean elevation of Nobles county above the sea, derived from these estimates, is 1588 feet, being almost identical with that similarly obtained for Murray county.

Soil. These counties have nearly the same character as to soil and agricultural value with all southwestern Minnesota, being very fertile and well drained, yielding bountiful harvests of wheat, corn, oats, potatoes, and the small garden fruits, and capable of producing every crop that belongs in this latitude. Stock-raising and dairying are also beginning to be an important part in the resources of the farmers through all this region.

At the surface is a black soil, from one to three feet deep, being usually about two feet, thus colored by vegetable decay, and consequently enriched for the nourishment of the new vegetation of successive years. Otherwise this soil is like the yellow subsoil, both being glacial drift. Everywhere a sufficient proportion of the carbonates of lime and magnesia are present to supply the best conditions for the cultivation of grain, and also to make the water of wells and springs hard; but the sulphate of magnesia, which occasionally appears as a white efflorescence where sloughs have dried up, is yet only a comparatively small ingredient of the soil and very rarely gives any perceptible taste to the water of wells.*

The only areas unsuitable for cultivation are frequent sloughs, valuable for their marsh hay; the steep banks and bluffs of creeks and rivers; and some portions of the morainic belts, which are so knolly and strown with boulders as to forbid ploughing, but are well adapted for pasturage.

Timber and prairie. Neither of these counties has any extensive tracts of timber, which occurs only on the borders of lakes and along the larger streams. In such situations it is wholly or partly protected from the annual prairie fires, and is supplied with sufficient moisture to enable it to maintain an existence. With double the rainfall that this region has, it would probably become covered with timber notwithstanding the partial checks which its spread must sustain from these fires; and with the climate continuing as now, if fires were prevented, a forest would similarly extend itself outward from the lakes and rivers over the whole of this district and of this state.

In Murray county the principal tracts of timber, consisting of elm. bass, bur oak, ash, poplar, cottonwood, wild plum, and other species, are in the space, nearly a mile square, enclosed by the Bear lakes; on the shores of lakes Sarah and Shetek, especially on the northeast side of the latter, in the vicinity of Fremont lake; and along Beaver creek and the Des Moines river. A grove of twenty or thirty acres, now wholly cut for fuel, was found by the first immigrants on the Chanarambie creek, in section 2, Moulton, and was named the "lost timber," because it was the only considerable patch of woodland in that region, the nearest to it being at Bear lakes, ten miles to the north.

Nicollet says of his trip through this county:† "I pitched my tents, during three days, about the group of Shetek or Pelican lakes, that occupy a portion of the space forming the Coteau des Prairies. This name belongs to the language of the Chippewas, and has been given to them by the voyageurs. The Sioux call this group of lakes the *Rabechy*, meaning the place where the pelicans nestle. Their waters are, in a great measure, supplied by a fork from the sources of the Des

*An analysis by Prof. Dodge (Tenth annual report, p. 202) of an "alkali" efflorescence from section 14, Iona, Murray county, showed it to be a hydrous sulphate of magnesia with slight traces of soda, potash and lime. The proportions of sulphur trioxide and magnesia were the same as in epsomite (Epsom salt), but it had less than half the percentage of water of crystallization required by epsomite.

†*Report on the upper Mississippi river*, 1843; p. 13.

Moines river. They contain an abundance of fish, and their shores are amply supplied with wood to admit the location of enviable farms. Hence we proceeded to the spot which I have designated on my map as the Great Oasis, and called by the Sioux *Ichan-ptaye-tanka*, translated by the voyageurs *la grande lisiére de bois*—the great skirt of wood" [at Bear lakes]. "This spot is a forest of limited extent, composed of lime trees, swamp ash, prickly ash, white birch, beaver-wood, white oak, etc., and surrounded by large lakes garnished with aquatic plants, swarming with muskrats, covered at certain seasons with wild fowl, and offering a safe protection against the annual firing of the prairies. The usual depth of these lakes is from 7 to 12 feet; and the soil of the borders is found well adapted to the cultivation of the potato, and the growth of culinary vegetables."

Mr. John H. Low enumerates the following species of trees and shrubs found in the woods of Bear lakes: bass, the most abundant tree, 40 to 60 feet high, American or white elm, also 40 to 60 feet high, and sometimes four or five feet in diameter, slippery or red elm, bur oak, white ash, wild plum, willows, climbing bitter-sweet, black raspberry, choke-cherry, prickly ash, black currant, and smooth gooseberry, common; the American aspen, box-elder, cottonwood, hackberry, frost grape, smooth sumach, wolf-berry, red raspberry, thorn, rose and sweet viburnum or sheep-berry, less common.

Nobles county has less timber than Murray, its principal localities being only narrow groves on the edge of the Graham lakes, of the Okabena lakes, of lake Ocheeda, and of Indian and State Line lakes.

Excepting these scanty tracts of wood, both Murray and Nobles counties are altogether prairie, without tree or shrub, none sometimes being within view all around for several miles, but universally covered by a beautiful mat of grass. This is ready for pasturage about the first or the middle of May, and in summer would supply from a half to one ton of hay per acre. Most of the hay gathered by the farmers, however, is from sloughs, which are wet in spring but in summer are usually so hard that horses can be driven over them. Their growth of grass is more than twice as heavy as that of the uplands, but of inferior quality, yielding from two to three tons per acre.

Owing to the scarcity of timber, and the difficulty in the present sparsely settled condition of the country to provide either wood from the Big Woods of central Minnesota or coal from Iowa, a large portion of the immigrants of these counties, probably half of all in southern Murray county, and three-fourths of all in Nobles county, burn hay for their only fuel throughout the year. A few have stoves to which the hay is supplied in a compressed mass, enclosed in a removable fire-box; but mostly it is burned in common coal or wood stoves. The hay used is the most rank growth of the sloughs, three to six feet long, consisting almost wholly of the fresh-water cord-grass (*Spartina cynosuroides*). Large wisps of this are twisted, doubled and tied by hand, being thus brought into compact and convenient form for putting into the stove. One or two of these twisted bunches are supplied every five or ten minutes, and they maintain a hot fire, as serviceable as that of wood or coal. The amount of hay thus used in a year for heating an ordinary room is from eight to twelve tons. An hour's time is sufficient for twisting up a winter day's supply of this fuel. With the more full settlement of this region, some systematic plan may be adopted for securing wood or coal by freight in large amounts and therefore at much lower cost than now, so that their expense will no longer prevent their general use. It also seems quite practicable for farmers to raise all the fire-wood they need by setting out and cultivating ten acres, more or less, of timber. The white willow, cottonwood, soft maple and box-elder are rapid-growing species which thrive well here when protected from the prairie fires. Species should be selected which spring up, like the willows, by new shoots from the stump and roots, when once cut down, so that the tract cut for one year's fuel may grow again and within a few years yield as much more. Allowing an acre of willows for each year, apparently an ample provision, it seems quite certain that ten acres will be sufficient for the needs of an ordinary household, thus leaving each acre of willows ten years to grow before cutting, in which time they attain a diameter of six to eight inches and a hight of twenty to thirty feet.

The surface of these counties, having for the greater part a smooth, gently undulating or rolling contour, with few or no boulders, presents a vast, fertile expanse, waiting only to be ploughed and sown to yield fifteen to thirty bushels of wheat per acre. Till thus changed into cultivated farms, it annually produces its thin growth of prairie grasses, one to two feet high, which are excellent for pasturage till the first severe frosts, about the middle of September; by which they are whitened and killed to the roots, not continuing green after frosts like the cultivated grasses. Then, after a few days of drying, it is ready to be swept by prairie-fires at any time when they come, until it is covered by the snow of winter; and, should it escape through the autumn, it is again in danger of fires during a month or more in spring, from the departure of the snow until the green grass shoots up anew.

The most abundant species of grass found upon the prairies of this part of Minnesota are as follows: beard-grass (*Andropogon furcatus*, Muhl.), commonly here called "blue-joint," Indian grass (*Chrysopogon nutans*, Benth.), muskit grass (*Bouteloua racemosa*, Lagasca), and porcupine grass (*Stipa spartea*, Trin.), common on land neither very dry nor very moist; another species of beard-grass (*Andropogon scoparius*, Michx.), and a second muskit-grass (*Bouteloua hirsuta*, Lagasca), common on dry swells; the fresh-water cord-grass (*Spartina cynosuroides*, Willd.), in sloughs, making the principal mass of their hay; and rice cut-grass (*Leersia oryzoides*, Swartz), with the last. The prairies also bear a great variety of flowers, including numerous species of aster, golden-rod, sunflower, and blazing-star or button snakeroot, and the rose, lily, harebell, phlox, fringed gentian, and many others.

GEOLOGICAL STRUCTURE.

Glacial and modified drift.

The bed-rocks of Murray and Nobles county have no outcrops, nor are they reached by any wells, so far as learned of in this survey. Drift forms the surface, consisting almost wholly of the unmodified deposit of the ice-sheet, which is called till, boulder-clay, or hardpan. Clay is the principal ingredient, containing always more or less of grit, gravel, and large stones, but boulders exceeding a foot in diameter are usually very rare, so that perhaps in some cases none would be found in ploughing a quarter-section. Though the soil to the depth of a foot or more appears to contain less gravel than the earth excavated in cellars and wells, some intermixture of gravel may nearly everywhere be noticed upon ploughed land; and the true loess, which thinly covers much of Rock county, does not extend east into the counties here described. Under the black soil, the till has a yellowish color to a depth that varies from ten to twenty-five or thirty feet, below which it is dark bluish. Important differences in its hardness are also noted in the sections of deep wells. How thick this drift-sheet is can only be conjectured, since it has not been passed through in these counties; but from what is known of its depth upon other parts of southern and western Minnesota, it is believed to vary from 100 to 200 feet or more in thickness. Here and there this sheet of till encloses layers of sand and gravel, from which comes the large inflow of water often met with in well-digging.

Creeks and rivers have excavated valleys in the drift, the deepest being those of Chanarambie, Champepadan and Kanaranzi creeks, and of the Des Moines river. These eroded valleys are 50 to 75 feet deep and generally a half or three-fourths of a mile wide, bordered by bluffs of moderately steep or sometimes quite abrupt slope. Their bottoms are partly till, like the enclosing bluffs; but much of the lowland adjoining the streams consists of deposits of gravel and sand or fine silt, being part of the alluvium formed during the process of erosion. Its lowest tracts still remain within reach of the high water which is produced by snow-melting in spring or by the largest rains, and these areas of flood-plain are annually increasing in depth by the deposits made during such inundations.

Modified drift, or beds of gravel, sand and clay, whose formation must be referred to glacial conditions, was not observed in these valleys. The only noteworthy deposit of this kind is that found in Grand Prairie, the most southwest township of Nobles county. Here a plain composed of stratified gravel and sand, but covered by a fertile soil, reaches six miles east from Kanaranzi creek, with a width of about four miles, including the southern two-thirds of this township. This nearly level tract is 20 to 40 feet above Kanaranzi creek, to which it supplies a small tributary that has cut a channel of similar depth. The bordering areas of till rise in massive, smooth swells, 40 to 75 feet above this plain.

Terminal moraines. Foregoing descriptions of the surface features of these counties have called attention to the most important distinction in their deposits of glacial drift or till, namely, the existence of two specially rolling and hilly belts, in part very rough and knolly, with an increased proportion, and sometimes an astonishing abundance, of boulders. The extreme limit reached by the ice in the last glacial epoch is marked by the western of these terminal moraines, which forms the summit of the Coteau des Prairies. This morainic belt is intersected in southern Nobles county by lake Ocheeda and Ocheyedan creek, and in southwestern Murray county by Chanarambie creek. A smooth expanse of till, from ten to twenty-five miles wide, intervenes between this and the eastern moraine, which has a course approximately parallel with the preceding. The second moraine marks the limit of the ice during a pause in its recession, the genial climate before which it had retreated being changed to one of severe cold again, when the ice-border, probably after some re-advance, was maintained steadily at this line during a long time.

In an earlier part of the glacial period a more extensive ice-sheet had overspread all this region, and reached far to the south into Nebraska, Kansas and Missouri, and its thick deposit of till continues beyond the farthest boundary attained by the last ice-sheet. The depth of the drift in the west part of Nobles county and farther westward, outside of these moraines, and certain features of the region included by them, as the remarkable chains of lakes in Martin county, prove that the greater part of the drift in this state was deposited by the ice of this earlier epoch.

Wells in Murray county.

Sections of the drift deposits of Murray county have been observed in well-digging as follows:

Holly. Daniel E. Way; S. W. ¼ of sec. 10: well, 20 feet; soil, 2 feet; yellow till, 17 feet, spaded, except its last five feet which were picked; much harder blue till, 1 foot, and extending lower; water filled the well six feet deep in one day, from a thin gravelly vein at the depth of 14 feet.

Des Moines River. A. H. Twiss; N. E. ¼ of sec. 10: well, 42 feet, dug 32 feet and then bored 10 feet; soil, 2; yellow till, all of it so hard that it had to be picked, containing many small pebbles, but none larger than six inches in diameter, 39 feet; blue till, very tenaceous, but not harder than the yellow till, 1 foot and more. Water rose to six feet below the surface in a half day, and stands there permanently. No layer of gravel or sand was found, and the well continued dry about one day after the boring was finished; then water broke into the well and rose rapidly as stated. This is the greatest thickness of yellow till learned of in Murray county.

Shetek. D. C. Greenman; sec. 20: well, 35 feet; soil, 3 feet; yellowish till, 25 feet; yellowish and darker gray till, interbedded, moister and softer than above, and including sandy streaks, 7 feet; from this lower part of the well water rose ten feet in one day.

D. J. Turner; sec. 26: well, 41 feet; soil, 2; yellow till, 37; harder blue till, 2 feet and reaching lower; water rose nine feet in two hours, and thirty feet, to its permanent level, in the first day, from sandy streaks in the last ten feet.

Murray. F. H. Barrows; sec. 29: well, 18 feet; soil, 2; yellow till, spaded, 16 feet; water comes from sandy streaks, mostly at 12 feet.

At Currie and in its vicinity the wells are from 10 to 20 feet deep, in till. No wood nor shells have been found in well-digging in this region; but small fragments of lignite occur frequently.

Lime Lake. At Avoca the Lincoln hotel has a well 96 feet deep, which was soil, 2 feet;

yellow till, 7 feet; blue till, 85 feet; and gravel, 2 feet, from which water rose to a depth of fifty feet. Most of the wells in this town and its vicinity are only 15 to 20 feet deep, in till like the foregoing, and have a plenty of good water through the whole year.

Bondin. The Fulda town-well, at the center of the village, has a depth of 147 feet. Its section was soil, 3 feet; yellow till, spaded, 32; much harder blue till, picked, 97 feet, containing more stones and gravel than the upper till; then again yellow till at 132 feet and thence 15 feet to the bottom, not apparently distinguishable in composition, color and degree of compactness from the ordinary yellow till of the surface, while its proportion of gravel and pebbles, the largest of which are three or four inches in diameter, appears to be greater; it was underlain by gravel, which yields a very large supply of water, as if from a running stream, as it rises only seven feet. A small piece of wood, seven inches long, resembling red cedar, was found in the blue till at a depth of 67 feet; and a few pieces of lignite, up to two inches in length, occurred at the top of the lower yellow till; but no other fossil remains were found.

The railroad-well at Fulda, about thirty rods southeast from the foregoing, is described by the station-agent to be 115 feet deep, in till, its last 3 feet being a very hard layer, below which the auger dropped nearly a foot; and from this vein water rose seventy feet. This well, however, became so frequently filled with quicksand that it was abandoned; and water is at present pumped for the railroad tank from the north one of the Seven Mile lakes.

Lake Sarah. T. J. Ward; S. E. ¼ of sec. 12: well, 33 feet; soil, 2; yellow till, about 25; blue till, moister and very tenacious, 6 feet; the well was bored, and at this depth was stopped by a boulder; but it is supplied with water which seeps from the yellow till.

Mason. J. M. Denison; N. W. ¼ of sec. 8: well, 20 feet; soil, 2; yellow till, 18 feet, enclosing occasional layers of sand and gravel up to six or eight inches in thickness; water seeps in moderate amount. This is on the south part of a nearly level plateau, much higher than the surrounding country.

Iona. T. Evenson; sec. 14: well, 25 feet; soil, 2; yellowish gray till, 23 feet, spaded; water seeps, usually three to five feet deep.

Lowville. John H. Low; sec. 8: well, 16 feet; soil, 2; yellow till, spaded, with occasional streaks of sand, 14 feet, to very hard blue till below; water seeps, plentiful and good.

Leeds. L. Lukkason; Hadley: well, 40 feet; soil, and yellow till, 15 feet; blue till, 25; both were picked; the only sand found was a thin layer, four to six inches thick, at the depth of 28 feet; water seeps slowly from this, and fills the well to that hight, twelve feet.

T. 105, *R.* 42. Darms & Fenton; N. W. ¼ of sec. 30: well, 14 feet; soil, 2 feet, containing scarcely any gravel; yellow till, picked, quite pebbly, 8 feet; stratified gravel and sand, caving in, 4 feet; the water, of excellent quality, is usually four feet deep, but sometimes fails.

A well dug for the Southern Minnesota railroad on sec. 4 of this township is reported to have gone through till about 220 feet, finding no water; but another well dug near by for this railroad on sec. 5, found at the depth of 15 feet a very large supply of water, enough to fill the railroad tank by rapid pumping without lowering the well.

Cameron. E. Conner; N. W. ¼ of sec. 22: well, 24 feet; soil, 2; yellow till, spaded, 12; blue till, picked, 10; water rose four feet from sand at the bottom. This is at the northeast border of the western moraine.

Moulton. N. M. Williams; sec. 28: well, 16; soil, 2; yellow till, 8; blue till, 6; water seeps, being usually three to six feet deep, of excellent quality, as are all the wells of this region. Fragments of lignite are rarely found.

Wells in Nobles county.

Graham Lakes. Nils Dahl; De Forest, in the west part of sec. 11: well, 25 feet; soil, 2; yellow till, spaded, 19; much harder blue till, picked, 4 feet; water seeps.

J. H. Anscomb; sec. 14: well, 16 feet; soil, 2; yellow till, 14, spaded through its first ten feet, but much harder and picked below; water rose four feet from a gravelly vein at the bottom.

Indian Lake. Charles L. Peterson; S. E. ¼ of sec. 4: well, 22 feet, all till, finding a good supply of water.

Frank Peterson; S. E. ¼ of sec. 16: well, 14 feet; soil, 2; a sandy layer, 1 foot; yellow till, spaded, 11 feet; water seeps, mainly from the sandy layer at the top.

Isaac Horton; sec. 34: well, 35 feet deep; soil, 4 feet; yellow till, spaded, 8 feet; darker, gray till, marly, very hard, "two to four times as hard to dig as the yellow till," all picked, 23 feet; water rose fifteen feet in three days, from springs in this till at the bottom.

Seward. Frank H. Radant; sec. 4: well, 22 feet; soil, 2; yellow till, 15 feet; much harder blue till, 5 feet, and reaching deeper; water seeps, abundant and good.

Worthington. Peter Tompson; in the town: well, 52 feet; soil, 4; gray till, 8 feet; blue till, 40; water rose suddenly from sand at the bottom to a permanent level twenty feet below the surface. Most of the wells here get an abundant supply of good water at 10 to 20 feet.

Wilson Ager; sec. 30: well, 24 feet; soil, 2; gray till, 18; gray sand, 4 feet; water plentiful, but not rising above the top of the sand.

Bigelow. E. S. Mills; sec. 31, near the village: well, dug 30 feet and bored below to 72 in all; soil, 2 feet; yellowish gray till, 10; blue till thence to the bottom. Several pieces of wood, from two or three inches to one foot long, apparently tamarack, were found in this well, at a depth of 26 feet, in the compact blue till; but no shells, nor other fossils, were learned of in this region.

The railroad well at Bigelow station, 52 feet deep, passing through blue till, is filled with water to twelve feet below the surface.

Bloom. Levi H. Baxter; sec. 24: well, 15 feet; soil, 2; yellow till, spaded, but very hard, 13 feet; water seeps, abundant and of good quality. Wells in this township vary from 10 to 20 feet in depth. Fragments of lignite are rarely found.

Summit Lake. A. Hovey; sec. 8: well, 20; soil, 2; yellow till, 18; water seeps, usually plentiful, but none in very dry seasons.

On Samuel Allen's farm, three-fourths of a mile northwest from the last, a well was dug and bored about 100 feet; finding plenty of water at first, but becoming filled with quicksand.

Dewald. Wells at Rushmore, in the south part of sec. 19, are 12 to 20 feet deep, finding plenty of good water. S. M. Rushmore here has a well 20 feet deep, which was soil, 2 feet, and then yellowish gray till, 18 feet, with water rising from gravel at the bottom and standing about eight feet deep. A boring close by this, at the southeast corner of his store, 60 feet deep, went into blue till at the depth of about 20 feet, and was all blue till below.

A. Roland; S. E. ¼ of sec. 22: well, 16 feet; soil, 2; yellow till for all below; water seeps, scanty. The well at his barn, 24 feet deep, all in yellow till, finds a large supply of water.

Ransom. S. G. Ferrin; S. E. ¼ of sec. 20: well, 22 feet; soil, 2; yellow till, picked, 20 feet; at the depth of ten feet this till contained a layer of water-deposited sand, four inches thick at one side of the well, but thinning out to nothing at the other side; water seeps, and is scanty in a dry season.

Olney. H. M. Ludlow; sec. 22: well, 22 feet; soil, 2; yellow till, 20; water seeps from the lower ten feet, and also comes from a spring in the till at the bottom, standing five to ten feet deep.

In Adrian, at the west side of this township, the Coleman hotel has a well 40 feet deep, the section of which was soil, 2 feet; yellow till, 14; blue till, 24; water rose twenty-seven feet in twelve hours from gravel at the bottom. This is the deepest well at Adrian; others find plenty of water at 15 to 25 feet.

Little Rock. William Wigham; sec. 18: well, 32 feet; soil, 3 feet; yellow till, spaded, but hard, 29; water seeps, mostly from the lower part of the well, abundant and of excellent quality.

W. W. Mallory; S. W. ¼ of sec. 34: well, 33 feet; soil, 3; yellow till, spaded, but hard, 15; much harder blue till, 15 feet and extending lower; water seeps, usually about six feet deep.

Leota. John Loy: sec. 28: well, 26 feet; soil, 2; yellow till, 18 feet; very much harder blue till, 4; sand and gravel, 2 feet, from which water rose six feet.

Lismore. Michael Brown; N. E. ¼ of sec. 21: well, 33 feet; soil, 2; yellow till, 28 feet; exceedingly hard blue till, 3 feet and extending lower; water rose ten feet in four hours, from sandy streaks at the base of the yellow till.

George W. Legros; N. W. ¼ of this sec. 21: well, 23 feet; soil, 2; sandy yellow till, 14 feet; quicksand, 3 feet; very hard blue till, 4 feet and deeper; water, three feet deep. Limy concretions were found in the yellow till.

West Side. Thomas Grace; near the center of this township: well, 62 feet; soil, 2; sand, 12; till, mostly yellow, 48 feet; water seeps, coming in considerable amount at the depth of 54 feet. This is at the top of the west bluff of Kanaranzi creek.

Grand Prairie. Benjamin Midboe; sec 14: well, 18 feet deep; soil, 2; gravel and sand, 16; water abundant and good. This is on the northeast part of a plain which occupies the southern two-thirds of Grand Prairie, having a subsoil of gravel and sand, in which wells go from 12 to 20 feet in depth.

MATERIAL RESOURCES.

The agricultural capabilities of Murray and Nobles counties have been noticed sufficiently on page 523.

No *water-power* is used in Nobles county; and the only one used in Murray county is on the Des Moines river at Currie, where the Lake Shetek mill, employed in the manufacture of flour, and owned by Currie & Crowl, has a head of eight feet. The dam here holds the stream above it level to lake Shetek; and a second dam, situated nearly a mile above this, close below the junction of Bear creek and the outlet of lake Shetek, raises the surface of this lake and creek four feet above the Currie dam, for which it thus forms a reservoir.

The only *stone for masonry* obtainable from these counties is supplied by the boulders of granite, gneiss, limestone, and other kinds, which are contained in the drift. In some localities, as along the bluffs bordering the east branch of Kanaranzi creek four miles northwesterly from Rushmore, in the moraine-like hillocks within a mile west of Adrian, and among the rough drift hills of Leeds and Chanarambie townships in western Murray county, these boulders are abundant up to five feet, and less frequent to ten feet in diameter.

Lime has been burned for the local demand, from drift boulders, in Bigelow and Dewald, Nobles county. The largest limestone block found in this region was on section 25, Dewald, measuring about 20 by 20 by 12 feet in dimensions. It was used for underpinning three houses, besides walling two cellars and three wells. Most of the boulders, whether of limestone, or of the granite and schists, are less than five feet in diameter, and larger ones are rare. Only a twentieth, or less, of the large boulders, but nearly half of the small stones and gravel in the drift, are limestone.

In Murray county, lime is burned by John Swenson, in section 34, Lake Sarah, usually only one kiln yearly.

Brick-making is not undertaken in these counties, because of the high cost of fuel.

Peat. Only scanty deposits of peat are found in this part of the state, and it is very rarely used. Prof. Winchell's report upon the peat of southern Minnesota, from explorations in 1873, mentions four localities in Nobles county, as follows:*

*Second annual report.

Dewald. "Land of B. S. Langdon, sec. 4. Here a turf-peat occurs, about 14 inches in thickness, lying on a side-hill or gentle slope, having a springy character when trod on. It is underlain by a black mud, which has been mistaken for non-fibrous peat. Of the turf several cords (perhaps a hundred) have been taken off, preparatory to excavating the rich(?) peat below, when it was discovered that it would not burn, but when placed in the fire turned out hard and heavy like burned clay. The turf itself will make a fuel that will compare well with any turf-peat discovered."

Bigelow. "Peat, eight or ten inches thick, exists on the railroad land, sec. 27, of a turfy character, but good quality. It lies over an acre or two, but may be taken out probably in other places along the different creeks that unite here."

"At Bigelow, there is a considerable thickness, perhaps two feet, of half-carbonized, pulpy, vegetable silt, lying entirely below the water of a lake, made up of decaying sedges and grasses and their roots. It is torn in pieces by the waves in the lake, and gathers about the shores and under the bog-turf, driven most abundantly to the side that faces the prevailing winds. It is often intermixed with fine mud and shells, especially near the bottom. It will probably furnish, if dry, a combustible material that would answer well for fuel, if it should prove obtainable in sufficient quantities, and especially if it were to be pressed and molded. It has not the necessary origin nor nature to be styled peat."

Indian Lake. "John Haggard takes out turf in a low patch on sec. 4. It occurs partly on state swamp land, partly on railroad land, and partly on the claim of Charles Peterson. It is in nature and position similar to the turf on B. S. Langdon's land, northwest of Worthington. Mr. Haggard takes it out with a spade, about a foot in depth, in large blocks. Then drawing it to the house he cuts it into convenient smaller blocks, and spreads and piles it for drying. After drying about five or six weeks it is fit for burning. It burns quickly but leaves considerable ash." This peat, according to an analysis by Prof. S. F. Peckham, contains when air-dried 11.93 per cent. of hygroscopic water; 33.48 of organic matter; and 54.59 of ash. A hundred pounds of it are estimated to be equal in value to forty-four pounds of oak wood.

Springs of excellent, cool water issue at many places from the lower part of the bluffs of the Des Moines river, and of Chanarambie, Champepadan and Kanaranzi creeks. On the narrow bottomland of Plum creek, in the N. W. ¼ of section 15, and the N. E. ¼ of section 16, Holly, the most northeast township of Murray county, are several chalybeate springs, which have formed mounds of ochery mud, one or two feet high, and ten or twenty feet in diameter. Other interesting mineral springs, supposed to be impregnated with both iron and sulphur, occur on the N. E. ¼ of section 12, of this township, three miles south of Walnut Grove.

ABORIGINAL EARTHWORKS.

An artificial mound, of the usual rounded form, about fifty feet across and three feet high, lies on the farm of L. Aldrich, close southwest of his house, in the north part of section 7, Murray, at a distance of about forty rods from the southeast shore of lake Shetek. Also, in the south part of the S. W. ¼ of section 8, several similar mounds occur, two to three or four feet high; and there are two others in the S. E. ¼ of the N. E. ¼ of section 18, all these being in Murray township, within two miles northwest from Currie.

North of lake Shetek, two or three of these aboriginal mounds, two to four feet high, were seen upon the top of swells, which rise 30 to 40 feet in hight, east of lake Fremont, and one upon a similar rounded hill west of this lake, these being in the west part of Shetek township.

In Nobles county, such circular mounds, from one and a half to three feet high, are found in the N. W. ¼ of section 18, Ransom; and also in the south part of Little Rock.

CHAPTER XVIII.

THE GEOLOGY OF PIPESTONE AND ROCK COUNTIES.

BY N. H. WINCHELL.*

Situation and area. These counties are in the extreme southwest corner of the state, Pipestone county lying north of Rock. They are named from the appearance of the Potsdam quartzyte, the former containing the famed region of the "red pipestone quarry," and the latter an extensive area in which the same quartzyte appears at the surface, and constitutes its most marked topographic feature, in "the mound" near Luverne. Rock county contains 308,910.15 acres, of which 1,174.04 are covered by water; and Pipestone has 296,493.51 acres, including 611.76 covered by water.

SURFACE FEATURES.

Natural drainage. With the exception of a small area in the northeastern corner of Pipestone county, on the east slope of the Coteau, mostly drained by the Redwood river, in which also is found the ultimate source of the Des Moines river, the whole of these two counties and portions of Nobles and Jackson are drained by streams that reach the Missouri river, these being the only waters in the state that take that course to the sea. The Rock river is the main stream, and runs from north to south through both counties, receiving several tributaries from the east, but none of importance from the west. Several streams, rising not far west of the valley of Rock river, flow westward and southwestward and finally reach the Missouri by way of the Big Sioux river, near Sioux City, in Iowa. These are the Flandreau, Pipestone, Split Rock, Beaver and Mud creeks. These streams are all small, and in the summer some of them are rather valleys, with occasional pools of standing water, than living streams. They furnish

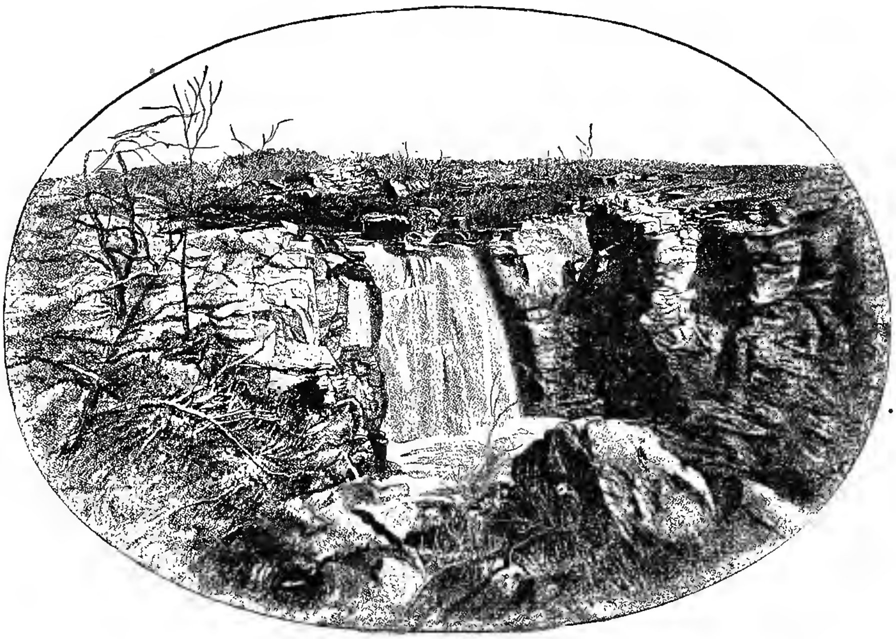
*Including copious notes by Mr. Upham. Compare, also, the sixth annual report.

but few powers that have been improved; though without doubt other parts of Rock river have sufficient fall for mill purposes. The falls of Pipestone creek near the Leaping Rock, are represented by figure 38.

Water-power mills are found at two points in the Rock river valley, viz.:

The Luverne mills, a quarter of a mile southeast of Luverne, owned by Allen & Webber. The fall here amounts to ten feet, and the mill has two run of stone. It is a grist and merchant mill.

The Ash Grove mills are in the southeast part of Clinton, about a mile north of the state line, owned by Mrs. Deborah Estey and son; fall seven feet; grist mill.



PIPESTONE FALLS
FIG. 38.

Topography. The contour ot the immediate surface is caused by the disposition of the drift, but the average elevation, throughout some broad areas, is dependent on the underlying rock-strata. Pipestone county is diversified in its eastern townships by long and broad swells running about north and south, corresponding to the low water-sheds. The central part of this county is a flat and monotonous prairie. The broad valley of Flandreau creek with an elevation of about sixteen hundred feet crosses it diagonally in the northwestern corner, and the elevated crest of the Coteau des Prairies cuts off diagonally its northeastern corner. The greatest unevenness of surface, as well as the greatest elevation in these counties, is found on this Coteau, the latter being somewhat over nineteen hundred feet above the ocean. Where Rock river leaves Pipestone county its water surface is fifteen hundred feet above the ocean, and where it leaves the state it is about 1,350 feet. This valley is about fifty feet below the general level in Burke township, but its bluffs increase in hight toward the south, reaching seventy-five and eighty feet in Osborne, the surrounding country being about twenty-five feet still higher. Chanarambie creek is likewise deeply channeled in the drift. There are here also a great many sharp ravines, like the ravines in the Bad Lands of Montana, that suggest the existence of some of the friable strata of the Cretaceous. The Rock river valley, farther south, is cut from seventy-five to one hundred feet below the general level of the country, and in Rock county receives a number of small tributaries from the east, each of which flows in a deeply cut valley from fifty to a hundred feet below the general level. This valley, which is furnished with a fertile bottomland from a half mile to one mile wide, is enclosed by bluffs in the southern part of Rock county that do not have the usual steepness, as if recently undermined by the current of the river, but which rise by moderate slopes to the general level of the undulating upland. The same feature is observable in the bluffs of Beaver creek, which, like the Kanaranzi, Champepadan, Elk and Split Rock creeks, have cut their valleys from forty to sixty feet below the general surface. Rock county in general has a surface that is broadly undulating, the swells sometimes showing a trending to a north-south direction.

These are emphatically and characteristically prairie counties, and are nearly level in some portions. They are more undulating in their eastern portions. The west-facing bluffs are usually more precipitous than the east-facing. They are also more stony with foreign boulders, a circumstance, however, that may be owing to the action of the prevailing western winds, combined with the drying effect of the southwestern sun in summer, which would uncover and keep bare the coarser materials of the surface by blowing away the sand and clay during the dry windy months of the year, while the bluffs on the west side would not only not receive such winds, but would serve to collect all particles flying toward the east from the prairie above.

The range of high land running northwestward from Mound in Rock county, is a conspicuous object in the horizon from the north and east.

Its highest point is where it breaks off squarely to the valley of Rock river, about three miles north of Luverne, where it is known distinctively as *the mound*, 1650 feet above the ocean. It here has an elevation of about 175 feet above the river, the uppermost forty to sixty feet consisting of rock. This range of high land extends northward into Pipestone county, and reaches there an elevation of over seventeen hundred feet, the same rock causing it throughout.

Elevations. By means of the railroad surveys that have crossed these counties there are some definite data respecting their hight above the ocean, and from these and estimates based upon them the contour-lines of the accompanying plate (No. 23) have been drawn.

Southern Minnesota division of the Chicago, Milwaukee & Saint Paul railway.

	Miles from La Crosse.	Feet above the sea.
Chanarambie creek, water at the last crossing	274.5	1521
Edgerton	276.0	1550
Rock river	279.0	1552
Hatfield	283.0	1662
Highest point on the road	285.5	1744
Pipestone City	289.0	1693
Pipestone creek, water	293.0	1577
Clausen	295.5	1629
Flandreau	303.6	1550

Woodstock branch of the Chicago, Saint Paul, Minneapolis & Omaha railway.

	Miles from St. Paul.	Feet above the sea.
Murray and Pipestone county line, grade	202.5	1839
Woodstock	204.3	1822
Rock river, water	208.3	1645
Summit	211.5	1785
Pipestone City	215.4	1715
Big Sioux river at Flandreau	230.8	1501

Sioux Falls branch of the Chicago, Saint Paul, Minneapolis & Omaha railway.

Summit, three miles east of the county line	199.5	1569
Drake	203.7	1516
Elk slough, grade	206.2	1469
Summit, grade	207.1	1515
Rock river, water	210.3	1423
Luverne	211.1	1451
Summit, grade	216.1	1543
Beaver Creek depot	219.3	1443
Beaver creek, water	219.8	1385
State line	224.4	1383
Valley Springs	225.2	1392
Sioux Falls	240.2	1394
Big Sioux river, Sioux Falls, low and high water	240.4	1381–1385

Branch from Luverne to Doon, Iowa.

Luverne	211.1	1451
Ash Creek depot	218.7	1396
State line	221.6	1374
Doon	238.9	1282

Mean elevation. The following figures express the estimated mean elevation of the townships of Pipestone and Rock counties:

Pipestone county. Ætna, 1,825 feet above the sea; Rock, 1.800; Burke, 1,700; Osborne, 1,625; Fountain Prairie, 1,840; Grange, 1,775; Gray, 1,740; Elmer, 1,650; Altona, 1,700; Troy, 1,660; Sweet, 1,660; Eden, 1,650. The average of these figures is 1,715 feet.

Rock county. Battle Plain, 1,550 feet above the sea; Vienna, 1,520; Magnolia, 1,490; Kanaranzi, 1,475; Denver, 1,620; Mound, 1,575; Luverne, 1,480; Clinton, 1,440; Rose Dell, 1,600; Spring Water, 1,525; Beaver Creek, 1,450; and Martin, 1,440. The average for Rock county is 1,510 feet above the sea.

Soil. But a very small portion of these counties is unsuited to farm tillage. The soil is generally composed of the till, or boulder-clay, which is so stony as to interfere with plowing only in the rolling tract of the Coteau, in small areas, in the northeastern corner of Pipestone county. And even there the stony knolls are interspersed with fertile valleys and slopes that afford good pasturage. In central Rock county, extending from *the mound* northwestward, and including some parts of Denver and Rose Dell, the surface is rocky, and the soil thin. With these exceptions, these counties are among the best in the state for all farming. In the most of Pipestone county, and in the northern part of Rock county occasional stones are found in the soil, but these become less frequent toward the south, and in the southern part of Rock county no stones at all appear on the surface, the soil being the same as the loam soils of the southeastern part of the state, consisting of a fine clay that varies in thickness, sometimes reaching ten or twenty feet.

Timber and fuel. From the vicinity of Luverne to the state line and farther south, timber is nearly continuous in a narrow belt along the Rock river. Its most abundant species are cottonwood, soft maple, white elm and white ash; box-elder and bur oak occur less frequently; and bass is absent. Wild plums, grapes and gooseberries are plentiful. Many beautifully spreading elms, fully 60 feet in hight, grow beside this river near Luverne. Farther to the north timber is found sparingly and in occasional groves along the Rock river. On the tributaries of this stream in Rock county, and on Split Rock and Beaver creeks, timber is absent or very scanty.

Mr. J. F. Shoemaker states that the following species of trees and shrubs have been observed by him in this county: White elm, white ash, cottonwood, willows, soft maple, box-elder, hackberry, bur oak, prickly ash, smooth sumach, frost grape, Virginia creeper, climbing bittersweet, wild plum, choke-cherry, black raspberry (common on the Mound), wild rose, thorn, June berry, prickly wild gooseberry, black currant, wolf-berry and elder.

Owing to the scarcity of wood, nearly all the immigrants, especially in Pipestone county, excepting in or near the villages and stations of the railroads, burn hay for their only fuel, which is best when cut before frost, or at the same time as for feeding. The cost of cutting and stacking this hay is $1 to $1.50 per ton.

THE GEOLOGICAL STRUCTURE.

Red quartzyte. The only known bedded rock in these counties is a red quartzyte, probably the equivalent of the New York *Potsdam sandstone*, but which Dr. C. A. White, of the Iowa survey, has designated the *Sioux quartzyte*, as it is seen to outcrop in the extreme northwestern corner of Iowa. Of this the largest exposures are in Rock county, but the best known is at the famous "pipestone quarry," near the center of Pipestone county.

As this locality has become somewhat famous on account of the extensive use made of the red pipestone by the Indians, and the difference of opinion expressed by scientists as to its origin and age, the following *resumé* will be of interest:

Historical resumé.

The first written account of the quarry was by George Catlin, in 1837*, found in the 38th volume of the first series of the American Journal of Science and Arts, p. 138, in a letter addressed to Dr. C. T. Jackson, to whom he also sent a sample of the pipestone for analysis. The journey was made on horseback from the falls of St. Anthony, in the summer of 1836, in company with "a young gentleman from England, of fine taste and education," and a single Indian guide. Mr. Catlin describes the quarry as "on the very top" of the Coteau des Prairies, which rises above the country about it with graceful and almost imperceptible swells. The quartzyte he regards "a secondary or sedimentary deposit," but no further defines its supposed age.

Jean N. Nicollet visited the quarry in July, 1838, as is plainly shown by his own name and date of that year, together with the initials of his companions, boldly and artistically cut on the quartzyte at the top of the ledge, near the "leaping rock," and a little north of where the creek passes over the brow of the escarpment.**

Prof. James Hall, next in chronological order, read a paper before the *American Philosophical Society* in June, 1866, in which, among notes on the geology of some of the western portions of Minnesota, he classes the red quartzyte as Huronian. He imagines the Coteau des Prairies caused by a vast synclinal in the rocks of this age.† He did not see the pipestone quarry itself, having gone only to lake Shetek.

Dr. F. V. Hayden visited and examined the locality in October, 1866, and his account is in the *American Journal of Science and Arts* for January, 1867, p. 15. After examining rock of the same kind on the James and Vermilion rivers in Dakota, and at Sioux Falls on the Big Sioux river, he gives an interesting detailed description of the quarry, and inclines to the opinion that the quartzyte is "supra-carboniferous, Triassic, perhaps, or an extension downward of Cretaceous No. 1.‡

Dr. C. A. White has given a description of a "Trip to the great red pipestone quarry" in the *American Naturalist* for 1868–9, but he does not there state anything concerning the age of these rocks, though elsewhere he has ranked them as pre-Silurian, and named the formation the "Sioux quartzyte."‖

The known area of this rock in Pipestone and Rock counties is approximately marked out on the accompanying map, but there is much probability of its being much greater and perhaps it includes the greater portion of both counties. The Cretaceous formation, no doubt, also occurs in the northern part of Pipestone county, and overlies unconformably the quartzyte in other places, but it has not been seen. Dr. Hayden has mentioned such facts in his account of the geology of southeastern Dakota, occurring at or near the mouth of Firesteel creek, on the James river, where he has identified the Fort Benton and Niobrara groups.

The pipestone quarry. At the red pipestone quarry (plate 24) there is a ledge of rock which runs north and south nearly three miles. This ledge of rock consists of layers of red quartzyte that have a low dip to-

FIG. 39. LEAPING ROCK.

*Compare page 62.

**See page 69. This inscription is about nine rods northwest of the waterfall (fig. 38) of Pipestone creek, and only two or three rods north of Leaping rock. The pillar of quartzyte, divided from the cliff by erosion, appears as in the adjoining figure.—UPHAM.

†Compare page 98.

‡Dr. Hayden misapprehends Prof. James Hall, in quoting his description. The "wall of red quartzyte" described by Hall is situated at Redstone, in Nicollet county, and not at lake Shetek.

‖Geology of Iowa, 1870. The reader is further referred to the first, second and tenth annual reports for reasons for believing these quartzytes are of the age of the Potsdam sandstone of New York. See also the reports on geology of Blue Earth, Cottonwood and Nicollet counties.

ward the east fifteen degrees south, so that the rock soon disappears under the prairie in that direction, but presents a nearly perpendicular escarpment toward the west, formed by the broken off heavy layers of the rock; though its greatest hight, which is not more than 25 feet, is a little north of the present pipestone quarry. It also gradually disappears under the prairie both toward the north and toward the south, the lower ground on the west of the escarpment slowly rising in these directions like the sides of a basin, and coalescing with that on the east of the ledge. A small stream, dry some parts of the year, known as Pipestone creek, works northwestwardly and passes over the ledge from the upper prairie to the lower with a perpendicular fall of about 18 feet. In the vicinity of this fall, and also at one or two places farther south, are dwarfed bur oaks and shrubs, but the country in all directions for many miles is a prairie, which has a great monotony of surface. It is not on the top of the Coteau des Prairies, as supposed by Catlin, that range of hills being 10 or 12 miles farther northeast. Mr. Catlin seems to have correctly described the eastern ascent of the Coteau as rising with almost imperceptible swells above the prairie farther east, but failed to observe when he passed down the western slopes, that the real Coteau dies out still more insensibly in the prairies on the western side.

The little stream which crosses the rock at the pipestone quarry (figure 38) widens out into a lake just before passing the ledge, making Pipestone lake, and again, after passing it, it forms Crooked, Duck and Whitehead lakes in the same way. In these lakes water stands constantly.

The rock itself in general is exceedingly hard, in heavy layers of one foot, or of two or three feet, and is separated by jointage planes into huge blocks of angular shape that lie often somewhat displaced or even thrown over entirely by the action of the frost through many winters. Thus there is a rough talus along the foot of the escarpment where grow a few bushes and small oaks, protected from the prairie fires by surrounding masses of fallen quartzyte. The rock is sometimes pinkish and massive; when blood-red it is more apt to be thin-bedded.

The real "pipestone quarry" is situated about a quarter of a mile west of this ledge and in the low land of the lower prairie. Earlier diggings seem to have been opened in the superficial outcropping of the pipestone layer, and to have followed along its strike north and south nearly a mile, without penetrating very deeply into the rock. The layer which furnishes the pipestone is about eighteen inches thick, and is embraced between heavy layers of the same rock as the ledge already described, and they all dip together toward the east, and of course run under the main escarpment. The present quarrying is a little east of the line of old diggings, but follows along the strike of the formation the same as the other, the only difference being in having greater depth (the pipestone layer is about six feet under the ground here) and in the difficulties encountered in removing about five feet of very firm pinkish quartzyte in heavy beds.

Southward from the region of the pipestone quarry the land continues high, and in some instances there are ridges, or long knolls, of drift, that are broad and evenly rounded over by a thin loam. The first exposure of the rock, in the vicinity of the road to Luverne, is on section 13, Eden, along the outside of the valley that crosses westwardly near the center of the section. It extends about a mile east and west. It here is seen to form an undulating floor on which the loam is thinly spread. It is hard, massive, pinkish-colored and superficially vitrified, in some places also showing two directions of glacial striæ, one being by the true meridian S. 10° W., and the other S. 42° E.

The same line of rocky outcrop extends westwardly to the Split Rock creek, and along that creek and its eastern tributaries as far as it continues in the state. It seems to have a changeable dip, but nowhere presents perpendicular bluffs.

On the N. E. ¼ of section 36, Eden, is another exposure of this quartzyte. It is along a shallow ravine that makes westward. It is seen again on the high prairie about half a mile farther south.

At a point about ten miles north of Luverne this rock becomes frequently exposed both in the valleys and on the hills, and continues so to the mound near Luverne, where it suddenly breaks off, along the west side of Rock river, and is not known to the south of that place. Throughout this distance it forms a high plateau three or four miles wide and about a hundred feet higher than the prairies east or west, but the surface, though frequently rocky, is not rough. It is undulating; and the plateau sinks gradually down to the level of the rest of the country on either side. This plateau terminates abruptly in a rocky and precipitous bluff facing southeastward, three miles north of Luverne, in what is known as "the mound." There is a very large rocky outcrop in sections 4, 5, 6, 7 and 8, Mound. There are frequent exposures in Mound and Spring Water townships. The Split Rock creek which crosses the northwest corner of Rock county has frequent exposures both in Rock and Pipestone; but in Pipestone the rock range veers toward the east, into the east part of Eden township, and disappears till reaching the region of the pipestone quarry. In the northwest part of Mound township the rock dips northwest with a throw, or twist, which, by slightly changing it, brings it soon below the surface. Indeed there seems to be a succession of ridges, or swells, with low, changeable dip, though the most observable is to the northwest. These ridges are not covered with gravel or sand like some ridges east of the Coteau, under the operation of glacial forces (ice and water), but while they occupy the grand divide of the county, they are nearly bare on their tops and along their slopes, or are thinly covered with a gravelly loam, while the drift, even the stony clay that has been attributed to ice, occupies the valleys between to the thickness of at least 30 or 40 feet.

All over these ridges, which vary from a quarter of a mile to three or four miles in length, and are for the most part thinly covered with soil and turf, there are little nests of large blocks of quartzyte piled so together that they seem to have been thrust up from below by some force. The edges of these blocks are squarely broken off, and slope toward each other, *i. e.*, toward the center of the pile, while the blocks themselves lie so that their upper surfaces slope in all directions away from the center. Similar upheaved spots occur on the red quartzyte outcrops near New Ulm.* These upheaved spots vary from five to fifteen feet in diameter, or perhaps more. They may have been caused by ice, *i. e.*, alternate freezing and thawing with the change of seasons, aided by the force of vegetation and a little soil gradually getting into the openings.

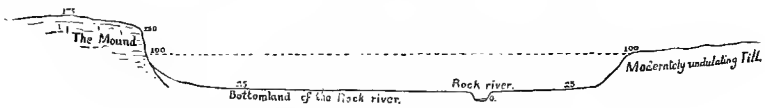


FIG. 40. SECTION ACROSS THE ROCK RIVER VALLEY AT THE MOUND.
Figures designate feet above the river.

At "the mound," where this high land terminates abruptly, and faces the valley of Rock river, the elevation is about 175 feet above the river. The perpendicular bluff of rock is from 40 to 60 feet in its highest part; but owing to a dip of about 10° from the horizon, nearly west, or partly northwest, and to the breaking off of the upper layers, causing a gradual slope from the brow of the hill backward through several rods, the actual thickness of beds visible may be 150 feet. The rock here also appears to be almost entirely a reddish or pink, heavy-bedded quartzyte. If wrought there might be some softer and thinner layers discovered in the angles of the talus, but the refractory nature of the great mass of it will cause it to be used but sparingly for building. The main bluff curves westwardly at both ends, and by reason of the dip and ravines that enter the valley from the west, its exposed layers gradually disappear under the soil in that direction, and the rock is lost in the prairie. From the base of the perpendicular wall of rock, which is about a hundred feet above the Rock river, a talus of blocks and fragments of quartzyte, mingled with glacial drift, curves gracefully down to the bottomland. At points in this slope the quartzyte beds are seen in place, and exhibit the general shape of glaciation but show no striæ, the surface indicating rather the action of water.†

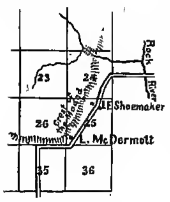


FIG. 41.
VICINITY OF THE MOUND.

Conglomerate. On the tops of some of the ridges in the northwest part of Mound township, apparently near the top of this formation, the rock is conglomeritic. This occurs in large superficial areas, planed and smoothed down (rarely glaciated), and the colors of the pebbles, usually not larger than beans, give these spots a blotched and variegated mottling. The pebbles are mainly white, but some are jasper red and some purple.

According to Mr. Upham, the quartzyte becomes conglomeritic about four miles southwest from Pipestone City. It may be seen by the side of the road to Dell Rapids, exposed along a depression for about fifteen rods, dipping at the rate of one foot in six or eight feet, or about eight degrees south, thirty degrees east. It is in layers from one to two feet thick and contains a multitude of pebbles of white quartz and red jasper, of sizes up to an inch in diameter. The edges of the layers, exposed toward the northwest, are polished, doubtless by the dust particles swept by winds. The surface in some places is as smoothly polished as can be done artificially by the utmost skill and patience.

An outcrop of a similar conglomerate, exposing about an acre of smooth rock, is reported in the west edge of Sweet township, on the southeast side of Pipestone creek, but little east of the state line.

The pipestone, or catlinite, of the pipestone quarry, is a fine clay varying in color from blood-red to pale red or pinkish, or even to a pale yellowish red. The lighter colors fade into the darker, but sometimes the light appears in the red as round spots, on a polished surface, but the red is not thus distributed through the lighter shades. It has of course suffered all the metamorphic influences that the quartzyte itself has, but it has not lost

*See the first annual report, p. 76.

†It appears that the Indians sometimes drove buffaloes over the rocky precipice with which the mound ends, thereby killing them. When Mr Shoemaker, who lives at the east side of this long line of cliff, first explored it, he found a buffalo's skeleton wedged among the huge blocks of quartzyte at its base.

its distinctive bedded structure, which may be seen when examined microscopically in polished thin sections. Indeed it seems to have a laminated structure; and the different shades of color appear sometimes to be due to openings and fissures produced in the red clay becoming filled with sediment of a lighter color. The following analyses* have been made of this substance. It is not truly a mineral but an indurated clay, and its chemical composition varies in consequence. Analysis No. 1 shows the results obtained by Dr. C. T. Jackson from the sample procured by George Catlin in 1837. Nos. 2 and 3 were obtained by the writer in 1877, and were analyzed by S. F. Peckham, the former being of a red color and the latter of a pinkish color. No. 4 was obtained by Mr. Upham from "the palisades" in Minnehaha county, Dakota. It is of a very light color, and is known as "chalk rock." Its color seems to have been derived accidentally, *in situ*, as it is in the line of extension of a bed seven feet thick of a mottled variety of pipestone. No. 5 was obtained by Prof. R. D. Irving at Devil's lake, Wisconsin, and is of a lilac-brown color, analyzed by Prof. W. W. Daniells.

	1.	2.	3.	4.	5.
Water	8.40	7.44	6.48	9.60	2.50
Silica	48.20	57.43	58.25	50.40	62.16
Alumina	28.20	25.94	35.90	33.30	29.67
Magnesia	6.00	....	....	0.17	....
Peroxide of iron	5.00	8.70	....	2.80	4.17
Peroxide of manganese	0.60	....	....	....	....
Lime	2.60	....	....	0.60	0.16
Alkalies	....	....	....	4.10	...
	99.00	99.51	100.63	100.97	99.36

This substance is found at various places in Minnesota and Wisconsin. Indeed it seems to graduate into red shale, and becomes in that form an important constituent of the formation in which it is found.† It seems to be only when this formation is greatly indurated that the inclosed shale beds are hardened to the condition of pipestone. In cases of greater metamorphism its heaviest deposits have been converted apparently into red felsite or quartz porphyries.

Although this substance has usually a red color, like that which pre-

*See page 62; also Am. Jour. Sci. (1). xxxv. 388; Dana's System of Mineralogy, fifth edition, p. 796; sixth annual report, p. 101; tenth annual report, p. 203; Geology of Wisconsin, vol. II p. 510
The analysis by T. Thomson, given on page 796 of the fifth edition of Dana's System of Mineralogy, is of a pipestone obtained from the Indians on the northwest coast of North America. It was of a "light grayish-blue color, not much harder than gypsum, and did not fuse *per se* before the blowpipe. Excluding the iron, the composition approaches that of an oligoclase. It has no relation to the catlinite."—[J. D. Dana in a letter to the writer]. Annals N. Y. Lyc. III., 9, 1827; Thomson's Mineralogy, I., 287, 1836; Dana's Mineralogy, second edition, 1844, p. 591; id., third edition.

†See the reports on Blue Earth, Scott, and Hennepin counties, records of deep wells; also Geology of Wisconsin, vol. IV. p. 578; also tenth annual report, pp. 30—34.

vails in the formation to which it pertains, it should be added that this redness suffers all the variations that it does in the quartzyte. It passes nearly to white, through pink; it is intensified to a brown, and in small patches it is deepened to lilac or lavender-brown, becoming reddish purple. It is only with a loose application of the term that it can be styled "gray," a color which is derived from a mixture of black and white, and which is applicable to the schists and quartzytes of the northern part of the state pertaining to a lower geological horizon.

Mr. Upham notes that Mr. McDermott found numerous pieces of pipestone about seven feet below the surface near the base of "the mound" near Luverne, in excavating to improve a spring near his house. This was partly light-colored, and partly of a deep red color, and was thought to be from a layer in place, near the base of "the mound." Mr. Upham also reports pipestone from section 20, Rose Dell, where it appears upon a little ridge about a quarter of a mile long from northwest to southeast, having the usual colors and character. This is on the authority of D. E. Runals, of Edgerton. Further statements respecting the uses of this pipestone, will be found under *archæology*, at the close of this chapter.

The drift. Till. These counties lie mainly outside of the great moraine that crosses the southwestern portion of the state, and their drift features present some peculiarities. They are still, in general, till-covered, that deposit exhibiting a thickness, and a general uniformity in its features equal to, if not greater than, many of the counties that lie within the morainic belt. That is to say, its composition does not change so frequently to gravel and sand, and its upper surface is not so frequently broken by hillocks, or depressed by short valleys. Yet toward the south it exhibits features that seem to indicate its greater age. Its gravel stones, particularly those of limestone, are rotted. Its boulders become less conspicuous and apparently less numerous, at least superficially, and it assumes a pebbly rather than a stony composition. Within it appear those limy concretions that have frequently been mentioned in describing the loam of the Mississippi and Missouri valleys. These concretions accompany this pebbly composition, until by the gradual withdrawal of the pebbles, there is found a fine, clayey loam which cannot be distinguished from the loess-loam of the Missouri valley. This transition does not involve the whole thickness of the till, but pertains to its upper portions.* At a few feet below the surface the till, even in the southern part of Rock county, is stony.

*Compare the report on Fillmore county, pp. 311-317.

Terminal moraine. The outer terminal moraine, formed at the border of the ice-sheet of the last glacial epoch, when it reached its maximum extent, lies in the northeast part of Pipestone county, which it enters from the southeast in sections 12 and 13, Rock, thence running northwest and passing into Lincoln county at the north side of sections 1 and 2, Fountain Prairie. The moraine here varies from one to two miles in width, and forms the crest of the broad area of highland called the Coteau des Prairies. In northeastern Rock, and from section 35 to section 28, Ætna, it consists of very roughly and prominently hilly till, diversified by many knolls and short ridges, of no well-marked uniformity in trend, much in contrast with the smooth surface of till, in long, gentle slopes and swells, lying 100 to 150 feet below this moraine upon each side. The till or boulder-clay constituting the moraine seems to differ from the same deposit in the smooth tracts only in containing a very much larger proportion of boulders and pebbles, which on the morainic hills and ridges are commonly at least twenty times and often evidently more than a hundred times as plentiful as they average upon the ordinary moderately undulating areas of till. Many of the knolls and hillocks of this moraine in Ætna are very stony with rock-fragments of all sizes up to five or six feet in diameter, mostly, however, not exceeding half this size. The water-courses on the flanks of this massive, knolly ridge are deep, steep-sided ravines; and sloughs and lakelets are rare. From the south part of section 20, Ætna, the next three miles of this moraine northwesterly are less knolly than usual; but farther to the northwest it is as irregularly broken as in southern Ætna and northeastern Rock.—UPHAM.

Loam-clay. The plate (No. 23) which represents these counties is so colored as to indicate an extension of the loess-loam of the Missouri valley over a small area in the southwestern part of Rock county; but it should also be added that this extension is limited rather by an ideal than an actual boundary, and is designed to include only that area which shows an unequivocal aqueous action in the form of more or less stratified clay. A gravelly clay, which, as already stated, seems to graduate on the one hand into the loam, and on the other into the common till, is found on the surface some miles farther north, but it is here colored as if a part of the till.*

*The sixth annual report, p. 104.

This finer till, or pebbly clay, seems to have the age of the till on which it lies, rather than of that accumulated by the last glacial epoch, and seems to require the presence and action of a lake of standing water at the moment of deposition.* The water in such case would not only produce such plasticity in the till as to allow the heavier and coarser components to seek the bottom of the mass, but perhaps to cause their dislodgment from the ice, and their deposition somewhat earlier than the great mass, the smaller stones and pebbles being retained and more thoroughly mingled with the clay.

Kame-like deposits. In the south part of Spring Water the surface is principally till, but knolls or swells are found occasionally to consist of gravel and sand ten to twenty feet deep. These deposits of modified drift seem to be of kame-like origin, and to be of the date of the earlier glacial epoch, due to the rapid action of rivers on the drift at the time of its deposition. Such water was probably confined within gorges in the ice, and had ample facility for washing the till as fast as brought forward by the ice, carrying away the clayey constituents and leaving only the coarser.

Other localities of similar deposits, consisting partly of till and partly of sand, are seen in the S. W. ¼ sec. 20, Denver. Here a few knolls and short, rough ridges, with abundant boulders up to two feet in diameter, rise from twenty-five to forty feet above the general level. Again, in the west part of section 8, Eden, Pipestone county, are other kame-like accumulations, largely consisting of till with many boulders, sometimes five feet in diameter, but mostly smaller. These rise from twenty to thirty feet above the surrounding country. Similar, but perhaps somewhat higher hills and swells are seen in the east edge of this township (probably section 13), and the adjoining part of Elmer.

The level terrace of gravel and sand, underlain by till, on which Edgerton is built, is about two-thirds of a mile in extent from west to east with a hight thirty to forty feet above the Rock river.

Boulders. The "three maidens" and the three others (smaller) that make up the cluster of six lying just outside the Indian reservation at the pipestone quarry, fig. 42, rest on the surface of the red quartzyte about sixty rods southeast of the quarry and at the foot of the long ledge or es-

*Compare Geology of Ohio, vol. i, p. 606: vol. ii, p. 232; Proc. Am. Assoc. Adv. Sci., 1872, vol. XXI., p. 182.

carpment that passes north and south. They evidently once constituted one immense boulder and have become six from the falling apart, under the influence of frost, of the granite along its natural seams or joints. Such a separation of large boulders sometimes is seen on the prairies in Minnesota under circumstances which demonstrate their former entirety. The largest three pieces, each about twenty feet long and twelve feet high, are the Three Maidens, so called. Another piece is about twenty feet long and eight feet high. Two other pieces, nine and twelve feet long, are four or five feet high. There is also a seventh fragment about five feet in length. Together they must have constituted, as remarked by Mr. Upham, the largest ice-transported block known in Minnesota, making a mass from fifty to sixty feet in diameter. The pieces are all alike, and no other boulders of any kind are seen in the vicinity. They consist of red, coarse-grained granite, similar to that seen in outcrop near New Ulm, a short distance west of the outcrop of conglomerate on the north side of the river. Other large boulders of red granite are found in Rock county, and, taken in connection with their size, they all indicate the close proximity of their source. It is probable that the rock that underlies the Potsdam in these counties consists of this red granite.*

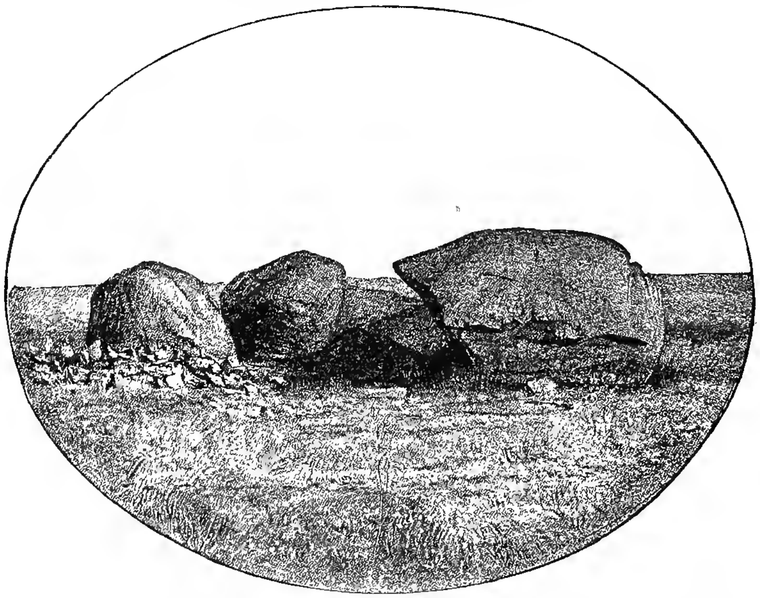


FIG. 42. THE THREE MAIDENS.

*See Catlin's speculations, page 64; also compare the report on Nicollet county. The name *three maidens* is applied to these boulders from the tradition that after the destruction of all the tribes in war, the present Indians sprang from three maidens who fled to these rocks for refuge.

In traveling over the plateau of quartzyte, about on section 16, Mound, a large, solitary granite boulder may be seen. It lies directly on the quartzyte. It is rough and granulated, and there is a circular excavation or concavity in the soil in which it lies. It is about ten feet long and five feet high, and has a groove horizontally circumscribing it about a foot in width and three or four inches deep. Taken altogether it immediately reminds the beholder, not less by its general shape than by this groove, of the artificial *stone hammers* sometimes found. Its size precludes its being one, but its shape is very like them. The groove may have been formed by the action of ice and water on its sides, as the rock has the appearance of lying, in ordinary seasons, in a little lake of water, which at the time of this examination was entirely dried up. This boulder, like the "three maidens," at the pipestone quarry, must be referred to the date of the earlier boulder-clay.

On the south slope of one of the drift hills mentioned in the vicinity of the line between Eden and Elmer, about two rods east of the road as it is now traveled, is a boulder of reddish granite, ten feet long and six feet wide. The earth all around this boulder, to a distance of ten or twelve feet, is hollowed out one to one and a half feet below the general level. This is an unusually large block, its hight now projecting being five feet. Smaller boulders, three to six feet in diameter, are seen quite frequently upon the vast prairie of southwestern Minnesota, similarly surrounded by a hollow. These depressions may have been started by the pawing and tramping of buffaloes, the pulverized earth having been then blown away by the winds. The ruts of roads on the prairies seem often to be deepened in a similar way by the winds blowing dust from them; and in winter the wind maintains similar circular depressions about solitary trees, when the surrounding country may be covered with two or three feet of snow.

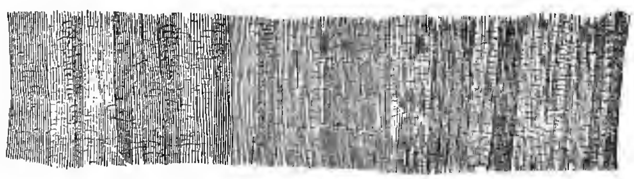
It has already been mentioned that there are but few boulders in Rock county. They are generally confined to the creek bluffs and valleys. Even on the plateau caused by the red quartzyte running from near Luverne northwestward they are not seen, or are so rare as to be noteworthy for their absence. This is an anomaly, and can be accounted for by the great lateral extent of the quartzyte plateau, so that not many fissures were produced by it in the ice-sheet, where running water could find passage. There would be no place, ordinarily, where foreign boulders would be found, in a drift-covered country, more thickly than on such rocky elevations.

Glacier-marks. There is evidence of glacier-action, or what has been recognized as evidence of glacier-action, in Rock county south of the Coteau. The quartzyte is polished, striated and sculptured superficially on the tops of the ridges in the central part of the county as only glacier-ice is known to do. At the pipestone quarry (near "the three maidens"), such marks run 32° W. of S. (true meridian). On the strike of the ledge at the same place they run N. and S., varying to 30° W. of S.* On section 13, Eden, they run in two directions, one direction being about S. 10° W., and the other S. 42° E., within the valley of a little stream. On the rock near the top of the southern side of this valley, which is a shallow depression, glacial marks run S. 32° W. This is but a few rods from the last observation above. At another point, about ten miles north of Luverne, glacial marks were observed running S. 10° W. On the rock at "the mound" they run 25° to 30° and 35° W. In many places they are conspicuous and abundant, and perfectly preserved, covering considerable areas.

*Allowing ten degrees for the variation of the needle to the east of the true north. Mr. Upham records glacial marks at the *three maidens*, and on the N. and S. ledge, both 25° W. of S.

It seems almost impossible that in so level and open a country, and on the same rocks, without apparent cause, the glacier which must have been hundreds of miles wide, if it existed here at all, could have taken such diverse directions in so short distances. It cannot be doubted, however, that this marking was done by a force that exerted a great pressure at the same time that the marks were made. This pressure is evinced not only in the marking itself, which is on the hardest formation found in the state, but in the minute cross-fractures that cover the surface where this rasping has taken place, and yet leave it in the main a smoothed and moutonnéd surface. These cross-fractures run curvingly downward at varying angles with the surface, and to all depths less than an inch, but usually less than one-sixteenth of an inch, and indicate perhaps an incipient crushing to the depth of at least an inch. They show in what manner the rasping reduced the original projecting knobs. Where the natural seams or planes of jointage cross the rock, causing the quartzyte to chip off sooner and deeper with a curving and conchoidal fracture, these little checks are larger. Their prevailing direction is transverse to the rasping force, so that the rock, along some grooves, has a short conchoidally fractured structure transverse to the grooves, penetrating it to the depth of a quarter to half an inch, exhibited now in a series of little curving furrows where the laminæ broke off successively, the convexities of the laminæ being toward the north.*

NORTH.



SOUTH

FIG. 43. GLACIAL MARKINGS ON THE RED QUARTZYTE.

This marking is represented in fig. 43, but the figure does not show a great many fine checks with which the surface of the rock is nearly covered. It shows correctly the prevailing direction of the curvature, and its relation to the moving force. This manner of glaciated marking is visible

*Compare the sixth annual report, p. 107. Dr. E. Andrews has recently described a similar cross-fracture striation seen on the northeast shore of lake Huron on a similar rock; his observation makes the convexities of the laminæ turned toward the moving force. *Bulletin of the Chicago Acad. of Sci.*, vol. i, No. 1. *Am. Jour. Sci.*, (3), xxvi, 101.

on section 13, Eden, and also on "the mound," near Luverne; also at Sioux Falls in Dakota. It can be compared to a cross-grained planed board, where the plane has been drawn against the grain, except that the cut edges are curved so as to present their convexity toward the cutting or planing force.

Thickness of the glacier in Rock county. This incipient crushing of the red quartzyte under the ice may be taken as a datum on which to compute the thickness of the ice at the time of its production. According to the table of the qualities of the building stones of Minnesota, already given (page 195), the red quartzyte from Pipestone City has a crushing resistance equal to 27,000 pounds per square inch. The specific gravity of ice is 0.92. Hence a column of ice nearly eleven miles in hight would be required to produce the pressure of 27,000 pounds. This calculation is subject to correction for the following sources of error: 1st. The ice may have carried a large amount of drift, rendering the comparative weight much greater, and requiring less perpendicular hight. 2d. The crushing produced is superficial, and is not the same as the breaking down of a cube of stone placed between steel plates. 3d. The fractures were formed by a rasping or scratching force and would be more easily produced than a total crushing down of the strata. 4th. The stones which were agents in the grasp of the ice in thus marking the quartzyte, presented only their tangential points, but must have supported a column of ice equal to the area of their horizontal periphery. 5th. The strength of the quartzyte may be overstated.* The import of this calculation therefore cannot be much more than to warrant the statement that the ice was very thick, perhaps several miles.

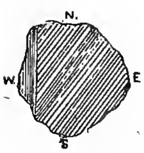


FIG. 44. Striated surface in Rock county.

Mr. Upham gives the following further observations on glacial striæ in Rock county: "Very interesting glacial striæ were seen on the quartzyte, one rod east of the road about a mile north of where the east road from Luverne to Pipestone City rises upon the quartzyte of the Mound, probably in the southwest quarter of section 23, Mound. At its west edge a width of two feet, as shown in the annexed sketch (fig. 44), is striated from north to south, while the rest is striated S. 35° W. The line dividing these areas, marks a definite change of plane in the rock surface, which is inclined downward at the west four or five degrees, and at the east about half as much; making a beveled angle of 5° or perhaps 7°. It seems to me that these striæ were probably engraved at different dates by one ice-sheet which had constantly covered this district. When the ice attained its maximum area, the current of this portion, would be nearly from north to south; but during the final melting, as its retreating western border came nearer and nearer to this place, the current must have been deflected southwestward,

*Comparative strength of Minnesota and New England granites, Proceedings of the American Association for the Advancement of Science, Minneapolis meeting, 1883. James Croll has estimated the present thickness of the ice on the antarctic continent at twelve miles, with a superficial slope of one half a degree.--*Climate and Time*, p. 375. Prof. J. D. Dana has estimated it at 5000 feet in New England during the glacial epoch.--*Am. Jour. Sci.*

approximating to a direction perpendicular to the ice-border. That the striæ bearing S. 35° W. belong to a later date than those from north to south, is made quite certain by the fact that the former is approximately the prevailing course of striation in this region; for the last glacial erosion upon any area must obviously efface the greater part of the earlier striæ.

"About a mile farther north, perhaps in the southeast quarter of section 15, Mound, on a similar small, low exposure of quartzyte, also only one rod east of the same road, similar striation was observed, the larger (west) part of this exposed rock-surface being striated from north to south; and the smaller (east) portion, S. 35° W. A slight difference in slope of these differently striated portions of the rock surface is also seen here, forming a beveled angle (fig 45). These observations agree in all respects with the preceding."*

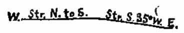


FIG. 45. Beveled angle.

Natural waters. The water of the Rock river at Luverne was examined chemically for the survey by Dr. W. A. Noyes in November, 1882, with the following results:†

Analysis of the water of Rock river. Chem. Series No. 133, *showing the composition of the residue from evaporation.*

	Parts per 1,000,000.	Percentage.	Grains per gallon.
Silica, SiO_2	21.0	7.6	1.22493
Alumina, Al_2O_3	1.0	.4	0.05833
Iron oxide, Fe_2O_3 (?)	8.8	3.2	0.51330
Calcium carbonate, $CaCO_3$	136.0	49.6	7.93288
Calcium sulphate, $CaSO_4$	6.4	2.3	0.37332
Calcium nitrate, $Ca(NO_3)_2$	traces		
Magnesium carbonate, $MgCO_3$	70.4	25.7	4.10643
Lithium phosphate, Li_3PO_4	minute trace		
Potassium sulphate, K_2SO_4	3.3	1.2	0.19249
Sodium sulphate, Na_2SO_4	25.6	9.3	1.49325
Sodium chloride, NaCl	2.0	.7	0.11666
	204.5	100.0	16.01159

Iodine and bromine were absent, as well as borates; the test by permanganate showed 1.1 parts of oxygen consumed by organic matter for each million parts of water; hardness, 17 degrees. This water is notable for the large amount of iron.

Springs. A spring that issues from the base of "the mound" on Mr. Lary McDermott's farm, is said to supply soft water. This can only be accounted for by supposing the water to pass only through the strata of the Potsdam formation, which in some places is quite open and pervious; since the drift deposits of the county, as well as the strata of the Cretaceous (if such exist in these counties), will only supply a hard water, and also very often one somewhat alkaline. Springs, from whose calcareous matter the peculiar deposit of travertine called "petrified moss" is being formed, occur on the northwest side of Chanarambie creek, in section 22, Osborne. Other springs, notably ferruginous, occur near by, and similar springs are found occasionally along Chanarambie creek for several miles above this point.

Two remarkable mineral springs, supposed to contain sulphur, occur about a quarter of a mile northwest of the east branch of Split Rock creek, on the S. E. ¼ of section 20, Eden.

Wells in Pipestone county.‡

Rock. John Hipes; S. E. ¼ sec. 4: well 20 feet; soil, 2; yellow till., picked, 18; water seeps.

Burke. The railroad well at Woodstock station, in the S. W. ¼ of section 2, was dug 54 feet, and bored 18, to a total depth of 72 feet; it was yellowish till for the first 40 feet, below which it was all darker, bluish till. The only water obtained seeps within the first sixteen feet from the surface, and fills the well to within ten feet, and sometimes within six feet below its top, but does not yield a large supply.

Osborne. J. B. Barlow, Jr.; Edgerton, in the N. E. ¼ of sec. 28: well dug to 40 feet, and bored 25 feet, to 65 in total; soil, 2 feet; sand and gravel (modified drift in the valley of Rock river and Chanarambie creek, on a terrace of which Edgerton is built), 16 feet; blue till, spaded

*See also page 504.
†Eleventh annual report.
‡Most of the notes on wells are by Mr. Upham; and many in Rock county are from Mr. Aaron Baer, of Luverne.

and bored, 47 feet, and extending lower; the only water found was in the lower part of the grave and sand.

Fountain Prairie. T. P. Woodle; S. W. ¼ of sec. 12: well, 18 feet; soil, 2; yellow till, 14; harder blue till, 2; water seeps. Another well, on the same quarter-section and same farm, after going only 7 feet, which was yellow till, found a spring (with no sand) from which water rose four feet in three hours.

Grange. Alfred Johnson; sec. 33: well, 22 feet deep; soil, 2; yellow till, spaded, 18; containing at 14 feet below the top of the well a layer of dry sand and gravel, three inches thick; harder blue till, 2 feet and extending lower; water comes in large amount between the yellow and blue till, rising six to eight feet.

Gray. Dr. William Taylor; N. W. ¼ sec. 18 (one mile S. E. from Pipestone City): well, 55 feet; till, mostly yellowish, with some darker layers, 52 feet, containing pebbles sparingly in its upper part, mostly limestone and small, also a white, soft, chalk-like powder, sometimes in part, or wholly, a hard and compact stone, in lumps up to three inches long, evidently of similar origin as the drift-pebbles, and below containing many pebbles and boulders of granite, syenite, and crystalline schists, up to six or eight inches in diameter; under this till is sand and gravel, 3 feet; water, only becoming three feet deep, is found in this stratified drift at the bottom.

Elmer. F. A. Bishop; sec. 30: well, 24 feet; soil, 2; yellow till, 22; water seeps, standing ten feet deep.

Sweet. Wells at Pipestone City are 20 to 45 feet deep, all till, yellowish above and dark bluish below; in the east part of Pipestone City, they strike quartzyte.

Eden. William F. Lange; sec. 6: well, 16 feet; soil, 3; yellow till, spaded, 13; water seeps, plentiful and of excellent quality.

Wells in Rock county.

Battle Plain. F. M. Snow; sec. 2: well, 34 feet deep; soil, 2 feet; yellow till, picked, 32 feet; water seeps, coming mostly at 20 feet and below. Frequent chalk-like concretions (or, more probably, pebbles of rotted limestone, as in Dr. Taylor's well) were found from two to ten feet below the surface, in till as gravelly and stony as any below.

John Boyes; sec. 12: well, 25 feet; soil, 2 feet; yellow till, all picked, 23; water seeps, of excellent quality, coming mostly about 13 feet below the surface, filling the well nine feet deep.

Vienna. William Maynes; sec. 26: well, 30 feet; soil, 2; yellow till, spaded, 28 feet; water seeps, excellent in quality, filling the well ten feet deep.

John P. Landin; sec. 28: well, 30 feet; soil 2; clayey sand, not caving in, containing no pebbles, 8 feet; yellow till, 20; water five feet deep.

Magnolia. A well on sec. 16, 24 feet deep, was, for all below the black soil, common yellowish joint-clay with gravel mixed (till); this well stopped at the top of the blue till, which was very hard and dry. "There was one well drilled here [sec. 16], 410 feet deep; soil, 3 feet; yellowish joint-clay [till], about 15 feet; then a grayish clay, about 10 feet; then it runs off into a mixed yellowish and bluish clay, the lower part being the bluer, 3 or 4 feet; then comes the regular blue or black clay, as it is commonly called; at 165 feet they struck quicksand of a light color, 4 or 5 feet thick; then it went off into the old black clay again. They struck some rock; I cannot tell whether bed-rock or boulders; as near as I can learn, they were of a darkish color and of a sandy nature, not so hard as our red Mound stone. I did not dig or drill this well; it was only a six-inch hole. . . . . . . Right by the side of this deep boring, I sunk a well four feet in diameter, 30 feet deep, and prospected down 100 feet from the bottom of the four foot hole (size of prospect hole three inches), finding nothing but blue clay [till]."

On section 19 a well 18 feet deep was soil, 4 feet; sand and gravel, 4 feet; the yellowish "joint-clay" (till), 10 feet; then black clay (dark bluish till). The foregoing wells in Magnolia, reported by Mr. Baer, appear to be all on the lands of the Rock County Farming Company.

The well at the western and larger farm-house of this company, in sec. 7, is 47½ feet deep; soil, 4 feet; yellowish or reddish till ("clay with a little sand and gravel mixed"), 3 or 4 feet; then gray or ash-colored clay (probably till), hard and dry, full of seams or joints, about 18 feet; yellowish or reddish clay and sand and gravel mixed (the sand and gravel in the clay being in pockets or irregular layers, and of a very red or rusty appearance and cemented together), 6 feet; then the same gray or ash-colored clay (doubtless till) as above, except that it contains a little more gravel mixed in, and also small deposits of silver-white sand in pockets varying from one to three inches in thickness, about 15 feet; at 47 feet was a layer of dark bluish clay, very soft, six inches thick, underlain by quicksand, from which water of excellent quality rose twenty-one feet in five minutes, the well being three feet in diameter.

Another well, 32 feet deep, situated twenty-five rods north of the foregoing, was the same as that for the first 18 feet; then a bed of water-bearing gravel was found, 1½ feet thick; beneath which the well went 12½ feet in soft grayish clay, probably till, full of seeping water.

In sec. 5 a well 10 feet deep, near the head of a slough, found soil 5 feet; soft, grayish clay with seep-water, 3 feet, and gravel with abundance of water, 2 feet. In this well, between the soil and the clay, was found "a lower jaw-bone of some graminivorous animal; one side was badly decayed, the other was sound; four of the big molars were in a perfect state of preservation." In the gravel were noticed "some small pieces of shells such as clams and snails."

Henry Halbert; S. W. ¼ of sec. 12; well 30 feet; "joint-clay" all the way; water good, seeps.

Frank P. Kennedy; sec. 32: well 100 feet deep, mostly the ordinary dark bluish till, not striking rock; water rose rapidly, filling the well half full.

Martin. G. L. Thaden; sec. 2: well, 24 feet; soil, 2; yellow till, spaded, 15 feet; compact gravel and sand, with boulders, rounded stones, up to one foot in diameter, making a "hardpan," yellowish, iron-rusted, 2 feet; blue till about the same in hardness as the yellow till, 5 feet, and extending lower; water comes at the top of the blue till, usually standing about five feet deep.

John B. Martin; S. E. ¼ of sec. 12: well, 22 feet; soil, 3 feet, containing no gravel, and very rarely any pieces of rock; yellow till, 10 feet; harder blue till, 9 feet, and extending lower; water seeps at the bottom of the yellow till, usually affording an ample supply. Mr. Martin states that chalk-like, limy concretions, one to three inches long, flattish or shaped like potatoes, were found quite numerously in the blue till of his well, which, as also the yellow till, has many pebbles and fragments of granite, hornblende schist, limestone, quartzyte, etc. These limy concretions were infrequent or wanting at this place in the yellowish upper portion of the till.

Kanaranzi. Jacob Rush; S. E. ¼ of sec. 6: well, 32 feet; soil, 2; yellowish till, 30 feet, slightly gravelly in its upper portion, all yellowish gray, excepting one foot, which was darker and harder than the rest, covering a part of the well at the depth of 28 feet, becoming more gravelly below, with the last foot holding frequent stones up to six inches in diameter; water rose six feet from the bottom, which seemed to be only a gravelly softer portion of the till. Soft chalk-like lumps, up to two inches in diameter, were found in Mr. Rush's well, mostly at 5 to 8 feet, but also to some extent all the way down to the bottom. This was in true till. Such chalk-like lumps (sometimes drift-pebbles from Cretaceous beds, but often evidently concretions of segregated calcareous matter, analogous with the concretions of the loess) are found quite commonly in wells of this region, both in the blue and the yellow till.

Mr. Shively; well, 22 feet; good water from sand at 18 feet, under "joint-clay".

William Macnab; N. W. ¼, sec. 18: on the upland east of Rock river: well, 62 feet; soil, 5 feet; reddish sand, 1 foot; yellow till, spaded, 5 feet; much harder bluish till, more gravelly, dark at first, bluish gray in the lower portion, 51 feet; this blue till was all the way moist, but had no springs, and no supply of water was found.

Mound. Lary McDermott; S. W. ¼, sec. 25: well, 28 feet; black soil, 6 feet, alluvial and partly wind-blown from the top of the mound, in whose lee this well is situated; yellow till, spaded, 19 feet; gravel and sand, 3 feet, enclosing occasional flat pieces of quartzyte, and yielding plenty of good water, which becomes one and a half feet deep.

Thomas Kennedy; N. W. ¼ of sec. 35; well, 42 feet; "a dangerous gas gathers in this well; struck black clay at the depth of 15 or 20 feet; and at the depth of 40 feet we struck a log, which the auger bored in two; it seemed to be petrified, and it looked like cedar, judging by the grain; at the bottom of this log, there seemed to be a black lot of rubbish, such as bark and leaves, appearing flaky, as leaves would be under such circumstances; the sand beneath was dark and the water poor, so that it could not be used."

Clinton. E. A. Brown; sec. 14: well, 30 feet; soil, 3; yellow clay, becoming dark below, thought to have no grit or gravel in it, but containing occasional small pieces of stone, probably twenty-five and perhaps fifty found in this well, which was bored about two feet in diameter, 27 feet; water seeps, becoming three feet deep. This well is situated close west of the bottomland of the Rock river, and about ten feet above it.

Spring Water. Edwin Chesley; sec. 30: well, 28 feet; soil, 2; yellow gravel and clay, 2 feet; then a gray layer, slanting a little to the south, very hard, 3 inches; typical yellow till, 8 feet; changing below to blue till, harder than the yellow, most gravelly below, and softer in its last four feet, 16 feet; water seeps at the bottom, in the last two feet.

Beaver Creek. Jacob Merkel; sec. 21: well, 28 feet; soil, 2; yellow till, spaded, 25 feet; gravel and sand, 1 foot, with yellow till below; water rose nine feet from the bottom in one day.

E. T. Sheldon's well, 18 feet deep; situated in the valley of Beaver creek, but on an island in time of high water: soil, 3 feet; sandy loam, somewhat gravelly, 3 feet; gravel, stones and shells, the lower two feet being sandy, 8 feet; gravel, 2 feet, with water; blue clay, containing wood, 2 feet. These shells, which seem to have been fresh-water univalves and clams, were so soft that they could be reduced to powder between the thumb and fingers, though some were perfectly hard. Water good.

Beaver Creek station, town well; N. W. ¼ of sec. 28: well, 62 feet; soil, 2; yellow till, 18; harder blue till, 42, its last foot being specially hard; water rose rapidly to be thirty feet deep, probably springing from a bed of gravel and sand at the bottom. A piece of wood two feet long and four inches through was found in the lowest very hard foot of the blue till. No other occurrence of wood in till could be learned of in this region; fragments of lignite, too, seem to be very rare, or altogether absent.

C. R. Henton; sec. 22: well, 48 feet; loam; blue clay; good water from a sandy layer in the blue clay; stone curbing.

W. T. Henton; sec. 30: loam; blue clay; stopped in blue clay; water foul from the wood curbing.

C. Williams; sec. 28: loam; blue clay; water seeps.

Wm. Grout; sec. 24; loam and clay; good water; the clay was all gravelly, except the very surface soil, with little bunches of sand; water seeps.

W. O. Crawford; S. E. ¼ of sec. 20: well 28½ feet; abundant good water in quicksand; in the stony blue clay, twenty feet from the surface, a stick with a grain like elm was taken out.

Luverne. A. L. Marsh; S. W. ¼ of sec. 4: well, 33 feet; "joint-clay" all the way, more compact at the bottom; water seeps.

Mr. Stone, Luverne: well, 13 feet; sandy loam, then loose stones, 6 feet; gravel, 8 inches; pebbly clay, 7 feet; then blue clay.

Allen Taylor; N. E. ¼ of sec. 10: well, 84 feet; soil, 4; sand, gravel and clay, mixed, 3; gravel, 10; yellowish clay, 2; blue clay, with two gravel pockets three to five feet through, with water in them, which having been pumped out the well remained dry, 30; the rest of the well was somewhat sandy, with lumps of clay in it, the whole being of a rather dark color, soft and moist, but yielding no supply of water; at 81 feet was found a piece of a shell, as if of a common clam, which was made into an ornamental pin. It had a beautiful color. Here were found also some fragments of wood. This sand was very plastic and clayey when wet, but like flour when dry.

Allen Taylor; N. E. ¼ of sec. 10: well, 12 feet; loam, gravel, and fine dry sand which sparkles in the sun; this sand is so fine as to be water-tight, and makes a reservoir for water.

Peter Webber; S. W. ¼ of sec. 8: well 42 feet; "joint-clay" all the way, with crystals of gypsum; at first no water, but afterward filled to within ten feet of the top with a poor (alkaline) water.

Sioux Falls railroad, sec. 17: well, 15 feet; 'joint-clay", water in loose stones and gravel; red clay below the gravel.

Samuel Spalding; sec. 20: well, 28½ feet; "joint clay or red clay", then blue clay; water from a sand vein in "joint clay".

Samuel Spalding; sec. 20: well, 10 feet; good water in gravel.

Luverne House, Luverne: well, 16 feet; good water in gravel.

The water of wells in the loam, or in the drift clay, is very hard. This is caused by a large amount of limestone gravel disseminated through all the materials of the drift, derived from the limestones of Winnipeg. There is occasionally a water which has a distinctly alkaline character, but this is not common. Many of the wells of the county are curbed with pine boards, and from that fact they supply a water that is now contaminated with the organic decay known to result from that practice, and a number were examined that were very foul from that cause.

The curbing of wells in the prairie regions with pine boards or planks is very common, owing to the lack of convenient stone, and the ease of constructing such curbs of wood; but it is a practice which all well-diggers should loudly and persistently protest against, and which all the owners of wells should discontinue, as it is a fruitful source of foul water, causing intestinal diseases and typhoid fevers.

MATERIAL RESOURCES.

These counties contain some of the best farming lands in the state. They are not broken by rock exposure (except through the central part of Rock county), so that nearly all their area is tillable. The rocks that underlie them are not known to hold anything of great economic value. They will serve as a building material, but are rather hard even for that, and it may be found more economical to bring in by railroad the building stones of the eastern counties. The main material product of these counties is now, and will always remain, *wheat*, of which they will produce as much to the acre as any county in the state.

Building stone. Near Pipestone City the red quartzyte is quarried on land of Mr. C. H. Bennett. Stone suitable for cellar walls and ordinary rough masonry is sold at three to four dollars per cord. Slabs about six inches thick and six or eight feet square can be obtained. Quarrying has also been done here by Mr. J. A. Phelps, leasing from Mr. Bennett. He sold about two hundred cords of stone in 1879, about one-third of it being used in Pipestone City, and nearly the same amount in Flandreau. His quarrying has been at two points; one at the base of the "three maidens," supplying a dark red stone similar in color to the red pipestone, the other a quarter of a mile southeast from that point where the stone is reddish-gray, being at each place very hard, strong and durable quartzyte.*

In the N. W. $\frac{1}{4}$ of section 25, Mound, some thirty rods east of the highest part of the mound, Messrs. Shoemaker and Kelly quarry the red quartzyte. They loosen and throw down the rock from the upper part of the vertical cliff, which is here about forty feet high. This work has been carried on

*Compare the chapter on building stones, p. 149.

since 1875, the annual sale being from fifty to a hundred cords, at three dollars per cord, with an increasing demand. The rock here lies in layers from six inches to two feet thick. The outside is usually the hardest. Samples from Mr. Shoemaker's quarry have been taken to Minneapolis for trial as millstones, of the kind called "enders." One piece sent for this purpose weighed five thousand pounds. Deeper within, the stone is most apt to be red; near the surface it is faded to a reddish gray.

In the S. W. ¼ of section 25, Mr. Lary McDermott has similarly quarried more or less during the past ten years, averaging about fifty cords per year, at three dollars per cord.

In these excavations upon the face of the cliff the rock often shows ripple-marked surfaces, and an oblique lamination of the sand grains.

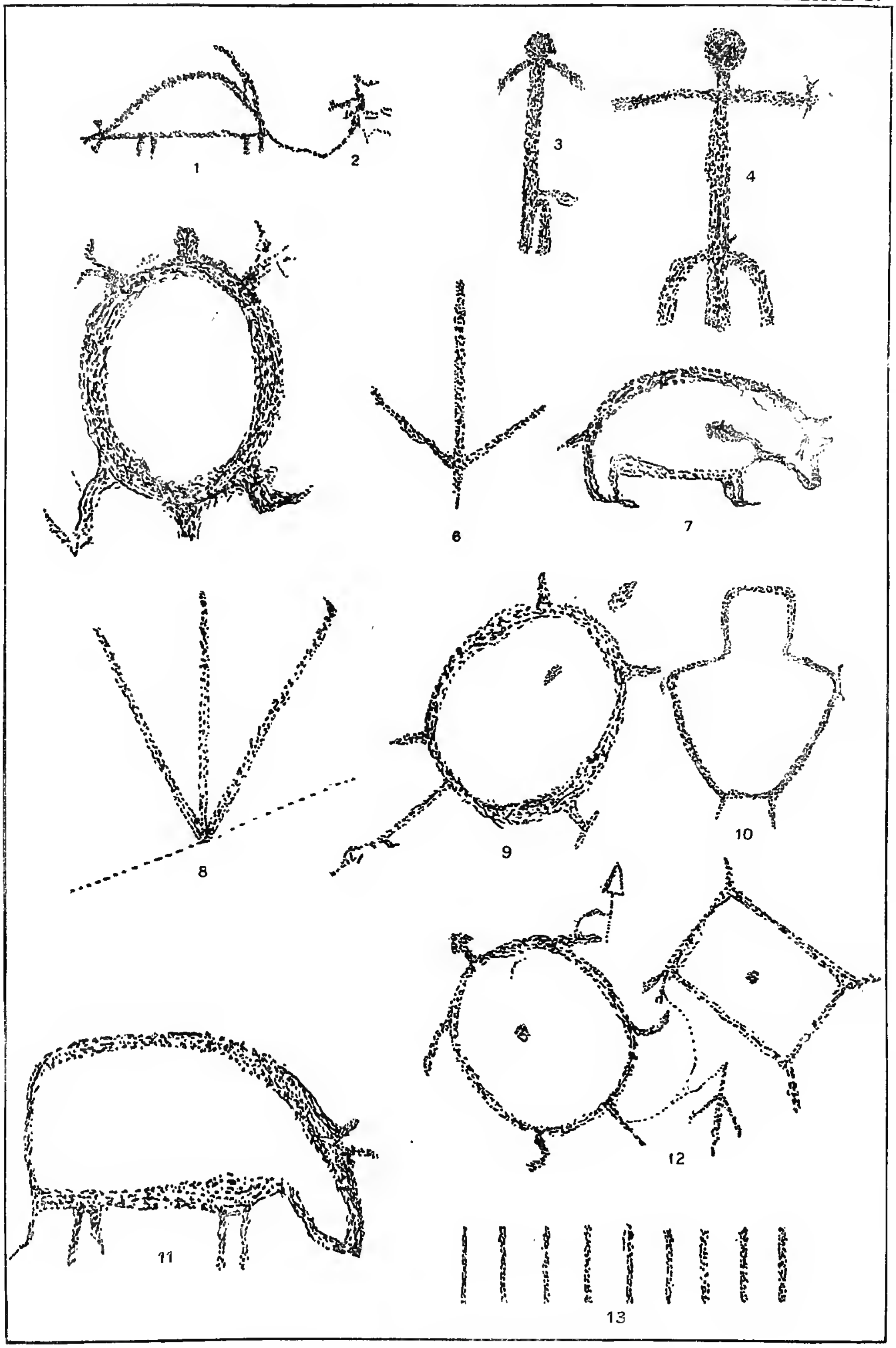
ARCHÆOLOGY.

On the glaciated surface of the quartzyte about the "three maidens", which is kept clean by the rebound of the winds, are a great many rude inscriptions which were made by pecking out the rock with some sharp-pointed instrument, or by the use of other pieces of quartzyte. They are of different sizes and dates, the latter being evinced by their manner of crossing and interfering, and by the evident difference in the weight of the instruments used. They generally represent some animal such as the turtle, bear, wolf, buffalo, elk, and the human form. The "crane's foot" is the most common; next is the image of men like No. 18, on plate J; next the turtle, like No. 12, or No. 5. It would seem as if any warrior or hunter who had been successful, and happened to pass here, left his tribute of thanks to the great spirit in a rude representation of his game, and perhaps a figure of himself, on the rocks about these boulders; or, perhaps, had in a similar way, invoked the good offices of the spirits of his clan when about to enter on some expedition. In some cases there is a connection of several figures by a continuous line, chipped in the surface of the rock, in such a manner as if some legend or adventure were narrated, but for the most part the figures are isolated.* This is the "sacred ground" of the locality. Such markings can be seen at no other place, though there is abundance of bare, smooth rock.† The excavation of the surface of the rock is very

*Compare Vol. II., Bulletins of the U. S. geological and geographical survey of the territories. 1876. p. 3—Article of W. H. Holmes, on the ancient ruins of southwestern Colorado. Col. Charles Whittlesey has described rock inscriptions in Ohio.

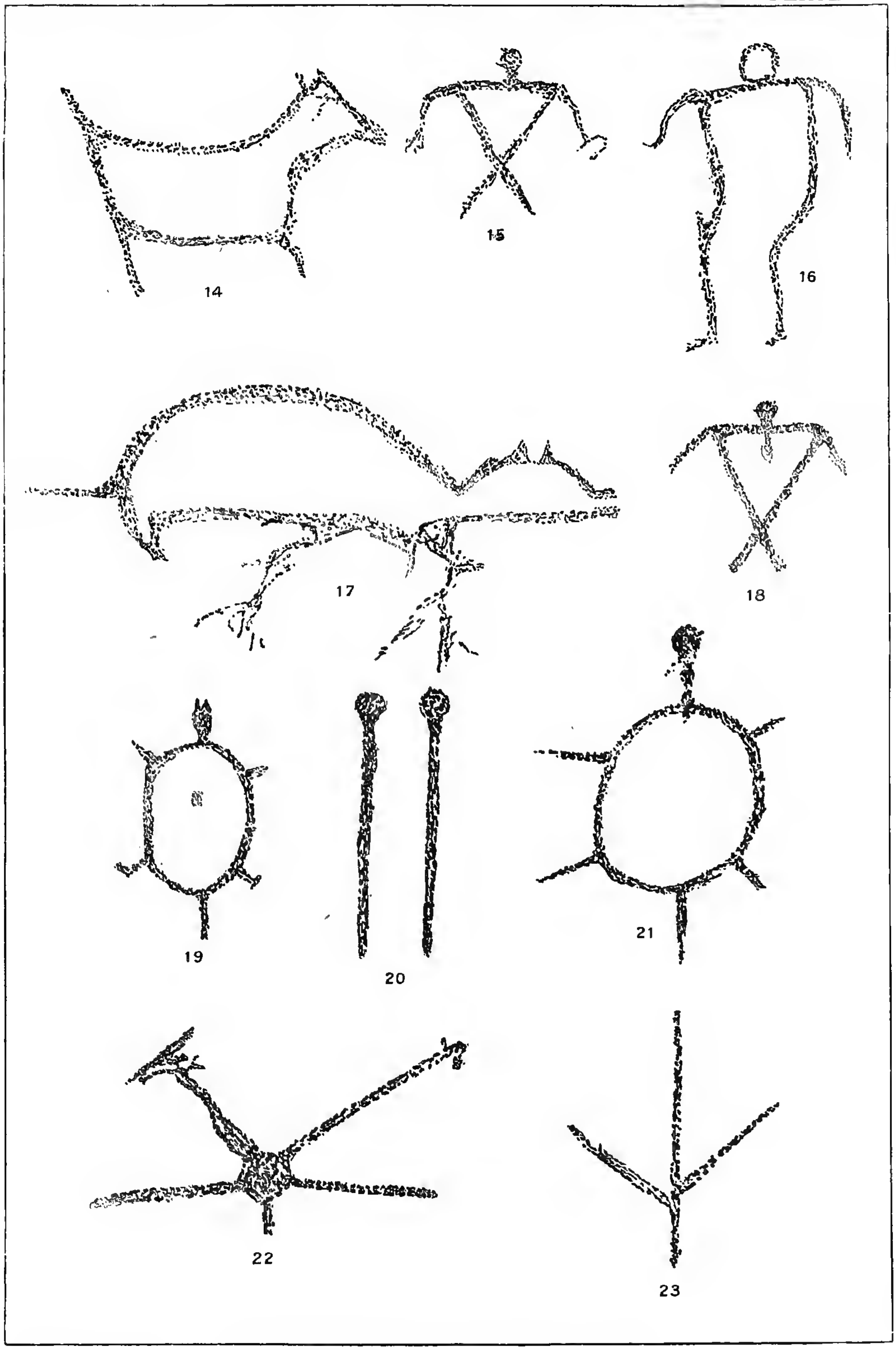
†Similar inscriptions are found on the red quartzyte in Cottonwood county. See p. 501.

PLATE I.



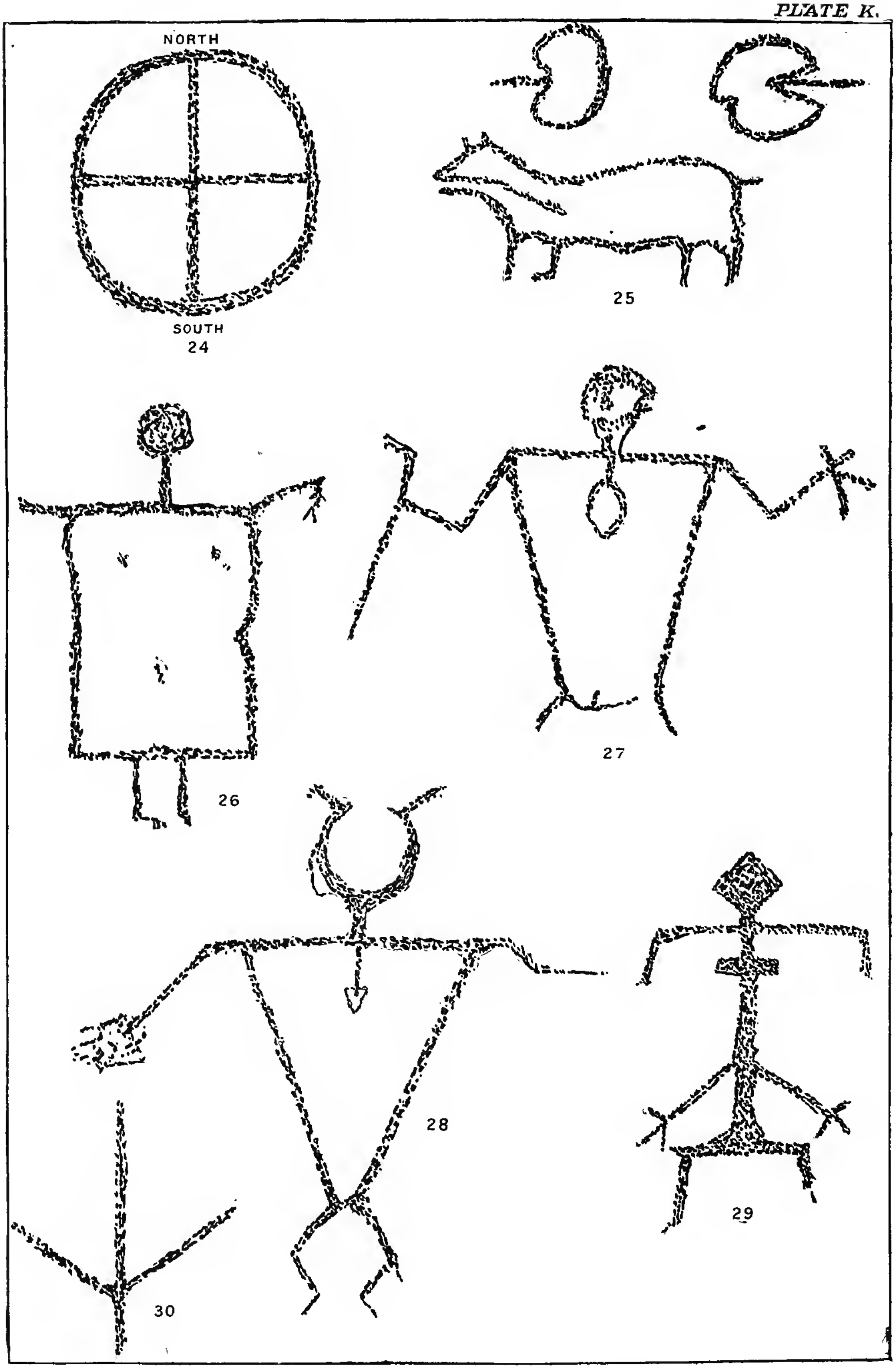
ROCK INSCRIPTIONS AT THE PIPESTONE QUARRY.

PLATE J.



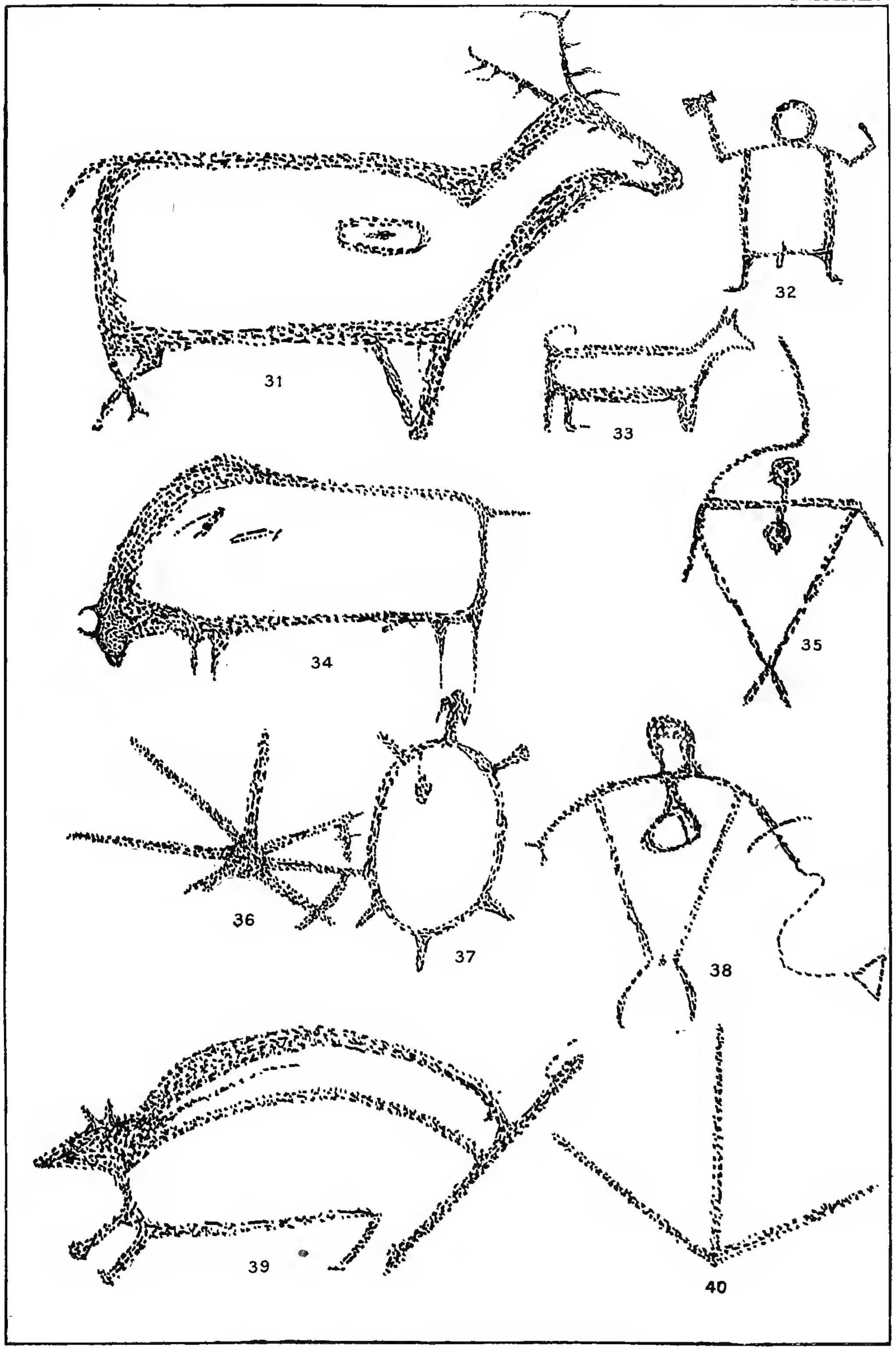
ROCK INSCRIPTIONS AT THE PIPESTONE QUARRY

PLATE K.



ROCK INSCRIPTIONS AT THE PIPESTONE QUARRY.

PLATE L.



ROCK INSCRIPTIONS AT THE PIPESTONE QUARRY.

slight, generally not exceeding a sixteenth of an inch, and sometimes only enough to leave a tracing of the designed form. The hardness of the rock was a barrier to deep sculpturing with the imperfect instruments of the aborigines; but it has effectually preserved the rude forms that were made. The fine glacial scratches that are abundantly scattered over this quartzyte, indicate the tenacity with which it retains all such impressions, and will warrant the assignment of any date to these inscriptions that may be called for within the human period. Yet it is probable that they date back to no very great antiquity. They pertain at least to the dynasty of the present Indian tribes. The totems of the turtle and the bear, which are known to have been powerful among the clans of the native races in America at the time of the earliest European knowledge of them, and which exist to this day, are the most frequent objects represented. The "crane's foot," or "turkey-foot," or "bird-track," terms which refer perhaps to the same totem-sign, the snipe, is not only common on these rocks but is seen among the rock inscriptions of Ohio,* and was one of the totems of the Iroquois of New York.**

The illustrations seen on plates I, J, K, L, are approximately one-fourth the size of the inscriptions. They show the most conspicuous and important of the inscriptions. There are others that are very indistinct, and some that are unintelligible from imperfect or designless cutting. Figure 17 is deeply cut, and was partly hid by overgrowing turf. Figure 24, having its diametral lines agreeing with the cardinal points of the compass, may be intended to express the line of the horizon, and the points north, south, east and west; and it may be so recent as to have been suggested by the modern compass. Figure 31 was interpreted, according to Mr. Sweet, by a Sioux Indian from Flandreau, with these words, " Indian kill elk, three miles," pointing toward the south. Figure 36, which interferes with figure 37, is the earlier of the two, as indicated by the difference in cutting.

The pipestone, which has long been used by the Indians for their calumets, or peace pipes,† has been described in its physical and chemical characters, under the head of geological structure.

It seems that many pipes were made by the mound-builders, of a "red porphyritic stone."†† These were exhumed in Ohio by Messrs. Squier and Davis; and others of red catlinite have been found in Iowa,‡ in each case associated with implements of copper and other objects characteristic of the mound-builders. Pipes of this material are comparatively rare in the mounds, even in the vicinity of the pipestone quarry. One found in Martin

*Proceedings of the American Association for the Advancement of Science. 1871, p. 405.
**Morgan; Contributions to North American Ethnology. Vol. iv, p. 7.
†Carver; page 24.
††Ancient monuments of the Mississippi valley.
‡Proceedings of the Davenport Academy of Natural Science, vol. i, p. 108 and p. 135.

county, taken from a mound, has been described on page 490, composed of a dark gray stone not at all resembling catlinite. A great majority of the stone pipes found in America are made of other varieties of stone, sometimes of steatite, or of serpentine, or "slate," or some very much harder material, even of granite.* A pipestone found on the international boundary, in Minnesota, is of greenish, chloritic rock, which becomes darker and harder in some places, and is properly described as gray.

The Indians of the Northwest have resorted to this place ever since their acquaintance with Europeans, for the purpose of getting this material for their pipes. If there be not a direct connection, genealogically, between the mound-builders and the Indians, there is at least an identity of practice in the quarrying and manufacture of pipes from this material, no less than in the mining and use of copper.†

At the present time the remnant of the Sioux Indians living at Flandreau, Dak., extract the catlinite from the same locality, in the rudest methods, and derive a substantial revenue from the sale of pipes, hatchets and various other articles made from it. In this manufacture the whites have begun to compete successfully with the Indians, and many ornamental as well as useful objects made of catlinite can be purchased in the open markets of Flandreau and Pipestone City.

*Squier and Davis, Ancient monuments of the Mississippi valley. p. 228.
†*Pop. Sci. Month.*, vol. xix, p. 601; Lewis H. Morgan, *Contributions to North American Ethnology*. vol. iv, p. 199.

CHAPTER XIX.

THE GEOLOGY OF BROWN AND REDWOOD COUNTIES.

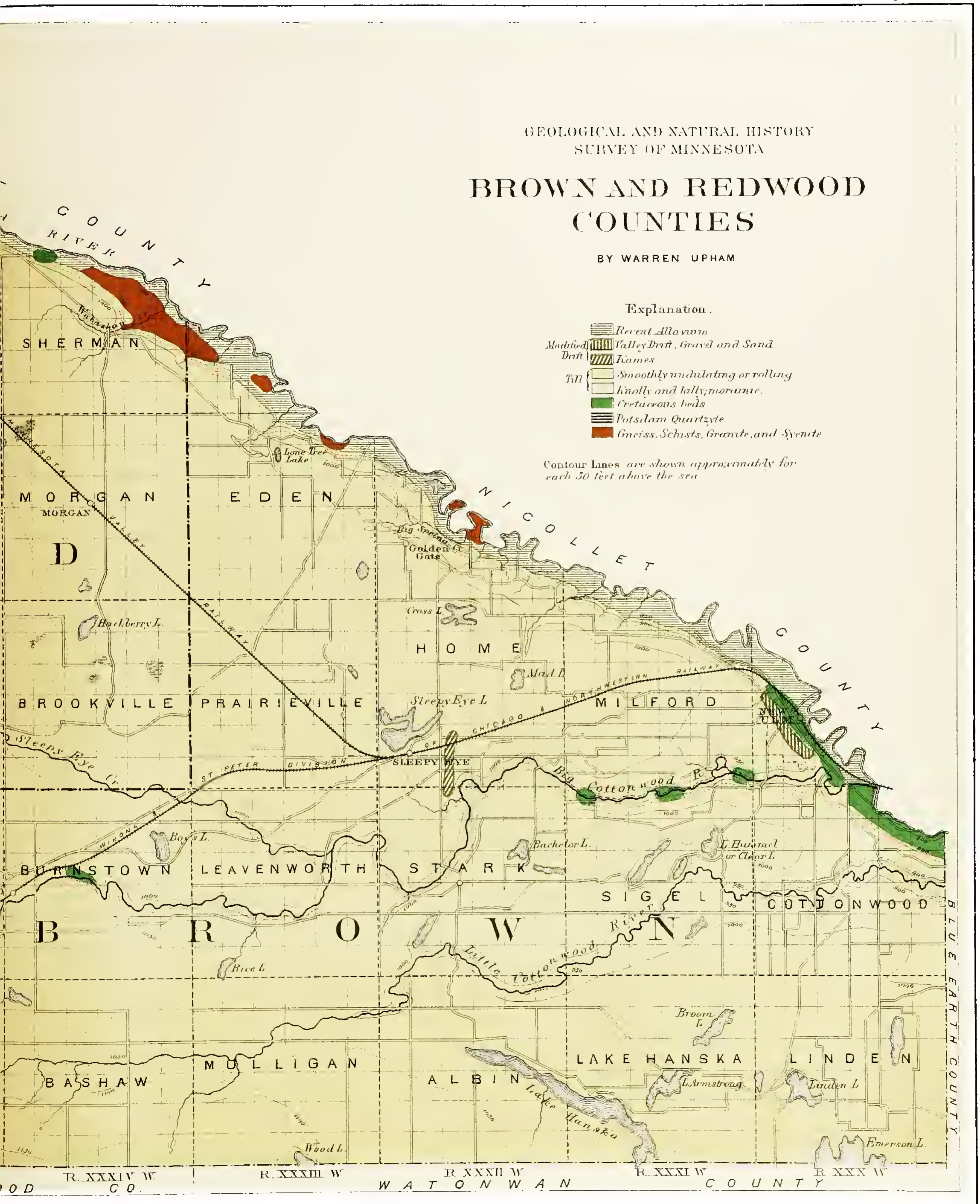
BY WARREN UPHAM.

Situation and area. Brown and Redwood counties (plate-pages 25 and 26) are situated in the central part of southern Minnesota, within the basin of the Minnesota river, which is their boundary on the north. New Ulm, the largest town and county seat of Brown county, is 36 miles east-southeast from Redwood Falls, which is the largest town and county seat of Redwood county. From New Ulm northeast to Minneapolis and Saint Paul is a distance, in straight course, of about 75 miles. Two tiers of counties intervene between these and the south line of the state; and two counties on the west divide Redwood county from Dakota.

The area of Brown county is 616.75 square miles, or 394,720.82 acres, of which 6,937.52 acres are covered by water; and the area of Redwood county is 893.83 square miles, or 572.052.87 acres, of which 14,930.13 acres are covered by water.

SURFACE FEATURES.

Natural drainage. The Minnesota river, at the north side of these counties, receives from them two large tributaries: the Redwood river, which flows east across the north part of Redwood county and enters the Minnesota about two miles northeast of Redwood Falls; and the Cottonwood (called by the Sioux the Waraju) river, which also runs easterly, crossing southern Redwood county, and dividing Brown county into nearly equal parts on its north and south sides, uniting with the Minnesota about one and a half miles southeast of New Ulm.



Julius Bien & Co. lith.

Besides these, the Minnesota river receives from these counties several small creeks, from one to five miles in length, the longest being Crow creek, five miles east of Redwood Falls, and Wabashaw creek, in Sherman, the most northeast township of Redwood county.

The most important of the small creeks that empty into the Redwood river in the county of this name is Ramsey creek, five miles long, in the south part of Delhi, the outlet of Ramsey lake. Its junction with the Redwood is about a half mile north of Redwood Falls.

Numerous creeks of considerable size join the Cottonwood river from the south in southern Redwood county, including Plum creek, which flows by Walnut Grove; Pell creek, in the west part of Lamberton; Dutch Charley's creek, which flows within a mile south of Lamberton, and after receiving Highwater creek, a large tributary, unites with the Cottonwood about two miles east of this station; and Dry creek, which joins this river in the southeast corner of Charlestown. Through this distance of twenty-five miles, the Cottonwood river has no affluent from the north.

In Brown county the Cottonwood receives only one noteworthy tributary from the south, namely, Mound creek, which has first a northeast and then a northwest course, the latter extending about four miles among morainic hills to its mouth, two miles east of the west line of this county. Sleepy Eye creek, the largest branch of this river, comes into it from its north side, in the east part of Leavenworth. This flows easterly, approximately parallel with the Cottonwood river, and three to ten miles from it, through a total length of about thirty miles, the first twenty-five of which are in Redwood county.

On the south side of the Big Cottonwood river, another companion stream, the Little Cottonwood river, also flows in a nearly parallel course easterly through the south part of Brown county, being from two to seven miles distant from the Big Cottonwood along its extent of more than thirty miles. It joins the Minnesota river two miles beyond the east line of this county. It receives no tributary of considerable size in its whole course.

Lakes. Both these counties have frequent lakes, and also sloughs, or marshy tracts, many of which are covered by water during the wet portions of the year. In Redwood county the most notable lakes are Ramsey lake, one mile long from west to east, in Delhi; Goose and Swan lakes, at the northwest side of Underwood township, each about a mile long; two lakes, three-quarters and half a mile in length, in Kintire; Horseshoe lake, curved, more than a mile long, in Westline; Hall lake, a mile in length from northwest to southeast, in Gales; Willow and Rush lakes, each a half mile or more in length, in Willow Lake township; the Three lakes, which give this name to the township in which they are situated; and Hackberry lake, three-fourths of a mile long, in the north part of Brookville.

Among the lakes of Brown county are Lone Tree lake, a half mile long, in section 9, Eden; Sleepy Eye, Cross and Mud lakes, respectively one and a half miles, one mile and a half mile in extent, in Home township; Boy's lake, a mile long from northwest to southeast, in the northeast part of Burnstown; a lake of similar size and trend in section 6, Bashaw; Rice lake, a mile long from north to south, in the southwest part of Stark; Bachelor lake, of smaller size in the same township three miles farther northeast; lake Hummel or Clear lake, a mile long from north to south, in the northeast part of Sigel; lake Hanska, seven miles long from northwest to southeast, and from an eighth to two-thirds of a mile wide, in Albin and Lake Hanska townships; lake Armstrong and Broom lake, farther northeast in Lake Hanska township, each about a mile long and trending southwesterly; lake Linden and another lake situated in sections 11 and 14, Linden, each exceeding a mile in length, with north to south trend, and lake Emerson, two miles long from west to east, crossed by the south line of this township. These lakes occupy hollows in the drift-sheet and many of them have neither outlet nor inlet.

Topography. These counties have almost universally a smooth, gently or moderately undulating surface of unmodified glacial drift or till. Some portions are nearly flat, and the whole country has this appearance when overlooked in any broad, far-reaching view; but mostly the contour is in broad swells of various extent, hight and direction, generally without any uniformity in trend, and sometimes oval or nearly round.

The highest portions of adjoining undulations vary from a few rods to a half mile or more apart; and their elevation is sometimes 5 to 15 feet, and again 20 to 30 feet, or rarely more, above the depressions, to which the descent is usually by very gentle slopes. These hollows have a form that is like that of the swells inverted, being mostly wide, and either in long and often crooked courses of unequal length, variously branched and connected one with another, or in basins from one to one hundred acres or more in extent, which have no outlet but are surrounded by land 5 feet or perhaps 10, 20 or 30 feet higher upon all sides. The small swamps which often fill the depressions are called *sloughs* or *marshes*, the former name being the most common in this prairie region, while the latter is applied to them in wooded parts of the state.

Many others of these depressions contain bodies of water, which vary from a few rods or a hundred feet to five or ten miles in length. All these are called *lakes*, and the term *pond*, which would be applied to them in the northeastern United States, is here restricted to reservoirs made by dams. The lakes of these counties usually lie in shallow basins, bounded by gently ascending shores, which, however, are here and there steep to the hight of 10 or 15, and rarely 20 to 25 feet. These higher banks are mostly at projecting points of the shore, and they have been formed by the undermining action of the waves. The foot of such banks is plentifully strown with boulders that had been contained in the till, all the fine parts of which have been thus washed away. Other parts of the lake shore, adjoining tracts of lowland or marsh, are frequently bordered by a flattened ridge of gravel and sand, often with intermixed boulders, heaped up by the action of ice in winters, in its ordinary freezing, thawing, and drifting, when broken up, before the wind. These ice-formed lake-ridges rise only from three to six feet above the line of high water of the lake, and are from two or three to five or six rods wide. They occur most frequently in situations where they separate the lake from a bordering marsh, whose area evidently was at first a part of the lake.

The most notable features of the topography of this region are the valleys or channels that have been eroded in its broadly smoothed and approximately flat expanse by creeks and rivers. The smaller streams generally flow 15 to 30 feet below the general level, with valleys from a few rods to a quarter of a mile wide. The valley of the Redwood river is of small depth, 25 to 50 feet, along all its course above Redwood Falls. At and below this town, within a distance of one mile this river descends a hundred feet in a succession of picturesque cascades and rapids, over granite and gneiss, decomposing portions of which form towering cliffs, 100 to 150 feet high, on each side, from an eighth to a quarter of a mile apart. This gorge, extending one and a half miles before it opens into the broader bottomland of the Minnesota river, is quite unique in its grand and beautiful scenery, with dense woods along its bottom through which the river flows, but crowned above by the verge of prairies whose vast expanse, slightly undulating but almost level in this extensive view, stretches away farther than the eye can reach.

In Redwood county the Cottonwood river lies in a depression from a third to a half of a mile wide, composed of level alluvial bottomland, 40 feet below the average surface. Through North Star and Burnstown, in western Brown county, this river flows about 50 feet below the average hight of the region, with a bottomland usually from a fourth to a third of a mile wide, of sand or gravel, or in part of fine silt, elevated 10 to 15 feet above the river at low water but overflowed by its highest floods. At Iberia, near the center of Brown county, four miles south of Sleepy Eye, the Cottonwood valley is 75 to 100 feet deep, and from a half to two-thirds of a mile wide, containing, on the northwest side of the river, terraces of gravel and sand, covered by a fertile soil, similar to that of the upland prairies. These terraces occupy a width of two-thirds of a mile, and form three or four successive levels or steps, 15 to 50 feet above the river. The bluffs that enclose this valley here and below are usually very steep, varying in slope from 30° to 45°. They have been formed, like the higher bluffs of the Minnesota valley, by the undermining action of the river, flowing along their base and wearing them away in its process of excavation. Mostly these slopes are wooded and lie at considerable distance from the river; but the stream may, in its gradual change of channel again impinge upon them, as it is now doing on its southeast side one and a half miles northeast from Iberia, exposing there a freshly undermined section of drift, 75 to 100 feet in hight, composed of yellow till for its upper 20 or 25 feet, and of dark bluish till below. Eastward the valley of the Cottonwood river, before uniting with that of the Minnesota, gradually increases in depth to 175 feet, with a width varying from a third of a mile to one mile.

The Little Cottonwood river through Bashaw, in southwestern Brown county, flows in a valley 25 feet below the general level, with an alluvial bottom an eighth to a fourth of a mile wide, not bordered by steep bluffs but by gentle slopes. Thence through the central part of the county this valley retains nearly the same features, and it is only in Cottonwood township, within a half dozen miles above its mouth, that its depth increases to coincide with that of the Minnesota river, to which it is tributary.

Lake Hanska, seven miles long but somewhat river-like in its narrowness and its rather crooked east-southeast course, bordered by moderately or gently sloping shores of till that rise 10 to 20 feet above it, may indicate an avenue of interglacial drainage, now in large degree filled and obscured by the till of the last glacial epoch.

The valley of the Minnesota river on the north side of these counties is from 165 to 180 and in some portions 200 feet deep, having a bottomland of alluvium 5 to 20 feet above low water and from three-fourths of a mile to one and a half miles wide, bordered by steep bluffs which rise to the general level of the country. Within this valley at numerous places are jutting knobs and small ridges of gneiss and granite, exposures of Cretaceous strata, and terraces of modified drift, which are described farther on in treating of geological structure. From the top of the bluffs the vast prairie stretches away beyond the horizon, having a smoothly undulating surface of till, which appears to be in general approximately level, though a considerable ascent, varying in amount from 75 to 150 feet, is made imperceptibly in a distance of twenty to twenty-five miles southwestward across these counties.

Here and there this sheet of unmodified glacial drift or boulder-clay, the direct deposit of the ice-sheet, is sprinkled with knolls, small and short ridges, or mounds, of gravel and sand, which rise sometimes by steep, but again by moderate or gentle slopes, 10 to 15 or 20 feet above the general level. The distribution and origin of these kame-like deposits of modified drift are more fully noticed on a following page.

In the southwest corner of each of these counties, their even contour, which to this distance from the Minnesota river may be called in general a vast plain, is changed; and a gradual rise of 200 or 300 feet takes place within a distance of a few miles, along a massive terrace which extends from northwest to southeast and east-southeast. This line of highland forms the northeastern border and first prominent ascent of the Coteau des Prairies, which farther west rises gradually and at length steeply again, to the much higher watershed between the Mississippi and Missouri rivers. The south part of Stately, the most southwest township of Brown county, lies upon the foot of the sloping border of the Coteau, which here is formed by the massive, mostly drift-covered ridge of red quartzyte that extends in a nearly east to west direction in northern Cottonwood county, its crest being one to two miles south of the south line of Stately. In northwestern Redwood county a gradual rise begins a few miles south from the Cottonwood river, and in six or eight miles southwestward to the corner of this county amounts to about 250 feet, beyond which a slower rate of ascent continues in the same direction to the belt of swelling and somewhat hilly till at the northeast side of lakes Shetek and Sarah, in Murray county. On the Winona & Saint Peter railroad, which makes this rise obliquely, running from east to west, the ascent from Lamberton to Walnut Grove, in ten miles, is 79 feet; and in its next eight miles, to Tracy, is 180 feet.

The only tract in these counties that exhibits a conspicuously morainic contour is in Stately, and reaches from the elbow of Mound creek six miles west into the edge of Germantown in Cottonwood county, with a width of three or four miles, bounded on the north by the Cottonwood river. It is crossed by the lower part of Mound creek, so named because of its mounds, ridges and hills, which are 25 to 75 or 100 feet high, abrupt and strown with boulders and pebbles.

Elevations, Winona & St. Peter division, Chicago & Northwestern railway.
From John E. Blunt, engineer, Winona.

	Miles from Winona.	Feet above the sea.
Minnesota river, bridge	162.50	821
Minnesota river, high water	162.50	807
New Ulm	165.31	837
Siding	169.00	994
Sleepy Eye	179.72	1034
Redwood Falls	205.00	1028

	Miles from Winona.	Feet above the sea.
Springfield	193.18	1025
Sanborn	201.56	1089
Lamberton	208.77	1144
Walnut Grove	218.98	1223

The elevation of the Minnesota river along the north side of these counties, at its ordinary stage of water, 20 to 25 feet below its high floods, is approximately as follows:

Minnesota river, low water.

	Feet above the sea.
At the northwest corner of Redwood county	845
Below Patterson's rapids, at the east side of Swede's Forest	820
At the mouth of the Redwood river	810
At the line between Redwood and Brown counties	798
At Fort Ridgely	793
At New Ulm	784
At the mouth of the Big Cottonwood river	782
At the east line of Brown county	778

The Redwood river enters Redwood county at a hight of nearly 1,100 feet above the sea, and its descent in twenty-four miles to Redwood Falls is some 150 feet. Thence to its mouth, in three miles, it falls about 140 feet, the greater part of this descent being in less than a half mile at Redwood Falls.

At the west line of Redwood county the Cottonwood river is about 1,120 feet above the sea, and it leaves this county and enters Brown county at an elevation of about 1,030 feet. Its hight at Iberia is estimated to be 900 feet, and at its mouth, as already stated, approximately 782 feet.

The Little Cottonwood crosses the south line of Stately, entering Brown county, at a hight of about 1,150 feet above the sea. In the central part of this county, two miles south of Iberia, its hight is estimated to be 960 feet; at the east line of Sigel, 900 feet; and at the east line of the county, 825 feet.

Brown county has its highest land upon the northern slope of the ridge of red quartzyte at the south side of sections 31, 32 and 33, of Stately, its most southwestern township, which reach to 1,200 or 1,250 feet above the sea, 200 feet higher than the Cottonwood river at the north side of this township, but 100 feet or more below the top of this ridge, a mile farther south. The lowest land of this county is where the Minnesota river leaves it, about 778 feet above the sea. The average hight above the sea-level of the townships of Brown county is estimated as follows: New Ulm city, 875 feet; Cottonwood, 950; Linden, 1,020; Milford, 950; Sigel, 990; Lake Hanska, 1,030; Home, 1,000; Stark, 1,000; Albin, 1,040; Eden, 990; Prairieville, 1,040; Leavenworth, 1,020; Mulligan, 1,060; Burnstown, 1,040; Bashaw, 1,090; North Star, 1,060; Stately, 1,150. From these estimates the mean elevation of this county is found to be approximately 1,025 feet.

The highest land of Redwood county is the southwest part of Springdale, its most southwestern township, about 1,400 feet above the sea, being some 300 feet above the Cottonwood river ten miles distant to the north, and about 600 feet above the lowest land of this county, the shore of the

Minnesota river at its northeast corner. Estimates of the mean elevation of its townships are as follows: Sherman, 990 feet; Morgan, 1,030; Brookville, 1,040; Honner, 900; Paxton, 1,025; Three Lakes, 1,060; Sundown, 1,070; Delhi, 1,000; Redwood Falls, 1,050; New Avon, 1,080; Willow Lake, 1,100; Charlestown, 1,120; Swede's Forest, 940; Kintire, 1,050; Sheridan, 1,070; Vail, 1,100; Waterbury, 1,125; Lamberton, 1,140; Vesta, 1,080; T. 111, R. 38, 1,120; Johnsonville, 1,125; North Hero, 1,175; Underwood, 1,120; Westline, 1,150; Gales, 1,175; Springdale, 1,275. The mean elevation of Redwood county, derived from these figures, is 1,090 feet above the sea.

Soil and timber. These counties have throughout their whole extent an excellent soil, well suited for the production of all the common cereals, garden vegetables and small fruits of this latitude. The principal crops cultivated are wheat and oats, corn and potatoes, sorghum for the manufacture of syrup, and flax for linseed oil. Stock-raising and dairying also receive considerable attention. A black soil, everywhere from one to two feet thick, and often reaching to a depth of three or four feet in the depressions, forms the surface, being glacial drift or till, colored by a small proportion of humic acid derived from decaying vegetation. This drift is principally clay, with which is an intermixture of sand and gravel, with occasional but not frequent boulders. Its composition makes it quite unfit for brick-making, but gives it a porous character, so that rains and the waters of snow-melting are soon absorbed by it, excepting the large part which is drained away by the gentle slopes and the numerous water-courses. Below the soil cellars and wells find a continuation of this till, yellow in color and commonly soft enough to be dug with a spade, to a depth of 10 to 20 feet or sometimes more, and then dark bluish and usually harder to a great depth beyond, which is seldom passed through.

The valley of the Minnesota river, 160 to 200 feet deep, has cut through this mantle of till. Along this valley, and in the last two miles of the Redwood valley before it joins the Minnesota, irregular knobs and ridges of gneiss and granite are exposed to view; and in some places these occupy nearly the whole width between the bluffs of the Minnesota river. Generally, however, the bottomland of the Minnesota river, as also of its large tributaries, are flat tracts of very fertile fine alluvium, or interbedded sand and gravel covered by a rich soil of fine silt. These *bottoms*, which would be called *intervals* in New England, are elevated 5 to 15 feet above the streams, being thus mostly within the reach of their highest floods in spring, but they are very rarely overflowed during the season of growing crops.

Both Brown and Redwood counties are mainly prairie, or natural grass-land, without tree or shrub, but one continuous green sward, often reaching in gentle undulations and swells, 5 to 20 feet high, as far as the view extends. Yet these counties have considerable timber skirting all their larger streams and lakes. A nearly continuous, though often very narrow strip of timber is found immediately bordering the Minnesota river through almost its entire course; but generally much of the bottomland is treeless. The bluffs on the northeast side of this river have for the most part only thin and scanty groves. The southwestern bluffs, on the contrary, are generally heavily wooded, excepting two miles next northwest from New Ulm. Next above this for about fifteen miles, through Milford, Home and part of Eden townships, both the bottomland and the southwestern bluff are densely timbered to a distance from the river varying from a quarter of a mile to one mile. The greater abundance of timber on the southern bluffs of this and other rivers in these regions of prairie appears to be due to their being less exposed to the sun, and therefore more moist, than the bluffs on the opposite side.

Along the Redwood river, and the Cottonwood river through Redwood county and in western Brown county, and along the upper part of the Little Cottonwood river, the width of woodland, excepting occasional interruptions, usually varies from a few rods to an eighth of a mile; but along the last twenty miles of the Cottonwood river, and the last eight miles of the Little Cottonwood, the timber generally fills their valleys, from a fourth of a mile to one mile wide.

The lakes of Redwood county and of western Brown county have only narrow margins of timber; but in central and eastern Brown county groves of considerable extent border Sleepy Eye lake, the southeast part of lake Hanska, and lakes Armstrong and Linden, and reach a mile southeast from the last, to Emerson lake.

At Sleepy Eye lake the principal species of trees are bur oak, bass, white and red or slippery elm, white ash, box-elder, cottonwood, poplar, hackberry, the Kentucky coffee-tree and the wild plum. Wood here is worth from $2.50 to $5 per cord, according to quality.

In northwestern Redwood county, Mr. Malcolm McNiven enumerates the following species of trees and shrubs occurring at Swan lake, on the west line of Underwood: white elm, white ash, box-elder, cottonwood, wild plum, willows, Virginia creeper, climbing bitter-sweet, frost grape, prickly ash, choke-cherry, black currant, and prickly and smooth wild gooseberries, common; and bur oak, hackberry, poplar or aspen, wolfberry, black and red raspberries, thorn, and wild rose, less frequent. Species not found at Swan lake, but common or frequent on the Redwood river, are bass, red or slippery elm, iron-wood and sugar maple. Red cedars grow on the cliffs of this river at Redwood Falls, and from them appears to have come the name of this river and thence of the county.

The Cottonwood river is said to have its name, which also has been given to a county, from a very large, lone cottonwood beside this stream in the south part of Redwood county, about seven miles northwest of Lamberton; but this tree has also a luxuriant growth throughout the timbered bottomlands of this river.

The northern limit of the black walnut appears to be at the walnut grove, of about a hundred acres, from which comes the name of the neighboring station and village on the railroad, the grove itself being on Plum creek in sections 25 and 36, Springdale, close to the south line of Redwood county, and one to two miles southwest from Walnut Grove village.

GEOLOGICAL STRUCTURE.

The foundation of Brown and Redwood counties, northwest from New Ulm, consists of metamorphic gneiss and granite, belonging to the great series denominated Eozoic or Archæan, which embraces the most ancient rocks known to geology. This is overlain by various shales, sandstones, limestones and clays, the latter sometimes holding beds of lignite, which are regarded together as of Cretaceous age. Exposures of these Cretaceous rocks continue in the Minnesota valley southeast from New Ulm, but there and through southern Brown county they probably lie upon red Potsdam quartzyte, which outcrops on each side. Upon the east this quartzyte is seen in Courtland, Nicollet county, two miles southeast from New Ulm. It is not exposed in this part of Brown county. Upon the west it makes a massive ridge, as described in the report of Cottonwood county. The north base of this ridge reaches into Stately, making falls in section 31 on one of the head-streams of Mound creek. Cretaceous strata, including lignite, outcrop in the bluffs of the Redwood river close north of Redwood Falls; in the southwest bluff of the Minnesota river a few miles farther east, near Crow creek; in the bluffs of Fort creek near Fort Ridgely, in the west extremity of Nicollet county and close to the

Minnesota valley, about sixteen miles below the last; and on the Cottonwood river in western Brown county. Fossiliferous and sometimes lignitic clays of Cretaceous age are occasionally encountered in the wells throughout this region, especially at Walnut Grove and northward in western Redwood county, and in Lyon county, adjoining this on the west. The sheet of drift which forms the surface is thus often separated by unconsolidated Cretaceous beds from the underlying floor of crystalline rocks. Within the area here reported this gneissic and granitic floor outcrops, away from the valley of the Minnesota river, at only one or two points, which are in T. **111**, R. **38**, Redwood county. These formations will be described in the order of their age, beginning with the oldest.

Gneiss and granite. These rocks have the same composition, being made up of quartz, feldspar and mica. Gneiss differs from granite in having these minerals laminated, or arranged more or less distinctly in layers. Nearly all the metamorphic rocks to be described here are varieties of gneiss, with which masses of granite, syenite and mica and hornblende schists occur rarely.

In the N. E. ¼ of section 12, T. **111**, R **38**, an exposure of rock extends ten rods in length from northwest to southeast, with half as great a width, rising 5 to 10 feet above the surface of the undulating prairie. It is light gray gneiss, much contorted, with its strike and dip obscure; intersected by few joints, which in some portions are absent across an extent of three or four rods; enclosing at the southeast two or three masses of nearly black mica schist, each two or three feet long.

About five miles farther west, the N. E. ¼ of the S. E. ¼ of section 6, in the same township, is said to have an exposure of similar rock, about three rods in extent, with a larger space around it where the rock lies only a few feet beneath the surface.

The depth of these rocks in this region is generally from 100 to 200 feet or more, so that they are not reached by wells nor by the channels of most of the rivers. Their only other outcrops in Redwood and Brown counties are within the Minnesota valley, and in the gorge of the Redwood river at and below Redwood Falls.

The Minnesota valley in the northwest corner of Swede's Forest, and in the edge of Yellow Medicine county, contains abundant ledges for two miles, reaching 40 to 75 feet above the river. A lone school house is situated among them, about a mile east of the county line. Half a mile west from this school house, the rock is reddish gray gneiss, dipping 15° N. N. W. A third of a mile west from the school house are massive granite cliffs, probably rising 75 feet above the river, divided by joints into nearly square blocks ten to fifteen feet in dimension. This rock may be found valuable for quarrying. An eighth of a mile east from the last, it is obscurely laminated gneiss, much intersected by joints, the principal system of which dips 15° S. At the east side of the school house, it is also gneiss, somewhat water-worn, dipping about 5° S.

Within the next few miles in following down the river, similar ledges are seen on its northeast side, in the N. E. ¼ of section 16, in Sacred Heart, Renville county, rising about 50 feet above the river; in the southeast part of section 17, Swede's Forest, rising at several points 25 to 40 feet; at south side of Big Spring creek, in section 20 and the west edge of section 21, Swede's Forest, about 50 feet above the river; and near the north line of section 27, small in area, and only about 20 feet high.

From the small creek a mile farther east in section 26, Swede's Forest, ledges of gneiss and granite abound in this valley through a distance of twelve miles, to the mouths of Redwood river and Beaver creek. They often quite fill the bottomland, occuring on each side of the river, and rising 50 to 125 feet above it. Between Redwood river and Beaver creek, frequent small ledges rise along the bottom of the Minnesota valley, in knobs 40 to 60 feet above the river, but yet leave much open, tillable land. Between Beaver and Birch Cooley creeks the outcrops are mainly on the north side of the river, rising 100 feet in their highest portions. Below the mouth of Birch Cooley they are mostly on the south side, occurring in great abundance for two miles above and three miles below the mouth of Wabashaw creek. The highest of these are a mile above this creek, rising 75 to 125 or perhaps 140 feet above the river. It will be remembered that the bluffs along all this part of the valley are about 175 feet high, so that none of these ledges were visible until the surface of the drift-sheet had been considerably channeled.

On the Redwood river where it enters the Minnesota valley, at Birum's mill, one and a half miles northeast from Redwood Falls, the rock is greenish, being apparently a "talcose quartzyte," or protogine gneiss, dipping 25° S. E. It forms cliffs 50 to 75 feet high, which are continuous on the west side of the river a quarter of a mile or more. The picturesque gorge of the Redwood river, at and below Redwood Falls, is principally cut through a similar gneiss, partly decomposed, and sometimes almost completely kaolinized, overlain by Cretaceous strata, which in turn are capped with glacial drift. The largest cascade, having a fall of about 25 feet, is over a ledge of this protogine gneiss, much contorted and jointed, often obscure in its lamination. The dip of the principal system of joints, which appears to coincide nearly with the lamination, is 20° to 30° N. At a cut which has been made through the rock two rods east of this cascade, it contains a nearly vertical trap dike, seen along an extent of some thirty or forty feet, bearing N. 40° E., about two feet wide, composed of dark and greenish, compact rock, which weathers to a reddish color, much jointed in planes parallel with its walls. Ten feet above the bottom of this cut, and higher, the cliff of gneiss is much decayed and changed to impure kaolin.

In Brown county no exposures of the Eozoic rocks have been examined, but their character has been learned from their outcrops along the northeast side of the Minnesota river, in Renville and Nicollet counties, under which they are fully described. Their outcrops in Brown county are of small extent, including only a few localities on the bottomland of the Minnesota valley along the northern boundary of Eden and Home townships. Their extent southeastward is to "Little rock," about five miles below Fort Ridgely, beyond which the only outcrop of these rocks in the Minnesota valley is a small area of granite opposite the southeast part of New Ulm.

Decomposed gneiss and granite. Very remarkable chemical changes have taken place in the upper portions of many of the exposures of gneiss and granite near Redwood Falls. The rock is transformed to a soft, earthy or clayey mass, resembling kaolin. It has a blue or greenish color, when freshly exposed; but when weathered, assumes a yellowish ash color, and finally becomes white and glistening. Laminæ of quartz are generally contained in this material, and have the same arrangement as in gneiss, so that the dip can be distinctly seen. Veins of quartz or feldspar, the latter completely decomposed, and the lines of joints, are also noticeable, just as in granite or gneiss; making it evident that this substance is the result of a decay of the rocks in their original place. Because of the enclosed quartzose laminæ, grains, and particles, of more or less gritty character, throughout these kaolin-like rocks, they appear to be unsuited for the manufacture of porcelain or any kind of ware. So far as can be judged from stream channels and other exposures, this decomposition reaches in some places to a depth of 20 or 30 feet, perhaps more. All grades of change may be found, from ledges where only here and there a few spots have been attacked and slightly decomposed, to portions where nearly every indication of the original structure has been obliterated.

Of these decomposed rocks on the Redwood river, Prof. Winchell wrote in the second annual report of this survey: "At Redwood Falls the granite is overlain by the kaolin, which has been mentioned, presenting, in connection with this substance, a very interesting series of exposures, and suggesting very interesting questions both economical and scientific. About a mile below the village, on the left bank of the river, is a conspicuous white bluff (probably that seen by Keating, and pronounced white sandstone), composed of white kaolin clay. Near the top of this bluff, where the rains wash it, it is silvery white, and that color is spread over much of the lower portions, though the mass of the lower part is more stained with iron, having also a dull greenish tinge. The white glossy coating which appears like the result of washings by rains, is spread over the perpendicular sides. On breaking off this glossy coating, which is sometimes half an inch thick, the mass appears indistinctly bedded horizontally, but contains hard lumps and irony deposits. Further down, the iron becomes more frequent, and gritty particles like quartz impede the edge of a knife. The bedding is also lost, and the closest inspection reveals no bedding. Yet there is, even then, a sloping striation or arrangement of lines visible in some places on the fresh surface, that corresponds in direction with the direction of the principal cleavage plane of the talcose and quartzitic slate already described. In other places this arrangement is not seen, but the mass crumbles out in angular pieces which are superficially stained with iron. The profile of the bluff here presents a singular isolated knob or buttress that rises boldly from the very river, connected with the main bank by a narrow edge along which a man cannot walk with safety. On either side of this bold promontory are retreating angles in the bluff along which a descent can be made. A careful inspection of these ravines and of the adjoining bluffs affords indubitable proof that this material, white and impalpable as it is, results from a change in the underlying granitic rocks.

"Just above this point is another exposure. It here supplies what is locally known as the 'paint rock', from an enterprise started several years ago in the manufacture of mineral paint from this material. The decomposed granite here has very much the same appearance as the kaolin at Birch Cooley, but contains more quartz, and is more stained with iron. It has a greenish color, but within might be blue. It passes upward into the greenish, and then white, kaolin clay already described, but it stands out in a crumbling, rusty buttress, exposed to the weather, and has quartzitic grains and concretions, iron-coated, and often an impure iron ore in considerable quantities. It shows silvery or shining talcose flakes, the same as seen in the so-called building rock, a short distance below the mill of Birum brothers.

"A short distance above this, nearly opposite Redwood Falls, is situated the rock which was quarried for the manufacture of paint. This has in every respect the same character and composition as that last described. It consists of a perpendicular bluff or point, standing out from a lower talus that rises about 75 feet above the river, to the hight of 75 feet more. On the top of this is the drift-clay hardpan, covered by four or five feet of sand and gravel, the whole bluff being about 150 feet above the river. This bold bluff, or promontory, stands between re-entrant angles, its face falling down sheer thirty or forty feet. There is here visible an irregular slaty or cleavage structure in the rock, that at a distance has the appearance of dip toward the S. E. 30°. This also contains quartz veins and deposits, accompanied by iron, in some places too abundantly to allow of being cut with a knife, though very much of it can be easily shaped with a knife. It shows 'slickensides,' or surfaces that seem to have been rubbed violently against each other, causing a scratched and smoothed appearance, even within the body of the bluff. These surfaces are concave or curving, like putty hardened after being pressed through a crevice."

Before the extensive denudation of the glacial period, it is probable that all the granite and gneiss of this region were covered by a similarly decayed surface. Upon the areas where decomposed rocks still exist, the glacial plowing was shallower than elsewhere. These kaolinized strata are exposed in a ravine north of the Minnesota river, opposite to Minnesota Falls; in the gorge of the Redwood river, below Redwood Falls; in many of the ledges of the Minnesota valley for several miles next below, especially in excavations made by roads at the foot of the bluffs; in the valley of Birch Cooley near its mouth; and occasionally for eight or ten miles farther southeast. They have been found also in well-digging at considerable distance from the Minnesota valley.

Potsdam quartzyte. The red quartzyte of southwestern Minnesota is destitute of fossils, but from its stratigraphic relations it appears to belong to the Potsdam age. Its outcrop two to three miles southeast from New Ulm lies in Nicollet county, to the report of which the reader is referred for its particular description. The only outcrop of this formation within the district here reported is in Brown county, less than a mile from its southwest corner, being in section 31, Stately.

This is the north edge of a large area upon which this rock forms a massive ridge, in northern Cottonwood county, 200 to 300 feet high, and reaching about twenty-five miles from east to west, mostly overspread by smooth glacial drift. In the north part of section 31, Stately, this red quartzyte, or metamorphic sandstone, occurs in its typical character, being very hard, varying in color from reddish gray to dark dull red, and much divided by joints into rhomboidal masses, mostly only one to two or three feet long. It is exposed upon a tract of four or five acres, forming a picturesque little water-fall on a southern branch of Mound creek, and reaching thence thirty rods or more to the east and south. The dip is about 5° S. In some places the layers are obliquely laminated, this false bedding being partly steeper to the south, and partly, in other places, level or slightly inclined northward.

Over this rock the streamlet falls about thirty feet, its descent for the last twenty feet being vertical, into a pool some four rods in diameter. Two rods east of this water-fall is a little gorge or canyon, cut in the quartzyte 6 to 10 feet wide and 20 feet deep, with vertical walls, extending about forty rods southeasterly in the solid rock, marking the place of an older water-fall, now diverted. About ten rods west of the principal fall is another interesting gorge perhaps twenty rods long, reaching from north to south. This rock also forms conspicuous ledges beside Mound creek an eighth and a fourth of a mile north of this water-fall; and less than a mile to the west, in the N. E. ¼ of section 36, Germantown, in Cottonwood county, it makes a still more interesting cascade and canyon on another of the head-streams of this creek.

Cretaceous beds. In western Redwood county wells occasionally have gone through the drift and passed into clay or shale below, apparently of Cretaceous age, and sometimes proved so by the enclosed fossils. Such sections are reported at Walnut Grove in North Hero township, and in T. **111**, R. **38**, as described on a following page, in the list of wells illustrating the glacial drift.

Cretaceous strata doubtless lie next below the drift upon the greater part of this district; but their only outcrops, excepting within the Minnesota valley and the gorge of the Redwood river, occur on the Cottonwood river in Brown county.

The first discovery of lignite, or brown coal, on the Cottonwood river was made in 1861 by John F. and Daniel Burns, of Burnstown, in its north bank, near the northeast corner of section

34, North Star. The upper part of this bank, which is about 20 feet high, consists of alluvial sand and gravel, a few feet thick. The section of the Cretaceous beds below, as recorded by Eames, in the report of his survey as state geologist in 1866, is, first, iron ore, much broken; then, marly shale, 3 feet; impure lignite, 2½ feet; and dark shale to the bed of the river, 10 feet. The third of these beds is a black, lignitic shale, enclosing a thickness of about four inches of quite clear lignite.

A quarter of a mile south from this outcrop, a shaft was sunk to explore for coal, a year or two before the date of Mr. Eames' report. He described the section below the drift as follows:

"1. Bands of ironstone, and crystals of selenite enclosed in shale, with a seam of imperfect coal........ 13 feet.
2. Yellow sandstone........ 3 feet.
3. Dark colored clay (siliceous), containing iron pyrites, argillaceous iron and sandstone alternating........ 64 feet."

"The clay in this formation is well adapted for refractory brick and the manufacture of pottery ware."

Later exploration for coal was made in 1875 and again in 1878, by shafts 40 or 50 feet deep, on the north side of the river near the point where the lignite is found in the river-bank, as before described. These encountered a layer of lignite, a few inches thick, at about the same level with its outcrop beside the river.

About two miles below this locality, and nearly a mile southwest from Springfield station, the north bank of the Cottonwood river in the N. E. ¼ of section 25, North Star, contains the following beds, according to Eames:

"1. Shaly marl........ 3 feet.
2. Impure coal........ 2 feet.
3. Sandstone, to bed of river, partially covered by talus........ 5 feet."

This sandstone, some portions of which are richly fossiliferous, is exposed along a distance of four or five rods, and has been somewhat quarried. A specimen of it, showing very distinct impressions of leaves, and another containing numerous casts of shells, have been presented to the survey by Mr. John F. Burns. A complete leaf is shown, 5 inches long and ¾ inch wide, lanceolate, entire, tapering into a short petiole. This has been identified by Dr. Leo Lesquereux as *Laurus Nebrascensis*, Lesq. He also reports with this *Salix proteæfolia*, Lesq., and a new species of *Ficus*.

Three miles farther down the stream, its north bank in section 16, Burnstown, has a similar exposure of rock, described by Eames as "buff and gray sandstone, thinly laminated, ten feet in thickness, descending to the bed of the river; it contains stems and leaves of plants, but t o much broken to decide either character or class."

The next localities where outcrops of Cretaceous beds are known to occur on the Cottonwood river, are in Sigel and Milford, about eight miles, and again about five miles, west from New Ulm. Sandstone of yellowish, iron-rusty color, nearly level in stratification, partly friable, but containing hard layers up to one foot in thickness, exposed along a distance of several rods and rising 5 to 10 feet above the river, is reported at two points in the south bank, about sixty rods apart, in the N. E. ¼ of section 6, Sigel. Above the rock-outcrops the wooded bluffs, probably consisting of till, rise about 100 feet.

In the N. W. ¼ of section 3, at the south side of Milford, the north bank of the Cottonwood river has a hight of 60 or 70 feet, and exhibits the following section: yellow till, about 15 feet; gray sandstone, containing lignitic particles, only one foot in thickness exposed; and dark, bluish clay, free from gravel or grit, but in some parts enclosing specks and small lumps of iron pyrites, which render it unfit for the manufacture of pottery, having a thickness of 25 feet clearly exposed; below which the remaining 25 feet of the bluff is concealed by the talus. From the wooded south bluff, in Sigel, a sixth of a mile farther southeast, but probably within the same quarter-section, clay nearly like the foregoing has been much excavated for use by the potters at New Ulm and formerly at Mankato. This clay is very fine and uniform in character, containing neither grit nor pyrites. It is dug between 40 and 60 feet above the river. These beds seem to have no fossils.

About a mile farther east, near the middle of section 35, Milford, the northern bank of the Cottonwood river shows very fine, nearly white, crumbling sandstone, alternating with shale, reaching in some places 30 to 40 feet above the river. The bedding is lenticular and inconstant. A layer of yellowish brown, ferruginous and more firm sandstone, with a dip of 3° or 4° toward the west, exposed here about ten feet above the river, contains plentiful impressions of dicotyledonous leaves of numerous species. A considerable collection of these has recently been made by Prof. Winchell, and determined by Dr. Leo Lesquereux, who states in correspondence that his observations of fossil leaves in 1856* were at this locality or in its immediate vicinity. The list is as follows: *Magnolia alternans*, Heer, *Andromeda Parlalorii*, Heer, *Cinnamomum Scheuchzeri*, Heer, *Platanus primæva*, Lesq., *Salix proteæfolia*, Lesq., *Populus cyclophylla*, Lesq., *P. elegans*, Lesq., *P. Lancastriensis*, Lesq. (probably the same with *P. cordifolia*, Newberry), *P. litigiosa*, Heer, *Populites cyclophyllus*, Lesq., *Protophyllum crednerioides*, Lesq., *Cissus* sp. nov., *Laurus* sp. nov., *Pinus* sp. nov., and fragments referred doubtfully to *Persea* and *Ficus*. Nine of these species, according to Dr. Lesquereux, have been recognized in the Dakota group, the lowest of the Cretaceous series, in Nebraska and Kansas, and two in the same group in Colorado.

Clay and an underlying more sandy deposit, which have been used together for the manufacture of fire-bricks, occur in the base of the north bluff of the Cottonwood river south of New Ulm. The entire section of this bluff is given by Prof. Winchell in the second annual report.

Section on the Cottonwood river south of New Ulm.

"1.	Hardpan drift, made up of clay and stones, seen about	30 feet.
2.	White sand, the age of which is uncertain, containing irony concretions and deposits. It is somewhat indistinctly stratified obliquely, like drift sand, and has some coarse grains. Its position in reference to the overlying hardpan drift, together with its thickness and purely white color, indicates its age to be Cretaceous	100 feet.
3.	Blue clay, containing some siliceo-calcareous, irony lumps; said by Mr. Dauffenbach to hold some coal; mixed with No. 4 for making fire-brick	4 feet.
4.	Fine, somewhat gritty clay, largely aluminous. This is white, and when long submerged, soft and fluid-like, but when dry has to be quarried by blasting. This mixed at the rate of two-thirds with one-third of No. 3 makes a fine, white fire-brick—seen	12 feet.
	Total hight of bluffs	146 feet."

"The above section varies in short intervals. . . . About half a mile further up the river a sandstone outcrop was encountered. It rises in a bluff immediately from the water, on the opposite side of the river. In this sandstone, which here appears firm and massive, and which is probably the equivalent of No. 2, of the foregoing section, are many irony mud balls, or concretions, having a fancied resemblance to plums or bananas. They vary in shape and size. They have been gathered as fossil 'fruits,' and sent east as rare curiosities."

The valley of the Minnesota river was explored by Prof. Winchell in 1873, and the greater part of the descriptions of the Cretaceous strata, as here presented, are from his report for that year. Some additional observations and information were gathered by the writer in 1879 and 1880.

In Cottonwood township, Brown county, near its east line, a bluff on the south side of the Minnesota river, situated on the land of John Gruebel, four miles below New Ulm, is described by Prof. Winchell, as follows:

Section in sec. 2, Cottonwood.

"1.	Black alluvium	2 ft.
	Passing below into—	
2.	Clayey alluvium, of a light-brown color	$4\frac{1}{2}$ ft.
3.	Red clay, containing some sandstone in masses; stratified	$2\frac{1}{2}$ ft.
4.	Belt of greenish sandy clay	1 ft

*U. S. geol. survey of the territories; vol. vi, *The Cretaceous Flora*, p. 6.

Passing into—

5. Sandy clay, of a light umber color........ 1½ ft.
6. Bedded sandy clay, of an earth color, (same as No. 2)........ 2 ft.
7. Greenish sand, the color coming from the mixture of green shale with the sand, the grains of sand being white quartz........ 2 inches.
8. White sandstone in one bed, or weathering into beds of two inches........ 1 ft.
9. Green bedded shale, or clay, with some fine sand grains, and some laminations or thick beds that are all white sand, but generally maintaining a green color, seen........ 18 ft.
10. Slope and talus........ 10 ft.

"The bedding seen in the foregoing section is horizontal, and shows no fossils. Although there is no opportunity at this place to determine whether this series of shales lies above or below the sandstone at Fritz's [four miles southeast, on the north side of the Minnesota river], by an observation made in the bank of the road at the crossing of the Waraju [Cottonwood river], it is believed to overlie that sandstone, but to underlie a series of calcareous beds that appear in the right bank of the river, about a mile below the mouth of the Waraju. The colors near the top of the foregoing section exchange places a little, in following the bluff along, drift boulders and gravel occupying the place of clay in No. 3. In some places the red irony stain passes down lower. It is likely that the red, brown and ochery colors are due to ferriferous waters, since the deposit of the Cretaceous, and to oxygen in the air. Hence it is not certain that the drift extends through the whole of No. 3, although drift boulders are mixed with it, or replace it, in some places. When evenly bedded and free from boulders, it undoubtedly belongs to the Cretaceous, the drift stopping with No. 2. When it is replaced by boulders, the Cretaceous is only so much the more worn away, the color pervading them, or passing down to lower beds."

Professor Winchell continues: "From the mouth of the Waraju [Cottonwood river] going down the right bank of the Minnesota, a regular terrace [35 to 50 feet above the river] is seen to rise several feet above the flood-plain. About a mile down, this terrace shows its origin and composition, in the banks of a ravine which cuts it. Before reaching that point, however, an outcrop of 'gray concretionary limestone' is seen on the top of the terrace plateau. This limestone here is overlain by a couple of feet of water-washed limestone, gravel and cobble-stones, mixed toward the top with the usual black alluvium. The appearance of the quarried stone is like *drift* pieces, and the bed from which it is taken is intersected variously with divisional planes, cutting the mass into irregular fragments, which, on being taken out, appear weathered. Yet there are crystal-lined cavities, some parts of it being mostly made up of calc spar. Since the formation of the crystals, calcareous water has again deposited lime on the edges of the crystals, which, having first been of the thin (axe-shaped) variety, have now the appearance of separate but crowded cock's combs, the little beaded accretions of lime being arranged on their edges. There is also a considerable quantity of uncrystallized lime on other surfaces. The interior of the stone is of a light gray or drab color, and when compact and free from crystals is very fine grained. It is said to make a white, strong quicklime, of which there can be no doubt. This limestone outcrop, which shows only about 16 inches, is within a mile of the red quartzyte outcrop near New Ulm, the bare, bald surfaces of which are visible from this point, on the other side of the Minnesota.

"A little below the last described exposure, is Mr. Wm. Winkelmann's limekiln and quarry. The stone here burned is in the same horizon, and comes from the banks of a ravine that here enters the Minnesota. The limestone is much mixed, confusedly, with shale, but the following general section can be made out, in which no fossils were seen:

Section at Wm. Winkelmann's, sec. 2, Cottonwood.

1. Alluvium and boulders........ 2 ft.
2. Green shale, interstratified with belts and irregular nodules or masses of gray limestone........ 15 ft.
3. Green shale........ 1 ft.
4. White sand, varying to green shale........ 1½ ft.
5. Green clay........ 2 ft.
6. Calcareous shale, or marl, with some argillaceous matter........ 5 ft.
7. Green shale, or clay, with blotches of red, seen........ 1 ft.

Total........ 25½ ft.

"The same kind of greenish marl is exposed up the Waraju, the immediate bluffs being somewhat wrought in it, to a point just back of New Ulm, where the bank is opened by Mr. Winkelmann for laying pipes to supply his machinery and brick-yard. The trench which he has dug passes through it just before reaching the bank of the Waraju river."

In a later examination of the strata at Mr. Winkelmann's, Prof. Winchell has noted about 40 feet of the green shale, with thin layers of concretionary limestone; underlain by red shale, of which a thickness of about 5 feet was seen, but it may extend below the river-level, which is some five feet lower than the base of the section exposed. Occasional layers of red shale were seen somewhat above its general mass, separated from it by green shale. There seems to be a very slight dip toward the south.

Prof. James Hall, in the paper referred to on page 98, mentions ferruginous sandstone, containing plant remains, interbedded with red marls, lying below the green shale and concretionary limestone in the vicinity of Mr. Winkelmann's limekiln. Four species of fossil leaves, collected in these beds by Hall, and found also in other states on the west and south, are described by Lesquereux, who regards them as proof that the formation belongs to the Dakota group at the base of the Cretaceous series.* The green shale and nodular limestone may belong to a later formation, and Prof. Winchell refers them provisionally to the Niobrara group. The highest divisons of the Cretaceous series seem also to be represented in these counties, at least by fossils derived from them, found in the drift as noted in the description of wells in Milford and Stately.

Of the Cretaceous strata seen at New Ulm Prof. Winchell writes: "The flat on which New Ulm stands seems to be made up by a terrace wrought in the Cretaceous. The surface of this flat is strewn with boulders. . . . . . The general section of the Cretaceous at New Ulm is as follows:

1. Drift, gravel and boulders, with a surface-loam in some places, or largely made up of sand....... .... 10 to 20 ft.
2. Fine clay, blue, bedded, weathering white, used for pottery or brick.... 4 to 10 ft.
3. Sand or fine gravel, not cemented, readily crumbling, containing magnesian balls, or rounded lumps made up of a fine white powder—seen 20 to 30 ft.

"The conspicuous Cretaceous terrace that occurs along the Minnesota at New Ulm, is due to this fine sand, overlain by a more tenacious clay or shale. The varying composition of the Cretaceous makes it difficult to establish the horizontality of different outcrops, but there cannot be much doubt that No. 3 above is the equivalent of No. 2 of the section on the Waraju." The section here referred to has been presented on page 574, its No. 2 being white sand, 100 feet thick, overlying the deposits that are dug for making fire-bricks.

The terrace at New Ulm thus formed of Cretaceous beds, overlain by drift, is more than a mile long, parallel with the river, and varies in width from twenty-five to fifty rods or more. Minnesota street, the principal business avenue, is on this terrace, sections of which, agreeing well with that just quoted, are exposed, especially near its south end, by ravines and gullies at its margin. Its hight is about 90 feet above the bottomland and river, and 40 feet above the depot, which is on an intermediate terrace. The west part of New Ulm, including State street, several churches and the county buildings, occupies a higher terrace or plateau of modified drift, which is elevated some 25 to 35 feet above Minnesota street, or 115 to 125 feet, approximately, above the river (see fig. 47, page 582). Further details respecting the topography and geology of the Minnesota valley in this vicinity will be brought out in treating of the glacial and modified drift.

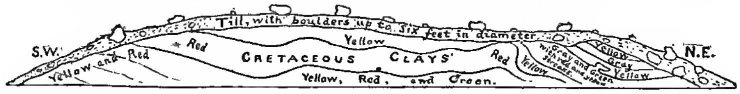


FIG. 46. SECTION ON THIRD NORTH STREET, NEW ULM.

In the north part of New Ulm the grading of Third North street close northeast of the railroad, exposes Cretaceous clays. This cut (fig. 46) is 14 feet deep and 200 feet long, with its top about 45 feet above the river. Its upper 4 feet are soil and drift, containing and overspread with

*U. S. geol. survey of the territories; vol. vi, *The Cretaceous Flora*, pp. 6, 68, 76, 90 and 93. These species are *Ficus (?) Halliana*, Lesq., *Laurophyllum reticulatum*. Lesq., *Bumelia Marcouana*, Lesq.(*Leguminosites Marcouanus*, Heer) and *Liriodendron Meekii*, Heer. The last two are figured in Dana's *Manual*.

boulders of granite, gneiss and schists, up to six feet in diameter. The remaining 10 feet are curved, contorted, and irregularly interstratified, red, yellow, green and gray clays. They are free from gravel, but contain flat, limy concretions, in some portions abundant up to one inch in diameter, and elsewhere joined in sheets a foot or less in length and a half inch or less in thickness, conforming with the stratification. These strata are eroded and covered unconformably by the drift.

In Sherman, Redwood county, Prof. Winchell records an exposure of Cretaceous beds of sandy marl, horizontally stratified, seen in the road that descends from the Lower Sioux Agency to the ferry. At this place in 1860 Prof. A. W. Williamson found in a cut for the road about 30 feet above the Minnesota river a large coiled shell, since lost, which agreed nearly with the figure of *Ammonites monilis* seen in an English text-book of geology.

About four miles farther northwest, or half way from the Lower Sioux Agency to Redwood Falls, a Cretaceous outcrop, including a thin layer of lignite, occurs in the south bluff of the Minnesota valley, above Tiger lake, being in the southwest corner of section 35, Honner, some three-quarters of a mile west from the mouth of Crow creek. Mining for the exploration of the lignite, which is an imperfectly formed coal, of inferior quality, yet valuable for fuel, was undertaken here. on land of George Johnson, in 1871, by William H. Grant and others, a horizontal drift, or adit, being excavated into the bluff to a distance of about 260 feet from its face southward. This followed the seam of lignite, which, or at least a black lignitic shale, was found continuous along all this distance, being level in the direction of the adit, but dipping to the west about three degrees, or five feet in a hundred. The adit is about a third of the way up from the foot to the top of the bluff, or some 60 feet above the river. Several tons of coal, sometimes quite clear for a thickness of six to nine inches, were obtained from the mine, and were used as fuel. The cost of the work, however, was about $2000, without discovering any portion of the bed that could be profitably mined.

Professor Winchell describes the formation here explored, and the similar lignite layer in the bluffs of the Redwood river, as follows: "This coal is from one of those layers in the Cretaceous that are usually known as lignites. It is earthy, passing sometimes into a good cannel coal, or into a bituminous clay. The compact cannel coal is in detached lumps, and occurs throughout a band of about four feet in thickness. This lignitic band was followed in drifting into the bank at Crow creek, and was found to divide by interstratification with black clay, showing some leafy impressions and pieces of charcoal.

"The 'coal' here is said to overlie a bed of lumpy concretionary marl. . . . . In some of the concretions are small shining balls of pyrites. . . . . Over the 'coal' is a blue clay, requiring a timbered roof in the tunnel. This clay is likewise Cretaceous. The underlying lumpy or concretionary white marl becomes siliceous, or even arenaceous, the concretions appearing more like chert. Some of it is also pebbly, showing the action of water currents.

"The same lignite coal occurs near Mr. Johnson's, on the land of Hugh Curry, Wm. H. Cornell, E. O. King and Mr. Riker, in the little ravines that enter the Minnesota, the exposures being kept fresh by the freshet waters. More or less exploring and drilling, besides that done by Mr. Grant, has been engaged in, in this vicinity, but never with any better success.

"Near Redwood Falls, on land of Mr. Birney Flynn, is another outcrop of carbonaceous deposit in the Cretaceous. This is seen in the left bank of the Redwood river. It is in the form of a black bedded clay or shale, five or six feet thick, more or less mingled with charcoal and ashes, the whole passing below into charcoal fragments mixed with the same ash-like substance. In the latter are sometimes large pieces of fine, black, very compact coal, the same as that already spoken of at Crow creek, as cannel coal. These masses show sometimes what appears to the eye to be fine woody fiber, as if they, too, were simply charred wood. Further examination will be needed to determine their origin and nature. They constitute the only really valuable portions of the bed, the light charcoal, which everywhere shows the distinct woody fiber, being generally mixed with the light ashy substance, and in a state of fine subdivision.

"A short distance above Mr. Flynn's land is that of George Houghton, where the Redwood Falls coal mine was opened. This mine consists of a drift into the bluff, forty feet, following a lignite, or charcoal bed in the Cretaceous. The bed here is seven feet thick, the greater part of it being made up of black, bedded shale or clay, though Mr. Flynn is authority for the statement that it showed a great deal more of the real charcoal than any other point discovered. Some fragments that lay near the opening, contained about nine parts of light charcoal to one of ash, the whole very slightly cemented, and so frail as to hardly endnre transportation. In this drift were also numerous pieces of what is described by the owners both here and at Crow creek, as 'stone coal.' It is the same as that mentioned as probably a cannel coal, occuring at Crow creek. It is these harder lumps that are found scattered in the drift throughout the southwestern part of the state."

This mining was done in 1868 or 1869, on the northwest or left side of the Redwood river, about one and a quarter miles north from Redwood Falls, on the south part of the S. W. ¼ of section 30, Honner, the hight of the drift being some 75 feet above the river, and about the same amount below the top of the bluff and general surface of the country. The lignitic bed is reported to dip slightly toward the southwest, and to be overlain conformably by shale, above which the upper part of the bluff is till. Next below the black coaly layer, is said to have been a marl, varying from reddish to white, six inches to two feet in thickness, underlain by yellow and blue clay. No exposure of gneiss or granite is visible at this locality.

Specimens from the lignite and lignitic deposits thus mined near Crow creek and Redwood Falls, and another from an outcrop of lignite west of Bismarck, in Dakota, were analyzed by Prof. S. F. Peckham. In the list of samples submitted for analysis, these are numbered and described as follows:

"No. 11. Cretaceous coal, cannel, from Crow creek, near Redwood Falls, Minn."

"No. 12. Coal, from the surface, near Bismarck, D. T., having the same external characters as the last."

"No. 13. Earthy coal, from Crow creek, near Redwood Falls, Minn."

"No. 14. A mixture of charcoal and ash, apparently, from the lignite beds of the Cretaceous, at Redwood Falls, Minn."

Professor Peckham writes:* "The specific gravity was first determined by sifting the dust from the finely granulated coal and weighing in a sp. gr. flask, after standing under water at least 12 hours. One gramme was then weighed in a platinum crucible and dried at a temperature of 215°-220° Fahr. until it ceased to lose weight. The loss is water.

"The residue was then heated over a Bunsen's burner for 3.5 minutes, and then over a blast lamp for the same length of time, and weighed. The loss was considered to be volatile combustible matter. The residue was bnrned to an ash and the ash weighed. The loss from combustion was considered to be non-volatile combustible material, or fixed carbon.

"The coals are quite unlike. Nos. 11 and 12 are semi-cannel coals. No. 13 consists of a mass of clay containing carbonaceous matter. No. 14 consists of an earthy mass, chiefly silica, containing fragments of mineral charcoal.

"No. 11 is homogeneous and brittle, of a dull black color, and cracks in a dry atmosphere. When heated it is non-caking, the pieces retaining their form and size, and in this respect it resembles some of the Cretaceous coals of the Pacific coast. The results of analysis are as follows:

Specific gravity, 1.441.

Water	13.53	per cent.
Volatile combustible matter	54.11	" "
Fixed carbon	29.49	" "
Ash	2.87	" "
	100.00	" "

The total amount of combustible matter in this coal is 83.60 per cent.

"No. 12 in some respects resembled No. 11. It is a semi-cannel in appearance, very friable in dry air, and non-caking. The results of analysis are as follows:

Specific gravity, 1.425.

Water	12.70	per cent.
Volatile combustible matter	38.32	" "
Fixed carbon	45.61	" "
Ash	3.37	" "
	100.00	" "

The total amount of combustible matter in this coal is 83.93 per cent.

*Fifth annual report, p. 57.

"No. 13 is a specimen of dark colored clay containing an unusual amount of organic combustible matter, not enough, however, to give it any value as fuel. It burns to a very light-colored ash consisting largely of alumina, and would therefore in all probability make very good brick if sufficient sand were mixed with it. The results of analysis were as follows:

Specific gravity, 1.968.

Water	29.55	per cent.	
Volatile combustible matter			
Fixed carbon			
Ash, consisting of clay	70.45	"	"
	100.00	"	"

The ash contained—

Insoluble portion, consisting of insoluble alumina and silicic acid	92.751	per cent.	
Soluble silicic acid	.490	"	"
Sulphuric acid	.282	"	"
Ferric oxide and alumina	2.894	"	"
Lime	1.076	"	"
Magnesia	.348	"	"
Undetermined matters	1.159	"	"
	100.000	"	"

"No. 14 consisted of a soft, siliceous rock, containing small fragments, grains and specks of mineral charcoal. The results of analysis are as follows:

Specific gravity, 2.141.

Water and combustible matter	26.54	per cent.	
Ash	73.46	"	"
	100.00	"	"

The ash contained—

Insoluble matter, chiefly silicic acid	96.549	per cent.	
Soluble silicic acid	0.836	"	"
Sulphuric acid	0.178	"	"
Ferric oxide and alumina	0.257	"	"
Lime	1.023	"	"
Magnesia	0.462	"	"
Undetermined matters	0.695	"	"
	100.000	"	""

It appears nearly certain that no workable deposits of coal exist in this region. Professor Winchell summarizes his observations and conclusions, upon this subject, as follows:

"1st. The rocks that have been explored for coal, on the Cottonwood and Redwood rivers, belong to the Cretaceous system, and do not promise to be productive of coal in valuable quantities.

"2d. The coal there taken out is of an inferior grade, though varying from cannel coal to charcoal." . . . . . The charcoal, "while it is the more abundant, is of less value for use as fuel. It is light, and quickly ignites. . . . . . It lies in irregular sheets, generally not more than half an inch thick when pure, but may be disseminated through a thickness of six or eight feet. It is very fragile, hardly bearing transportation." The cannel coal "is black, or brown black, lustrous, compact, rather hard, and presents every aspect of a valuable coal. It occurs in isolated lumps or pockets, in the same beds as the charcoal, but less abundantly. It readily burns, making a hot fire. In the air, when it has become dry, it cracks and crumbles something like quicklime, but not to a powder."

"3d. As the rocks of the Cretaceous period are believed to have existed throughout the most of the state, the only probable exception being in the southeastern portion, including half a dozen counties, such coal is likely to occur at a great many places.

"4th. The 'float' coal which has so often attracted the attention of the people, is derived, so far as yet known, from the disruption of the Cretaceous rocks by the glaciers of the ice period. It is scattered through the drift, and is met with in wells and other excavations, and may be often picked up along the beds of streams."

Glacial and modified drift. Glacial striæ are plainly seen on the southwest part of the outcrop of quartzyte that forms the water-fall in section 31, Stately, having a course S. 50° to 55° E., with reference to the true meridian; and upon the ledge of gneiss in section 12, T. **111**, R. **38**, bearing S. 50° to 60° E.

The surface of Brown and Redwood counties is principally till, or the mixture of clay with smaller proportions of sand and gravel and occasional enclosed boulders, which was thus deposited in a mingled unstratified mass by the ice-sheets of the glacial period. Its thickness in these counties is generally from 100 to 200 feet. Within the till are found occasional layers of sand or gravel, which often yield large supplies of water in wells. Many of these veins of modified drift were probably formed by small glacial streams, and they cannot be regarded as marking important divisions of the ice age. It is shown, however, by shells, remains of vegetation and trees, found evidently in the place where they were living, underlain and overlain by till, that this very cold period was not one unbroken reign of ice, but that this retreated and re-advanced, or possibly at some times was nearly all melted and then accumulated anew.

Two principal glacial epochs can be distinguished:* in the first of which all of Minnesota except its southeast corner was deeply covered by the continental ice-sheet, and its border was several hundred miles south of this district, in Nebraska, Kansas, Missouri, and southern Illinois; whereas in the later very severely cold epoch, the ice-fields were of less extent, and terminated from 50 to 300 miles within their earlier limit, covering all the basin of the Minnesota river, but not enveloping a large tract in the southwest corner of Minnesota and leaving uncovered a much larger area than before in the southeast part of the state. Between these glacial epochs the ice-sheet was melted away within the basins of the Minnesota and Red rivers, and probably from the entire state. The greater part of the till appears to have been deposited by this earlier ice-sheet; and during the retreat of the ice this till was overspread in some places, especially along the avenues of drainage, by beds of modified drift, or stratified gravel, sand, and clay, washed from the material that had been contained in the ice and now became exposed upon its surface to the multitude of rills, rivulets and rivers that were formed by its melting.

In the ensuing interglacial epoch, this drift-sheet was channeled by water-courses till its valleys were apparently as numerous and deep as those of our present streams. The interglacial drainage sometimes went in a different direction from that now taken by the creeks and rivers; and the valleys then excavated in the drift, though partly refilled with till during the last glacial epoch, are still, in some instances, clearly marked by series of lakes, as described in the report of Martin county (pages 479 to 485). More commonly the interglacial water-courses must have occupied nearly the same place with the valleys of the present time; and there seems to be conclusive proof that this was true of the valley of the Minnesota river. A long period intervened between the great glacial epochs; the earlier ice-sheet gradually retreated northward; a lake was formed in the Red river valley by the receding ice-barrier on the north; the outflow from this lake, and the drainage of the Minnesota basin itself, appear to have excavated the valley of the Minnesota river nearly as it now is; and the further recession of the ice-sheet probably even allowed the drainage

*Compare the first annual report, p. 61; the fifth, p. 177; and the reports of Martin and Dakota counties.

of the Red river basin to take its course northward, as now, to Hudson bay, this being indicated by fossiliferous beds enclosed between deposits of till within the area that had been covered by this interglacial lake and was afterward occupied by lake Agassiz at the close of the last glacial epoch.

Again a severely cold climate prevailed, accumulating a vast sheet of ice upon British America and the greater part of Minnesota. By this glacial sheet the valley of the Minnesota river was partly refilled with till, but it evidently remained an important feature in the contour of the land surface. During the final melting of this ice-sheet, its waters, discharged in this channel, quickly removed whatever obstructing deposits of drift it had received, and undermined its bluffs, giving them again the steep slopes produced by fluvial erosion. This partial re-excavation and sculpture were then followed immediately, during the retreat of the ice-sheet, by the deposition of the stratified gravel, sand and clay, 75 to 150 feet deep, remnants of which occur as terraces on the sides of this valley, from its mouth to New Ulm, and less distinctly beyond. Had not the great valley existed nearly in its present form through the last glacial epoch, it could not have become filled with this modified drift, which must belong to the era of melting of the last ice-sheet. After the departure of the ice, the supply of both water and sediment was so diminished that the river could no longer overspread the former flood-plain of modified drift and add to its depth, but has been occupied mainly in slow excavation and removal of these deposits, leaving remnants of them as elevated plains or terraces.*

Terminal moraines. The morainic tract in Stately (page 565) is probably a portion of the third terminal moraine, formed at the boundary of the ice of the last glacial epoch during a pause in its recession. This moraine is well exhibited in Martin county and thence to Forest City and Pilot mound in Hancock county, Iowa, as described on page 478. In Redwood county it is not prominent, and its course, which is believed to coincide approximately with that of the Cottonwood river, has not been traced. Close south of the valley of this river in the N. W. ¼ of section 14, Gales, numerous small hillocks and ridges, 10 to 20 feet high, rough with abundant boulders, were observed to occupy a width from a few rods to an eighth of a mile, reaching a half mile or more in length from east to west; and from a bridge in section 10, Gales, a noteworthy hill, perhaps 60 feet high, is seen in the view westward, situated not far from where the Cottonwood river crosses the county line. Farther northwest, this morainic belt is clearly traced across Yellow Medicine and Lac qui Parle counties, its most conspicuous accumulations being the Antelope hills.

During later stages in the recession of this ice-sheet, when the fourth and fifth terminal moraines of its Minnesota lobe were formed, its southern extremity was successively at Kiester in Faribault county and at Elysian in Le Sueur county, and its southwest boundary doubtless crossed Brown and Redwood counties, but the marginal accumulations of drift belonging to these stages have not been traced here. A shallow lake extended along the edge of the ice-sheet across these counties (page 461), and acted to partially level down and smooth the morainic deposits. It seems likely, however, that they are still recognizable, and by careful observation might be mapped approximately. At the time of the fourth or Kiester moraine, the ice-margin probably extended through the central part of Brown and Redwood counties; and the kame-like deposits (page 582) near Sleepy Eye, and in **T. 111, R. 38,** and the northwest part of Vesta, may in part represent this moraine. The fifth or Elysian moraine is probably indicated similarly in section 33, Swede's Forest.

The valley of Mound creek, across the morainic area in Stately, has a level bottom from 500 to 1000 feet wide, and appears as if in some former time, which was doubtless the epoch of melting of the last ice-sheet, it had been the water-course of floods pouring southeastward from the upper part of the basin of the Big Cottonwood river into the Little Cottonwood valley.

Modified drift of the earlier glacial epoch. Thick deposits of stratified sand and gravel, found enclosed in the till near New Ulm, and occurring below a considerable depth of till ten miles farther southeast in Courtland, Nicollet county, are believed to be portions of the modified drift which was deposited at the close of the earlier glacial period, as explained in the foregoing brief history of the ice age. The locality first mentioned is on the extension of Center street a half mile west of New Ulm, where it rises to the top of the bluff, 180 feet above the river, but only some 100 feet above its old channel which lies between New Ulm and this bluff (fig. 47). The hight here

*See pages 445, 576 and 583; also, compare article on the Minnesota valley in the ice age, *Proc. of Amer. Assoc. for Adv. of Science*, 1883, and *Am. Jour. Sci.* (3), xxvii, 1884.

reached is the general level of the vast prairie of gently undulating till, through which the Minnesota valley is excavated. The grade cuts to a depth of about 40 feet at the edge of the blu ff and thence ascends, with decreasing depth of cut, along a distance of some twenty-five rods, to the surface of the drift-sheet. This section exhibits two beds of true till, separated by modified drift which is probably an interglacial formation, supplied, as already stated, at the time of final melting of the earlier ice-sheet and spread beyond its receding margin upon the unchanneled surface of the till that had been formed during that earlier part of the ice age. The upper bed of till, apparently representing the total thickness of the drift deposited here in the last glacial epoch, is 16 to 18 feet thick, and is an entirely unstratified yellowish gravelly clay, containing occasional rock-fragments up to six or eight inches in diameter, but showing only two or three of larger size, these being two or three feet in diameter. Portions of this till, within six to eight or ten feet below the top, are gray, with limy concretions and limy layers that have been gathered by percolating waters. The bottom of this upper till, seen clearly exposed along a distance of about 250 feet, is an almost exactly level line. Next below is the earlier modified drift. Its thickness is also 16 to 18 feet, levelly stratified throughout, but having the horizontal layers often obliquely laminated. The dip of this lamination, which marks the direction of the current of water that brought this sediment, is to the east or northeast, toward the Minnesota river, and varies in amount from two or three to fifteen or twenty degrees. Floods produced by glacial melting, and carrying gravel, sand and clay that had been contained in the ice-sheet, appear to have taken their course along the central depression of the Minnesota basin, coming from ice-fields which still covered its upper portion, with their retreating border probably only a few miles distant at the time when this stratum was deposited. Its largest pebbles are six to eight inches in diameter. The underlying till was seen along an extent of 100 feet, the greatest depth cut into it being about eight feet. Its upper line, separating it from the modified drift is approximately level but undulating, with its highest points two or three feet above the lowest. This till, like the upper bed, bears no marks of stratification; and neither shows any interbedding or transition, but both are bounded by definite lines, at their junction with the intervening gravel and sand. The lower bed of till is dark bluish, excepting for about twenty feet from the face of the bluff inward, where weathering has changed it to the same yellow color that characterizes the modified drift and upper till.

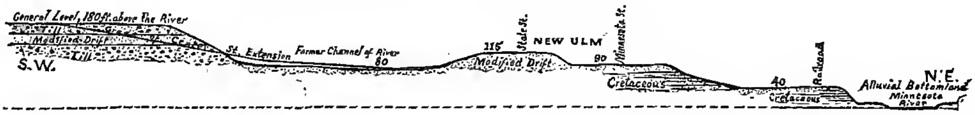


FIG. 47. SECTION OF THE MINNESOTA VALLEY, SOUTHWEST FROM THE RIVER, AT NEW ULM.

The modified drift below till, mentioned in Courtland, ten miles southeast from this locality, is made known by a well that was bored to a depth of 100 feet at the house of Carl Richert, in the S. W. ¼ of section 11, upon the upland or general level, even in hight with the top of the bluffs of the Minnesota valley, from which its distance is about an eighth of a mile. Its section was soil, 2 feet; yellow and gray till, 30 feet; sand, mainly yellow, but in considerable part white near the bottom, 54 feet; and yellowish gravel, 14 feet and extending lower. No water was obtained, and the well was given up.

Modified drift of the last glacial epoch. Upon the sheet of till which covers these counties are frequently noticed mounds and knolls or short ridges of gravel and sand, 10 to 20 feet, or rarely 30 feet or more, in hight, which in any excavation are seen to be irregularly interstratified and obliquely bedded. These deposits appear to have been formed by streams that flowed from the drift-strown surface of the departing ice-fields of the last glacial epoch; having a similar origin with the eskers or kames, which form prolonged ridges, or series of interlocking ridges and mounds, in Ireland and Scotland, in Sweden, and in New England. Conspicuous kame-like deposits of modified drift in Redwood county were observed in the N. E. ¼ of section 33, Swede's Forest, where a mound of this class rises some 30 feet above the general level; in the northwest part of Vesta, which has numerous hillocks and short ridges of gravel and sand, 10 to 40 feet in hight, trending from north to south more commonly than in other directions; and in T. **111**, R. **38**, and thence southwestward to the Cottonwood river. In Brown county a notable series of kames, or short ridges and knolls of gravel and sand, 25 to 40 feet high, occurs about a mile east and southeast of Sleepy Eye, extending from north to south through the S. W. ¼ of section 28, and in the W. ½ of section 33, in the south part of Home.

The modified drift which was deposited in the Minnesota valley, as shown on page 581, is represented at New Ulm by the plateau of gravel and sand, a mile long and about an eighth of a mile wide, on which the west and highest part of the city is built (fig. 47). A hollow, about forty feet lower and a quarter of a mile wide, lying between this plateau and the bluff, was formerly a channel of the river, since which time the valley has been cut eighty feet below it. Other remains of the valley drift are seen on the southwest side of the river for two or three miles northwest from New Ulm; and on the northeast side it forms long and wide terraces in Courtland, about 150 feet above the river, and a narrow terrace, nearly as high, generally discernible along the bluffs through West Newton township.

Below the modified drift, New Ulm is underlain by Cretaceous beds which have been already described. These differ in hardness and ability to withstand the river's erosion in cutting its valley, which characters have been elements in determining the position and outlines of the lower terraces of this city, as that of Minnesota street, about 90 feet above the river, and that of the depot and brick yard, 50 to 40 feet above the river, and of the continuation of the latter, about 40 feet in hight, along the valley some three miles below New Ulm, reaching beyond the Cottonwood river, as also of a terrace at nearly the same elevation on the opposite side of the Minnesota river. A considerable thickness of modified drift forms the surface of these terraces, including the clay at Aufderheide's brick-yard; but their lower portions are Cretaceous beds, from which pottery clay has been taken near the southeast end of Minnesota street, while the terraces about 40 feet high, at each side of the Minnesota river contain beds of nodular gray limestone, much of which has been burned for lime, interstratified with green and red clay and shale. The cut in Cretaceous clays upon Third North street in New Ulm (fig. 46, page 576) is at nearly the same horizon, but in that vicinity it forms no well marked terrace.

Alluvium. The bottomland at New Ulm and generally along the Minnesota valley at the north side of these counties, is from a half mile to a mile wide. It is composed of recent alluvium, mostly sand and fine silt, having a hight from 5 to 15 feet, and sometimes more, above the river, which meanders through this lowland, here and there sweeping quite to its border. The highest floods, formed by snow-melting in spring or by heavy rains, cover the greater part of this bottom or flood-plain, and at each inundation add slightly to it by their sediment.

Water-worn boulders. Very remarkable water-worn boulders occur in the Minnesota valley within two miles east from the west line of Redwood county, in sections 17, 18 and 7, Swede's Forest. The river road here winds among outcrops of gneiss and granite, before described, and along their whole extent of one and a half miles in Swede's Forest, detached blocks or boulders of the same formation are seen frequently beside the road and at a distance from it, of all sizes up to fifteen feet in diameter. A large proportion of these boulders, probably a quarter part of all, are very noticeably water-worn, in shallow pot-holes, grooves and indentations, so that some of them, to compare great things with small, have forms like those stamped upon balls of dough or clay by finger-impressions. One of these water-worn boulders, fifteen feet in diameter, lies close beside the road three-quarters of a mile west of the school house which was mentioned on page 569. Again, several large water-worn blocks are seen near together, about twenty-five rods southeast from this school house; one of them, twelve feet long and nine feet high, having its east side remarkably sculptured, like the channel of a water-fall. Boulders water-worn in this peculiar manner are unknown in the ordinary glacial drift, and it appears that these blocks, if not thus worn where they now lie, which seems improbable, were formerly united in a ledge over which the river flowed at some point not far distant to the northwest, probably near the present county line.

Wells in Brown county.

Examples of the sections made in the drift by wells in Brown county, are as follows:

Linden. M. O. Breste; sec. 31: well, 16 feet; soil, 2; yellow till, spaded, 14 feet; water comes from sandy streaks in the till.

Milford. William Skinner; sec. 33, at south side of the township: well at house, 30 feet; all yellow till; water seeps, filling the well twelve feet. About eight rods northwest from this, a well 50 feet deep was in yellow till for its upper 25 feet, with blue till for all below; scarcely any water; the bark of wood and fragments of *Baculites*, in a sandy layer one or two inches thick, were found in this till 34 feet below the surface; and several pieces of lignite were found in the till of each of these wells, derived, like the *Baculites* fragments, from Cretaceous beds.

Sigel. Joseph Flor; sec. 24: well, 14; soil, 4 feet; gravel and sand, 10 feet.

John Kratsch; sec. 36: well, 20: soil, 3; yellow till, 17; water rose four feet in an hour, from gravel and sand at the bottom.

Lake Hanska. Christian Ahlness; sec. 13: well, 14; soil, 2; yellow till, spaded, 12; water seeps.

E. G. Pahl; sec. 26: well, 20; dug 17 feet, and bored two inches in diameter for the remaining three feet; all yellow till, hard and picked, with occasional sandy and gravelly streaks; water rose from gravel or sand at the bottom, with such force that it could not be plugged, and came to a permanent level ten feet below the surface.

Home. Horatio Werring; sec. 6: well, 40 feet; soil, 2; yellow till, 10; harder blue till, 24; cemented layer, 6 inches; blue till, 1½ feet; coarse sand, 2 feet, containing water, which did not rise above this stratum of modified drift.

The wells at Golden Gate in this township are 12 to 20 feet deep, in till.

Sleepy Eye, in Home township. P. Randall; well, 23 feet; soil, 2; yellow till, 16: harder blue till, with yellowish gravelly streaks, 5 feet. A piece of wood, sixteen inches long, appearing like a splintered limb of elm, was found in the lower part of this well.

Joseph Troutman; well, 71; soil, 2; yellow till, 18; harder blue till, 15; changing to soft blue till, 16 feet; then, hard, dark bluish sand, free from gravel stones, 20 feet, remaining stable when bored, but caving when the water came, which rose seven or eight feet in the first day, from gravel at the bottom, and within a few days became forty feet deep, thought to be all from the bottom. Other wells equally deep near find only gravelly clay or till.

The blue till in this vicinity is usually harder than the overlying yellow till; the lowest one or two feet of each are specially hard; at the base of the blue till, next overlying the water-bearing gravel and sand, is often a layer firmly cemented with iron or lime. Water is commonly found 50 to 60 feet below the surface, and rises in most wells 10 to 20 feet above the stratum in which it is found. Lignite frequently occurs, in fragments up to six inches in diameter.

A well was bored 195 feet deep at Sleepy Eye for the railroad company, apparently not passing through the glacial drift, which was yellowish till for about 25 feet, and dark buish till below, probably to the bottom, where a log of wood, resembling elm, was encountered, stopping the work. Water filled this well to twenty-five feet below the top, and was a large supply; but the well is not now used.

Stark. William Kuehn; Iberia village: well, 26 feet; soil, 2 feet; yellow till, 17; sand, 2 feet; blue till, 5 feet and deeper; water comes from the sand; these tills are about equally hard, both needing to be picked.

Eden. F. Hartwick; Lone Tree Lake post-office, sec. 5: well, 20 feet; soil, 2; gravel, 2; sand, finest at the bottom, 16; unfailing water. This is on a kame-like swell, and most of the land all around is till.

Leavenworth. John Youngmann; sec. 2: well, 32 feet; soil, 2; yellow till, 18; blue till, easier to bore, 12; water rose twelve feet in four hours from sand at the bottom.

Burnstown. John F. Burns; sec. 19: well, 22 feet; soil, 2; yellow till, containing sandy streaks, 15; much harder blue till, picked, 4; sand, 1; water rose six feet in one day. Wells in this township are 15 to 30 feet deep; no fossils found, excepting lignite in pieces up to six inches in diameter.

Bashaw. C. L. Thor; sec. 26: well, 24 feet; soil, 2; yellow till, 10; blue till, moist and softer, 12; water rose twelve feet in six hours from gravel.

Stately. John Wood; sec. 14: well, 28 feet; soil, 2; yellow till, 12; harder blue till, 14; water rose five feet in a half day from gravel and sand at the bottom; numerous fragments of lignite were found.

A. B. Dickerson; S. W. ¼ of sec. 30: well, 33 feet; soil, 2; yellow till, picked, 31; enclosing, but only at one side of the well, a narrow vein of coarse gravel, one foot thick, 15 feet below the top; in the lower part interbedded with layers of darker bluish till, which was the material at the bottom; water seeps, three to six feet deep.

D. H. Semans' well in sec. 34, close north of the Little Cottonwood river, found in its lower part, about 30 feet below the surface, fragments of *Baculites* and a cast of an *Inoceramus*, resembling *I. umbonatus*, M. & H.; a piece of wood, perhaps red cedar, some nine inches long and three inches wide, at 25 feet; and several pieces of lignite. These were probably in glacial drift, a large part of which was derived from Cretaceous beds.

Wells in Redwood county.

Sherman. J. M. Little; sec. 6: well, 33; soil, 2; yellow till, spaded, 28; gravel, 3 feet, and extending lower; water rose seven feet in a half day.

Delhi. Thomas H. King; sec. 31: well, 20; soil, 2; yellow till, picked, 6; blue till, somewhat easier to dig, 12; water burst up from sand at the bottom, rising twelve feet in fifteen minutes.

Redwood Falls. Town well, 70 feet deep: soil, 2; yellow till, 18; blue till, harder to bore, 50 feet, and extending lower; the only water found in this well seeps from the yellow till.

Swede's Forest. Nels Hanson; sec. 35: well, 55 feet; soil, 2; yellow till, spaded, 28 feet; harder blue till, picked, 25 feet, and below; no sand found, and no water.

Vail. Chauncy Bundy; sec. 6: well, 36 feet; soil, 2; yellow till, spaded, 16: sand and gravel, ½ inch, with some water; softer blue till, 16 feet, yielding several small pieces of lignite, and a piece of wood (perhaps willow) about a foot long, the last being in the lowest foot of this till; an interglacial bed of vegetable mould, 1½ inches thick, containing many willow leaves and the leaves and stems of rushes, "looking like a lake-shore drift," extending over the whole area of the well, six feet in diameter; bluish, clayey quicksand, 2 feet and below; water rose eight feet in a half day.

David Weaver; N. E. ¼ of sec. 28: well, 28 feet deep; soil, 3 feet; yellow till, spaded, 12 feet; blue till, also spaded, 12 feet; very hard, compacted gravel, 1 foot and deeper; water rose from the gravel eight feet in one day.

Waterbury. Hans Hanson; N. E. ¼ of sec. 34: well, 18; soil, 2; yellow till, picked, 10; harder blue till, 5; gravel, 1 foot and deeper; water rose four feet in a half day, a large supply, of excellent quality. Several pieces of lignite, up to six inches in diameter, and nodules of pyrite, were found in this well.

Lamberton. Praxel & Schandera; Lamberton village: well, 50 feet; soil, 2; yellow till, 3; blue till, with occasional layers of dry sand up to six inches thick, 45; water rose six feet in a half day. A few pieces of lignite were found.

Arnold C. Ells; sec. 10: well, 40 feet deep; soil, 2; yellow till, picked, 23; harder blue till, 15; water rose from gravel and sand at the bottom twenty-two feet in two days, rising the first ten feet in three hours. Pieces of lignite and Cretaceous shells were found in this till.

T. 111, *R.* 38. Absalom Ames; sec. 8: well, 24 feet; soil, 2; yellow till, 12; yellowish, and darker, bluish till, interbedded, 6; blue clay, soft and moist, considerably filled with fragments of Cretaceous shells, 4; water came in a small and narrow vein of fine gravel, about six inches in diameter, enclosed in this blue fossiliferous clay, and rose six feet in one day.

Walnut Grove, in North Hero township. Most of the wells here are from 12 to 30 feet deep, their material being yellow and blue till, containing occasionally small pieces of lignite, and rarely of wood. W. J. Masters in 1878 bored with a hope of finding coal (lignite), to a depth of 76 feet in the southwest part of this corporation, the section being soil, 2 feet; yellow till, 14; harder blue till, containing few pebbles, 60; no coal; water rose to the surface. A second boring for coal, near the foregoing, went only 27 feet, because of finding a large amount of water in quicksand. Its order of materials was soil, 2 feet; yellow till, 5; blue till, 20; with quicksand below, from which water rises to the top and eight feet above the surface. This fountain has been running since 1878, and is the only such flow of water found in this region.

The railroad well here is about 80 feet deep, finding the yellow and blue till, of ordinary character, to a depth of 60 feet; below which was a very hard and compact clay or shale, free from gravel, adapted for making pottery, probably of Cretaceous age, bored into about 20 feet, but found so hard that the work was stopped in this deposit, without obtaining water.

Underwood. Malcolm McNiven; sec. 6: well, 34 feet; soil, 2; yellow till, 15; blue till, much harder, 17; water rose suddenly eight feet from gravel at the bottom. Fragments of lignite were found.

Westline. Garrett Murray; sec. 14: well, 30 feet; soil, 2; yellow till, 13; harder blue till, 14; gravel, 1 foot and below, with water rising from it five or six feet.

Gales. S. S. Gale; sec. 10: well, 27 feet; soil, 2; gravel and sand, 4; yellow till, picked, 6; blue till, also picked, but softer, moister, and less gravelly, and containing occasional pockets up to six inches in diameter, of fine gray sand, 15 feet, and extending lower; at this depth of 27 feet, the compact till contained many fragments of wood. Another well, fifteen rods south of the last and on ground about ten feet lower, was 15 feet deep, finding soil and gravel and sand, 3 feet; with very compact till, which was picked, for all below, containing, close to the bottom of the well, a prostrate trunk of a tree, six inches in diameter, reaching five feet across the well, at each side of which it was chopped off. Both these wells thus encounter an interglacial forest-bed.

MATERIAL RESOURCES.

The excellence of these counties for agriculture, and their areas of woodland and prairie, the latter far exceeding the former, have been noticed in treating of their soil and timber. Besides the fertility of the land, this region possesses an invigorating, healthful climate, and almost invariably good water in its wells and springs. The material resources which remain to be mentioned are water-powers, building stone, lime, bricks, pottery, and mineral paint. Explorations made for coal, its mode of occurrence, and the improbability that it exists here in any valuable amount, have been spoken of in the account of the Cretaceous strata. No ores of any practical importance have been found. The principal resources of this part of the state are the products of its rich soil, and the water-powers afforded by many of its streams.

Springs of water, often impregnated with iron, occur along the ravines and valleys of many of the creeks and rivers in these counties, one worthy of mention being Mound creek in its course through sections 28, 21 and 22, Stately. A "big spring," well known by this name, moderately irony, supplying nearly all the water that is used in the dry season for running a grist-mill a mile farther east, is in the N. E. ¼ of the S. W. ¼ of section 19, three-quarters of a mile northwest from Golden Gate, in Home township. Both these localities are in Brown county. At the southwest side of the Minnesota valley in the north part of section 30, Swede's Forest, near the west line of Redwood county, is a "boiling spring," also irony; from which a stream three or four feet wide, and six to twelve inches deep, flows away. This is at the northwest side of a rivulet, in a ravine some 50 feet below the general level. These springs issue from the drift, and show that large water-courses exist in sand and gravel veins or strata, enclosed in the till. Such subterranean streams are often struck in wells, with the water sometimes flowing constantly through them at the bottom; but more frequently, when the outlet of the spring is distant, the water soon rises to fill the well permanently, 10, 20, or 30 feet in depth.

Water-powers. The water-powers used in Brown county, all employed by flouring mills, are as follows:

Leavenworth mills: F. Schieltz; in the east part of sec. 14, Leavenworth; head, about ten feet.

Iberia mills: Schwerdtfeger & Plath; in the west part of sec. 16, Stark; head, ten feet: canal about forty rods long.

Francke Brothers' mill; in the S. E. ¼ of sec. 36, Home; head, eleven feet.

Cottonwood mills: Frank & Bentzin; at the northeast corner of sec. 4, Cottonwood, one and a half miles south from New Ulm; head, nine feet; two run of stone; a custom grist-mill.

The foregoing are on the Cottonwood river. Only one other utilized water-power was learned of in Brown county, this being at the Golden Gate mill, a custom grist-mill, owned by J. Heimerdinger & Sons, on Big Spring creek, in sec. 20, in the north part of Home township; head, about twenty feet.

The only water-powers used in Redwood county are on the river of this name at and below Redwood Falls. These, in descending order, are as follows: Delhi mills, owned by A. A. Cook & Co., with a head of twenty feet; Redwood mills, owned by Worden & Ruter, with a head of eighteen feet; E. Cuff's mill, with a head of thirteen feet; and E. Birum's mill, with a head of fourteen feet. Between the second and third is the cascade called "Redwood falls," which descends twenty-five feet; and between the third and fourth about ten feet of fall is unused. The foot of Birum's dam is 30 or 40 feet above the Minnesota river; and the top of Cook & Co.'s dam is 140 feet, approximately, above the Minnesota river, being some 75 feet below the general level of the prairie and town. The beauty of this deep, rock-walled gorge, about one and a half miles long, with its cascades and rapids and meandering river, can scarcely be over-stated. Its geological formations are equally interesting, by reason of their variety and uncommon character.

Less than a half mile northwest from this gorge, Ramsey creek, a tributary of the Redwood, has a perpendicular fall of 30 feet, over the same granitic rock which forms the Redwood falls.

The Minnesota river at the north side of Swede's Forest, Redwood county, has a considerable descent, probably amounting in all to 25 feet, in a succession of rapids, which alternate with intervals of slow current, along a distance of about seven miles, known as Patterson's rapids.

Building stone. New Ulm obtains considerable supplies of stone for common masonry from the red quartzyte which outcrops two miles farther east on the north side of the Minnesota river, in Nicollet county. Drift boulders may also be collected, and are used, in most parts of this county, in the amount needed for stone-work on common farms, as for foundations, cellar-walls, and wells. The only quarrying for these purposes in Brown county is of small amount, in an outcrop of Cretaceous sandstone, at the north side of the Cottonwood river in section 25, North Star, about a mile southwest from Springfield station. The recent calcareous deposit generally known as "petrified moss," occurring in the bed of a small rivulet tributary to the Minnesota river near the east line of Home township, has been somewhat used as a building material.

The gneiss and granite of the Minnesota valley at the north side of Redwood county have not yet been quarried to any considerable extent. The only stone worked for masonry in this county, excepting boulders, is the gneiss, somewhat decomposing, at the bottom of the gorge of the Redwood river, about an eighth of a mile north of Redwood Falls.

Lime. Three miles southeast from New Ulm, beside the Minnesota river in section 2, Cottonwood, William Winkelmann's kiln has burned lime during the past ten years or more, from the nodular limestone of the low Cretaceous terrace before described. The yearly product is about 3,000 barrels of lime, which is sold at $1 per barrel. This lime is gray, and slacks to a pure white. One to two hundred barrels of lime are burned yearly from drift boulders by Hanson Fisk, in Swede's Forest, Redwood county.

Bricks. The brick-yard at New Ulm, situated close southeast of the city, on a terrace about 40 feet above the river, formerly owned by William Winkelmann, was purchased in 1879 by Fritz Aufderheide, who made about 1,000,000 bricks here in 1880, selling them at $6.50 per thousand. These are red bricks, of fair quality. No sand is required for tempering. The clay used is modified drift, probably overlying Cretaceous beds. It is dug near the brick-yard, on the same terrace, showing a section of about two feet of fine, silty, black soil, in which, and scattered over the surface, are occasional boulders up to four feet in diameter; underlain by yellow clay, finely laminated, nearly horizontal, but slightly undulating and irregular in stratification, containing a few layers, up to one or two inches in thickness, of ferruginous sand, having a vertical exposure in this excavation of seven feet and extending lower.

Before his work here, Mr. Aufderheide had made bricks five years in the N. W. ¼ of section 12, Milford, three miles northwest from New Ulm, using a similar stratified, yellow clay. He made 700,000 to 800,000 there yearly; but the business at that locality is now discontinued.

At Sleepy Eye, a kiln of bricks was made several years ago from the pebbly clay of the till, failing because of limestone particles, by which the bricks were cracked after burning.

Bohn & Lamberton, at Redwood Falls, in 1878, made two kilns of red bricks, amounting to about 200,000, which were sold at $8 per thousand. The clay and sand used are a deposit of modified drift, situated near the top of the bluff of Redwood river, on its west side, about thirty rods north of Cook & Co.'s mill, and nearly 50 feet above their mill-pond. The section here is black soil, 2 feet, gradually becoming yellow in the next 2 or 3 feet; thence, compact yellow clay extends to 9 feet below the surface, divided by darker partings into layers from four inches to eight inches or a foot in thickness, which dip 2° or 3° E. These layers are distinctly continuous along the whole extent of the excavation, about four rods. They are probably the depositions of successive years; the finer, dark partings being the sediments of the season of low water; while the great mass of each layer was made by high floods, with stronger currents and bearing more abundant detritus, supplied from the melting ice-sheet during the warm portion of the year. Below the depth of 8 or 9 feet the clay changes to yellowish sand, obliquely bedded in layers from a quarter of an inch to one inch thick, separated by harder films of iron rust. Too much sand was mixed with the clay in this brick-making, so that the bricks were somewhat deficient in hardness and durability; but the clay seems to be excellent for this use.

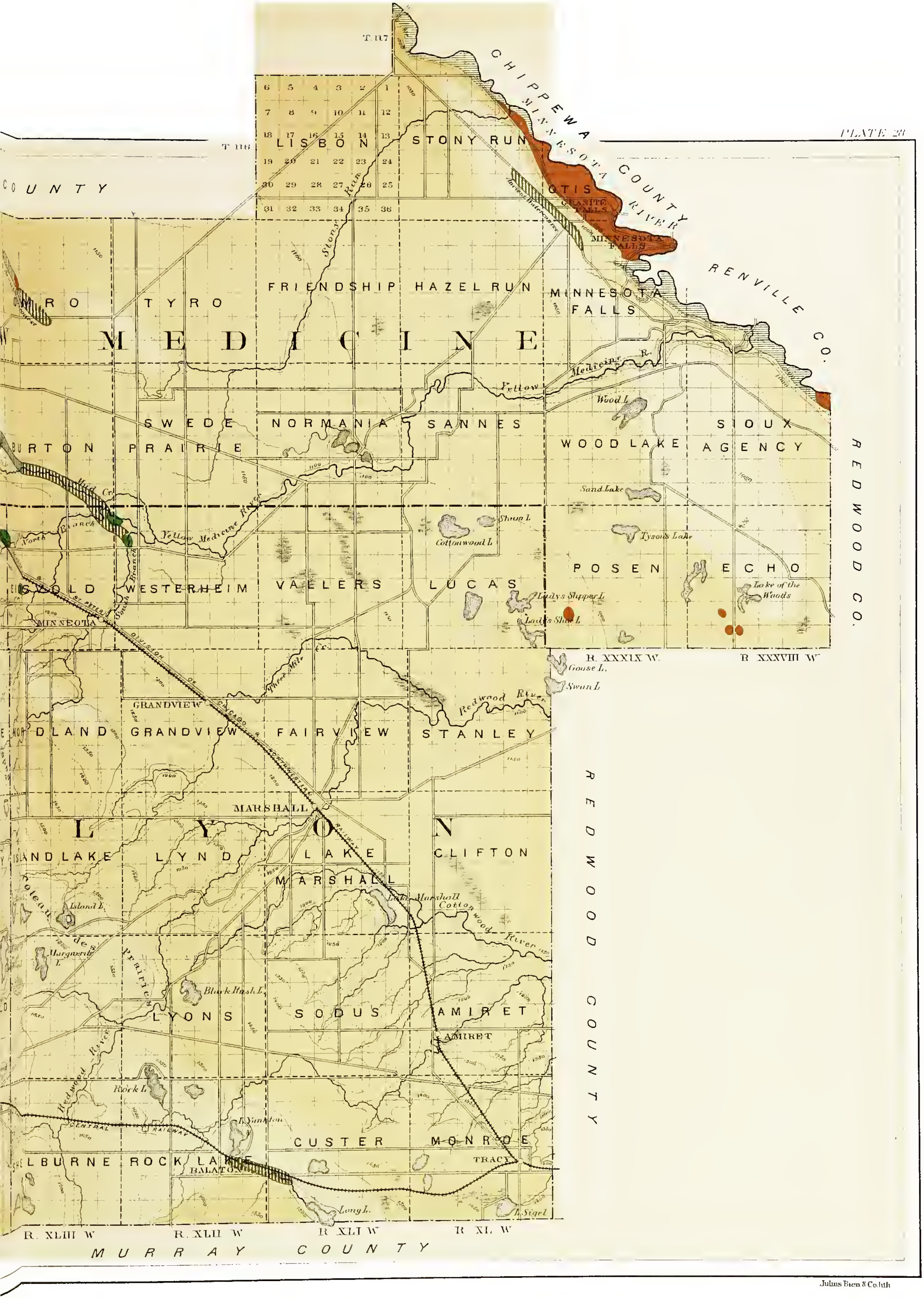
Fire-bricks. From Cretaceous beds on the Cottonwood river, good fire-bricks have been made by Christian Dauffenbach, by William Winkelmann, and by John Stœckert, at New Ulm. The characters of the deposits used, and in what proportion, have been stated already in the description of the section in which they occur (page 574).

Pottery. Cretaceous clay, also obtained from the bluffs of the Cottonwood river, a few miles farther west, as described on page 573, has been used in New Ulm by the same Messrs. Dauffenbach, Winkelmann, and Stœckert, potters. In 1879 and 1880, the two former had given up the manufacture both of fire-bricks and pottery; but these lines of business are still carried on by Mr. Stœckert, his products being some $2000 worth yearly.

Mineral paint. A good and durable paint was manufactured in 1868 or 1869 from ferruginous portions of the kaolinized gneiss and granite mentioned in the vicinity of Redwood Falls. The material thus used was obtained from the northwest or left bank of the Redwood river in its gorge, about a mile north of Redwood Falls, in the N. ½ of the N. E. ¼ of section 36, Delhi. Of this business Prof. Winchell wrote in his second annual report: "At Redwood Falls the kaolin which has resulted from the decomposition of the granitic rock, has become stained with iron, and has a brownish or greenish-brown color. It contains, generally, some silica. From this stained kaolin a good mineral paint has been manufactured. Messrs. Grant and Brusseau commenced the enterprise, and carried it far enough to demonstrate the quality of the product. The manufactured article is said to have been equal to that of Brandon, Vt.; but the cost was so great that, after transportation to St. Paul, it could not be offered in the market so cheaply as the Brandon paint. Their process was very simple. The raw material was obtained from the banks of the Redwood river, and was of a rusty-brown color, having also a greenish tinge. It was broken or crushed to the fineness of corn or wheat. It was then dried in a large pan placed over a fire, and ground by water-power, between two burr-stones. In that condition it was ready for use by simply mixing with boiled or raw linseed oil. . . . . . The color produced was a reddish umber. By making some selections various lighter shades, of the same general character, were produced. It had a heavy sediment, consisting probably of iron and silica. The quality of the paint is said to have been superior to that from Ohio, and fully equal to that from Brandon, Vt. The surface of the wood painted becomes hardened and glazed, but remains smooth."

ABORIGINAL EARTHWORKS.

The only aboriginal mound observed or learned of by inquiries in Brown and Redwood counties, is situated a little more than a mile northeast from Redwood Falls, being on the high prairie, about ten rods northwest from the road and twenty-five rods south from the edge of the southwest bluff of the Minnesota valley. It has the usual circular, dome-like form, and is six feet high.



Julius Bien & Co. lith

CHAPTER XX.

THE GEOLOGY OF YELLOW MEDICINE, LYON AND LINCOLN COUNTIES.

BY WARREN UPHAM.

Situation and area. These counties (plate-pages 27 and 28) lie in southwestern Minnesota, together forming a district which is bordered on the northeast by the Minnesota river and on the west by Dakota. The south boundary of this district is 48 miles north of the Iowa line. Its largest towns are Granite Falls and Canby in Yellow Medicine county, the former being the county seat; Tracy, Marshall and Minneota, in Lyon county, on the Winona & Saint Peter division of the Chicago and Northwestern railway, Marshall being the county seat; Balaton, in the south part of the same county, on the Dakota Central railway, a branch of the foregoing; and Tyler, Lake Benton and Verdi, on the same railway, in the south part of Lincoln county, of which Lake Benton is the county seat. The distances from Minneapolis and Saint Paul west to Granite Falls, measured in a direct line, are about 112 and 120 miles; from these cities to Marshall, which is about 28 miles south-southwest from Granite Falls, the distance is approximately 135 miles; and to Lake Benton, which is again 28 miles southwesterly from Marshall, the distance west-southwest from Minneapolis is about 160 miles, and from Saint Paul, 165 miles.

The areas of these counties, in square miles, is as follows:

	Land.	Water.	Total.
Yellow Medicine,	752.60	10.52	763.12
Lyon,	709.50	11.16	720.66
Lincoln,	522.43	19.56	541.99

SURFACE FEATURES.

Natural drainage. The streams of this district are tributary to the Minnesota river, excepting the southwest corner of Lincoln county which lies within the basin of the Big Sioux river, and a small tract at the south side of Lyon county, drained to lake Shetek and the Des Moines river. Four great branches of the Minnesota river gather their waters partly or wholly in these counties, namely, in their order from northwest to southeast, the Lac qui Parle, Yellow Medicine, Redwood and Cottonwood rivers. Only the second of these has its entire basin and course within this district.

Lac qui Parle river receives the drainage from an area of about 60 square miles in northwestern Lincoln county, and 210 square miles, approximately, in the west part of Yellow Medicine county. Its principal head-streams in this district, in order from northwest to southeast are Florida and Canby creeks, and the East branch of Lac qui Parle river, the last of which receives the overflow of lake Hendricks on the state line. Between this basin and the Yellow Medicine river, the creek called Stony run, tributary to the Minnesota river, drains a tract of about 150 square miles, lying wholly in Yellow Medicine county.

The name of the *Yellow Medicine river*, from the stream applied to the county, is the translation of the Dakota name *Pejuta zizi*, which signifies, according to Mr. T. M. Young, the long and slender, bitter, yellow root of the moonseed (*Menispermum Canadense*), used by the Indians as a medicine. This plant is found commonly along the banks and bluffs of streams throughout the state. The basin of the Yellow Medicine river includes about 260 square miles in the central and northeastern portions of Lincoln county; about 140 square miles in northwestern Lyon county; and some 200 square miles in Yellow Medicine county; its whole area being thus approximately 600 square miles. The farthest source of this river is lake Shaokatan, fifty miles southwest from its mouth. Besides these tributaries, several small creeks, two to four miles long, join the Minnesota river in Yellow Medicine county, mostly produced by large springs which issue from the bluffs of the Minnesota valley, or within the ravines which their outflow has channeled.

The basin of the *Redwood river* in this district embraces about 450 square miles, 125 of which are in southeastern Lincoln county, the remainder being a belt that crosses Lyon county from southwest to northeast. Lake Benton, the farthest source of the Redwood river, is sixty miles from its mouth. The largest tributary of this river in its whole course is Three Mile creek, which flows from the west line of Lyon county northeastward twenty miles, nearly parallel with the Redwood river and three to five miles northwest from it.

An area of about 240 square miles in southern and southeastern Lyon county is tributary, by many creeks, to the *Cottonwood river*. The most northwestern branch of this river flows eastward nearly through the center of Lake Marshall township, being only two to three miles southeast from the Redwood river. Another important branch rises in northwestern Murray county, runs northeasterly between Rock lake and lake Yankton, and crosses the Winona & St. Peter railroad close south of Amiret.

Each of these four large tributaries of the Minnesota receives numerous small creeks in these counties from the northeastern slope of the Coteau des Prairies, the base of which extends from the southeast part of Lyon county northwest across this district, and enters Dakota at the northwest corner of Yellow Medicine county. The waters that have sunk into the drift-sheet upon the higher plateau-like portion of the Coteau, which extends fifteen or twenty miles farther west, re-appear in springs along the great slope, about five miles wide with a descent of 250 to 500 feet, which forms the limit of this highland toward the northeast, notably distinguished on the maps by its many small streams flowing northeastward.

Lake Shetek, tributary to the *Des Moines river*, lies close south of this district in Murray county, and its area of drainage extends into Lyon county at the middle of its south side so as to include fifteen or twenty square miles of Rock Lake and Custer townships.

Nearly a hundred square miles in southwestern Lincoln county, lying southwest of the highest ridge of the Coteau des Prairies, are drained into the *Big Sioux river*, by Medary and Flandreau creeks. This area includes Verdi, and parts of Shaokatan, Drammen and Lake Benton townships. Its surface is a smooth expanse of till, sloping gently to the southwest, characterized by the absence of lakes, like Pipestone and Rock counties on the south, which, with this tract, lie west and outside of the western and outer terminal moraine.

Lakes. East of this outer moraine, lakes and sloughs are frequent in this district, excepting the central and north parts of Yellow Medicine county. They are most abundant upon the Coteau des Prairies between its two morainic belts. The largest are lakes Benton, Shaokatan and Hendricks, respectively six, three, and three and a half miles long, trending from northeast to southwest, lying in Lincoln county close to the western moraine, with the description of which these lakes will be noticed more fully. More than thirty other lakes, varying from a half mile to one and a half miles in length, most frequently having the longer axis from north to south, occur in central and southeastern Lincoln county. Among these are Eagle lake, more than a mile long from northwest to southeast, crossed by the line between Royal and Limestone townships; lake Stay, one mile long from north to south, which gives name to its township; lake Nova, formerly called Dead Coon lake, one and a half miles long from north to south and half as wide, in the northeast part of Marshfield; and Cottonwood lake, about a mile long from northwest to southeast and a half mile wide, in the south edge of Marshfield and close north of Tyler station. The basin of the last named lake was dry some fifteen years ago; in 1875 it held a lake of the area mentioned and five to ten feet deep; in 1880 it it was again wholly dry, and had been so for two or three years, being all hard mowing-land, yielding coarse marsh-grass and sedges, with cattle pasturing there, and having a dwelling-house on the lake-bottom. These changes are a register of variations in the average annual rain-fall.

In southwestern Lyon county the continuation of this region of lakes includes Goose lake and Island lake, each about three-quarters of a mile long from north to south, in the south part of Island Lake township; lake Marguerite, more than a mile long from north to south, in the north part of T. **110**, R. **43**; Black Rush lake, about a mile in extent, filled with rushes, near the center of Lyons; two lakes, each about a mile long, in southwestern Shelburne, near the corner of the county; Rock lake and lake Yankton, each more than a mile long from north to south, in Rock Lake township; Long lake, a mile long from northwest to southeast, in the south part of Custer; and lake Sigel, about a half mile in diameter, in southwestern Monroe, two miles south of Tracy.

The only other lakes to be mentioned in Lyon county, are lake Marshall, one and a half miles long from northwest to southeast but narrow, in the southeast part of Lake Marshall township; Swan and Goose lakes, crossed by the east line of the county at the east side of sections 12 and 1, Stanley; and Lady's Shoe, Lady's Slipper and Cottonwood lakes, each about a mile long, and Sham lake, of smaller size, a mile east from the last, all situated in Lucas, the most northeast township of the county.

The greater part of Yellow Medicine county has no considerable lakes. This area probably was covered by a broad and shallow expanse of water during the recession of the ice-sheet, by which the surface, consisting of till, in some parts slightly modified, was smoothed, and its hollows that would have held lakes were filled; as the nearly flat sheet of till that forms the southern part and the sides of the great plain of the Red river valley was smoothed by lake Agassiz at this epoch. Upon the Coteau at the west end of this county occasional lakelets are found nestled among its knolls and irregular short ridges of morainic drift; and on the moderately undulating or rolling tract of till in the southeast part of the county are numerous lakes from a half mile to one and a half miles long. These include a group of three in the central part of Normania; Wood and Sand lakes, each more than a mile long, and trending respectively from northeast to southwest and from east to west, in Wood Lake township; Tyson's lake, a mile long from east to west, in the north part of Posen; and two lakes, of irregular form, each a mile or more in extent, in Echo, the eastmost, situated near the center of the township, being called the lake of the Woods.

Topography. The Minnesota valley along the northeast side of Yellow Medicine county is from one to one and a half miles wide, and consists of an alluvial bottomland, mostly within reach of the highest floods, and steep enclosing bluffs, from whose top a vast prairie of undulating till or glacial drift stretches away on each side in an apparently almost level expanse as far as the view extends.

In these twenty-five miles the Minnesota valley grows deeper from northwest to southeast, its depth being approximately 100 feet at Montevideo; 150 feet at Granite Falls; 165 feet at Minnesota Falls; and 175 feet at the mouth of the Yellow Medicine river. This tributary has cut a valley equal in depth, along the lower part of its course, to that of the Minnesota, and from a half mile to one mile in width, leaving between these valleys in the north part of Sioux Agency township a promontory or plateau, some three miles long and less than a mile wide, upon which the ruins of the buildings of the Upper Sioux Agency remain. At Sorlien's mill, in the south edge of section 35, Minnesota Falls, about four and a half miles above its mouth, the valley of the Yellow Medicine river is 75 to 100 feet deep. Westward in this county and the northwest part of Lyon county, its depth is diminished from 75 to 40 or 50 feet; and at the foot of the Côteau, where its head-streams are crossed by the railroad, they flow in channels only 20 to 30 feet below the average surface. The bluffs of both the Minnesota and Yellow Medicine valleys are cut by many short ravines, occupied by springs and rivulets, and all their tributary creeks have formed channels that increase in depth as they approach these great valleys. The branches of the Lac qui Parle river, from the foot of the Coteau to the north line of Yellow Medicine county, flow 30 to 40 feet below the general level; and valleys of about the same depth have been eroded by the Redwood river in the vicinity of Marshall and thence to the east line of Lyon county; by its tributary, Three Mile creek, from Grandview to its mouth; and by the most northern and main stream of the Cottonwood river.

Excepting the valleys which have been thus cut by streams, a gently undulating or in some portions moderately rolling sheet of till covers the northeastern half of this district, reaching from the Minnesota river twenty-five to thirty miles southwest to the Cottonwood river and Marshall lake in eastern Lyon county, and to the Winona & St. Peter railroad in its course thence through Marshall, Minneota and Canby, and nearly to the state line. This expanse has a gradual ascent southwestward of six to ten feet per mile, so that the railroad between Marshall and Canby is from 150 to 250 feet above the general level of the country adjoining the Minnesota valley.

The most rolling portions of this area are in two belts. One of these lies in eastern Yellow Medicine county, within four to eight miles west from the Minnesota valley, including Stony Run, the northeast part of Hazel Run, Minnesota Falls, eastern Wood Lake, Sioux Agency and Echo. In going westward from Granite Falls, the first one and a half miles are on the bottomland, which here averages 20 feet above the river and has many scattered knobs and small ridges of gneiss, 10 to 40 feet higher; then the southwestern bluff of the valley is ascended, to the general surface of the prairie, some 150 feet above the river. This is moderately undulating for about a half mile, at which distance from the Minnesota valley it is marked by a depression, from an eighth to a quarter of a mile wide, and 20 to 30 feet deep, bordered by gently sloping sides, and reaching several miles from northwest to southeast, parallel with the Minnesota valley. The entire extent of this hollow was not traced. It is believed to have been excavated by drainage during the final melting of the last ice-sheet. Similar old water-courses, now dry, extend in the same direction through Omro and Wergeland in the west part of this county. These are described, and the mode of their formation explained, in treating of the glacial drift. West of this channel the surface is quite rolling for two or three miles, in smoothed swells and mounds, 20 to 30 or sometimes 40 feet high, mostly trending from northwest to southeast. Thence the contour becomes gradually more even, so that at six or seven miles from Granite Falls, and onward, it is nearly flat and very smooth, undulating only 10 to 20 feet in long slopes. Southeastward from the Yellow Medicine river, by the east side of Wood and Sand lakes to the lake of the Woods, some portions of the surface are more prominently rolling than west of Granite Falls, having here and there massive swells, 25 to 50 feet above the average of this region, which both in its hilly and in its nearly level areas is till.

In western Yellow Medicine county, a few miles northeast from Canby and the Winona & St. Peter railroad, we find another rolling belt, more broken and irregular in contour than the preceding, with steeper knolls and short ridges, from 15 or 20 to 40 or 50 feet in hight, but occupying a narrower area, which varies from an eighth of a mile to one mile, or at the most only two or three miles, in width. These drift accumulations consist of till, with many boulders, and appear to be a terminal moraine, heaped along the border of an ice-sheet. They extend in a continuous series, from near the south line of Yellow Medicine county, northwesterly to the Antelope hills in Lac qui Parle county, and onward through that county into Dakota. At the west side of this low range of knolly and hilly drift, between it and the massive highland of the Coteau des Prairies, there intervenes a belt of smooth, slightly undulating till, three to six miles wide, called the Antelope valley. This is part of the undulating area, approximately a plain, that rises imperceptibly from the Minnesota river to the Coteau; and its somewhat valley-like appearance is due to its being separated from the broad eastern part of this expanse by the moraine, which attains a hight 25 to 100 feet above the general level, culminating in the Antelope hills.

The Coteau des Prairies. A large area extending from southeast to northwest through southwestern Minnesota, including the southwest half of this district, has an elevation from 500 to 1000 feet above the Minnesota river, and from 1300 to 2000 feet above the sea. Upon this highland are the sources of Lac qui Parle, Yellow Medicine, Redwood and Cottonwood rivers; of the Des Moines river; and of the Little and Big Sioux rivers, tributary to the Missouri. This elevated tract, throughout its course of two hundred miles, was called by the earliest French explorers the *Coteau des Prairies*, meaning the Highland of the Prairies. Nicollet applies this name to an area ten to thirty or forty miles wide, its width through this district being twenty to thirty miles.

This highland may be described, in general, as a long plateau or massive ridge, in part smoothly undulating or rolling in contour, but having two belts (terminal moraines) which are very irregularly broken by steep hills, knolls, and small ridges, 25 to 100 feet above the intervening hollows. If we except the massive ridge of red quartzyte in northern Cottonwood county, no exposure of the bed-rock is known along the entire extent of the Coteau des Prairies, and its surface everywhere is a thick sheet of the unstratified glacial drift, called till or boulder-clay. On its smooth areas this deposit has few boulders; but in the two roughly hilly belts it has very abundant boulders and increased proportions of gravel and sand.*

Elevations, Winona & St. Peter division, Chicago & Northwestern railway.
From John E. Blunt, engineer, Winona.

	Miles from Winona.	Feet above the sea.
Tracy	226.55	1403
Amiret	233.65	1283
Marshall	243.85	1174
Grandview	250.75	1173
Minneota	256.52	1179
Canby	274.03	1243
Gary	284.62	1484

Elevations, Dakota Central railway.

Tracy	226.55	1403
Balaton	239.55	1528
Redwood river	246.60	1592
Redwood bridge	246.60	1631
Tyler	253.70	1750
Lake Benton, station	261.50	1759
Lake Benton, water	261.50	1754
Summit, grade	262.50	1762
Depression, grade	265.50	1715
Verdi	267.60	1771

*For Nicollet's description of the Coteau des Prairies, see p. 68; compare also pp. 494, 519, 539 and 544; and for a more full discussion of both its topographic and geologic features, consult a later part of this chapter.

The elevation of the Minnesota river along the northeast side of Yellow Medicine county, at ordinary low water, above which its highest floods rise 15 to 20 feet, is approximately as follows:

	Feet above the sea.
At the extreme northern point of Yellow Medicine county, opposite to Montevideo and the mouth of the Chippewa river	913
Above Granite Falls	908
Below Granite Falls	870
Below Minnesota Falls	856
At the mouth of Yellow Medicine river	848
At the east line of this county	845

The East branch of Lac qui Parle river crosses the north line of Yellow Medicine county at an estimated hight of 1150 feet above the sea. From Alta Vista and Minneota the descent of the Yellow Medicine river to its mouth is about 300 feet. At the east line of Lyon county the elevations of the Redwood and Cottonwood rivers are about 1100 and 1120 feet, respectively, above the sea. Lake Benton, at the source of the Redwood river, is 650 feet higher, being 1754 feet above the sea, which is also approximately the altitude of lakes Shaokatan and Hendricks. The general elevation of the Coteau des Prairies has been already stated. Its highest points in this district, upon the outer terminal moraine, are from 1900 to 1975 feet above the sea, being the highest land in southwestern Minnesota. From the west line of Lincoln county to the Head of the Coteau, in Dakota, this moraine, lying upon or near the summit of the Coteau des Prairies, has an elevation of 1900 to 2050 feet above the sea, or about a thousand feet above lakes Traverse and Big Stone. This highland is very prominently seen in the view westward from the vicinity of these lakes, and from central Yellow Medicine county, and less conspicuously from northern and northeastern Lyon county. The inner moraine, situated on the eastern slope of the Coteau, is in this district from 1500 to 1700 feet above the sea.

Yellow Medicine county has a difference in elevation of about 900 feet between its highest point, on or near the Dakota line, in the southwest corner of the county, about 1750 feet above sea-level, and its lowest land, the shore of the Minnesota river at its eastern boundary. The average hights of the townships of this county are estimated as follows: Sioux Agency, 1010 feet above the sea; Echo, 1050; Otis, 950; Minnesota Falls, 1000; Wood Lake, 1060; Posen, 1090; Stony Run, 1020; Hazel Run, 1060; Sannes, 1075; Lisbon, 1075; Friendship, 1100; Normania, 1110; Tyro, 1130; Swede Prairie, 1150; Omro, 1175; Burton, 1180; Oshkosh, 1220; Wergeland, 1240; Hammer, 1260; Norman, 1400; Florida, 1450; and Fortier, 1600. From these figures the mean elevation of the whole county is found to be about 1165 feet.

The highest land of Lyon county, in its southwest part, is about 1750 feet, and its lowest land, where the Redwood river crosses its east line, is about 1100 feet above the sea-level. Estimates of the average elevation of its townships are: Lucas, 1125 feet; Stanley, 1130; Clifton, 1160; Amiret, 1225; Monroe, 1400; Vallers, 1150; Fairview, 1175; Lake Marshall, 1200; Sodus, 1300; Custer, 1460; Westerheim, 1175; Grandview, 1200; Lynd, 1300; Lyons, 1450; Rock Lake, 1560; Eidsvold, 1200; Nordland, 1350; Island Lake, 1500; T. 110, R. 43, 1625; and Shelburne, 1700. The mean elevation of Lyon county is thus about 1320 feet, or a quarter of a mile, above the sea.

In Lincoln county the greatest elevation is the top of the outer moraine west and south of lake Benton, 1950 to 1975 feet above the sea, and about 200 feet above this lake. The lowest land of the county is near its north-east corner, where the Yellow Medicine river crosses the east line of Alta Vista, about 1175 feet above the sea, or 800 feet below this crest of the Coteau des Prairies, twenty-five miles distant in the southwest part of the county. At the southwest corner of Lake Benton township, where the channel that extends south from the "Hole in the Mountain" is crossed by the county line, its hight is about 1675 feet, being some 90 feet below its highest point, which is a mile southwest from Lake Benton. The mean hights of the townships of Lincoln county are nearly as follows: Alta Vista, 1325 feet above the sea; Limestone, 1600; Lake Stay, 1700; Marshfield, 1750; Hope, 1775; Marble, 1550; Royal, 1700; Ash Lake, 1760; Diamond Lake, 1800; Lake Benton, 1850; T. 113, R. 46, 1725; Hendricks, 1775; Shaokatan, 1825; Drammen, 1875; and Verdi, 1850. According to these estimates the mean elevation of this county above the sea is approximately 1725 feet.

Soil and timber. The soil throughout this district is almost everywhere the somewhat stony and gravelly clay of the unmodified glacial drift. Vegetable decay has enriched this and colored it black to a depth that averages about two feet, but varies from one to four feet, being greatest in depressions and least upon swells or knolls, especially on the hillocks and small ridges of the moraines. Below this soil the drift, mainly consisting of the same boulder-clay, extends from fifty to a hundred or two hundred feet in depth, being yellowish and usually soft enough to be dug with a spade for a thickness of ten or twenty feet, and thence dark bluish and harder, requiring to be picked. This deposit, called till, is made up of the materials gathered during the ice age from near and remote portions of a large district northward, mingled and spread in an unstratified mass, which nearly everywhere is principally clay, but also includes considerable proportions of sand and gravel, and occasional boulders. The majority of its large boulders are granite and gneiss, while most of its clay is probably derived from Cretaceous beds of clay and shale. Magnesian limestone, occurring in fragments, from blocks ten or fifteen feet in diameter to the smallest pebbles, and pulverized, forming then an indistinguishable part of the till, is one of its most important ingredients in this region and through all western Minnesota. Dissolved in the waters of wells and springs, it makes them hard, diminishing their desirability for washing and for use in the boilers of steam-engines, but not for drinking and cooking. On the other hand this element contributes a large share toward making the very fertile soil of this district, and producing the magnificent harvests of wheat, which are its principal export and source of wealth.

Much of the water that falls as rain is absorbed by the land and is gradually given up to growing crops; while the surplus waters of heavy rains and of snow-melting in spring are soon drained away by the undulating slopes of the surface, and by its many water-courses. Here and there, however, on the approximately level parts of the district, frequent shallow depressions, mostly of small area, are left without outlet and continue marshy till the driest season or through the whole year. These wet tracts, which are called sloughs, bear luxuriant grass, and are valuable for their hay, the yield of which is from two to three tons per acre.

Nearly the whole of this district is prairie, or natural grass-land without trees or bushes. Excepting a tenth or twentieth part, occupied by sloughs, this is dry, undulating or rolling upland, which affords excellent pasturage, but yields less than half as much hay per acre as the wet lowlands. Its smooth areas are ready for plowing and sowing, and are mostly occupied by farms, though as yet only a small part of the land has been brought under cultivation. Its yearly product of wheat to the acre is ten to twenty-five bushels. Many other crops grow well, including oats, corn, barley, potatoes, and the common garden vegetables and small fruits.

The agricultural value of the belts occupied by the terminal moraines, with their small and steep knolls and ridges, and abundant boulders, is much less than that of the smooth drift which covers the other parts of this region. Among the hills of this formation, however, are found considerable areas which have a smooth surface, nearly free from boulders, and possess a rich soil; while the portions which are too knolly and stony for desirable cultivation are valuable for grazing.

Timber occurs in this district only in narrow belts along the rivers and in groves of small area bordering lakes. At the northeast side of Yellow Medicine county, it fringes the bank of the Minnesota river, but leaves much of the bottomland treeless, excepting an extent of about three miles, lying below (southwest and south from) Minnesota Falls, where the entire side of the valley west of the river, a quarter to a half mile wide, is occupied by a stately forest of bass, elm, bur oak, white ash, box-elder and other species. The bluffs of this part of the valley have frequent groves, especially in ravines, but their only portion continuously and fully wooded is in the tract just mentioned, within a few miles below Minnesota Falls.

Wood lake and the lake of the Woods, in the southeast part of Yellow Medicine county, derive their names from the small patches of timber that skirt their shores. The principal species of trees found at Wood lake, in their estimated order of abundance are white elm, white ash, red or slippery elm, box-elder, bass, bur oak, hackberry, wild plum, willows and cottonwood. The lowest ten or fifteen miles of the valley of Yellow Medicine river have considerable woodland, and bushes and small trees border its banks along much of its upper portion; but the greater part of this stream and of the Lac qui Parle, Redwood and Cottonwood rivers, from the foot of the Coteau des Prairies to the border of this district, are destitute of timber or only scantily wooded. On the northeastern slope of the Coteau, the ravines of the creeks which form the head-waters of these rivers contain many groves and narrow belts of timber, the largest amount being in the deeply excavated valley of the Redwood river in Lynd. Farther westward most of the lakes upon the Coteau are fringed with wood on some part of their shores, but there are no notably large tracts of timber in this part of the district. At the Coteau lakes, near the crest of this highland, in central Deuel county, Dakota, thirteen miles west of the state line, a tract of woods about a mile long and a third of a mile wide, almost enclosed by a group of four lakes, has the following species of trees and shrubs, according to Mr. J. C. Godard, who lives there: bur oak, white ash, white elm, box-elder, wild plum, willows, Virginia creeper, climbing bittersweet, frost grape, smooth sumach, black and red raspberry, choke-cherry, thorn, rose, black currant, red elder, prickly and smooth wild gooseberries, and waahoo, common; and cottonwood, hackberry, black cherry, wild red cherry and sheep-berry, less common.

GEOLOGICAL STRUCTURE.

Eozoic rocks. A broad belt of granite, syenite, gneiss, and related crystalline schists, of Eozoic or Archæan age, extends from northeastern Minnesota southwesterly to the Minnesota river. Its outcrops in this district are confined to Yellow Medicine county, within the deeply eroded Minnesota valley, and at three localities from ten to twenty miles farther southwest, lying in Echo, Posen and Omro townships.

At Granite Falls and Minnesota Falls ledges of gneiss rise on both sides of the river, filling the valley with a multitude of knobs and short ridges, 30 to 75 feet high. These rocks begin five miles above Granite Falls, near the mouth of Stony run. Along this distance they are principally on the southwest side of the river. In the N. E. ¼ of section 24, Stony Run, the strike for an eighth of a mile is S. 80° E., the dip being 75° N. 10° E. Generally, however, the strike is nearly N. E. to S. W., the dip being southeasterly. In the northwest edge of Granite Falls, the dip is 60° S. E., but more commonly it ranges between 25° and 40° In a few places at Granite Falls the dip is toward the northeast or north. At Minnesota Falls it was noted in one place to be 58° S. 10° E., and near by 85° in the same direction. These are exceptions, while the prevailing inclination is toward the southeast. The strata are reddish or gray gneiss, frequently so disintegrated by the weather that its outcrops have become turfed, varying occasionally to more enduring gray and red granite. These rocks also sometimes include trap dikes, of massive, very heavy, dark green rock, as at the rapids, recently used for manufacturing, one mile above Granite Falls, where two dikes, respectively twenty and forty-eight feet wide, occur fifty-four feet apart, their course being N. E. to S. W., conformable with the strike of the rocks. Elsewhere the gneiss may include a bed or lenticular mass of hornblende schist, as is seen at the east end of Granite Falls bridge and dam. Marks of water-wearing occur on these ledges in the vicinity of Granite Falls to a hight of 20 or 30 feet above the river. Gray syenite, probably valuable for building and ornamental purposes, occurs about a half mile south of Minnesota Falls. A large specimen of it, elegantly polished, was shown me by Mr. Park Worden of this place. It is composed of white quartz and black hornblende, in nearly equal parts, somewhat schistose as to the direction of its grains. The trap dikes, hornblende schist, syenite and granites, are together but a small portion of these rocks, which are mainly gneiss. Its outcrops from Granite Falls to one mile below Minnesota Falls are very prominent, rising in irregular and picturesque confusion throughout the entire valley, nearly two miles wide. Lower ledges continue less frequently for a mile or two beyond these. The next outcrops noted, also consisting principally of gneiss, are six miles down the river, beginning in section 12, Sioux Agency, and extending eastward into Swede's Forest, Redwood county.

In Echo, the most southeast township of Yellow Medicine county, several outcrops of these rocks occur from a half mile to one mile southwesterly from the lake of the Woods, being about ten miles southwest from the Minnesota river. On land of Samuel Mathes, in the N. E. ¼ of section 32, they appear in three considerable ledges, besides other small exposures. The largest of these ledges extends some eight rods from southeast to northwest, is three rods wide, and rises four or five feet above the general surface. It is mainly a reddish, compact gneiss, much contorted. At its northwest end the dip of its lamination is 60° N. W.; elsewhere the dip varies somewhat, and is mostly obscure. In its north part this gneiss encloses a mass of dark, nearly black mica schist, fifteen feet long and two feet thick, its length being in the same direction with the lamination of the gneiss. This included mass is bounded by sharply defined lines. Its southwest end tapers to a point, but at the other end it is abruptly truncated by an elsewhere obscurely bounded vein of coarse feldspathic granite. Ten feet farther east is a second mass of this dark micaceous rock, of irregular but well-marked outlines, about three feet long and one foot wide, surrounded by coarse feldspathic granite and cut by a vein of the same, from one-fourth of an inch to one inch wide. Similar very coarse granite also forms the southeast end of this rock-outcrop, gradually changing to the gneiss which makes up the greater part of this ledge. Thin veins of white quartz are seen here in a few places. About six and twelve rods northwesterly from the foregoing are two other exposures of gneiss, the northern one having a length of about fifty feet, and a hight of five feet. At its north end the dip is 80° N. N. W. Other low outcrops of small extent are found at a short distance eastward, on the N. W. ¼ of section 33, and at about a half mile to the northwest, near the center of section 29.

Seven miles west from these rock-exposures, and at a distance of about fourteen miles southwest from the Minnesota river, nearly on the line between sections 29 and 30, Posen, an outcrop of reddish granite covers an area about ten rods long and eight rods wide, rising five to fifteen feet above the adjoining land. It lies in a depression at the east side of a slough, and the top of the ledge is slightly lower than the average hight of this region. This granite is mostly medium-grained, but in some places of small extent, especially in its south part, it is very coarse and principally made up of feldspar crystals, three or four inches long. It contains here and there short quartz veins from two to six or eight inches wide.

In section 17, Omro, about twenty miles southwest from the Minnesota river, hornblende schist is exposed in two outcrops. The largest of these lies in the south part of the southeast quarter of this section, covering an area about ten rods long from north to south and six rods wide, and rising ten or twelve feet above the average surface near it. This ledge varies in texture from ordinary hornblende schist to a very compact and hard, black, trap-like rock. It is more hornblendic and more broken by joints than the other outcrop, contains fewer quartzose seams, and for the most part has only thin veins of white quartz, in laminæ no thicker than paper. The second of these ledges, about a fourth of a mile northwest from the foregoing, extends six rods from northeast to southwest, is from two to four rods wide, and reaches a hight about five feet above the general level. This is much divided by joints and is traversed in many portions by thin quartzose seams, which are harder and stand out from a half inch to one inch upon the weathered surface. More rarely this rock encloses here and there veins of white quartz. The dip in both these outcrops is 45° N. W. They are situated in a valley, which is 25 to 40 feet lower than the average hight of the adjoining slightly undulating prairie. It has a width of sixty to eighty rods, and extends from northwest to southeast fully two miles in each direction from these ledges.

Cretaceous beds. Sandstone, clay, and shale, of Cretaceous age, are believed to underlie the glacial drift throughout the greater part of this district; but their only natural exposures found during this survey are a few low outcrops of sandstone in northwestern Lyon county and northeastern Lincoln county. Clay and shale, bearing characteristic Cretaceous fossils, have been encountered by wells in Wergeland, Yellow Medicine county, and in Eidsvold and Grandview, Lyon county, townships lying between Canby and Marshall. Though these observations are limited to the central part of this district it seems probable that Cretaceous strata occupy hollows among the Eozoic rocks in Yellow Medicine county, and that farther southwestward they attain greater thickness and make the principal mass of the Coteau des Prairies, hidden beneath the thick drift-sheet which everywhere forms the surface of this highland.

The most eastern outcrop of the Cretaceous sandstone is near the center of section 7, Westerheim, Lyon county, in the west or left bank of the South branch of Yellow Medicine river, about a half mile from its junction with the North branch. A hard, gray, somewhat calcareous sandstone is here exposed at several points along a distance of eight or ten rods, rising three to seven feet above this creek. So far as can be seen in these somewhat broken ledges, the layers of this rock appear to be two to three feet or more in thickness and nearly level. In some parts their weathered surface shows concretionary structure, being dotted with roundish masses from an eighth to a quarter of an inch in diameter, which have resisted the disintegrating effects of frost and rains, so that they stand out slightly from the rest of the stone.

About a mile northwest from this place, numerous blocks of the same sandstone, up to six or eight feet in length, were seen in the channel of the North branch of Yellow Medicine river, in the S. E. ¼ of section 1, Eidsvold, but no ledge of it in place was observed here. One of these blocks, about five feet long, showing the concretionary character mentioned, contains numerous small flakes and particles of lignite and soft peaty matter. Another has become sculptured by natural agencies, perhaps influenced by some massive concretionary structure, so that in form it resembles the trunk of a tree. Mr. Simon Hovland, who owns and lives on this quarter-section, believing it to be a fossilized tree, has removed it to a location near his house. The length of this stone is 6½ feet, and its diameter at one end is 3½ feet and at the other end 2½ feet. Its stratification is plainly seen at the smaller end, being in layers from one to four or five inches thick. Iron-rusted laminæ, a twentieth of an inch thick, sometimes mark the planes of bedding. The weathered surface is in part perforated with holes from a quarter of an inch to one inch long and about a twentieth of an inch in diameter, similar to those of worm-eaten wood. Other portions exhibit a concretionary structure in small roundish masses and inosculated ridges, a fourth of an inch in diameter or width. Sulphuret of iron is seen in two or three places, in somewhat cylindrical masses, about one and a half inches long, consisting of straight fibers, and surrounded by stains of iron-rust. At another point near the foregoing, soft white matter fills a straight tube in this stone, one and a half inches long and a quarter of an inch in diameter. These are believed to be in the places originally occupied by fragments of wood, but are the only trace of organic remains seen in this block. Its surface is soft and easily cut with a knife to a depth of about a quarter of an inch, but farther within it is very hard.

This rock is exposed about five miles to the southwest, in the N. E. ¼ of section 20, Eidsvold, on land of Henry Jacobs, being visible along an extent of about four rods in the bed of a small creek and rising one to two feet. It is a compact hard sandstone, blue inside, but brownish gray on the surface. The characteristic concretionary structure was seen here only in a detached block, which, however, was doubtless derived from this underlying ledge. Again, near the west line of this township and county the same formation outcrops along an extent of about twenty feet, with a hight of one to two feet, in the north bank of the North branch of Yellow Medicine river, in the S. W. ¼ of the N. W. ¼ of section 7, Eidsvold.

In Alta Vista, the most northeast township of Lincoln county, this rock has a low outcrop of similar extent with the last, in the south bank of the same stream, in the N. E. ¼ of the S. E. ¼ of section 12, about ten rods west of the county line. This is on land of Col. Samuel McPhail, some forty rods north of his house. The next and last outcrop of this formation is about a third of a mile farther west, being in the S. W. ¼ of the N. E. ¼ of this section 12. It is on land of George B. Mason, by whom this ledge, which is light gray calcareous sandstone, has been slightly quarried, beginning in 1879, the price at which it is sold being $4 per cord. An excavation about 80 feet long, 25 feet wide and 3 feet deep, has been thus made. The stone is in layers from one inch to one and a half feet in thickness, dipping one to two degrees, or from two to five feet in a hundred, to the east-northeast. In several places the bedding planes bear ripple-marks, about three inches in width. These planes and the fissures of joints show on fully half of all their exposed surfaces abundant concretionary rounded masses, an eighth to a quarter of an inch in diameter; but this structure is not apparent within the stone to a greater depth than a half inch or one inch, and is evidently brought into notice by weathering. No fossils could be detected here nor in any of these outcrops; but the formation through its extent of seven miles from east to west is nearly uniform in character, and is evidently the source of the masses noted in section 1, Eidsvold, which contain particles of lignite and traces of wood.

In section 11, Custer, Lyon county, on land of James Morgan, much lignite in small fragments is found along the large southern branch of the Cottonwood river, which there and thence northeast to Amiret has cut a valley 75 to 100 feet deep. A tunnel has been dug into the lower part of the bluff by Mr. Morgan, where springs occur at the top of a light bluish clay that is supposed to be of Cretaceous age, and in this tunnel pieces of lignite and of wood were found.

Clay or shale, containing fossils characteristic of the Fort Pierre and Fox Hills groups, the upper divisions of the Cretaceous series, has been encountered in numerous instances by wells in Yellow Medicine and Lyon counties near the foot of the slope which forms the eastern boundary of the Coteau des Prairies. Doubtless some of these wells have reached Cretaceous strata in place; but others evidently have been wholly in the glacial drift, containing disrupted and transported masses of Cretaceous shale with fossils. The frequency of these fossils in the drift* indicates that the upper Cretaceous formations originally covered much of this district and supplied a large part of the drift, and that they probably underlie the drift here and in the Coteau des Prairies. Notes of several of these sections are as follows:

Wergeland. Peter Palmer; S. W. ¼ of sec. 2: well, 51 feet; yellow and blue till, as usual, with gravelly and sandy layers, 40 feet; then blue clay, containing many fragments of *Baculites* and other fossils, pieces of lignite, concretionary nodules of pyrite, one to one and a

*Compare also the occurrence of *Baculites* in drift deposits in Brown county, pages 584 and 585; and in Nobles county, *Am. Jour. Sci.* (3), iii, 24, 1872.

half inches in diameter, and clusters of selenite (gypsum) crystals; water rose sixteen feet from gravel at the bottom.

Eidsvold. Norman Webster; N. W. ¼ of sec. 8: well, 14 feet, on low land; soil, 2; yellow till, 8; blue clay, 3 feet, containing many fragments of *Baculites* and other Cretaceous fossils; white quicksand, 1 foot, from which water rose one and a half feet.

Parmer Crampton; S. W. ¼ of sec. 8: well, 35 feet; soil, 2; yellow till, 18; very fine, light yellowish sand, 5; blue till, 10 feet, its upper two or three feet including boulders up to one foot in diameter, its lower seven or eight feet harder and very compact, enclosing numerous pebbles of white limestone and irony concretions, with many *Baculites* fragments up to three inches long, and many other Cretaceous fossils, mostly broken, occurring throughout this thickness of seven or eight feet; from yellowish, soft clay at the bottom of this well, water rose in one night fifteen feet, but is very disagreeable to smell and taste. *Baculites ovatus*, Say, *Scaphites Nicolletii*, Morton, *Placenticeras (Ammonites) placenta*, Dekay, and an *Inoceramus* which may be *I. problematicus*, Schlot., were obtained in this well.

Grandview. Peter Schmitz; sec. 27: well, 26 feet; soil, 2; yellow till, picked, 13; blue clay, 10 feet, easy to dig, but very tenacious, free from gravel, not noticeably laminated, but containing bivalve and gasteropod shells; an *Inoceramus* was found at the depth of 21 feet; next was blue sand, dug into one foot and extending deeper, from which water rose four feet. Two or three fragments of lignite were found in the fossiliferous clay, but no crystals of selenite nor nodules of pyrite. In digging his cellar, Mr. Schmitz found in the till masses one to two inches in diameter of white pulverulent matter, resembling chalk, occurring in the same manner as pebbles, and doubtless derived from Cretaceous beds.

In S. W. Lathe's well, sec. 28, fragments of *Baculites* and other Cretaceous fossils, and crystals of selenite were found. *Baculites* fragments also are reported in Selden Coleman's well, in the N. W. ¼ of sec. 26.

Near *Marshall* a bed of clay found 36 feet below the surface in digging a well, supplied the following fossils, which were presented to the state museum by Rev. E. D. Alden: *Placenticeras placenta*, Dekay, three specimens, each about four inches in diameter; and *Nucula cancellata*, M. & H., one specimen, measuring in length 1.25 inches, in hight, 0.90, and in convexity, 0.62, being thus about a third larger than the measurements stated for this species by Meek.*

Glacial and modified drift. Glacial striæ were noted at several places on the gneiss in the southeast part of Granite Falls, east of the river, bearing S. 45° to 50° E. They were also distinctly seen on the ledges in section 32, Echo, bearing S. 50° to 55° E. The glacial striation that originally marked the surface of the rock-outcrop in the southwest part of Posen has been nearly effaced, but the direction in which the ice-sheet moved is shown by very remarkable furrows, two or three feet deep and from three to six feet wide, which bear S. 50° E. One of these glacial furrows reaches continuously across the entire ledge, ten rods; and another, fifteen feet farther northeast, extends fully a hundred feet. Others, of smaller dimensions or shorter, are also noticeable. The formation of these vast grooves was evidently facilitated by the presence of a system of joints, which extends in this direction, intersecting the rock at intervals from one to ten feet apart. Conspicuous examples of these joints coincide in position with

*U. S. geological survey of the territories; vol. ix, *Invertebrate Cretaceous and Tertiary fossils of the upper Missouri country*, p. 102, and plate 28. The other fossils before mentioned are also described and figured in this volume.

the deep glacial furrows. On the other rock-outcrops seen in this district the glacial striæ have been effaced by weathering.

Till, or the unstratified boulder-clay deposited by the ice of the glacial period, forms a thick sheet, probably averaging a hundred feet in depth, upon the surface of all this district, the underlying rocks being seen only in the deeply eroded valley of the Minnesota river and in the few other outcrops which have been described.

Though no exposures of strata older than the drift have been found upon the Coteau des Prairies in this district and northwestward, the underlying formations are believed to rise here much higher than on either side, in the basins of the Minnesota, Big Sioux and James rivers. The altitude of the Coteau is doubtless thus caused by the greater hight of the formations, probably Cretaceous, upon which these drift deposits lie, rather than by extraordinary thickness of the drift beyond that which it commonly has throughout southwestern Minnesota.

The depth that is added to the general drift-sheet by the accumulations of the terminal moraines does not appear to average more than 50 to 75 feet. Upon the Coteau des Prairies the knolls and hillocks of the morainic belts rise 20 to 50 and rarely 75 or 100 feet above the adjoining hollows; and the thickness which they add to the drift-sheet appears to be from 50 to 150 feet. That the prominence of this highland is not due to these morainic accumulations is shown in Dakota at Goodwin and farther north, by the greater elevation that is reached within a distance of two to five miles by the smooth sheet of till at their west side, which there forms the water-shed, and beyond descends to the Big Sioux river.

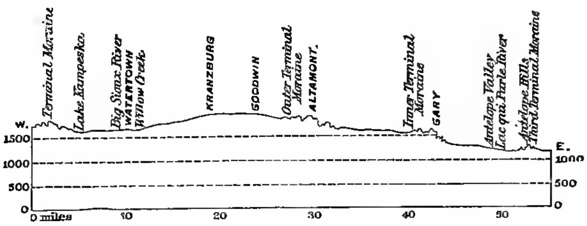


FIG. 48. SECTION ACROSS THE COTEAU DES PRAIRIES IN YELLOW MEDICINE COUNTY, MINNESOTA, AND DEUEL AND CODINGTON COUNTIES, DAKOTA.

In crossing the Coteau from northeast to southwest, there is generally a very gradual, smooth slope, rising 100 to 200 feet in a few miles; then comes a steeper ascent, which amounts to 300 feet or more within a width of two or three miles, coinciding through the greater part of its extent across southwestern Minnesota with the tract of knolly and hilly drift that forms the inner belt of the moraine. The average hight beyond, sometimes after a slight descent, continues to rise, but only slowly, amounting to 100 or 150 feet in crossing the smoother, undulating or rolling area, ten to fifteen miles wide, between this and the outer morainic range, which next rises 100 to 200 or 300 feet within two or three miles, and forms the crest of this highland along nearly its whole extent. West of this moraine in Lincoln county the surface soon drops 50 to 100 feet, this descent being greatest at the south and diminishing northward; and thence a smooth slope of till falls southwesterly some 200 feet within ten miles. Farther to the north, from lake Hendricks nearly to Goodwin, a gently undulating expanse of till, slightly lower than this western belt of drift-hills, extends from them westward approximately level for a width of several miles, beyond which a similar slope falls to the southwest. On the Winona & St. Peter (Chicago & Northwestern) railroad, the traveler going west enters the inner morainic belt of the Coteau at the west edge of Minnesota, a little east of Gary, about 1450 feet above the sea (fig. 48). The line crosses this belt obliquely, occupying about four miles, and ascending some 200 feet; then six miles are moderately rolling, mainly in smooth swells; and the next six miles, lying partly on each side of Altamont, are among the knolls and small hills of the outer moraine, 1750 to 1950 feet above the sea; succeeded by a smooth, slightly undulating area of till, which rises to the summit of this line near Goodwin, 2000 feet above the sea, extends thence nearly level to Kranzburg, and then descends 250 feet by a very gradual slope to Watertown.

From Canby southwestward the eastern ascent of the Coteau is first a gradual and smooth slope of till, rising some 250 feet within four miles. Into this the East branch of the Lac qui Parle river, three miles south of Canby, has cut a channel 75 feet deep. Next to the southwest the ascent is among rough drift hills and prominent swells, which cover a belt eight to twelve miles wide, their west boundary being three miles east of lake Hendricks. Southwest from Minneota, Grandview and Marshall, and onward through Lyon county, the smooth foot-slope of the Coteau is from six to ten miles wide, and ascends 200 feet, or more, before coming to the knolls and hillocks of the inner moraine. The upper part of this smoothly sloping sheet of till is channeled to a depth of 100 feet by the Redwood river at Camden and Lynd, and to a depth of 80 feet by the south branch of the Cottonwood river where it is crossed by the railroad near Amiret station, while the smaller streams all flow in narrow ravines.

The outer or western terminal moraine, accumulated on the southwest border of a lobe of the last ice-sheet,* forms the summit of the Coteau des Prairies in Lincoln county, rising in a conspicuous series of drift hills, which continues thence north-northwest as a belt of very knolly and hilly drift from one to five miles wide, to the Head of the Coteau, west of lake Traverse. Throughout this distance its material is till with abundant boulders and pebbles, principally of granite, syenite, gneiss and schists, but also including many of limestone. Its surface is broken by a multitude of mounds, short ridges and hillocks, from 10 to 50 feet above the hollows, which occasionally contain sloughs and lakelets.

In Lincoln county the outer moraine is about two miles wide, and extends by the west ends of lakes Benton and Shaokatan, passing through the middle of Lake Benton township, the southwest corner of Diamond Lake, the center of Drammen, and southwestern Shaokatan. Its hight from its east edge is 100 to 200 feet, and from its west edge 40 to 75 feet. In other words, the surface of the drift-sheet adjoining it through this county, along an extent of twenty miles, averages a hundred feet lower on its east than on its west side. This difference was probably in considerable part produced by the ice-sheet of the last glacial epoch, in eroding the earlier drift upon which it lay, the material thus obtained being pushed forward and upward to form the moraine Yet the mass of its terminal deposits at this line is small in comparison with the area, reaching fifty miles to the northeast, that was covered by ice which slowly moved, more or less directly, toward this boundary. The entire mass of morainic drift here accumulated, if spread uniformly over this area, could not exceed a depth of six feet; and if it were all spread on the adjoining belt five or ten miles wide, to supply the amount that was apparently eroded from that part of the previously existing drift-sheet, it would scarcely raise the surface more than to the uniform slope which was probably its earlier contour. It thus appears that the greater part of the region covered by this ice-lobe contributed very little to its terminal moraine, and that if much material was eroded far within the ice-covered area, nearly all of it was again soon deposited, without being far removed from its previous position; the work of the ice-sheet in its central portion being chiefly to excavate and re-deposit, sculpturing the surface anew, but conveying only a small amount of drift to its border. Near the edge of the ice, however it plowed up and carried away to its termination a great freight, and even dug, as appears in the following pages, forty feet below the present surface, its bottom being as low as the beds of lakes Benton, Shaokatan and Hendricks. The drift which is now spread above the beds of these lakes east of the moraine, was apparently contained in the glacial sheet, and deposited at its final melting; but most of it had doubtless been eroded from beneath, or had been brought only a few miles, and it seems very unlikely that as much material was held suspended in the ice throughout the central portions of its area.

*Compare p. 406; also the ninth annual report.

Channels through the outer moraine. This morainic belt, and the thick sheet of till which is massed against its west side and descends thence westward, are cut in the west part of Lake Benton township by a deep channel or valley, which is called, translating its Sioux name, the "Hole in the Mountain." The railroad between Lake Benton and Verdi goes south-southwest four miles through this gap, bounded on each side by picturesque bluffs which are buttressed by steep spurs and cut by deep tributary ravines. Its depth, wholly in the glacial drift, is from 150 to 200 feet below the knolly surface of the moraine, and its highest point is about ten feet above lake Benton, which has its outlet eastward into the Redwood river. This valley, from an eighth to a fourth of a mile wide, was evidently excavated by a river that flowed from northeast to southwest across this great ridge, which is the highest land in southwestern Minnesota, being 1,000 feet above the Minnesota river on the northeast, 350 feet above the Big Sioux on the west, and about 1960 feet above the sea. For three-fourths of a mile southwest from lake Benton, this channel is double, being divided by a remnant of the morainic range, which rises nearly as high as the enclosing bluffs. The east pass is called the "Dutchman's gap", and through it the carriage road goes south and then southwest to the "Hole in the Mountain."

At three other places, eleven, fourteen and eighteen miles northwest from lake Benton (see fig. 49), similar channels have been eroded through the massive ridge of this moraine and through the smooth sheet of drift that slopes downward from its west side.

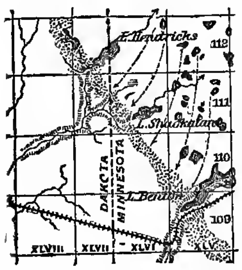


Fig. 49. Map of the region of lakes Benton, Shaokatan and Hendricks.

The first of these channels begins at the southwest end of lake Shaokatan, and extends about two miles southwest, in the same course with this lake, through the knolly belt of the moraine, beyond which its course for the next three miles is northwest along its west side, crossing the state line, from section 31. Shaokatan, to the east part of section 21, T. 111, R. 47. There it is joined from the northeast by the second of these channels, which enters the moraine in the S. W. ¼ of section 7, Shaokatan. This is the only one of these gaps through which drainage now takes place, as at the time of their excavation, from the northeast to the southwest side of the morainic range. Bluffs 75 to 100 feet high form the sides of these valleys, enclosing a nearly flat bottomland which varies from twenty to fifty rods in width. Lake Shaokatan outflows northeastward to the Yellow Medicine river; but the highest part of the valley that extends from it southwest and then northwest, is only slightly elevated above it. The southwest course of the second channel is continued two and a half miles below their junction, having about the same depth and width to the center of section 30, T. 111, R. 47, where it enters the last of these remarkable valleys. This lies wholly in Brookings county, Dakota. It extends six miles southward from the southwest end of lake Hendricks, and then, about a half mile beyond the confluence of the valley from lake Shaokatan, it turns west-southwest. Its depth for the first two miles south of lake Hendricks, where its bluffs are capped by the knolls and short ridges of the moraine, is from 150 to 200 feet. Along the remainder of its course to the mouth of the tributary channel, its bluffs ascend steeply about 100 feet, and from their top a moderate slope rises 40 to 50 feet higher. Below this junction the valley slowly diminishes in depth, and after six miles reaches an area of low land in the northwest part of T. 110, R. 48, which stretches thence to the Big Sioux river. A nearly flat bottomland from thirty to eighty rods wide extends from lake Hendricks the entire length of this valley. Its highest part, one and a half miles from the lake, is some fifteen feet above it, the outlet of this lake being northeastward to the Lac qui Parle river. The channel which has been last described, running south from lake Hendricks, was called by the Sioux "the Brother of the Hole in the Mountain," because of its close likeness to the pass southwest from lake Benton.

The west ends of lakes Benton and Hendricks, for about a mile of each, are bordered by hillocks and high bluffs, and occupy the extremities of these channels at their entrance within the limits of the moraine. Lake Benton is six miles long and from a half mile to one mile wide, its greatest width being at the northeast. Its highest stage of water is four and a half feet above the lowest. This lake is fed by many springs, some of which are ferruginous, along the southwestern half of its shores; and it also appears that springs issue in the bottom of the lake, by which some portions of its surface are kept unfrozen through nearly the entire winter. Bird island, in this lake, is about 25 feet high, and is wooded. At the ordinary low stage of water, it is joined to the north shore by a bar of gravel and sand, several hundred feet long and only from a few inches to one or two feet above the water. Lake Shaokatan is about three miles long, and from an eighth to three-fourths of a mile wide, its maximum width being near the middle. Its highest stage is some four feet above the lowest. The southwest end of this lake is at the northeast edge of the morainic belt. Lake Hendricks is three and a half miles long, and its width varies from one-fourth to three-fourths of a mile, being greatest near its northeast end. The maximum depth of each of these lakes is reported to be about 15 feet; and they are bordered on all sides excepting the west by smoothly undulating till, which varies from 10 to 30 feet, or rarely 50 feet, above them. Thus the hollows in which they lie sink about 40 feet below the general level of the drift-sheet at the east side of the morainic range, and 25 or 30 feet below the highest part of these channels which are continuations from them through the moraine and the thick sheet of till at its west side.

Nowhere else for at least fifty miles next to the northwest from Murray county is this massive ridge intersected by any similar channel, and its altitude throughout this distance is from 100 to 200 feet above these lakes. Its highest portion, forming a belt about two miles wide, marked by many hillocks and hollows, appears to have been pushed out at the margin of an ice-sheet that lay upon its northeast side. The excavation of these channels took place at the same time with the accumulation of this moraine, or more probably at the close of this part of the last glacial epoch, when the ice was being rapidly melted, but before it had receded to its inner line of moraine; for the thick mass of the ice-sheet, rising high above its terminal deposits, is the only barrier that we can suppose to have existed to turn the course of drainage across this highland, which is now the water-shed between the much lower basins of the Minnesota and Big Sioux rivers, and after this was withdrawn to its later limits at its inner moraine, extending from Spirit lake to lake Shetek and Gary, a lower avenue was opened southward to the Little Sioux river. Without reference to this barrier, it is evident that the course of the waters that eroded these valleys was southwest, because of their extent and fall in this direction. The channel that reaches south from lake Hendricks and then southwest, descends from the summit, one and a half miles south of the lake, with a very gradual slope which probably amounts to 75 or 100 feet in the next ten miles, its width continuing nearly the same as where it intersects the moraine. Another proof that the course of drainage was southwest is the confluence in this direction of the three valleys that cross this range at lake Shaokaton, three miles farther northwest, and at lake Hendricks. On the other side of the moraine no well marked valleys extend northeastward from these lakes; and their outlets, which run only at unusually wet seasons, are turned in a meandering course by slight undulations of the surface.

There seems to be no indication that the channels through the moraine have been partially filled since their excavation, raising them to their summits, ten to fifteen feet above lakes Benton, Shaokatan, and Hendricks; while yet the position and form of these lakes demonstrate that the portions of the drift-sheet which would have filled their depressions, were carried away by the rivers that cut these gaps. Now it is clear that the overflow from a lake lying between the ice-sheet and its moraine could not excavate a hollow several miles long below a summit which it afterward crossed. Respecting the possible action of subglacial rivers we have little knowledge, but it appears improbable that they could erode such hollows, carrying the material forward through higher channels. It is, however, nearly certain that this removal of the drift belonging upon the areas occupied by these lakes took place while the ice-sheet still covered these areas and reached to its terminal moraine; but near the end of this time, when a warmer climate was rapidly melting its surface every summer, pouring down large rivers to its margin. By such melting the drift which had been gathered into the ice-mass would become exposed upon its surface, and in and near its principal avenues of drainage would be washed away. Only in this manner could the material of the drift-sheet corresponding to the depressions of these lakes be removed by the usual agency, that is, by the current of descending streams. If this be the true explanation, it involves a very important conclusion respecting the amount of drift contained in the ice-sheet and finally exposed by the melting of its surface. Modified drift and kames, as also certain features of the till and of the terminal moraines, prove that the ice of the glacial period became considerably filled with the material of the drift, gathered up into its mass from the land over which it moved. This explanation of the origin of these lake basins indicates that the ice-held drift here amounted to a sheet at least forty feet thick; but much of it may have been in the lower two hundred feet of the ice, below the top of its terminal moraine.

The second terminal moraine of the last ice-sheet, which is the eastern or inner belt of knolly and hilly drift upon the Coteau des Prairies, extends northwesterly in a nearly straight course from the Blue mounds near Windom, in southern Cottonwood county, to Gary in the edge of Dakota. In Lyon county its northeast boundary passes through the center of Custer, Lyon and Island Lake townships, and follows approximately the line between this and Lincoln county for the next six miles, at the west side of Nordland. It crosses northeastern Lincoln county from the southeast corner of Alta Vista to section 3, Marble, six miles south of Canby; and in Yellow Medicine county its course is from section 33, Norman, to section 7, Florida. The most rough and hilly part of this moraine is from a half mile to one and a half miles wide at its northeast side, where it usually has many irregular knolls, short ridges, and hills, which rise from 25 to 50 feet, and occasionally 75 to 100 feet above the intervening depressions. Their conspicuous appearance, as seen from the northeast, is due to the ascent westward of the country upon which they lie. From the specially hilly northeast margin of this morainic belt its width reaches five to fifteen miles southwestward with a rolling and in some places knolly or hilly surface, including the greater part of the distance to the parallel outer range of drift hills, but leaving next to that a smooth, slightly undulating tract, three to five miles wide. In Marshfield and Lake Stay this smooth contour extends eight miles north from Cottonwood lake and the east end of lake Benton, its limit being here twelve miles from the outer moraine. All these areas are till, with abundant boulders upon the portions which are most broken by knolls, hills, and hollows.

A third terminal moraine, consisting of knolls, hills, and short ridges of till, 15 to 50 and rarely 75 or 100 feet high, with many large and small rock-fragments, is found in Yellow Medicine and Lac qui Parle counties, lying eight to twelve miles northeast from the inner morainic belt of the Coteau, and extending north-northwest forty miles within the limits of this state, beyond which it continues with the same course in Dakota. The width of this morainic series in Minnesota is usually from a quarter to a half of a mile, being less than that of the specially knolly belts upon the Coteau des Prairies. It appears like them to have been accumulated at the margin of the ice-sheet of the last glacial epoch; but its location shows that it belongs to a later time in this epoch, after two distinct recessions of the ice. From sections 32, 29 and 19, of Burton, this formation continues through sections 13, 11 and 3, of Wergeland, with similar outlying hillocks and ridges in sections 9, 15, 16, 21, 22 and 23, of this township; and for the next six miles northward it lies in the southwest edge of Oshkosh and the northeast edge of Hammer. In the south part of Lac qui Parle county it forms the two conspicuous clusters of the Antelope hills, in sections 27 and 16, Freeland, elevated 40 to 100 feet above the smoothly undulating till of that region.

The southeastern continuation of this third moraine may be represented by the rocky drift knolls, 10 to 20 feet high, which occur about the north end and at the northeast side of lake Marshall, in a region which has mainly a very smooth contour. Again, twelve miles farther to the east-southeast, a belt of typically morainic knolls, about twenty rods in width, and a half mile or more in length, was noted close south of the Cottonwood river, in sections 14 and 15, Gales, in Redwood county. It is probable that a connection southeastward may be found, along some line of more or less knolly and hilly drift, including these two localities and the morainic tract in Stately, Brown county, to the belt of morainic deposits that extends from Fairmont in Martin county southeast to Pilot mound in the northeast corner of Hancock county, Iowa. This view was suggested to me by Prof. T. C. Chamberlin, state geologist of Wisconsin, who first pointed out the continental extent of these terminal deposits of the ice-sheet.

Professor Chamberlin has also suggested* that these first, second and third terminal moraines may be named respectively the *Altamont*, *Gary* and *Antelope* moraines (see fig. 48, page 601).

The Antelope valley. Between the third or Antelope moraine and the foot of the Coteau des Prairies on the west is the Antelope valley, so named by the Sioux. This is a broad shallow depression, or rather a part of an inclined plane (page 593), with a slightly undulating surface of till, being three to ten miles wide, and reputed to extend a hundred and twenty-five miles, from Minneota, in the most northwest township of Lyon county, to the south bend of the Sheyenne river in Dakota. The moraine of the Antelope hills and the smooth area of till on its east side average 25 to 50 feet higher than the adjoining eastern border of the Antelope valley, but have some lower portions, allowing streams to cross both the valley and the moraine in their northeastward course from the Coteau to the Minnesota river.

**Third annual report of the U. S. geological survey*, 1883.

Ancient water-courses. Definite channels, which appear to have been formed by drainage during the final melting of the last ice-sheet, are found extending from northwest to southeast at three places in Yellow Medicine county. One of these, lying about a half mile from the Minnesota valley west of Granite Falls, and another at the outcrops of rock in section 17, Omro, have been described on pages 592 and 598. The third, situated in Wergeland and Burton, has been traced farther than either of the others, but its full extent in either direction remains to be explored. It reaches from the East branch of Lac qui Parle river in section 5, Wergeland, southeasterly through sections 9, 15, the south part of 14, and the north part of 24, in this township; and thence in a nearly east-southeast course, through sections 19, the south edge of 20, the northeast part of 29, and through 28, 27 and 35, in Burton, to the south half of section 1, Eidsvold, in Lyon county. In section 28, Burton, and for the next two miles southeastward this depression is followed by Mud creek, and in section 1, Eidsvold, it is crossed by the North branch of Yellow Medicine river, and lies on its south side. This ancient river-course, now dry or occupied by insignificant streams, has along this explored extent of twelve miles a width that varies from a quarter to a half of a mile, consisting of a nearly flat bottomland whose subsoil is gravel and sand, bordered by areas of moderately rolling or morainic till, which average 30 to 40 feet higher. A large river is believed to have flowed southeastward here during the departure of the ice-sheet after the formation of its third moraine, which seems to cross this channel at the southeast corner of section 19, Burton. The receding ice-fields on the northeast prevented drainage from taking its present courses, and their melting supplied unusual floods. Beyond this water-course the ice-margin southeastward to Faribault county was bordered by a long and shallow lake, which overflowed by the way of Union slough in Iowa (page 461). Similar water-courses were afterward channeled, alongside the west border of the melting ice-fields at successive stages of their recession, in Omro, and near Granite Falls, respectively seven and twenty-three miles farther northeast.

The fourth, fifth and sixth terminal moraines of the last ice-sheet,* formed at successive stages in its recession, clearly exhibited farther east in the vicinity of Kiester, Elysian and Waconia, seem to be represented in this district by the morainic knolls and mounds of drift, with more than the ordinary proportion of boulders, which are found associated with the water-courses mentioned in Omro and near Granite Falls. A morainic belt, apparently reaching a considerable distance from northwest to southeast, was crossed in section 30, Tyro, a few miles east of the Omro valley; and another, described on page 592, probably representing the fifth and sixth moraines, lies at the west side of the eastern channel, and consists of prominent smooth swells, occupying a width of two or three miles from three to six miles west of Granite Falls, and expanding farther south in Wood Lake, Sioux Agency and Echo, to a width of six miles.

Modified drift. No extensive areas of modified drift were observed in this district. In a few places, however, small deposits of gravel and sand, partly kame-like, form the surface. A noteworthy cut in such beds was seen near Balaton, in southern Lyon county. A sixth of a mile southeast from this station, close southwest of the railroad, in a rounded hillock, an excavation has been made for ballast to a distance into the hillock of a hundred and fifty feet, the section exposed being twenty rods or more in length and about 20 feet high in its highest part. It consists of gravel, yellowish and in many portions ferruginous, mostly very coarse and containing abundant pebbles up to six or eight inches in diameter, nearly all of them plainly water-worn or rounded. At 4 to 7 feet below the top, for a length of a hundred feet or so at the highest part, the material is fine, sandy gravel, obliquely bedded in slopes of 5° to 25° eastward. At the east end of this a portion 10 to 15 feet below the top and 20 feet long is represented in fig. 50. The central mass here is sand while the enclosing strata are gravel, mostly with pebbles less than three inches in diameter, but in some places holding pebbles up to five or eight inches in diameter. The lenticular mass of sand occurring here shows two small faults at its center, each of three or four inches, the lower side being at the east. The stratification of this deposit is conformable with the slope of its surface, showing that it remains nearly or quite in the same form as it was left by the glacial floods.

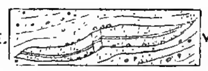


Fig 50. Section in modified drift, near Balaton.

Only two fragments of rock that exceeded a foot in diameter, were seen in this excavation. These were one and a half and three feet long. About one-third of the pebbles here, both large and small, are limestone; nearly all the rest are granite and crystalline schists; only a few pebbles,

*Compare pages 461, 463 and 581; and chapters XXI and XXII.

as of shale, which could be certainly referred to the Cretaceous, were seen; and no quartzyte nor conglomerate. Many of the limestone fragments are obscurely fossiliferous. The top of this cut is about 30 feet above lake Yankton, and perhaps five feet below the top of the mound in which it is made. Similar gravel forms the subsoil, and extends to a depth of 30 feet in wells at Balaton station, and reaches thence a half mile to the northwest beside the lake, and two or three miles easterly along the railroad.

Terrace-like outlines, noticed at a few places, as near the mouth of Stony run, upon the bluffs bordering the Minnesota river in Yellow Medicine county, appear to have been wrought in the till of the general drift-sheet during the excavation of this great valley. A terrace of modified drift on the opposite side of the river in Chippewa county, indicates that this part of the valley has been filled with gravel and sand to a depth of 30 or 40 feet above the present river.

Boulders. Very abundant boulders occur upon the bluff of the Minnesota river along an extent of two miles between one and three miles southeast from the mouth of the Yellow Medicine river, in sections 34, 3, 2, 11 and 12, Sioux Agency. The bluff here is knolly and in many places thickly covered with large and small rock-fragments from the bottom to a hight 100 to 125 feet above the river; but the till which forms the upper 50 feet of the bluff and the prairie at its top, has only the usual small proportion of boulders. This feature was not noticed elsewhere upon the bluffs in Yellow Medicine county, but is remarkably displayed in many places through the next fifty miles in ascending the Minnesota river. It appears to be due to the occurrence in the drift-sheet of a stratum of till thickly filled with boulders; and its origin is probably from a terminal moraine accumulated in the early part of the ice age, and afterward covered by the more extended ice-sheet of the later epoch, by which its mounds and hills of coarsely rocky drift were spread in a nearly level layer and buried under an additional thickness of ordinary drift containing few boulders. Some portions of the ledgy bottomland two to five miles up the valley from Granite Falls are very plentifully strown with boulders, which were probably derived from this layer of the drift-sheet. They are especially noticeable in section 24, Stony Run, where, along an extent of about a quarter of a mile, rock-fragments of all sizes up to six or eight feet in diameter form almost the greater part of numerous drift-ridges that extend twenty to forty rods from northwest to southeast, and rise some 20 feet above the general level of the valley.

Wells in Yellow Medicine county.

Examples of sections of the drift found by common wells in Yellow Medicine county are as follows:

Echo. Frederick Mecklanburg; sec. 8: well, 52 feet, bored two feet in diameter; soil, 2; yellow till, 17; blue till, much harder, "like stone," 33; sand, 8 inches, with blue till below; water rose eighteen feet in a half hour.

Otis. R. W. Crandle; sec. 31: well, 52 feet; soil, 2; yellow till, 15; very hard, dark blue till, 35; this well was given up as a failure at the depth of 50 feet; but Mr. Crandle decided to bore down the length of a carpenter's auger, when, at two feet lower, water was struck and spouted up six feet, rising in a short time thirty feet. This is on the high prairie, about 150 feet above the Minnesota river.

Granite Falls. C. P. Griswold; well, 55 feet; soil, 2; very coarse gravel, containing rounded stones up to a foot in diameter, becoming below less coarse, and gradually changing to ordinary gravel, 10 feet, containing a small supply of water in its lower part; hard yellow till, 5 feet; tenacious, sticky, hard, dark bluish till, 38 feet; some gray streaks were found in this lower till, but no sandy layers and no water.

Wood Lake. B. G. Hall; sec. 23: well 26 feet; soil, 2; sandy till, easy to dig, 6; yellow till, picked, in the lower part mixed with bluish and ferruginous streaks, 14 feet, containing pulverulent and soluble, white particles, in appearance like coarse sand; then, a bed of sand, 2 feet, from which water slowly seeps, bitterish; underlain by blue till, much harder than the upper till, 2 feet and reaching lower. Another well, on lower land, fifteen rods distant, gets good water at 12 feet. Through all this region the blue till extends to a great depth, and is much harder than the overlying yellow till. The wells of this township are mostly in till, and vary from 10 to 40 feet in depth, the shallow wells having generally the best water.

John Besmern; sec. 26: well, 16 feet; all caving gravel and sand; situated on the southeast slope of a kame-like knoll, fifteen feet above the general level. The top of this knoll, partly excavated for a cellar, is found to be sand, but its surface bears occasional boulders up to four or five feet in diameter.

In the central part of Yellow Medicine county most of the wells are shallow, being from 10 to 30 feet deep, in till, which is yellowish near the surface, but dark bluish and harder below.

Burton. P. G. Wells; sec. 6: well, 18 feet; soil, 3; yellow till, spaded, 12; much harder blue till, 3 feet and extending lower; water seeps.

P. C. Bayard; sec. 22: well, 54 feet; soil and yellow till, 20; blue till, 34; this was bored three feet in diameter to the depth of 48 feet, and two inches in diameter for the remaining 6 feet; water rose from sand and gravel at the bottom so rapidly that in half an hour it reached its permanent level, 22 feet below the surface, filling 26 feet of the portion bored three feet in diameter.

Victor A. Anderson; N. E. ¼ of sec. 30: well, 34 feet; soil, 2; yellow till, 12; blue till, easier to bore, 20; water rose from sand at the bottom nine feet in twenty minutes. Several fragments of lignite up to two or three inches in length were found in this well.

Oshkosh. Mr. R. M. Strong, well-borer, reports the following section of a well, 27 feet deep in sec. 28: black soil, 1½ feet; yellow clayey loam, 3 feet; gravel, 2 inches; yellow clay, with rusty lumps and concretions, but thought to contain no stones, 17 feet; blue clay, 5 feet; both the last are said to be in layers; next was quicksand, containing water, which was impregnated with iron and soon became offensive to taste, though not contaminated with wooden curbing, none of any kind being used in the lower fourteen feet.

Norman. A. G. Gulmon; sec. 32: well, 72 feet; yellow and blue till, 56; sand, 16; water came in a large supply, but is only one or two feet deep at the bottom of the well.

Canby. Wells at Canby, in the S. W. ¼ of sec. 3, Norman, are from 15 to 22 feet deep, passing through yellow till, to quicksand and coarse gravel at the bottom, from which water rises only one or two feet. Several wells here are said to have found bivalve shells in this water-bearing layer.

Gary. Wells at this town, in the edge of Dakota, near the west line of Yellow Medicine county, are in till and 15 to 30 feet deep.

Wells in Lyon county.

Stanley. N. F. Frary; sec. 34: well, 33 feet; soil, 2; yellow till, 15; blue till, 16; water rose fifteen feet from sand at the bottom. This well is curbed with wood, and in some parts of the year has a bad taste.

George Bissett; sec. 26: well, 26½ feet; soil, 2; yellow till, picked, 22, containing no fossils; sand and gravel, 2½ feet, enclosing numerous gasteropod and bivalve shells; water, not rising, plenty and good. Another well, twelve rods farther south, on land three feet lower, found black soil, 3 feet; yellow sand and gravel, 3 feet, with water, a flowing spring, at the bottom of this layer; below was 20 feet of blue till, containing no water; gasteropod shells, derived from Cretaceous strata, were found in this blue till.

Amiret. The town-well, 27 feet deep, is all yellow till; water rose ten feet from sand at the bottom.

Tracy, in the east part of sec. 23, Monroe. Wells are in till, mostly only 12 to 20 feet deep, finding plenty of water. The railroad well at this place, dug under the superintendence of Mr. John McAllister, of Winona, is reported by him as follows: depth, 119 feet; dark soil, 2 feet; yellow clay [till], 15 feet; tough, blue clay, mixed with pebbles [till], 80 feet; hardpan [a harder layer of till], 16 feet; [in this hardpan was found a fragment of *Baculites*, five inches long and three-fourths of an inch in diameter;] quicksand, 3 feet; underlain by blue clay, which was bored into 3 feet; the water then rose so fast, probably from the quicksand, that the work could not be continued; it gradually rose during thirty hours, attaining a depth of sixty-five feet. This supply, however, partially failed after a month, and is insufficient for the needs of the railroad engines.

The water in many of the wells about Tracy, Marshall and Canby, is offensive to taste and smell. Most of these wells apparently become so because curbed with wood and left stagnant. Nearly all the wells in this district which are curbed with stone or iron pipe or cement pipe, especially when frequently drawn from, have good water.

Lake Marshall. Wells at Marshall and in its vicinity are mostly between 10 and 30 feet deep. They generally find the yellow till 8 to 12 feet deep. Then the majority of these wells go through a black, mucky clay, free from gravel, 3 inches to 2 feet in thickness, almost always containing small gasteropod and bivalve shells, described as " like those of the present lakes," and frequently pieces of wood thought to be willow, and also, occasionally, small concretions of iron pyrites. Below this, there is commonly found a foot or two of gravel and sand; next to which, or, where this bed is wanting, directly beneath the fossiliferous mud, is dark bluish till, more gravelly, but containing fewer large boulders than the upper till. This bluish till, not harder than the yellow till above, but very tenacious, extends 5 to 50 feet before coming to a water-bearing vein or layer of gravel and sand, from which the water usually rises considerably.

C. H. Whitney; sec. 4: well, 42 feet; soil, 2; yellow till, 15; dry sand, 2 inches; blue till, 23; water was found in sand and very coarse gravel, holding rounded boulders up to a hundred pounds in weight, at the bottom, dug into 1½ feet, yielding for the first two months a depth of about two feet of water of excellent quality; but one morning this well was found filled to a depth of twenty feet with water too disagreeable in smell and taste to be used, and having an oily scum floating on its top. During the process of digging, a current of water had been heard at one side of the well, running in the ground about twenty feet below the surface, and it is supposed that this had broken through.

Grandview. A. A. Farmer; sec. 20: well, 45 feet; soil, 2; yellow till, spaded, 8; blue till, easier to bore, 35; water, of good quality, rose from gravel and sand at the bottom thirty-five feet in five minutes.

Lynd. O. C. Gregg; sec. 30: well, 33 feet; soil, 2; yellow till, 23; blue till, harder to excavate because it is so tenacious, but not harder to drive a spade or pick into, becoming very hard and compact in drying, 8 feet; abundance of good water seeps from the till, from the depth of 20 feet to the bottom of the well.

A flowing well, about 20 feet deep, was dug in the northwest part of Lynd, situated on land nearly as high above neighboring depressions as the depth of the well. After digging here in till about 20 feet, this well was left for the night with the tools in it that had been used; and the next morning water, which had broken into the well and filled it, was found running over the top.

Z. O. Titus; S. W. ¼ of sec. 26: well, 40 feet; soil, 4; yellow till, hard, but spaded, 36 feet and extending below, in its lower part showing some intermixture of blue till; water came from a thin vein or crevice in the till at the depth of 16 feet. Another well, twenty rods farther north and on land some eight feet lower, is 11 feet deep, finding soil and yellow till to the depth of 10 feet, the last foot being in blue till; water comes at 9 feet in the yellow till.

Lyons. J. M. Millard; sec. 14: well, 23 feet; soil, 2; yellow till, 17; sand, 1 foot; blue till, 3 feet and extending lower; water from the sand soon rose and usually fills the well sixteen feet deep.

Balaton, in the N. W. ¼ of sec. 23, Rock Lake. Moore & Weberg's well, 30 feet deep; soil, 1½; all below is caving gravel, with occasional layers of sand up to one foot in thickness.

Eidsvold. Most of the wells in this township are 10 to 30 feet deep, in yellow and blue till. The thickness of the yellow color of the till is 10 to 20 feet on the swells, but only 5 to 10 feet in hollows. The yellow till is usually easily dug with a spade; the lower, bluish till is more compact, harder to drive a spade into, more moist and sticky, and less stony.

Minneota. In this village, situated in the southeast part of Eidsvold, the shallow wells are 10 to 16 feet deep; in soil, 2; dark till, 5; and sand and gravel, 5 to 10; finding good water, in sufficient supply for ordinary use. Deeper wells go below this 10 to 15 feet in blue till; at 25 or 30 feet these strike water in bluish quicksand, from which it rises to about ten feet below the surface. The water is good at first, but most of the deep wells are bored and curbed with pine, and these become offensive when not abundantly used. The shallow wells are not curbed.

Shelburne. E. F. Dickson; sec. 24: well, 21 feet; soil, 2; yellow till, hard, mostly picked, 16; harder blue till, 3 feet and reaching lower; water seeps.

Wells in Lincoln county.

Marshfield. G. W. Cutler; sec. 29: well, 30 feet, in yellow and blue till; water seeps.

Tyler, in sec. 3, Hope. Railroad well at the station, 94 feet deep; soil, 2; yellow till, 10; blue till, 80; fine white sand, 2, from which water rose thirty-six feet in one night; it is not regarded, however, as a sufficient supply for a tank to be used from by engines. At the section-house, thirty rods west of the station, the well, 9 feet deep, was all the way in yellow till to sand at the bottom from which water rose six feet, and proves to be an ample and permanent supply.

Lake View House: well, 78 feet; soil, 2; yellow till, spaded, 16; blue till, 60; water seeps, sometimes filling the well to five feet below the top.

Diamond Lake. G. H. Bradley; sec. 28: well, 24 feet; soil, 2; yellow till, partly spaded, 10; harder blue till, all picked, 12, and reaching below; water seeps from sandy streaks in the blue till, and stands twelve feet deep.

Lake Benton. A. W. Morse, in the town, sec. 8: well, about 40 feet; yellow till, 15; blue till, 25; water seeps from sandy streaks in the yellow till, filling the well to the top of the blue till.

Hendricks. Wells in this township are 10 to 35 feet deep, in yellow and dark bluish till.

Shaokatan. Samuel D. Pumpelly; sec. 14: well, 14 feet; soil, 2; yellow till, spaded, 12; water, abundant and of excellent quality, rose three feet from sand and gravel which was dug into six inches.

A. J. Crane; sec. 23: well, 27 feet; soil, 2; yellow till, spaded, 25; water seeps, filling the well four feet deep, but it is too poor to be used.

Travertine. The water of wells is generally good throughout this district, but its dissolved carbonates of lime and magnesia, derived from the drift, render it hard and cause it to deposit scale rapidly when it is used in the boilers of engines. Sometimes this mineral matter is deposited by springs, as a porous stone, a kind of travertine, preserving the form of leaves, sticks, and moss, which it has encrusted, so that it is commonly called "petrified moss." Fine specimens of this are obtained in several little ravines near Camden mills, in section 32, Lynd, the best locality being about thirty rods southeast from the mill. At Gary, in the edge of Dakota, an extensive deposit of it is found near Capt. Herrick's, and has been considerably burned for lime. It is on one of the small, irregular mounds or hillocks of till, belonging to the second terminal moraine, where its origin seems difficult to be explained, except by referring it to deposition from waters that trickled down from the melting, drift-laden surface of the ice-sheet, probably flowing thus in greater amount or more constantly, and during a longer time, than at most other points on the ice-border.*

Springs. Large chalybeate springs occur on the south branch of the Cottonwood river in the northeast part of Custer, a few miles southwest from Amiret station. The springs on the shores of lake Benton have been before mentioned. Near Mr. J. G. Bryan's house, at the west end of this lake, are two springs, only a few feet apart, which differ much, one being pure, cold, excellent water; while the other seems warmer, and is much impregnated with mineral matter that makes an iron-rusty deposit, the water not being adapted for drinking and cooking.

The amount of *alkaline matter*, or sulphates of magnesia, soda and lime, contained in the drift of this district, is seldom so great as to perceptibly affect the water of wells and springs; but it appears to hasten the decay of wood when this is used as curbing, soon causing the water to become offensive, unless the well is so plentifully drawn from that it is being constantly supplied with fresh water. It is, of course, much preferable to use stone curbing or iron or cement pipe. The grayish white alkaline efflorescence that is occasionally seen in this district in shallow depressions from which pools of water have dried up, forming a crust resembling frost, sometimes a fourth or a third of an inch thick, made up of flakes and columnar spicules, has been concentrated from the inflowing and evaporating waters of a long period. These lands may be reclaimed by being drained, and sown with wheat, which uses much of the alkaline ingredients of the soil; and after several years in wheat, with deep plowing, they can usually be planted successfully to other crops.

MATERIAL RESOURCES.

The soil, the timber and prairie, and the grand agricultural capabilities of this district, which are its chief resource, have been treated of in earlier parts of this chapter. Items remaining to be mentioned here are water-powers, building stone, and the manufacture of lime and bricks.

*See the second annual report, pp. 195-6.

Water-powers. The utilized water-powers of this district are all employed for flouring mills. Four powers are used on the Minnesota river, as follows:

Hixson Brothers; one mile west of Granite Falls; head, about eight feet.

Banner mills; Stoddard & Libbey; in the north part of Granite Falls; head, ten and a half feet.

Granite Falls mills; W. W. Pinney; head, twelve feet. It is estimated that there is a fall of eight feet within a third of a mile below this mill.

Minnesota Falls mills; Austin & Worden; head, ten feet, but it may be increased to fifteen feet.

The Minnesota river at Granite Falls is about 150 feet wide. It usually has sufficient water for running the mills during the driest part of the year.

On the Yellow Medicine river one power is used, about five miles from its mouth, by E. H. Sorlien & Brother, in section 35, Minnesota Falls. This is at the neck of a long loop of the river, across which a canal twelve rods long carries the water to the mill, the head or fall being about twenty feet.

The Redwood river in Lyon county has three utilized powers, as follows, in descending order:

Camden mills; V. M. Smith; in the S. E. ¼ of section 32, Lynd; head, twenty-one feet.

H. R. Marcyes' mill; in section 23, Lynd; head, twelve feet.

Marshall mills; J. A. Rea; in the west edge of Marshall; head, about nine feet.

No water-powers are used in Lincoln county, and none on the Lac qui Parle and Cottonwood rivers in this district.

Building stone. No quarrying of any importance has been yet undertaken in the gneiss, granite and syenite of the Minnesota valley, nor in their other outcrops lying farther west in Yellow Medicine county. It is probable, however, that some portions of these exposures will furnish good stone for ordinary masonry, and perhaps even of sufficiently fine quality for ornamental work. The only quarry in this district is George B. Mason's, in section 12, Alta Vista, Lincoln county, in the Cretaceous sandstone, which has already been fully described on page 599.

Boulders of gneiss, granite and limestone, usually are sufficiently abundant for the ordinary masonry needed by farmers, in cellar walls and foundations of buildings, in curbing wells, and making culverts for roads. These boulders are especially plentiful upon the morainic belts of the Coteau des Prairies, being mostly of smaller size than five feet, but sometimes ten or fifteen feet or more in diameter.

Lime. In the northeast part of Sioux Agency, the most eastern township bordering the Minnesota river in Yellow Medicine county, lime has been burned from boulders by Ole Swenson and Iver Olson. It is white, strong lime.

At Minnesota Falls, Simon Christianson and William C. Darby burn lime from boulders, each making some 300 barrels yearly, and selling at $1.50 per barrel. It is white, and of excellent quality.

Several farmers burn lime from boulders within ten miles to the north and west of Canby.

At Gary lime is burned by David Bradley, who leases Capt. H. H. Herrick's kiln. Boulders, collected from the neighboring morainic hills, yield white lime; and the deposits of travertine, or calcareous tufa, mentioned on page 610, situated at and near the kiln, supply a dark, but equally strong lime. The former is sold for $1.25 per barrel, and the latter for $1, the yearly product of both together being 400 or 500 barrels. Soft wood, brought on the cars, costs $3 to $4 per cord.

In western Lyon county, Tobias Trana, living in the S. W. ¼ of section 30, Nordland, burns lime from boulders, gathered mostly on morainic hills within one or two miles westerly in Limestone township, Lincoln county; yearly product, about 200 barrels, sold at $1.25 per barrel. Abundant limestone boulders, sometimes ten to fifteen feet long, occur in northern Lincoln county, and have given names to Limestone and Marble townships.

One mile farther south, a fine drift-gravel, cemented by carbonate of lime, occurs in the S. W. ¼ of section 31, Nordland, on the west side of the South branch of Yellow Medicine river, the exposure being about 40 feet in length, and 4 to 6 feet in vertical thickness, at 35 to 40 feet above the creek. It is underlain by sand and gravel, and ten or fifteen feet below this cemented stratum a large spring of very irony water issues, and is still forming a calcareous deposit, working in nearly the same way as the waters by whose agency the cementation of this gravel was effected. For fifteen or twenty rods thence to the south, at a hight of 10 to 20 feet above the creek, masses of calcareous tufa, free from gravel, but holding impressions of sticks and moss, are found and have been burned by Mr. Trana, yielding a dark lime.

At Island Lake post-office, also in western Lyon county, J. R. King has burned lime from boulders eight years, averaging 200 barrels yearly, selling it at $1.25 to $2 per barrel. The greater part of this is white lime, but about one piece in twenty is yellowish. The largest slab of limestone found by Mr. King was about ten feet square and four feet thick. In the south edge of this county, A. W. Bean burns lime from boulders in the southeast part of Rock Lake township.

In Lake Benton, Lincoln county, Ira Scott and John Snyder burn lime from boulders, white and of excellent quality, selling at $1.50 per barrel. A few others burn lime in small amount elsewhere in this county.

Bricks. Before the Indian outbreak in 1862, but not since that time, bricks were made at the old town of Yellow Medicine, on the bottomland of the Yellow Medicine river, in the southwest corner of section 29, Sioux Agency.

At Minnesota Falls two small kilns of bricks, amounting to about 100,000, were made in 1879 by Simon Christianson, about twenty-five rods south from the mill, partially failing because of small limy concretions in the clay and limestone particles in the sand used for tempering, which cause the bricks to crack after burning. He intended to continue this business, expecting, after these experiments, to produce bricks of good quality. The bricks are cream-colored or light reddish, sold for $8 per thousand. They are made of recent alluvium, some 20 feet above the river. About a foot at the surface is removed; then the next four to six feet of dark alluvial clayey silt is used for this brick-making, mixed with considerable sand.

Brick-making was undertaken at Granite Falls in 1876 and 1878, first a half mile southwest from the bridge, and later near Stoddard & Libbey's mill, failing as at Minnesota Falls because of the presence of limy concretions.

Two miles northeast from Canby, a small kiln of bricks, containing about 10,000, of fair quality, dull gray in color, were made in 1878, beside Canby creek, from clay that is free of gravel, tempered by a considerable intermixture of sand.

In section 28, of Eidsvold, the most northwestern township of Lyon county, Anon Olson in 1880 began brick-making, using clay and sand in the proportions of three and one. These are red bricks, sold in Minneota, three miles distant, at $10 per thousand.

At Marshall the business is carried on by W. A. Crooker, in the northeast edge of the town, and by James M. Lockey, in its southwest edge, on the road to Lynd, both having begun in 1878. Mr. Crooker made 500,000 bricks in 1880. They are cream-colored, but vary to pinkish, are of good and durable quality, and command $7 to $8 per thousand. The material used is the alluvium of the Redwood river, lying about ten feet above this stream, but not overflowed at its ordinary high water. It contains no gravel nor limy concretions, and no sand is mixed with it. Mr. Lockey makes about 300,000 yearly, of similar color and quality, using the alluvium of an old lake-bottom, which was covered by water in 1875. He mixes sand with it in the proportion of one to three.

In section 22, Verdi, the most southwest township of Lincoln county, John Enke began brick-making in 1880. This is about five miles southwest from Lake Benton.

ABORIGINAL EARTHWORKS.

The only artificial mounds observed during the examination of these counties are near Lake Benton station. About three-quarters of a mile northwest from this town, and within sight from it, upon the top of the bluff 175 feet in hight, which forms the northwestern side of the "Hole in the Mountain," are three mounds near together, of the usual circular form and about five feet high. They are in the S. W. ¼ of section 5, Lake Benton, on the crest of the Coteau des Prairies, and are visible from the lower land on the northeast at a distance of many miles. One of these mounds, excavated by Mr. C. M. Morse, contained several skeletons of men whose stature was fully six feet. Another mound, also about five feet high, is situated on a high swell a half mile east of Lake Benton station, in the center of the cemetery.

CHAPTER XXI.

THE GEOLOGY OF BIG STONE AND LAC QUI PARLE COUNTIES.

BY WARREN UPHAM.

Situation and area. Big Stone and Lac qui Parle counties (plate 29) are in western Minnesota, adjoining Dakota. They lie on opposite sides of the Minnesota river, which forms the boundary between them. Both these counties and also Lac qui Parle river, township and village, derive their names from those of long lakes through which the Minnesota river flows. The name of Big Stone lake alludes to the conspicuous outcrop of granite found in the Minnesota valley one to three miles below the foot of the lake; and the French name *Lac qui Parle,* meaning the Lake that Talks, is a translation of its aboriginal title, applied to it because of echoes thrown back by its bordering bluffs, or, as some say, on account of the loud sound of waves dashing on rocky portions of its shore. Lac qui Parle village, which is the county seat, two miles south from the foot of the lake, is 130 miles, in a direct line, west from Minneapolis, and 140 miles from St. Paul. Ortonville, the county seat and largest town of Big Stone county, situated at the outlet of Big Stone lake, is 34 miles northwest of Lac qui Parle, and about 160 and 170 miles distant, respectively, from Minneapolis and Saint Paul; and its distance north from the southwest corner of the state is 125 miles.

The area of Big Stone county is 536.31 square miles, or 343,234.75 acres, of which 26,737.33 acres are covered by water, including Marsh lake and half the width of Big Stone lake; and the area of Lac qui Parle county is 771.93 square miles, or 494,037.40 acres, of which 1,227.57 acres are covered by water, not including the lakes on its northeast boundary.

SURFACE FEATURES.

Natural drainage. Lac qui Parle county lies wholly within the basin of the Minnesota river, which also includes nearly all of Big Stone county. The only exception is an area equal to about one township at the north side of this county, including the north part of Graceville, about the Tokua lakes, and the adjoining northeast part of Tokua and northwest part of T. **124**, R. **45**, which have a slight descent northward, sending their surplus waters into lake Traverse and thence to Hudson bay by the Red river of the North.

The creeks of Big Stone county are small, and include four or five, varying from two to four miles in length, tributary to Big Stone lake; Stony run, having an extent of about ten miles, flowing southward and uniting with the Minnesota river some six miles below this lake; and Five Mile creek in the southeast edge of the county, about two miles east from Correll station, flowing into the east part of Marsh lake. Besides Big Stone and Marsh lakes on its boundary, this county has numerous others, the largest of which is Artichoke lake, about five miles long and a half mile to one mile wide, in the east part of Artichoke township. A narrower lake, about three miles long, lies in the same township a mile farther west. More than fifty smaller lakes, ranging in size from a quarter of a mile to one or two miles, appear on the map; these have not yet received names, excepting the group of Tokua lakes, close southwest of Graceville, and the Tokua Brothers lakes, six miles farther west.

The Minnesota river receives three important tributaries in Lac qui Parle county, namely, Whetstone, Yellow Bank and Lac qui Parle rivers. The first of these drains a considerable area in Dakota, and joins the Minnesota river about a mile below Big Stone lake. Yellow Bank river, so named from the color of its newly undermined banks of till, has the greater part of its basin in Dakota, whence its north and south forks flow into Minnesota, and meet about five miles east of the state line in Yellow Bank township, some seven or eight miles by the course of the river from its mouth, which is ten miles below Big Stone lake. Lac qui Parle river joins the Minnesota about a mile below Lac qui Parle. Its basin reaches beyond this county west into Dakota, and south across Yellow Medicine county and the northwest part of Lincoln, its remotest source being a stream that flows into the west end of lake Hendricks, fifty miles southwest from its mouth. The only noteworthy tributary to the Minnesota in this county below Lac qui Parle river, is a creek three miles long, the outlet of a little lake, which, both lake and creek, are in the township of Camp Release. Ten Mile lake, which gives its name to the township next southwest, is the only other lake that lies wholly in Lac qui Parle county. Salt lake, or lake Rosabel, a beautiful expanse of clear but brackish water, some three miles long from east to west and about a third of a mile wide, lies mostly in northwestern Mehurin, but its west part is crossed by the state line.

In a subsequent part of this chapter, relating to the glacial drift and the history of the ice age, will be found descriptions of the Minnesota river, its remarkable valley and its lakes, Big Stone, Marsh and Lac qui Parle.

Topography. Both these counties have, through most of their extent, a moderately undulating or rolling surface of unmodified glacial drift or till. Any extensive view shows that the contour, as a whole, is approximately level; but it differs from a flat expanse in having everywhere small and large swells or elevations, disposed without order or system, and rising

in prolonged, smooth slopes to hights 10 to 20 or 30 feet above the similarly irregular depressions. In these hollows lie the lakes and sloughs of this region, from 5 to 25 feet below the average hight of their vicinity. The lake shores are often gentle slopes, but in many places have been eroded by the action of waves, until they form a steep bank 5 to 15 feet high, bordered at its foot by boulders and coarse shingle that have been left while the finer portions of the till have been washed away and strown upon the lake-bed and along other parts of the shore.

The absence of lakes in most of Lac qui Parle county, as also of Yellow Medicine county on the south, seems quite remarkable in contrast with their frequent occurrence in Big Stone and other adjoining counties, and indicates that different conditions attended the deposition of the till upon these districts. A shallow glacial lake (page 461) seems to have bordered the ice-sheet in its recession across Lac qui Parle county, somewhat leveling and evening up the surface of the drift, thus filling many hollows which would otherwise be occupied by lakes.

The most interesting feature in the topography of this region is the deep channel or valley that was excavated by the river Warren, the outlet of lake Agassiz, and is now occupied by lakes Traverse and Big Stone and the Minnesota river. Its description, and its origin and history, and notice of the series of drift hills and knolls forming the third terminal moraine, which crosses western Lac qui Parle county, are presented farther on, in treating of the glacial drift.

Channels have also been eroded in the drift-sheet by the tributaries of this main valley. These increase in depth and width from their sources to their mouths. Indenting their bluffs, as well as those of the great valley, are frequent ravines, cut by rivulets, some of which are fed by perennial springs, while others are dry through most of the year. The branches of the Yellow Bank and Lac qui Parle rivers have excavated channels 25 to 50 feet below the general level; and from their junctions to the Minnesota valley, these rivers are bordered by bluffs 50 to 75 feet high.

Elevations, Hastings & Dakota division, Chicago, Milwaukee & St. Paul railway.

From profiles in the office of George H. White, engineer, Minneapolis.

	Miles from Hastings.	Feet above the sea.
At the east line of Big Stone county	184.1	987
Correll	186.9	980
Odessa	194.3	963
Stony run, track	195.1	965
Stony run, water	195.1	958
Summit, grade	199.0	1002
Ortonville	200.9	990
Big Stone lake	202.0	962.5

Elevations, Brown's Valley branch, St. Paul, Minneapolis & Manitoba railway.

From profiles in the office of C. A. F. Morris, engineer, St. Paul.

	Miles from St. Paul.	Feet above the sea.
Johnson	177.6	1127
Graceville	184.6	1107
Hilo	190.5	1105
Beardsley	177.8	1096
Top of the bluff east of Brown's Valley, grade	201.4	1096
Depression at foot of this bluff, surface	204.3	973
Brown's Valley	204.7	978
Minnesota river, water	204.7	970.5
Lake Traverse, one mile north		970

The hight of the Minnesota river at ordinary low water, along the boundary of Big Stone and Lac qui Parle counties, is approximately as follows:

	Feet above the sea.
At the village of Brown's Valley, about a half mile north of the northwest corner of Big Stone county	970.5
Big Stone Lake	962.5
At the mouth of Pomme de Terre river	934
Lac qui Parle	926
At the mouth of Chippewa river, close below the east line of Lac qui Parle county	913

Big Stone county, excepting the valley of Big Stone lake and the Minnesota river, is mostly about 1,100 feet above the sea. Its highest land appears to be a rolling tract, 1,125 to 1,175 feet in elevation, crossed by its north line four to seven miles east from Brown's Valley. The most prominent swells along a belt that extends thence southeastward, crossing the central part of the county to the vicinity of Artichoke lake, have nearly the same altitude. Odessa and Akron have considerable land less than 1,100 feet in hight, their southern portion, next to the Minnesota valley, being about 1,050. Making the reduction required by this valley, which is 125 feet lower than the general level, the mean elevation of Big Stone county above the sea is estimated to be very nearly 1,090 feet.

The highest land in Lac qui Parle county, about 1,400 feet above the sea, is at its southwest corner, on the foot-slope of the Coteau des Prairies, nearly 500 feet above its lowest land, on the shores of Lac qui Parle and the Minnesota river. From the top of the bluffs bordering the Minnesota valley there is a gradual ascent of about 250 feet in the distance of twenty-five miles southwest to the foot of the Coteau. These bluffs rise 100 to 125 feet above the river, being highest northwestward, and their elevation above the sea is from 1,075 or 1,100 to 1,025 feet, descending to the southeast with nearly the same slope as the valley. The base of the Coteau is about 1,300 feet, and the east side of the Antelope valley 1,200 to 1,225 feet above the sea. Next on the east, the hight of the third terminal moraine is mostly about 1,250 feet, and of its highest points, the Antelope hills, approximately 1,300 feet.

Estimates of the mean hights of the townships of Lac qui Parle county are as follows: Camp Release, 1,025 feet above the sea; Lac qui Parle, 1,020; Baxter, 1,050; Ten Mile Lake, 1,100; Hantho, 1,030; Cerro Gordo, 1,060; Riverside, 1,080; Maxwell, 1,120; Lake Shore, 1,050; Madison, 1,100; Hamlin, 1,125; Providence, 1,160; Yellow Bank, 1,080; Perry, 1,100; Arena, 1,150; Garfield, 1,175; Freeland, 1,240; T. 119, R. 46, 1,160; Augusta, 1,225; Mehurin, 1,250; and Manfred, 1,300. These figures give 1,120 feet as the estimated mean elevation of this county.

Soil and timber. The soil generally throughout these counties is the glacial drift or till, made up principally of clay, but containing a noticeable intermixture of sand and gravel and frequent small stones, with here and there boulders, seldom exceeding two or three feet in diameter. These rock-fragments are very rarely so abundant as to be a hindrance to cultivation. At the surface the till has been enriched by the decaying vegetation of centuries, and forms a very fertile, black soil, commonly from one to two feet deep, but often having a depth of three or four feet in depressions. Much of the rain-fall is absorbed by this soil, and the surplus of heavy rains and snow-melting is soon drained off by the gentle slopes and finds its way into creeks and rivers or into the permanent sloughs and lakes. Wheat, oats, corn and potatoes are the staple products, the first being the chief crop for export, with an average yield of fifteen to twenty bushels per acre. Dairying and stock-raising, and the ordinary vegetables and small fruits of the garden, are also important resources in the agriculture of this region.

Prairie, naturally bearing a luxuriant growth of nutritious grasses and many beautiful flowers, as the prairie-clovers, blazing-stars, golden-rods and asters, but having no trees nor shrubs, extends over almost the whole of Big Stone and Lac qui Parle counties. Timber occurs only along the rivers and on the borders of lakes. All the townships of Big Stone county, with its many lakes, have patches of woods; but they are less frequent, owing to the fewness of the lakes, in Lac qui Parle county, timber being there confined to the stream-courses. The bluffs of this part of the Minnesota valley are mostly treeless, or have only scattered small trees and thin groves; and the thick woodland is restricted to a narrow belt beside the river, and to tributary valleys and ravines. About Big Stone lake, timber generally fringes the shore; occurs of larger growth in the ravines of its bluffs; and covers its islands, situated within five miles above its mouth. The species of trees observed by Prof. Winchell near the foot of this lake on its northeast side, are the following in their order of abundance: white ash, bur-oak, bass, white elm, box-elder, cottonwood, hackberry, ironwood, soft maple, wild plum, slippery elm, and willow. The shrubs recorded in the same locality are grape, prickly and smooth gooseberries, wolfberry, black currant, prickly ash, red and black raspberries, elder, sweet viburnum, red-osier dogwood, climbing bitter-sweet, choke-cherry, red and white rose, Virginia creeper, waahoo, and smooth sumach.

GEOLOGICAL STRUCTURE.

Granite and gneiss. The only outcrops of the bed-rocks in Big Stone and Lac qui Parle counties consist of granite and gneiss, and are found in the Minnesota valley, where the thick mantle of drift was cut through by the outflow from lake Agassiz. No rocks older than drift, excepting a bed of Cretaceous shale, exposed in the edge of Dakota, as described on a following page, are seen along Traverse and Big Stone lakes, or between them.

One mile below Big Stone lake, a coarse reddish granite begins and thence occupies nearly the whole valley for three miles, lying in Ortonville and the northwest part of Yellow Bank, its highest portions rising 50 to 75 feet above the Minnesota river.

It again appears in low outcrops two and three miles easterly from the foregoing, in sections 30 and 32, T. **121**, R. **45**, the first of these being in Odessa, on the north side of the river a little west of Stony run, and the second in Yellow Bank, at Mr. Frederick Frankhaus', south of the Minnesota and a half mile west from its ford. At the last named locality this rock has few joints, their distance apart being sometimes ten feet or more.

Two to six miles farther southeast, in T. **120**, R. **45**, which extends from the mouth of Yellow Bank river to Marsh lake, similar granite forms abundant outcrops, mainly on the southwest side of the Minnesota river, in Yellow Bank township, rising 50 to 75 feet in their highest portions. Professor Winchell describes the formation here as follows: "The crystals of feldspar are large and flesh-colored, or red. Yet the granite also varies to a lighter color, in which the feldspar is nearly white. It shows, in the latter case, a perpendicular jointing, the planes being one or two or three inches apart. The whole exposure consists of bare, massive, rounded knobs, cut into angular rhomboidal blocks, by jointing planes, but in no place showing the dip seen lower down the Minnesota river."

North of the last, two ledges of this rock, small in extent and rising only a few feet from the surface of the drift, but lying at hights 40 or 50 feet above the river, were noted about a mile apart, half way between Odessa and Correll stations, the west one being a little south of the railroad, while the east one is crossed by it. All the foregoing exposures are granite, very hard and durable, but mostly too coarse and variable in grain or texture and too much jointed to promise well for quarrying. From the color of its predominant ingredient, the feldspar, this granite takes its prevailing reddish tint. It is variously intersected by joints, but does not exhibit the gneissic lamination which is generally noticeable in the southeastward continuation of these rocks.

For fifteen miles from the upper part of Marsh lake to the middle of Lac qui Parle we have no observations of ledges. In section 32, T. **119**, R. **42**, an island of rock occurs in Lac qui Parle, and two ledges outcrop on its southwest side. About two miles southeast, or one and a half miles above the foot of the lake, are several small and low exposures of rock, occuring at each side and also as islands. On the northeast side this is gneiss, mostly with N. E. to S. W. strike. The following description of this vicinity, by Prof. Winchell, who examined the Minnesota valley in 1873, is taken from the second annual report of this survey. "Near the lower end of Lac qui Parle lake, granite appears on both sides of the lake. It is usually inaccessible from the prevalence of water; but in the dry months of the year it can be reached on the northeast side without any trouble, except from tall grass and bushes. There are three or four small bare spots on the southwest shore that can be seen, and three or four others that rise up in the midst of the lake. Two of these spots of bare rock also occur on the northeast side, near the foot of the lake. This rock, so far as can be seen on the northeast side, shows very much the same composition as farther down the river. It contains quartz, mica and flesh-colored feldspar, with patches and veins of quartz, some of which are mingled with porphyritic feldspar. The exposed surfaces are annually submerged, or nearly so, and do not exhibit very plainly such markings as indicate sedimentation or dip. There seems to be an indistinct arrangement of the mica scales, so as to give the rock a schistose structure, but this, although generally running N. E. and S. W., does not have that direction invariably, and does not at all represent the lamination or bedding seen below" [farther southeast along the Minnesota river]. "In only one small area can there be seen what looks like the same bedding, and there it is but six inches in thickness, the beds being one or two or three inches, with a dip of 75° toward the S. E. Jointing planes divide the whole mass into blocks and rhombs, four or five or six feet in thickness. There is considerable low land about the lake, much of which is flooded at the wet season of the year, but it is stony and bushy, and has the appearance of rock in a great many places near the surface. Such appearances are seen the whole length of the lake, and especially on the northeast side. About three miles above the foot of the lake, rock can be seen on the southwest side at two points, rising plainly above the general level of the bottoms, and ascending in the slope from the prairie."

Below Lac qui Parle no outcrops of rock were observed in this county. Its next exposures found within the Minnesota valley are nine to twelve miles southeastward, where gneiss occurs in small ledges one mile west of Montevideo and close south of this town, and in extensive outcrops one to two miles farther southeast. All these are in Chippewa county, on the northeast side of the Minnesota river, opposite to the east end of Camp Release, the next eastern township of Lac qui Parle county.

Cretaceous shale. The granite and gneiss of this district are probably in many places overlain by Cretaceous beds, but no exposures of them have been discovered within the limits of these counties. A layer of shale of this age that outcrops on the Dakota side of the Minnesota river, very nearly opposite to the northwest corner of Big Stone county, is described by Prof. Winchell, as follows:*

"About a half mile, a little west of south from the stage station at the head of Big Stone lake, in Dakota, an exposure of Cretaceous occurs in the right bank of the upper Minnesota. It shows superficially only a weathered, sliding talus of shale, which is black and somewhat slaty, but which on digging becomes moister and soft and somewhat flexible, yet parting into small chips. Over the surface of the ground, where this shale outcrops, the turf is prevented from growing, and two conspicuous objects, weathered out from the shale, are seen. 1st. Little angular crystals of pure gypsum, the largest seen weighing not over half a pound. 2d. Little angular bits of yellowish red ochre, that are hard and thin, but can be cut with a knife. There is also an occasional piece of brecciated, clayey, or at least aluminous rock, the cracks and surfaces of which are filled and coated with crystals of calc-spar. When broken by the hammer, these part along the numerous planes that on either side are lined by this calc-spar, and each fragment is entire, appearing itself a mass of calcite. It is only by several attempts that a view of the interior, on which these coatings are formed, can be obtained. The thickness of this shale bed cannot be ascertained. The angular bits of ochre are most numerous near the top, where the drift supervenes, but the gypsum crystals are scattered over the whole outcrop. The indications are that the gypsum and ochre are embraced within the shale, and become superficial by weathering. The whole may be twenty-five feet thick.

"This shale bed is the cause of a terrace in the descent from the high prairie, and of numerous springs that issue below the drift, about sixty feet below the prairie level. These springs excavate narrow ravines and 'gulches' in the shale, the whole being smoothly turfed over, except at the point above described. These alternating gulches, and the intervening short pieces of the remaining terrace, make the bluff in general appear hilly, in its ascent from the bottomland. These ravines, in the wet season of the year, are very soft, and since they appear practicable for a horse, are the cause of many misfortunes to the traveler. Many such treacherous, springy places are described as occuring along the shores of lake Traverse, at some elevation above the waters of the lake. The same rolling ascent from the bottomland to the high prairie can be seen also at the head of Big Stone lake, on the Minnesota side, and it is there doubtless due to the same cause."

Glacial and modified drift.

The ledges ot granite near the foot of Big Stone lake are quite remarkably glaciated, having been planed, rounded and worn smooth by ice which moved from northwest to southeast, as shown by the direction of large grooves and hollows on the rock-surface and by its being most noticeably

*Second annual report, p. 190.

sculptured on the northwest side of projecting knobs. "The whole rock," as Prof. Winchell writes, "including the upper surface and the sides of the mounds, is planed off. The best exhibition of these markings is seen on the northwestern slopes, in which direction there is a system of jointing planes, dividing the granite into blocks that have at first sight a strong semblance of dip, the masses breaking off more nearly at right angles on the southeast side." Again, at Mr. Frankhaus' in Yellow Bank, glaciation from northwest to southeast has rounded the projections of the rock, and marked it with large furrows; but the fine striæ both there and near Big Stone lake have been effaced by weathering.

The sheet of drift which overspreads these counties probably averages a hundred feet or more in thickness. It is principally till, or unmodified glacial drift. Its material was gathered by the ice from a large region on the north and northwest, being quite certainly derived in large part from beds of Cretaceous clay and shale. Most of its boulders are granite, gneiss and schists, similar to the bed-rocks of this district and of northern Minnesota. About half of the gravel contained in the till, and a small proportion, perhaps averaging one in twenty, of its boulders larger than one foot in diameter, are fossiliferous magnesian limestone, whose nearest exposures, in the direction from which the ice-sheet moved, are in the vicinity of Winnipeg, in Manitoba. This rock, pulverized and in masses as pebbles and boulders, is thus a considerable ingredient of the drift, whence it is dissolved by infiltrating waters.

Soft rain-water, soaking through the drift, is changed to hard water before it finds its way into wells or issues in springs. The carbonates of lime and magnesia which it has taken up form a scale on the inside of tea-kettles and the boilers of engines; and are occasionally deposited by springs as an incrustation of moss, leaves, or other objects, or as a porous bed upon the surface of springy ground. Interesting springs of this kind occur at the foot of the bluffs on the southwest side of Big Stone lake, two and a half miles from its mouth. Their calcareous deposit is commonly called "petrified moss," from the fact that it becomes covered with growing moss, the lower part of which is being slowly encrusted and its form preserved by this accumulation. It is a light gray, very porous mass, one to two feet thick. Other deposits of similar character occur near by, where no springs now exist, on the dry bluff-side, some 75 feet above the lake.

From the Cretaceous strata the drift obtains a small admixture of the sulphates of lime, magnesia and soda, which are also held in solution by the waters of wells, springs, lakes and streams; but their amount is seldom sufficient to impart a perceptibly alkaline taste. Salt lake, crossed by the west boundary of Lac qui Parle county, is an exceptional case, being rendered so bitter that horses and cattle refuse to drink of it. Where shallow pools have dried up, they sometimes leave a whitish alkaline efflorescence, resembling frost, gathered by the inflowing and evaporating waters of many years. The till also contains rarely small fragments of Cretaceous lignite, similar to that which is mined thirty-five miles west of Bismarck, Dakota.

The Coteau des Prairies, rising a thousand feet above Big Stone lake and the Minnesota river, is conspicuously seen in the view westward from these counties; and the base of its eastern slope, composed of smooth till, below the knolly and stony, rough belt of the second moraine, reaches into Manfred, the most southwest township of Lac qui Parle county.

Antelope valley and moraine. Bordering the foot of the Coteau is a tract of smooth till, known as the Antelope valley, three to six miles wide, and reaching in a north-northwest course across Yellow Medicine county, southwestern Lac qui Parle county, and onward in Dakota to the south bend of the Sheyenne river. In Lac qui Parle county it includes the west part of Freeland, eastern Manfred, the greater part of Mehurin, and the west side of Augusta. Northwestward in Dakota the north branch of Whetstone river and the south and north forks of the Minnesota river lie in this depression. Its valley-like appearance is due to its situation between the massive Coteau des Prairies on the west and the third terminal moraine on the east. The smoothly undulating belt which thus somewhat resembles a valley and is so called, gradually rises 10 or 20 feet per mile westward. Beyond a distance of a few miles this scarcely perceptible ascent is changed to the steeper slope of the Coteau, on which the smooth surface soon gives place to the hillocks and small, short ridges, of the second or Gary moraine. The Antelope valley is virtually the continuation of the smoothly undulating or rolling expanse of till which reaches with slight ascent from the Minnesota river westward across Lac qui Parle county to the third or Antelope moraine.

This third series of terminal deposits of the last ice-sheet, like the two farther west on the Coteau, consists of hills and knolls and small ridges of till, containing many boulders, chiefly of gneiss, schists, granite and syenite, with a small proportion of limestone. It has been traced in a north-northwest course across Yellow Medicine and Lac qui Parle counties, a distance of about forty miles, in this state, and it continues with the same course in Dakota. Its width varies from one mile, or less, to two or three miles, and the hight of its elevations is usually from 40 to 100 feet above the contiguous east side of the Antelope valley. In southern Lac qui Parle county this moraine forms the two conspicuous clusters of the Antelope hills, in sections 27 and 16, Freeland, which rise about 100 feet above the smoothly undulating till of their region, and afford "a magnificent view of the prairies on all sides and of the Coteau toward the west." Continuing northward, it runs from section 32, Garfield, in a nearly straight course to section 33, T. **119**, R. **46**. One of its hills, about 60 feet high, at the north side of the west branch of Lac qui Parle river, in section 18, Garfield, has been named mount Wickham. It is also sometimes called Antelope mound. Thence for five miles northerly, in the northeast part of Mehurin and southeastern Augusta, this stony belt, 10 to 40 feet above the general level on each side, is known as the Stony ridge. In the east edge of Dakota, these accumulations rise prominently in the fractional T. **120**, R. **47**, and are called Yellow Bank hills, from the river of this name which flows through them. Mount Tom, their highest point, in or near the N. E. ¼ of section 32 of this township, has an elevation of about 100 feet. A belt of rolling till, about three miles wide, higher than the more gently undulating areas on each side, continues from these hills northwesterly across Grant county and into the Sisseton and Wahpeton reservation, lying two to six miles southwest of Big Stone lake, and crossed a few miles west of Brown's Valley by the road to the Sisseton Agency.

The fourth or Kiester moraine seems to be represented in T. **119**, R. **46**, by a series of knolly drift deposits, composed of till with plentiful boulders, which extends from the northwest corner of this township five miles southeastward to the elbow of the South fork of Yellow Bank river. A width of only one mile separates the third and fourth moraines at the state line, but they diverge to a distance of three miles apart at the South fork. The farther course of the fourth moraine south-southeast to Omro and Tyro in Yellow Medicine county (page 606) has not been traced, but this formation was observed in 1873 by Prof. Winchell in the south part of Lac qui Parle county, probably near the middle of Providence township. After describing the Antelope hills, he adds that "a similar range of drift knolls, but much smaller, was seen about six miles east of this range, running also in the direction N. and S."*

Later moraines. During the stages in the recession of the Minnesota lobe of the last ice-sheet when its fifth, sixth and seventh (or Elysian, Waconia and Dovre) moraines were formed,

*Second annual report, pages 193-4.

its southwestern border appears to have extended across Big Stone county, but traces of these moraines have not been sufficiently looked for there. They are probably indistinguishably blended in the area of rolling till, 50 to 75 feet higher than the average of this county, that was noted a few miles east of Brown's Valley (page 616), and the somewhat rolling, lake-sprinkled surface that stretches thence southeastward.

Glacial lake in the basin of the Blue Earth and Minnesota rivers. When the ice-sheet, dissolved by a warmer climate, was retreating northeastward across Lac qui Parle county, the waters of its melting were carried to the southeast along the margin of the ice, which was a barrier preventing their flow in the direction of the present drainage. After the ice had receded from the Antelope moraine, a glacial lake (page 461) with its surface 1150 to 1200 feet above the sea, probably increasing somewhat in elevation from southeast to northwest, was formed in the Minnesota basin along the front of the ice and reached from Faribault and Blue Earth counties to Big Stone lake. Its overflow was by Union slough in Iowa, until the continued retreat of the ice-sheet permitted a lower outlet to the Cannon river, at first about 1,075 and afterward 1,025 feet above the sea. By this submergence the drift in Lac qui Parle county and upon a large part of the Minnesota basin farther southeast was spread more evenly, and many of its hollows that would have held small lakes were filled. This modification in contour doubtless is accompanied by a partial stratification, especially on low areas; but nearly everywhere the drift in this county and throughout this basin is a clay containing gravel and occasional boulders, seldom showing such assorting action as to transform it from till to modified drift. During the somewhat later recession of the ice across Big Stone county, free drainage could take place from its border, and the drift presents a more undulating and rolling surface, dotted by many little lakes.

River Warren. The excavation of the remarkable valley, or channel, occupied by lakes Traverse and Big Stone and the Minnesota river, was first explained in 1868 by Gen. G. K. Warren,* who attributed it to the outflow from an ancient lake, since named lake Agassiz,† that filled the basin of the Red river and lake Winnipeg. The hights of lakes Traverse and Big Stone are respectively 970 and 962 feet above the sea, and the lowest point of the divide between them is only three feet above lake Traverse. These lakes are from one to one and a half miles wide, mainly occupying the entire width of this trough-like valley. Lake Traverse is fifteen miles long; it is mostly less than ten feet deep, and its greatest depth probably does not reach twenty feet. Big Stone lake extends in a somewhat crooked course from northwest to southeast twenty-six miles; its greatest depth is reported to be from fifteen to thirty feet. The portion of the channel between these lakes is widely known as Brown's valley. As we stand upon the bluffs here, looking down on these long and narrow lakes and the valley which extends across the five miles between them, where the basins of Hudson bay and the gulf of Mexico are now divided, we have nearly the picture that was presented when the melting ice-sheet of British America

*"On certain physical features of the upper Mississippi river," *American Naturalist*, vol. ii, pp. 497—502, Nov., 1868; *Annual report of the chief of engineers, U. S. army, for* 1868, pp. 307—314; "An essay concerning important physical features exhibited in the valley of the Minnesota river, and upon their signification," with maps, *Report of chief of engineers*, 1874; "Valley of the Minnesota river and of the Mississippi river to the Ohio. Its origin considered—depth of the bed-rock," with maps, *Report of chief of engineers*, 1878. (General Warren died August 8, 1882.)

†Compare the eighth and eleventh annual reports.

was pouring its floods along this hollow. Then the entire extent of the valley was doubtless filled every summer by a river which covered all the present areas of flood-plain, in many places occupying as great width as these lakes. It seems fitting that this river, which flowed in the ice age where lakes Traverse and Big Stone and the Minnesota river now are, should be called the *River Warren*, in honor and *in memoriam* of general G. K. Warren, the author of the first adequate description of this valley.*

The hights of the bluffs, composed chiefly of till, but sometimes having rock at their base, which form the sides of this valley in the portion adjoining these counties, are as follows, stated in feet above the lakes and river: along lake Traverse, 100 to 125; at Brown's Valley and along Big Stone lake, mainly about 125, the highest portions reaching 150; at Ortonville, 130; and at Marsh lake, along Lac qui Parle, and at Montevideo, about 100. The outflow from lake Agassiz was divided at two places, seven and ten miles below Big Stone lake, where isolated remnants of the general sheet of till occur south of Odessa station and again three miles southeast. Each of these former islands of the river Warren is about a mile long, and rises seventy-five feet above the surrounding low land, or nearly as high as the bluffs enclosing the valley, which here measures four miles across, having a greater width than at any other point.

Gen. Warren observed that lake Traverse is probably due to a partial silting up of the channel since the outflow from the Red river basin ceased, the Minnesota river at the south having brought in sufficient alluvium to form a dam; while Big Stone lake is similarly referred to the sediment brought into the valley just below it by the Whetstone river. The deep, winding channel of Whetstone river near its mouth is quite remarkable; and its level alluvium, about five feet above the lake, fills the valley, a mile wide, between Big Stone City and Ortonville.

Fifteen miles below Big Stone lake, the Minnesota river flows through Marsh lake, which is four miles long and about a mile wide, shallow and full of reeds and grass. This lake may be due to the accumulation of alluvium brought into the valley by the Pomme de Terre river, which has its mouth about two miles below. Twenty-five miles from Big Stone lake, the river enters Lac qui Parle, which extends some ten miles, with a width varying from a quarter of a mile to one mile, and a maximum depth of twelve feet. This lake, as Gen. Warren suggested, has been formed by a barrier of stratified sand and silt which the Lac qui Parle river has thrown across the valley.

As soon as the retreat of the ice-sheet allowed lake Agassiz to be drained northward into Hudson bay, this deeply excavated water-course, which had been formed by its outflow to the south, began to be partially filled by the deposits brought into it by small tributary streams at their stages of high water. The valley was thus changed from its original continuously descending slope, and portions of its extent which have been dammed by these deposits of tributaries are occupied by long and narrow, picturesque lakes, bounded by partly wooded bluffs, 100 to 150 feet high.

The beautiful scenery of Big Stone lake has already made Ortonville and Big Stone City popular resorts of summer tourists. Small steamers carry excursion parties to the head of the lake, a distance of nearly thirty miles, or for picnics to wooded portions of the lake-shore, or to a group of wooded islands, three to five miles from the foot of the lake. These, which are the only islands of Big Stone lake, belong to Dakota. They are low, rising only ten to fifteen feet. The largest, called Chamberlain island, from the name of its owner, is about a mile long and contains approximately one hundred and twenty-five acres. Another, lying a little farther northwest, has an area of about seventy acres, and is known as Paradise or Wheaton island. With these are several more of small size, each containing a few acres. The highest water of this lake, due to the rain-fall or snow-melting, rises five feet above its lowest stage. Another cause of fluctuation is wind, which, blowing strongly a half day or more from the south, lowers the lake

*This name was proposed in a paper entitled "The Minnesota valley in the ice age," at the Minneapolis meeting of the American association for the advancement of science, August, 1883; see also the *American Journal of Science* (3) xxvii, 1884.

at Ortonville one to one and a half feet, while an equal rise is occasioned by a similar northwest wind.

The Minnesota river along its first ten miles below Big Stone lake, at its ordinary stage of water in summer, averages only one to two feet in depth. In its next fifty miles, before reaching Granite Falls, it receives three large affluents, the Lac qui Parle, Pomme de Terre, and Chippewa rivers; and its width is expanded to about a hundred and fifty feet, with volume sufficient to furnish power for large flouring mills. During the high water of spring about twenty years ago, a steamer, said to have been a hundred and twenty-five feet long, was run from Saint Paul up the Minnesota river to a point near the east line of section 33, Odessa, nine miles below Big Stone lake, where, becoming grounded in the channel of the stream, it was abandoned and afterward burned, excepting the bottom of its hull which still remains. It was expected to float this steamer into Big Stone lake and thence into lake Traverse and the Red river. At the highest floods produced by snow-melting in exceptional years, such a feat may be possible, as the water where the divide between Big Stone lake and lake Traverse would be crossed, close to the east bluff a half mile north of Brown's Valley station, is then three or four feet deep. This water comes mainly from the overflow of the Minnesota river whose banks at Brown's Valley station are a few feet higher than this lowest point of the water-shed. Currents of the flood brought into the valley by the Minnesota river often go thence both to the north and south; but probably no outflow passes southward from lake Traverse into Big Stone lake.

Modified drift and alluvium. Four to six miles southeast from the north end of Big Stone lake, much of the slightly undulating surface consists of water-deposited gravel and sand, instead of the unmodified glacial drift which prevails elsewhere.

In Lac qui Parle county modified drift, or alluvium, perhaps filling an ancient water-course, borders Florida creek on its west side in sections 19, 20 and 29, Garfield; where it is a mile wide and extends two miles from north to south, being five to ten feet above the creek and some twenty-five feet below the average hight of the adjoining areas of till. A few miles farther south this creek is again bordered by a similar alluvial area in the east part of sections 5 and 8, Freeland. This depression and its deposits of modified drift lie close east of the low knolls, strown with boulders, which form the terminal moraine in Garfield, but appear to extend southward on the west side of the Antelope hills, and may be found to be continuous in this direction to the old water-course which has been described in the report of Yellow Medicine county, crossing Wergeland and Burton townships.

On the surface of the sheet of till which covers these counties, are rarely found small knolls or short ridges of gravel and sand, five to ten feet above the average hight of their vicinity. These appear to have been brought by streams that descended from the drift-laden surface of the ice-sheet at the epoch of its final melting. Their origin is thus like that of the long ridges of gravel and sand called kames in Scotland and eskers in Ireland. The only typical kame observed in the examination of these counties lies near the state line and southwest corner of Yellow Bank township. It is composed of gravel and sand, and is 10 to 20 feet high and a quarter of a mile or more in length, running approximately from east to west. At its eastern end a more prominent morainic ridge of coarsely rocky till runs from southeast to northwest.

The bottomland of Brown's Valley, about a mile in width and reaching four miles from lake Traverse to Big Stone lake, is alluvial gravel, sand and silt, along its most depressed portion; but till forms the plateau, about 40 feet above the Minnesota river, close south of Brown's Valley village, and also, in some places, it forms slopes of moderate ascent next to the base of the bluffs. Along Traverse and Big Stone lakes the bluffs of this valley often rise directly from the lake-shore, leaving no considerable width of bottomland; and the margins of the lakes in some portions is made wholly of boulders, up to six feet in diameter, which form a wall five to eight feet high, piled against the foot of the bluff. An instance of this was seen on the northeast shore of Big Stone lake, close south of William H. Bowman's in section 18, at the west side of Prior. The broadest area of cultivatable bottomland adjoining the northeast side of Big Stone lake is in the fraction of T. **122**, R. **47**, which makes the southeast part of Prior township. S. P. Lindholm lives on this bottomland, which in sections 11 and 13 has a width of about a half mile, consisting principally of till and ascending by a gradual slope from the edge of the lake to a hight of 40 or 50 feet at the foot of the bluff of till, which next rises steeply 75 or 100 feet. At Mr. Jacob Hurley's, in section 19, Big Stone, about five miles north of Ortonville, the surface of moderately sloping till between the lake and the bluff is about forty rods wide, and rises some 40 feet in this distance. On the Dakota shore of Big Stone lake, similar foot-slopes of till, below the steep bluffs, vary from an eighth to a half of a mile in width, along the greater part of the southeastern half of the lake, but they are wanting farther northwest.

A deposit of alluvium, consisting mostly of sand and clayey silt, brought into the valley by Whetstone river, forms a nearly level bottomland about a mile wide at the foot of Big Stone lake; and a similar deposit extends two or three miles next below Lac qui Parle, having been brought by the river of the same name. Other portions of the Minnesota valley on the borders of these counties generally have an alluvial flood-plain an eighth to a fourth of a mile wide, while the greater part of the area enclosed between the bluffs is till, somewhat modified at the surface by the waters that eroded the valley.

Terraces. Southeast from the village of Brown's Valley, the railroad in its ascent from the base to the top of the bluff is located upon an inclined terrace which rises southeastward along the side of the bluff at the rate of about 40 feet to the mile, extending three miles. Where this terrace is crossed by the carriage road a mile easterly from the northwest corner of Big Stone county, its width is some forty rods, in which distance its hight from its verge to the base of the higher part of the bluff rises some 25 feet. On the west side of the valley, a terrace of similar width but approximately horizontal, lying at half or two-thirds of the hight from the base to the top of the bluff, extends from opposite Brown's Valley nearly to Big Stone lake. "Along this lake, also," Prof. Winchell writes, "are terraces that have a slope or dip striking across the bluff. One may be seen at Mr. Hurley's; . . . it can be traced three or four miles, passing, in that distance, down from union with the prairie level to the bottoms, or so far down as to be blended in the bottomland. A similar vanishing terrace can be seen on the Dakota side" [a few miles west from Mr. Hurley's] . . . . "Within the space of about three miles, its form can be seen to pass obliquely across the face of the main bluff, from top to bottom, sloping to the east or southeast, and disappearing in the bottomland."

At Ortonville and for a mile or more southeastward, a terrace occurs about 75 feet above the lake and 50 feet below the top of the bluff. It varies from a few rods to an eighth of a mile in width, and in this width ascends 10 or 15 feet. The rise of 50 feet thence to the highest land is by an irregular slope, less steep than the bluff below this terrace. These features, however, are much broken by gullies and ravines. A similar narrow bench in the bluff of till on the opposite side of the Minnesota valley is seen in the northwest part of Yellow Bank township along a distance of four miles next southeast from Whetstone river and Big Stone City.

Professor Winchell has noted other terraces farther southeast in this valley, and attributes their form to erosion in Cretaceous strata which are supposed to be only thinly covered by drift. "A terraced condition of the bluffs may be seen at a little lake, caused by the enlargement of the river on T. **120**, R. **44**, [Marsh lake,] as well as in the bluffs of Lac qui Parle. Here an observation was made that plainly indicates the origin of these benches. They exhibit a slope or dip toward the S. E., running successively down to the bottoms, higher ones occurring in their places. This can plainly be seen from the opposite bluff. This slope is believed to be due to the dip of the rocks of the Cretaceous, though no outcrop of these rocks was seen at that place, the bluffs of the river and of all ravines being smoothly turfed over."

Modified drift of the earlier glacial epoch. In the report of Brown and Redwood counties (page 582) mention is made of a cut in the bluff southwest of New Ulm, where the amount of drift deposited in the last glacial epoch appears to be a bed of till, 16 to 18 feet thick, overlying a bed of stratified gravel and sand of about the same thickness, which was probably formed during the recession of an earlier ice-sheet. A closely similar section was observed on the Hastings & Dakota railroad, about fifteen rods south of Mr. Oehler's brick-yard at Big Stone City. Here a cut is made through a ridge of drift which belongs to the general drift-sheet, but has been left by erosion as a level-topped plateau jutting southward toward the Whetstone river. The cut is about 45 feet deep and twenty-five rods long. At the top is a stratum, 15 feet in thickness, composed of yellowish sand and gravel, fine above but coarse in its lower three to five feet. Underlying this is unstratified boulder-clay or till of the usual character, forming a bed 15 to 18 feet thick, its maximum thickness being at the east end of the cut. This has the dark bluish color usually characteristic of the deep portion of the till, except that at each end of the cut, next to the face of the slopes bounding this plateau, it has the ordinary yellow color of the upper part of the till to a depth of thirty feet from the surface at the west and fifteen feet at the east. It is bounded by definite, nearly level lines both above and below, and is underlain by obliquely bedded yellow gravel and sand, which has a thickness of about 15 feet exposed to the grade of the track and also extends deeper. My interpretation of these deposits would refer the lower gravel and sand to an interglacial epoch, their origin being from the earlier ice during its departure; the till was quite surely deposited by the last ice-sheet; and the overlying gravel and sand is probably modified drift belonging to the immediately succeeding epoch of its recession and final melting.

A buried moraine. There are many reasons for believing that several successive ice-sheets have been accumulated and pushed forward upon the northern part of the continent, repeatedly overspreading nearly all of Minnesota; and if this be true, some of them doubtless formed terminal moraines, which were afterward covered and their mounds and hills of coarsely rocky drift spread in a nearly level stratum by the more extended ice-sheet of a later epoch. Such a buried moraine is exposed by the deep channel of the upper Minnesota river. The till here is found to contain, at a depth of 40 to 50 feet below the general surface, a stratum that abounds in boulders, usually producing a narrow shelf or terrace upon the bluffs.

About Correll station, in Big Stone county, this rocky layer in the till has caused an extensive plain to be left in the process of erosion, some 50 feet below the top of the bluffs and 50 to 75 feet above the river. The west end of this plain is in section 6, T. **120**, R. **44**, about three miles west of Correll; and it thence extends eight miles east to the Pomme de Terre river, having a width of one and a half to two miles in its western half, and expanding to a greater breadth farther east. Its first one and a half miles at the west is not remarkably sprinkled with boulders, but has one immense block, thirty feet or more in diameter, on section 5, about one and a half miles west of Correll station. Very abundant boulders, however, are found on the southern verge of this part of the plain, covering the upper ten or twenty feet of the escarpment, 50 to 60 feet high, which descends to the bottomland in the southeast part of section 6, and near the south line of section 5. A little farther east, probably in the northwest corner of section 9, and about three-quarters of a mile southeast from the large boulder before mentioned, another was observed in the escarpment of this plain, measuring twenty feet in diameter, and consisting of gray granite, in which are seen at one side several fragments of hornblende schist up to three and four feet in diameter. A great profusion of boulders occurs here along the margin of this plain through a distance of two miles or more, and the same feature probably continues all the way east to the Pomme de Terre river, near which it was again observed in section 19, Appleton. On the south, in the region of Marsh lake, are occasional knolls and short ridges, composed mainly of boulders, extending ten to twenty rods and rising ten to fifteen feet above the marsh. For a mile west from Correll station, and all the way east to the Pomme de Terre river, this plain is much sprinkled by boulders of all sizes up to six or eight feet. Between Five Mile creek and the Pomme de Terre river, the east part of this area somewhat loses its plain-like contour, and becomes in part quite undulating and broken, having numerous knolls and ridges twenty to forty rods long, running mostly from west to east, five to twenty feet high, so thickly strown with boulders of all sizes up to five or ten feet in diameter that often they cover three-quarters of the surface. These small elevations and depressions have been shaped by the eroding action of water, being more regular in their outlines than typical terminal moraines, which they resemble in their multitude of boulders. It appears that here a terminal moraine, accumulated in one of the early glacial epochs of the great ice age, has been crossed by a later ice-sheet. Partly leveled and buried under the later till, a section of it is exposed to view by the excavation of this valley.

The ancient water-courses, now deserted, which are found in Chippewa county northeast of Lac qui Parle, connected with the Minnesota valley and running approximately parallel with it, reaching 40 to 80 feet below the general level of the drift-sheet, and varying from an eighth to a half of a mile in width, frequently have their bed upon this stratum of boulders. On the bluff of till which rises at the southwest side of the lower half of Lac qui Parle, this layer in some places, as in sections 4, 5 and 9, of Lac qui Parle township, forms a rocky, very narrow terrace, at a horizontal line about 75 feet above the lake and 25 feet below the top of the bluff and surface of the adjoining country; and the more gradually sloping ascent from the northwest half of Lac qui Parle shows many very rocky places 40 to 60 feet above the lake, which are probably also a part of this buried moraine. A similar narrow terrace-mark, abundantly strown with boulders, is generally noticeable upon the bluffs at each side of the Minnesota river, at a hight of 50 to 60 feet above it and some 50 feet below the general level, all the way from Lac qui Parle to Montevideo. Further exposures of this rocky stratum in the till are seen in the Minnesota valley below Lac qui Parle county, at many places, to a point three miles below the mouth of the Yellow Medicine river.

Northwesterly from the remarkable Correll plain, boulders are occasionally seen in great abundance within the valley or on the bluffs that enclose the Minnesota river and Big Stone and Traverse lakes. About two and a half miles east of Odessa station, a boulder of exceptional size, being fully twenty feet in diameter, lies at the north side of the railroad. Within a mile farther west are several very rocky knolls and short ridges, extending five or ten rods, trending approximately from west to east, and rising 15 to 30 feet above this part of the bottomland, which is not reached by the highest floods of the Minnesota river.

Two other localities also deserve mention, as exhibiting very plentiful boulders, the origin of which is difficult to suggest, unless they are outcropping portions of this buried moraine. One is at the southeast corner of section 15, in the west part of Prior, where a ravine, about six rods wide and twenty feet deep, has the upper part of the slope on each side very profusely sprinkled with granite boulders up to three or four feet in diameter, while only a few boulders are seen on the surface of the region adjoining or along the bottom of the ravine. The same feature is also noticeable in a less degree upon other ravines northeast of Big Stone lake, while in the same region are seen occasional knolls or swells, 5 to 15 feet high, abundantly covered with large and small rock-fragments.

The second locality where boulders are specially remarkable is at a cut on the Hastings & Dakota railroad about five miles west of Big Stone City. This cut is 5 to 10 feet deep and an eighth of a mile or more in length, and is approximately at the average hight of the surface of the drift-sheet in its vicinity. Boulders here are exceedingly abundant of all sizes up to ten feet in diameter, but are confined to the surface and the upper two or three feet, and are comparatively rare below, being not more plentiful than is usual in the till throughout Minnesota. Next west of this cut is a valley 15 to 20 feet lower and nearly an eighth of a mile wide, almost destitute of boulders though apparently till, while the land at its west side again exhibits a surface over which they are thickly strown.

Red till. Besides the upper yellowish till (changed to this color by weathering) and the lower dark bluish till, which ordinarily make up the whole thickness of the glacial drift in this region, it exhibits at a few places, below the foregoing, a distinctly reddish till, quite different in color from the other two, and like the red till which overspreads northeastern Minnesota from lake Superior to Saint Paul and Minneapolis. In that part of the state the direction of glacial motion was southwesterly, and the red color of the drift appears to be due to the large proportion of its material which was gathered from areas of red sandstone and shales in the region of lake Superior. Upon the western two-thirds of Minnesota the ice-currents moved mostly toward the south and southeast, bringing the dark bluish till, weathered above to yellow, which covers this area. The following include all the observations of red till which have come to my knowledge in western Minnesota and eastern Dakota.

In the N. W. ¼ of section 24, T. **123**, R. **48** (the west township of Prior), a red till was found at the bottom of J. P. Edward's well, 77 feet below the surface, underlying yellow and blue till. The section of this well is stated on page 629.

About two miles west of Big Stone City, the lower part of a newly undermined bluff on the north side of the Whetstone river consists of till which has the same red color that characterizes the till of northeastern Minnesota. The upper portion of this bluff, to a depth of about 20 feet, is yellowish gray till; and this is directly underlain by red till, exposed along a distance of a third or a half of a mile, with a vertical thickness of 20 or 30 feet, and extending below. The same bluff of till reaches a half mile farther east, but has there become obscured by falling down. Its top, about 50 feet above the river, is probably 40 or 50 feet below the average surface of the drift-sheet.

This red till appears to extend southwesterly, under the yellow and blue till, nearly or quite to the foot of the Coteau des Prairies. It is reported by Alonzo Wardall, who lives in the S. W. ¼ of section 12, T. **120**, R. **50**, in Grant county, Dakota, seventeen miles west-southwest from Big Stone City. He has bored about seventy-five wells within that county and Big Stone and Lac qui Parle counties, frequently finding red till in considerable thickness in the bottom of deep wells.

At Montevideo, in Chippewa county, a mile northeast from the east end of Lac qui Parle county, an excavation for a cellar in the base of the bluff at the east side of Main street exhibited the section, about 15 feet in depth and 40 feet in length, shown by fig. 51. This is the east bluff of the valley that is now occupied by the Chippewa river. It is composed of till, and rises nearly a hundred feet above this excavation, to the general level of the adjoining country. The position of the section here seen, and the order and character of its materials, suggest that they are probably a talus fallen down since the valley was eroded. Here and there this cut shows thin layers of sand, and in part its diverse tills are imperfectly stratified, with contorted bedding; but they are gravelly and stony clay, and doubtless the bluff above this point embraces three corresponding kinds of unmodified glacial drift. Next below the soil is a dark gray till, from 2 to 6 feet in thickness. This rests for its greater part upon yellowish till, of which a thickness of 6 to 12 feet is exposed, having the color usually seen near the surface; but on the west the latter abuts upon a small ridge five feet high and scarcely twice as wide, which also underlies the dark gray stratum and is composed of red till, identical in color with that of Minneapolis and Saint Paul and northeastern Minnesota. A little projection of red till appears to have extended here in the form of a ridge from north to south, for it was exposed with nearly the same dimension and relation to the rest of the section at the south side of this excavation, twenty feet distant.

FIG. 51. SECTION IN MONTEVIDEO.

These observations seem to have their most probable explanation in supposing that during an early glacial epoch an ice-sheet was pushed west-southwesterly from the region of lake Superior quite across Minnesota, bringing these deposits of red till. This may have been when the ice reached its greatest extent, covering all of this state except its southeast corner, which lies within a driftless area. Some of its till, derived in large part from the red shales and sandstones, retained a distinctly reddish color; but we must suppose that at such distances the admixture of other drift, brought by convergent glacial currents from the north and northwest, would commonly give to the deposits of that ice-sheet a prevailing bluish color, like that of the till spread over this region by the southeasterly-flowing ice of the last glacial epoch. Nuggets of copper, which were almost certainly transported from the region of lake Superior when the ice had its maximum extent, are found rarely west of the driftless area in the till of southern Minnesota and of Iowa. The directions of the striæ, and the course of the terminal moraines of the last ice-sheet, show that these masses of copper could not have been brought from their northeastern source during the last glacial epoch. It seems thus to be proved that ice flowed farthest southwestward from lake Superior at an earlier date; and that ice-sheet is believed to have deposited the red till found in this district.

Wells in Big Stone county.

Prior. G. Knutson, sec. 8, T. **23,** R. **148:** well, 45 feet; soil, 2; yellowish till, 18; dark, bluish till, soft to dig, 25; water rose from the bottom four feet.

Mr. Chesley; S. W. ¼ of sec. 14, T. **123,** R. **48:** well, 48 feet; yellow till, 25; gravel, 4 inches; blue till, 20 feet; gray gravel, 3 feet; quicksand, not dug into. Water is found in the gravel and sand at the bottom, not rising. Lumps of clay, as large as one's fist, occur in the upper part of this water-bearing gravel. Lignite is found in nearly every well in this vicinity, the largest pieces being four or five inches in diameter.

J. P. Edwards; N. W. ¼ of sec. 24, T. **123,** R. **48:** well, 78 feet; soil, 2; yellow till, picked, 32; dry gravel, 4 inches, containing gas but no water; softer blue till, 37 feet; gray, clayey gravel, 7 feet, having plenty of water, which does not rise. Under this was a reddish till.

Samuel Varco; sec. 18, T. **123,** R. **47:** well, 102 feet; upper, yellowish till, 45; blue till, 30; dark sand, 27. Water comes in large amount, but does not rise. Gas is usually found in the same layer with the water in this neighborhood.

J. T. Crippen; sec. 28, T. **123,** R. **47:** well, 80 feet; soil, 3; gray till, with dark bluish and reddish portions, 57; hard blue clay, 4; sand, 16, easy to dig, with water in its lower part. Several pieces of lignite were found.

Thomas Jennings; sec. 30, T. **123,** R. **47:** well, 67 feet; hard, yellowish gray till, 40, containing in its lower part lumps of blue clay, three to six inches in diameter; dry sand and fine dark silt, interstratified, 27 feet, and extending lower; well not finished; no water found in this depth.

A. J. Scofield; sec. 32, T. **123,** R. **47:** well, 76 feet; soil, 2; yellowish till, 30; dark, bluish till, 36; sand, 8; water comes slowly in the lower part of this sand, not rising. Drawing one barrel empties this well.

E. T. Hanes; sec. 5, T. **122,** R. **47:** well, 20 feet; black soil, 4; yellowish till, very hard, 5; clayey sand, 8; quicksand and water, 3. This water rises and falls with Big Stone lake, which is ten rods distant.

Tokua. W. E. Nannary; sec. 1: well, 75 feet; soil, 2; gray upper till, 18; gravel, 1½ feet, with a little water; blue till, soft and sticky, 53 feet, containing no sand veins and supplying no water; sand, 6 inches, not dug farther into, full of water, which rose ten feet quickly, and afterward slowly filled the well to a depth of fifty feet.

Graceville. John Garvey; in the village, in the N. E. ¼ of sec. 9: well, 36 feet; soil, 1½ feet; brown loam, 1½; yellow till, 15; soft blue till, 18; the only water found seeps from the upper till.

E. Dunlap; sec. 8: well, 70 feet; soil, 2; yellow till, 18; harder blue till, 50; water comes at the junction between the yellow and blue tills, none being found in the lower till.

In the north part of this township, several wells go 90 to 110 feet, mostly in blue till, sometimes finding no water or only a scanty supply.

Ortonville. Lake View hotel: well, 38 feet; soil, 3; sand and gravel, 7; hardpan, bluish and gray till, 14; yellow gravel, 5; yellow quicksand, 9 feet, with plenty of water, which rises five feet above the top of this quicksand.

Henry Jacobs; also in the town: well, 29 feet; soil, 3; gravel, 8; dark bluish till, 10; yellow gravel, 4; sand, 4; water plenty, rising three feet.

Chamberlain island, in Big Stone lake. C. A. Chamberlain; well, 14 feet; soil, 1½; yellow till, picked, 8; quicksand, 4½; water plentiful, rising and falling with the lake.

Trenton. G. Amundson; sec. 8: well, 27 feet; soil, 2; yellow till, hard, 25; to gravel, from which water rose fifteen feet in two days.

Artichoke. Olaus Hanson; sec. 2: well, 45 feet; soil, 2; yellowish till, 20; darker bluish till, 23; water rose from the bottom several feet.

Correll. The railroad well at this station was bored 145 feet deep, but its section was not learned. Water rose from gravel to a hight eighteen feet below the surface.

Wells in Lac qui Parle county.

Yellow Bank. Horace Leavitt; sec. 20, T. **120,** R. **46:** well, 35 feet; soil, 2; yellow till, 25; harder blue till, 6; gravel, 2, from which water rose seven feet.

T. W. P. Lee; N. W. ¼ of sec. 29, T. **120,** R. **46:** well, 24 feet; soil, 2; hard yellow till, 18, requiring to be picked, but containing streaks of sand; harder blue till, 4; water rose eleven feet from gravel at the bottom.

William Glage; sec. 18, T. **120**, R. **46**: well, 60 feet; soil, 2; yellow till, 30; softer blue till, 28; water seeps from the lower part of the blue till.

D. A. Murray; sec. 30, T. **120**, R. **45**: well, 28 feet; soil, 3; yellow till, containing only very little gravel or other rock-fragments, 22; bluish sand, 3 feet, with water, which does not rise; gravel lies next below.

Mehurin. R. Kinmore; sec. 2: well, 33 feet; soil, 2; yellow till, spaded, 21; sand and silt, not caving in, 10; with coarser layers of sand and gravel containing water at the bottom, from which it rose only one foot.

G. J. Hardy; sec. 4: well, 30 feet; soil, 2; yellow till, picked, 20; gravel, 2; dark bluish clay, probably till, 6 feet, to a boulder a foot or more in diameter, which stopped the boring. Bitterish water comes from the gravel between the yellow till and blue clay.

Freeland. C. B. Ford; sec. 10: well, 20 feet; soil, 2; yellow till, 8; dark bluish hardpan, very dry and hard in digging, but becoming quicksand when mixed with water, 2; blue till, 8; water in twenty minutes rose five feet from quicksand at the bottom. Both these tills required to be picked. The wells of this township vary from 15 to 25 feet in depth, and are all in till.

Riverside. J. B. Sumner; sec. 34: well, 26 feet; soil, 2; yellow till, spaded, 10; sand, 1; blue till, picked, 8; dark gravelly hardpan [also till], much harder than the last, 5; water of excellent quality rose three feet from sand at the bottom.

Lac qui Parle. J. H. Brown; hotel in village: well, 74 feet; yellow till, 25; very hard blue till, 49; the only water found seeps from the lower part of the yellow till. A piece of wood, splintered, sixteen inches long and three inches wide, was found in this till at the depth of 52 feet.

W. M. Mills; N. E. ¼ of sec. 30: well, 31 feet; soil, 2; clayey silt, 8; yellow till, spaded, 7; sand, 6 inches; the only water found in this well, a scanty supply, is from this sand; blue till, very hard, picked, 14 feet, including thin layers of dry sand. The upper ten feet contained numerous bivalve shells. The blue lower till in this region is reported to be generally twice as hard and compact as the yellow upper till.

MATERIAL RESOURCES.

Agriculture must evidently be always the chief industry and source of wealth in this district, attended, in villages and towns, by needed branches of trade and manufactures.

Water-powers are available but have not yet been utilized in these counties. Sufficient fall occurs on the Minnesota river two to five miles below Big Stone lake, and at other points; and this lake may serve as a reservoir, to be raised at least two or three feet by a dam, for use at times of drought. The Lac qui Parle river has a valuable water-power on land of W. M. Mills, at the east side of section 30, Lac qui Parle, two and a half miles west of the village. Mr. Mills states that by excavating a tunnel here for a canal ten rods in length, through a ridge of drift at the neck of a loop of the river, a fall of 24 feet might be obtained, the descent of the stream in this loop, two miles long, being 14 feet, to which 10 feet more may be added by a dam.

Building stone is usually attainable in the amount required by farmers, for foundations and the walls of cellars and wells, from the granitic and limestone boulders of the drift, though they are seldom so numerous as to be objectionable in the cultivation of the land. The outcrops of granite in the Minnesota valley may be advantageously worked to supply such masonry and for buildings; but they have not yet been quarried, except that some rough stone, used at Ortonville, has been taken from their surface, and from a railroad cut, about one and a half miles southeast of this town.

Lime is burned by several farmers on the northeast shore of Big Stone lake, from dolomyte boulders of the drift, the fuel being obtained from the border of the lake. These lime-burners, in their order from northwest to southeast, are Amund Ericson, in section 23, Brown's Valley, one and a half miles southeast from the head of the lake; W. H. Bowman, in section 18, at the west side of Prior, burning about 300 barrels of lime yearly, which is sold for $1.25 per barrel; E. T. Hanes, in section 5, at the south side of Prior, burning some 150 barrels yearly, selling at $1 per barrel; Jacob Hurley, in section 19, Big Stone, producing 150 barrels yearly since 1870, selling for $1.25 per barrel at the kiln; and Alfred Knowlton, in section 5, Ortonville, a mile north from the town, producing annually 300 to 500 barrels of lime, which is sold for $1.25 per barrel, used in Ortonville and Big Stone City. About a tenth or twentieth part of these boulders yield yellowish or cream-colored lime, while the remainder make lime of snow-like whiteness. In Lac qui Parle county lime is burned in similar small amount from boulders by Mr. Peterson, in the north part of Hantho; by Ole Gunderson, one and a half miles northeast from Lac qui Parle village, selling at $1.25 per barrel; and by Henry Johnson and Andrew Amarude, in Camp Release township.

Brick-making has not been undertaken in Big Stone or Lac qui Parle counties; but at Big Stone City, in the edge of Dakota, this business was begun in 1879 by Tobias Oehler, who made 240,000 that year and about 800,000 in 1880, selling at $10 per thousand. These are light red bricks, of good quality. The deposit from which they are made lies upon the general surface of the drift-sheet, about a hundred feet above Big Stone lake and the Minnesota river. After stripping off the black soil, the next three feet, consisting of yellow clay free from gravel, is used, mixed with one-fourth as much sand. This clay extends lower, but is there somewhat gravelly. It is said to cover several acres, and is apparently a bed of modified drift, formed when the last ice-sheet retired.

ABORIGINAL EARTHWORKS.

At Big Stone City two aboriginal mounds of the usual circular form, each having a hight of about six feet, were noticed upon the verge of the bluff of the Minnesota valley a quarter of a mile north of the Whetstone river. Their distance apart from north to south was about six rods. Two or three other mounds, of similar size, are seen also on the top of the bluff near its edge, three-quarters of a mile south from these.

In Lac qui Parle township, four mounds occur similarly on the verge of the bluff at the southwest side of the Minnesota valley, about a quarter of a mile east of the Lac qui Parle river, and one and a half miles northeasterly from the village of this name. These mounds lie in a nearly straight line, extending about twenty rods from northwest to southeast, parallel with the edge of the bluff and only three or four rods from it. The most northwestern mound here is seven feet high, and the others five to three feet in hight, decreasing toward the southeast; but they cover nearly equal areas, each being about fifty feet in diameter.

CHAPTER XXII.

THE GEOLOGY OF LE SUEUR COUNTY.

BY WARREN UPHAM.

Situation and area. Le Sueur county (plate 30) is in the southern part of Minnesota, and is bounded on the west by the Minnesota river in its course northward from its great bend at Mankato. The distance from Le Sueur, the county seat and largest town, northeasterly to Saint Paul and Minneapolis is 50 miles; east to lake Pepin, 80 miles; south to the Iowa line, 67 miles; and west to the Dakota line, 125 miles. Other considerable towns and villages in this county are East Henderson, Ottawa, East Saint Peter, Kasota, and Caroline, on the Chicago, Saint Paul, Minneapolis & Omaha railway; New Prague, at the north line of the county, lying partly in Scott county, Montgomery, Kilkenny and Waterville, on the Minneapolis & Saint Louis railway; and, between these lines, Heidelberg, Lexington, Cordova, Cleveland, Marysburgh, and Elysian. The area of Le Sueur county is 472.48 square miles, or 302,388.18 acres, of which 17,891.77 acres are covered by water.

SURFACE FEATURES.

Natural drainage. The Minnesota river receives the drainage from three-fourths of this county; and the remainder, a tract of about 120 square miles in its southeast part, is drained easterly to the Mississippi by the Cannon river.

The principal tributaries of the Minnesota river in Le Sueur county are Shanaska creek, about seven miles long, the outlet of lake Washington, which enters the Minnesota river between Kasota and East Saint Peter; Cherry creek, about thirteen miles long, the outlet of Scotch, Decker, and other small lakes in Cleveland and Cordova, which unites with the Minnesota close south of Ottawa; Le Sueur creek, nearly twenty miles long, the outlet of Rice lake in Sharon and other lakes, which joins the Minnesota close north of Le Sueur, after receiving from the northeast, about a mile above its mouth, the Little Le Sueur creek, some twelve miles long, whose sources are Clear lake and lake Mary near Lexington and School Section lake in the southeast corner of

Derrynane; a small creek, about seven miles long, which flows from Clark's lake in Scott county southerly into Tyrone and enters the Minnesota at East Henderson; and Sand creek, which drains the north part of Derrynane, all of Lanesburg except its southwest corner, and the northeast part of Montgomery, lakes Pepin and Sanborn, and Hunt lake, in the two last named townships, at the head of this stream, being sixteen to eighteen miles in a straight line from its mouth, which is two miles north of Jordan in Scott county.

The highest sources of the Cannon river are several lakes in Shieldsville, Rice county, whence this stream flows westerly twelve miles, crossing Kilkenny, receiving the overflow of lakes Dora and Volney, and entering lake Gorman at Cordova. Next its course is southerly eight miles, passing through Saber lake in section 30, Kilkenny, and entering the west part of lake Tetonka in Waterville. Above Saber lake this is called Big Cannon river, to distinguish it from a smaller stream, known as Little Cannon river, which flows into Saber lake from the east. About a mile above its mouth into Lake Tetonka, this river receives a tributary from the west, which is the outlet of lake Bossuot in sections 29, 32 and 33, Cordova, and of German and other lakes in the north part of Elysian. In Waterville the Cannon river flows through lakes Tetonka and Sakata, which together extend from the west to the east line of this township, being connected by a stream only about a quarter of a mile long. A considerable creek, whose basin extends into northern Waseca county, enters the west part of lake Sakata. The townships of Le Sueur county which are partly or wholly drained by the Cannon river are Waterville, excepting perhaps half a section in its southwest corner, the northeast half of Elysian, the southeast half of Cordova, all of Kilkenny, and the southern third of Montgomery.

Lakes. Among the lakes of Le Sueur county the following deserve mention: lake Jefferson, lying principally in Washington and the northwest corner of Elysian, five miles long from east to west and from an eighth to two-thirds of a mile wide, very crooked, with an arm or branch on the south about two miles long; lake Washington, also of quite irregular form, having an area of about two and a half square miles, lying mostly in the southwest part of Washington; lake Emily, mainly in section 26, Kasota, two miles east of Saint Peter, similarly irregular in outlines, but only a little more than a mile long, very picturesque, bordered partly by woods, but mostly by fertile and well cultivated farms, its west end being near the verge of the bluff which descends two hundred feet from this lake to the bottomland of the Minnesota valley; Scotch lake, one and a half miles long from east to west, in sections 22 and 23, Cleveland; Clear lake, three-fourths of a mile in diameter, in section 10, Lexington; lake Pepin and lake Sanborn, each about a mile long, in Lanesburg; lake Dora, nearly two miles long from northwest to southeast, in the north part of Kilkenny; lake Gorman, one and a quarter miles long from north to south, and from a half mile to one mile wide, lying mostly in sections 12 and 13, Cordova; German lake, covering about a thousand acres, mainly in sections 4 and 5, Elysian, and lake Francis, three miles long from east to west, in the south part of this township; lake Elysian, whose north end is crossed by the south line of the county at the south side of sections 35 and 36, Elysian; and lake Tetonka, four miles long from west to east and averaging a half mile in width, lying mostly in sections 19, 20, 21 and 22, Waterville, and lake Sakata, about three miles long and also averaging a half mile wide, extending eastward from Waterville and reaching into Rice county.

Topography. The terminal moraine accumulated on the east side of the Minnesota lobe of the last ice-sheet, consisting of hills, mounds and ridges of till, occupies the east edge of Le Sueur county and the adjoining western half of Rice county. Its west border extends from near the northeast corner of Le Sueur county southward by lake Sanborn, Montgomery, Greenleaf lake, lake Volney and Saber lake, to Waterville. The hills of this tract, constituting the highest part of the county, are 50 to 75 feet above the intervening depressions, or from 1100 to 1125 feet above the sea. In Montgomery and Kilkenny they are principally massive swells with smooth slopes, only 30 to 50 feet in hight. The most prominent hills seen in this county are south of lake Sakata, one to two miles east of Waterville. They were found by Nicollet to be 134 feet, according to the barometer, above this lake, which makes their tops 1137 feet above the sea.

West of this moraine, the greater part of the county is slightly or moderately undulating till, approximately level, to the valley of the Minnesota river. The bottom of this fertile and beautiful valley is from 200 to 225 feet below the general level. The tops of its bluffs of till are from a half mile to two miles, and between Ottawa and Le Sueur four miles, distant from the river. Within these bluffs are high terraces of modified drift, the largest of which, called "Le Sueur prairie," extends five miles south from Le Sueur, with a width that varies from two to four miles; terraces of Shakopee limestone, underlain by Jordan sandstone, occurring at Ottawa and from Kasota south to Mankato; and bottomlands, which are usually from an eighth to a fourth or half of a mile wide, but attain a width of one and a half miles for a distance of three miles in the north part of Kasota.

The contour of the drift-sheet between the eastern moraine and the Minnesota valley varies from moderately undulating or rolling to nearly flat. Its most uneven portion is a belt near the south side of the county, in Elysian, Washington and Kasota, extending westerly from Waterville and Elysian to German lake and lakes Jefferson, Washington and Emily. The undulations and swells here are mostly from 25 to 50 feet high, having smooth outlines and long slopes; but between lakes Tetonka and Elysian the surface is in part quite irregularly broken in small hills and short ridges, which one and a half miles northeast of Elysian are about 75 feet high. This belt is apparently a moraine formed on the south side of the ice-lobe during a pause in its recession.

The south part of Kasota, from lake Washington four miles west to the valley of the Minnesota river is only slightly undulating, with the highest portions 5 to 15 feet above the lowest. Cordova, Lexington, Derrynane and Lanesburg are moderately undulating, with crests 20 to 30 or 40 feet above the hollows and frequent lakes. These townships show a somewhat gradual change from the morainic contour on their east side to the slightly undulating and in some portions nearly level surface of Cleveland, Sharon and Tyrone in the range next west.

Elevations, Minneapolis & Saint Louis railway.

From Robert Angst, assistant engineer, Minneapolis.

	Miles from Minneapolis.	Feet above the sea.
New Prague	42.6	975
Montgomery	50.0	1063
Mulford's siding	54.6	1060

	Miles from Minneapolis.	Feet above the sea.
Town-line road between Montgomery and Kilkenny	54.9	1056
Lake Dora, grade	55.8	1044
Lake Dora, high water	55.8	1040
Cannon river, grade	56.9	1045
Cannon river, water	56.9	1038
Kilkenny	58.6	1056
Little Cannon river, grade	59.1	1037
Little Cannon river, water	59.1	1019
Summit, grade	62.3	1070
Summit, highest natural surface	62.3	1089
Summit, highest grade	63.0	1080
Cannon river, bridge	65.0	1004
Cannon river, water	65.0	994
Waterville	65.4	1008
County-line road between Waterville and Iosco	67.0	1049

Elevations, Saint Paul & Sioux City division, Chicago, Saint Paul, Minneapolis & Omaha railway.

From profiles in the office of T. P. Gere, superintendent, Saint Paul.

	Miles from St. Paul.	Feet above the sea.
East Henderson	56.8	740
Le Sueur creek, bridge	60.1	745
Le Sueur creek, water	60.1	730
Le Sueur	61.5	759
High water in the Minnesota river at Le Sueur	61.5	741
Ottawa	67.6	796
East Saint Peter	73.4	754
Shanaska creek, grade	74.7	785
Shanaska creek, water	74.7	747
High water of the Minnesota river here	74.7	756
Kasota Junction	75.9	806
Summit, grade	77.8	843

Elevations, Winona & Saint Peter division, Chicago & Northwestern railway.

From John E. Blunt, engineer, Winona.

	Miles from Winona.	Feet above the sea.
Kasota	133.8	804
Minnesota river bridge	135.0	791
Minnesota river, low and high water	135.0	733–756

Surveys by the United States engineer corps, and for railroads, have supplied the following elevations of the

Minnesota river.

	Feet above the sea.
At East Henderson, low and high water	711–727
At Le Sueur, low and high water	717–741
At Ottawa, low water	723
At East Saint Peter, low water	730
At the Winona & Saint Peter railroad bridge, low and high water	733–756
At the south line of Le Sueur county, low water	743

Estimates of the average hights of the townships of Le Sueur county are as follows: Lanesburg, 1,020 feet above sea-level; Montgomery, 1,050; Kilkenny, 1,050; Waterville, 1,040; Derrynane, 975; Lexington, 980; Cordova, 1,020; Elysian, 1,050; Tyrone, 940; Sharon, 940; Cleveland, 975;

Washington, 975; Le Sueur, 810; Ottawa, 860; and Kasota, 880. The mean elevation of the county derived from these figures is 985 feet above the sea.

Soil and timber. The black soil of this region has generally a depth of about two feet. It is clay with some admixture of sand and gravel and occasional stones and boulders, being the upper part of the glacial drift, colored by vegetable decay. Below this black stratum, the subsoil is the same gravelly clay, yellowish for the next ten or twenty feet, and then darker and bluish to a great depth which is seldom passed through by wells.

In the fertility of its soil and its agricultural capability Le Sueur county is the peer of any in Minnesota. The undulating surface causes the water of rains and of snow-melting to be soon drained away, excepting the portion which the soil absorbs to be given out for the growth of plants. Perhaps a tenth part of this county is occupied by its abundant lakes, its equally numerous but smaller marshes, which are not wooded and bear excellent wild hay, and by the bluffs and ravines of streams; the remaining area (excepting occasional small tracts of the moraines, more than ordinarily knolly and stony) is adapted for cultivation. The staple crops are wheat, oats, barley, corn, hay, flax, sorghum, potatoes, and the common vegetables and small fruits of the garden.

This county lies within the southeast part of the extensive forest, a hundred miles long from north to south and forty to fifty miles wide, which is commonly called the Big Woods, being a southern lobe of the great wooded region of northern Minnesota and British America. Heavy timber originally covered the whole county, except small tracts of marsh, which would be called sloughs in a prairie district, and certain areas in the Minnesota valley, as the Le Sueur prairie and the terrace of limestone south of Kasota. Since the first immigration, some twenty-five years ago, much of this timber has been cleared off and the land brought under cultivation, the stumps being got rid of within ten years by burning and pulling, leaving the fields smooth for the plow and the reaper. The principal kinds of trees found here are bass, sugar maple and soft maple, box-elder, wild plum, the wild red cherry and black cherry, American crab-apple, Juneberry, white and black ash, white or American elm and slippery or red elm, hackberry, butternut, black walnut, bitternut, black and bur oaks, ironwood, water beech, paper or canoe birch, common poplar or aspen, the large-toothed poplar, cottonwood, and (rarely) red cedar. The last two occur mostly beside rivers and lakes. Nearly everywhere through this forest, its two largest and most plentiful species of trees are the bass and the white elm. Its shrubs include prickly ash, smooth sumach, frost grape, Virginian creeper, climbing bitter-sweet, red and black raspberries, wild rose, thorn, choke-berry, prickly and smooth gooseberries, black currant, two or three species of cornel, wolfberry, honeysuckle, elder, sweet viburnum, high-bush cranberry, hazel-nut, and willows.

GEOLOGICAL STRUCTURE.

Jordan sandstone and Shakopee limestone. The only exposures of the bed-rocks of this county consist of two members of the Lower Magnesian or Calciferous series, namely the Jordan sandstone and the overlying Shakopee limestone, which form terraces about 75 feet high in Kasota and Ottawa, within the valley of the Minnesota river. Fluvial erosion, since the ice age, has excavated this great channel through the sheet of till which forms bluffs on each side of the valley 150 feet above these rock-formations; but a river that flowed here long before the ice age, had cut deeply into the rocks and sculptured them nearly as they are now seen. Their terraces are produced by the persistence of the hard limestone lying above the soft and easily eroded sandstone. These formations are nearly horizontal in stratification and mainly conformable with each other; as if in the same sea, with no evidence of important change in level or in the relations of land and sea, the deposition of sandstone, after having formed a stratum fifty feet or more in thickness over a large area, was succeeded by the formation of an equally extensive and thicker stratum of magnesian limestone.

The Jordan sandstone is white or light gray, excepting small portions where it is stained by infiltrating ferruginous waters. In texture it varies from a fine-grained to a coarse-grained deposit, and rarely encloses small pebbles. Nearly all its material is quartz, the particles of which are mostly rounded by water-wearing. When exposed to the air in dry situations, it becomes harder and more firmly cemented than in its natural bed, where it is so friable that it can be excavated by a shovel and pick. Its name is from Jordan in Scott county, where this formation is well exhibited and has been considerably used as a building stone.

The overlying Shakokee limestone, so named from the town where it is best exposed in Scott county, is a hard, buff-colored, mostly thick-bedded, in many portions siliceous and cherty, magnesian limestone or dolomyte. The whole thickness of this formation in Le Sueur county was apparently from 50 to 75 feet or more, but only its lower 10 to 25 feet remain in the outcrops of Le Sueur county.

The terrace of these strata in Kasota is from one to one and a half miles wide. It is about 75 feet above the river, and extends eight miles from Kasota to Mankato, its northern half, four miles long, being in Le Sueur county. On its surface is generally spread a coarse, water-worn gravel, from one to five feet thick, holding multitudes of rock-fragments of all sizes up to one foot in diameter, chiefly derived from the limestone which forms the terrace. In some places, also, it is sprinkled with boulders, mainly of granite, gneiss, and schists, of all sizes up to five feet in diameter and rarely larger. The railroad well at Kasota station went through drift, mostly limestone gravel, 8 feet; solid limestone, 21 feet, and sandstone, 6 feet. Here and generally in this vicinity, the base of the limestone is approximately 40 feet above the river; but it sinks to about half this hight in going one and a half miles northward in Saint Peter, from the railroad bridge to the highway bridge.

Ottawa is situated on another terrace, one and a half miles long and three-fourths of a mile wide, composed of the same formations of limestone and sandstone. Their junction in the bluff near Charles Schwartz's limekiln is about 45 feet above the river. The terrace generally rises 20 or 25 feet higher, which is about the average depth remaining of the limestone.

In both these formations fossils are usually absent; but they occur numerously in some layers of each at a few localities. Dr. B. F. Shumard, who assisted Owen, reports that in outcrops of the sandstone a mile above Traverse des Sioux, in the bed of the Minnesota river near its most eastern bend in the north part of Kasota, "one of the layers is highly charged with casts of *Euomphalus Minnesotensis*." He also found this gasteropod and the pygidium of a small trilobite at Kasota in this sandstone in the river-banks. The cliff formed by these strata beside the Minnesota river at Ottawa is called by Dr. Shumard the White Rock bluff. Its hight is stated to be 72 feet, the base being concealed by a talus to the hight of 30 to 40 feet, above which are in ascending order, "white and brown sandstone, composed of rounded, rather coarse, semi-transparent grains of quartz, loosely cemented, 20 feet; green siliceous earth, 1 foot; seam of grayish oölitic chert, with a thin incrustation of whitish decomposing chert, 2 to 3 inches; light salmon-colored magnesian limestone, with dendritic markings, and cavities lined with crystals of calcareous spar, in layers from a few inches to two feet in thickness, containing *Lingulæ*, *Orthis*, and trilobites, 11 feet. The magnesian limestone at this locality . . . . contains two kinds of *Lingulæ*; one, an elegant little species, of an ovate shape, with fine concentric striæ, is not distinguishable from *Lingula Dacotaensis*, a form which characterizes the Lower Magnesian limestone, at the quarry near Stillwater, and other localities throughout the Chippewa Land District; the other, of which we obtained only a few fragments, is much larger, but the specimens are so imperfect that the characters of the species cannot be made out. Associated with these *Lingulæ*, we find the cast of a small *Orthis*, with fine radiating striæ, and portions of the cephalothorax of a trilobite, related to the family *Olenidæ*." Again, in this limestone at Kasota, Dr. Shumard detected "*Lingula Dacotaensis*, and the remains of a species of trilobite, apparently identical with that occurring at White Rock."

An analysis of the Shakopee limestone at Ottawa, given in Dr. Shumard's report, is as follows:

Carbonate of lime	58.65
Carbonate of magnesia	29.15
Insoluble matter	7.25
Alumina, oxide of iron, and manganese	1.55
Water	2.65
Loss	0.75
	100.00

Analyses of this limestone in Kasota, made by Prof. S. F. Peckham, are as follows, the first being the stone extensively quarried for building, and the second that burned for lime by Mr. Clapp near Caroline station:*

	1.	2.
Calcium carbonate	47.904	52.22
Magnesium carbonate	35.227	36.04
Calcium sulphate	......	6.74
Insoluble matter, chiefly silica	13.85	2.82
Aluminic and ferric oxides	1.49	1.39
Water and alkalies, undetermined	1.529	.....
	100.00	99.21

In the southern part of Kasota the upper layer exposed of this limestone has been used for lime-burning. Of its character here Prof. Winchell writes:† "George C. Clapp's lime-kiln and quarry are five miles below Mankato, on section 17, township of Kasota, within the main drift bluffs of the Minnesota, but on the terrace formed by the Shakopee limestone, and about a mile from the river. His quarry, located near his kiln, exposes a fine gray limestone, about two feet thick, sometimes less or more, graduating into the Shakopee stone which underlies. It is very firm, little porous, and contains *Orthis*, at least, and affords the finest and purest limestone hitherto seen in the Shakopee stone. . . . . . This fine, compact texture, and gray color, are not continuous in the same horizon, in other places the harsh magnesian grain and arenaceous quality existing in the same beds. Running along the river for several miles, sometimes touching the river, and sometimes exposed back of islands that show the same, this limestone forms a bluff of solid beds. Although there is usually a heavy talus covering the foot of this bluff, yet at several points the identity of this horizon with that at St. Peter, and hence with that at Shakopee, is fully established by the exposure of the underlying sandstone. It is seen at a point about two miles below Mr. Clapp's farm. This bluff shows a good stone, as at St. Peter and Kasota, but is not much quarried. Perhaps it is more arenaceous in patches. It is blotched with whiter spots and with soft chert."

At the Kasota quarries the section, below the 3 to 5 feet of alluvial limestone gravel which forms the surface, is this Shakopee limestone, thin-bedded for its first 4 or 5 feet, the lower part of this being used for flagging; then thick-bedded, in level layers up to two and a half feet thick, of pinkish buff color, supplying the best quarry-stone, 4 feet; next, less evenly stratified, in layers only one foot or less in thickness, and light-colored, 3 feet; beneath which it lies in irregularly curved beds, is coarse-grained and contains little cavities, as at Shakopee, and is mottled, in the usual manner of this formation, with yellowish and pink tints. This limestone extends here some 20 feet in depth, being underlain by the Jordan sandstone about 40 feet above the river.

Opposite to the city of Saint Peter, about a mile south of the highway bridge, and a similar distance northeast from these quarries at Kasota, Prof. Winchell describes "another exposure of the limestone, in a bluff along the roadside. It seems here to be more shattered and irregular, and like the Shakopee stone. Lime burned here cannot be distinguished from the Shakopee lime. About eighteen feet are seen, the lower part being in good heavy beds. The upper surface is water-worn, and in the openings the Cretaceous has been deposited."

*Seventh annual report, p. 33; eighth report, p. 151.
†Second annual report, p. 144.

Four to five and a half miles farther north is the rock-terrace on which Ottawa is built. The section of this terrace, as shown by a well 55 feet deep, at Levi Case's former residence in the west part of the village, about a sixth of a mile southeast from the ferry, is as follows: soil and gravel, 3 feet; yellow clay, 3 feet; Shakopee limestone, of the usual character, hard, yellowish-buff in color, partly siliceous and cherty, in beds from a few inches to one or two feet thick, 25 feet; and soft, white Jordan sandstone, 24 feet and extending lower, containing water, which fills the well to a depth of nine feet. At Charles Schwartz' limekiln, in the N. W. ¼ of section 27, Ottawa, a mile north of the village, the bluff composed of these strata rises 55 feet above the Minnesota river, which flows at its foot. This bluff also reaches a quarter of a mile or more southward with nearly the same hight. Its upper 10 to 15 feet are the yellowish Shakopee limestone, enclosing occasional sandy patches and layers, levelly stratified, in beds from two or three inches to a foot, or rarely more, in thickness. The sandstone, as usual, is friable, partly fine and partly coarse, and consists almost wholly of water-worn quartz grains. It is level in stratification, but often its horizontal layers show an oblique lamination. It is mainly white, but in some parts is stained yellow by iron-rust; and it is streaked with green and pink in its upper one or two feet, next to the limestone. By the recent undermining of this bluff, the sandstone is shown to extend to the level of the river, being thus at least 45 feet thick.

An outcrop of the Jordan sandstone alone is found at William Matheny's house, about twenty-five rods east of the Ottawa ferry, having an extent of some fifty feet, but not exposing more than five feet in vertical thickness. Its hight is about 35 feet above the river. The upper layer, eight inches thick, is more cemented and harder than ordinary, and of a pink color; while the lower part is softer, friable and white. The horizon of this ledge is probably the top of the Jordan formation; for Prof. Winchell states that a little ravine, cutting the bluff a mile farther north, near Schwartz' kiln, shows the upper portion of the sandstone there to be a hard, reddish bed, one foot thick, underlain by the usual white, crumbling sandrock.

Cretaceous clay. Hollows and crevices in the Shakopee limestone at Ottawa have been filled by clay, which is commonly white or, before weathering, light bluish or green, but on Cherry creek is mostly a red ocher, colored by the anhydrous sesquioxide of iron. These deposits are believed to be of Cretaceous age. They are similarly exhibited in water-worn cavities of this limestone in Kasota and Saint Peter, and in Mankato and South Bend, Blue Earth county; and in the report of that county a more full notice of their character and probable origin has been presented.

At John R. Clark's quarry in Ottawa, a vertical seam or crevice in the limestone, one or two feet wide, extending six feet and more in depth, the bottom not being reached in this quarry, and exposed along a distance of eight rods in nearly a straight course from east to west, is filled by white clay of this kind. Nearly in the direction of this crevice, the same white clay was found about twenty-five rods farther east, in Charles Needham's well, filling a similar crevice or the continuation of this, in the limestone.

A half mile south of Ottawa, Cherry creek has cut a channel or valley about 20 feet deep in this terrace, its upper ten feet being the Shakopee limestone, with the Jordan sandstone below. In the lower part of this limestone, along a distance of an eighth of a mile, are frequent water-worn, pocket-like cavities, which are filled with this clay, partly white, but in more places brick-red and suitable for paint. It has been so used, and is said to work well, and is durable.

Glacial and modified drift.

The thickness of the drift-sheet which covers Le Sueur county, excepting the Minnesota valley, where it has been eroded, is from 150 to 250 feet. It is mainly till or the unmodified deposit of the ice-sheet, but encloses occasional layers of stratified gravel and sand, commonly only a few inches or at most a few feet thick. From these veins or beds of modified drift, wells often obtain a large supply of water under such pressure that it rises considerably above the stratum in which it is found.

The only well in this county that has gone deep enough to strike the bed-rock beneath the drift east of the Minnesota valley is at Montgomery, and was bored to supply water for Miller & Phelps' flour mill. Its depth is 246 feet, the section being till, yellow near the surface and dark blue below, 186 feet, containing a layer one and a half feet thick of blue sand at the depth of 130 feet; then sand, mostly soft, but hard in occasional layers six to twelve inches thick, 55 feet, to white sandstone, probably the Saint Peter formation, into which the well was bored only 5 feet. Water, coming plentifully from this porous sandstone, rose 130 feet. No fossils were observed.

A bed of cemented gravel and sand, made a hard conglomerate rock by the deposition of carbonate of lime and magnesia from infiltrating water, occurs in the modified drift about a half mile east of Le Sueur, being in the east side of a ravine near the center of section 36, where the Le Sueur prairie descends to the second terrace. The thickness of this stratum is about 10 feet. It has been quarried by John Bachmann to supply the stone for waling his cellar.

About one and a half miles farther east, probably in the N. E. ¼ of section 31, Tyrone, the road along the south side of the Little Le Sueur creek, in ascending to the surface of the general drift-sheet, has made several cuts in till, which is weathered to a yellowish color, and here contains thin, light-gray, calcareous veins or seams, apparently concretionary in their origin, varying from an eighth to a half of an inch in thickness, and extending at least three or four feet, interlocking with each other in crookedly vertical, oblique and horizontal directions. The only observation similar to this, which I can refer to, was near Mankato Junction, and is described and figured on page 442. Finely pulverized magnesian limestone is a considerable ingredient in the drift of all southern and western Minnesota.

Terminal moraines. In the description of the surface features of this county, the contour of the terminal moraines which cover its east edge and cross its southern part has been already described. The material of these rolling and hilly belts is generally till, containing more numerous boulders and a larger proportion of small stones and gravel than in its smoother tracts. The morainic swells and hills in this county rarely show any uniformity or system in their trends; but the lakes in the southern townships are quite noticeably elongated from east to west, thus trending in parallelism with the course of the moraine there. Modified drift is occasionally found within these areas, as was seen at the southeast edge of the village of Waterville, where a cut on a hill-side to the depth of twenty feet, having its top forty feet above lake Sakata, is sand and fine gravel obliquely and irregularly stratified, as in kames.

The broad belt of morainic drift upon the east side of this county and in Rice county is a compound formation, consisting of the eastern marginal deposits of the Minnesota lobe of the last ice-sheet, accumulated while this side of the ice-lobe remained nearly stationary through a long time, during which its southern and western border had formed five distinct moraines and had retreated great distances from its farthest limit. When its first or Altamont moraine was accumulated at the extreme boundary of the ice in this epoch, it reached south to Des Moines; when the second or Gary moraine was formed, it terminated on the south at Mineral ridge, in Boone county, Iowa; at the time of the third or Antelope moraine, it had farther retreated to Forest City and Pilot mound in Hancock county, Iowa; the fourth or Kiester moraine was formed when the southern extremity of the ice-lobe had retreated across the south line of Minnesota and halted a few miles from it in Freeborn and Faribault counties; and the fifth or Elysian moraine, crossing southern Le Sueur county, marks the next halting-place of the ice in its recession northward. At the time of formation of this fifth moraine the south end of the ice-lobe had been melted back a hundred and eighty miles from its farthest extent, and its southwest side had retired thirty to fifty miles from the crest of the Coteau des Prairies to the east side of Big Stone lake and the east part of Yellow Medicine county; but while these great changes in the area of the ice-lobe were taking place, its eastern boundary in Rice and Le Sueur counties had fluctuated only slightly, so that a broad compound morainic belt there represents the five moraines which were formed on the south and west. During the next recession of this ice-lobe, it was melted away from the whole of Le Sueur county, and its southeast extremity was withdrawn to Waconia in Carver county, where it again halted, forming its sixth or Waconia moraine.*

It is evident that when the ice began to retreat its increased melting caused the prevailing westerly winds, sweeping over the western side of the ice-sheet upon the Coteau des Prairies and eastward, to become more laden with moisture than in the earlier part of this epoch when there was comparatively little melting upon the surface of the ice in this latitude; and that the increased temperature enabled these winds to carry their moisture farther than when the ice had its greatest extent. As a result, the snow-fall became greater than before upon the east portion of this ice-lobe, maintaining and even in part enlarging its area on that side during the early stages of the recession from its farthest limit southwestward.†

*Compare pages 406, 463, 478, 581, 605-6 and 621.

†The climatic conditions indicated by the unequal rates in the final melting of the west and east sides of this ice-lobe, were first pointed out in a paper entitled "Changes in the currents of the ice of the last glacial epoch in eastern Minnesota," *Proc. Amer. Assoc. for Adv. of Science*, 1883.

A glacial lake covered much of Le Sueur county during the recession of the ice, which was a barrier upon the lower part of the Minnesota basin. The outflow from this lake in its latest stage appears to have been by the route of lakes Tetonka and Sakata and the Cannon river.*

Terraces of modified drift. The valley of the Minnesota river in this county, and in Nicollet county opposite, contains high terraces or plains of modified drift, elevated about 150 feet above the river and bordered by bluffs of till that rise 50 to 75 feet higher. These terraces are evidently remnants of an ancient flood-plain of the Minnesota river, which was deposited after the valley had been excavated through the sheet of till. Their frequent occurrence along a distance of a hundred miles, from New Ulm to the mouth of the river, shows that this valley was here filled with deposits 75 to 150 feet thick, sloping about two feet per mile, through which the channel has been cut anew. Extensive portions, however, of the bluffs on each side in this part of the valley are destitute of any traces of modified drift, which has been wholly removed by the river, besides perhaps some encroachment upon the bluffs of till.

Remnants of the valley drift in Le Sueur county are a terrace east and south of Kasota, and the Le Sueur prairie. The first reaches from the S. E. ¼ of section 28 to the S. E. ¼ of section 8, Kasota, being three and a half miles long. Its width is from one-third to two-thirds of a mile. In hight it is approximately 75 feet below the plain of till which begins at the top of the bluff on its east side, 75 feet above the railroad and plain or terrace of Shakopee limestone on its west side, and 150 feet above the river. A mile from its north end it is crossed by Shanaska creek, in the S. E. ¼ of section 33. Thence through one and a half miles southwest to the south side of section 5, the outer part of this bank of modified drift for an average width of a quarter of a mile is 20 to 25 feet below its main portion, thus constituting a lower terrace, 50 feet above the limestone plain. These terraces, below the soil, are composed in part of laminated clay or silt, but are mostly fine gravel and sand, extending in at least one place to a depth of 60 feet, as shown by a well. They have no boulders, excepting upon the slope at their west side and in its short ravines, where ordinary granitic and gneissic boulders up to five feet in diameter are often quite abundant. These probably belong to a ridge of till underlying the west border of the stratified drift.

Le Sueur prairie extends five miles, from the middle of sections 25 and 26, Ottawa, north to the middle of section 36, Le Sueur. In width it varies from two to four miles, the greatest width being from the east part of section 17, Sharon, to the west side of section 14, Ottawa. This area is mainly a plain about 150 feet above the river, descending ten or fifteen feet northward in its length of five miles. Its material is sand and fine gravel, with thin layers of clay, extending from 50 to 100 feet in depth, as shown by wells, which find till below. A few miles southwest, on the opposite side of the river, a similar extensive plain of modified drift, at about the same hight, lies northwest of Saint Peter, and is known as the "Sand prairie". Both these tracts are properly included within the Minnesota valley, for its bluffs of till rise to the general level, 50 to 75 feet above them, at the border of each on the side away from the river. The south branch of Le Sueur creek flows through the east part of Le Sueur prairie in Sharon, from the church in the S. E. ¼ of section 19 to Glen mills, beyond which to its mouth it forms the northern boundary of this area of modified drift. A mile farther west this plain is crossed from south to north by a channel which the Minnesota river excavated during the process of removing its plain of valley drift, the rem-

*For the history of this glacial lake, see pages 461, 606 and 622.

nants of which we have here and in the Saint Peter "sand prairie". The length of this ancient channel is three and a half miles, beginning a mile northeast from Ottawa and extending diagonally northeast across section 23, and along the east side of sections 14, 11 and 2. For the greater part of its course it is about a fourth of a mile wide, but at its southern end its width is half a mile or more. Its depth is 40 feet below the Le Sueur prairie, two to three miles wide at its east side, and the same below the part of this plain, one-fourth to three-fourths of a mile wide, which lies west of this channel, constituting a plateau that reaches from a point one and a half miles northeast of Ottawa to a cemetery situated on its north end about three-quarters of a mile south of Le Sueur.

Two other terraces of valley drift, or stratified gravel, sand and clay, occur at Le Sueur, intermediate in hight between the Le Sueur prairie and the bottomland. That next to the upper prairie is at its northwest side, and forms a plain a quarter to a half of a mile wide and two miles long from southwest to northeast, occupying a considerable part of section 2, Le Sueur, the southeast part of section 35, and most of section 36, except its southeast quarter. The east margin of the town of Le Sueur, and Wetter's brick-yard, are upon this terrace. Its hight is 40 feet below the Le Sueur prairie and about 110 feet above the river, being on a level with the ancient channel which intersects the higher plain and opens at its north end upon this terrace. The next lower terrace, on which the main street of Le Sueur lies, is from twenty to forty rods wide and about three-quarters of a mile long from south to north. In hight it is 60 to 70 feet below the terrace last described, and it slopes northward from about 50 to 40 feet above the river.

Alluvium. The bottomland is mostly from 5 to 15 or 20 feet above the river, and is overflowed by the high water in the spring of nearly every year. The river winds from side to side through this tract of recent alluvium, and in some places directs its current against the higher banks on its border. The width of bottomland on each side of the river thus varies from nothing to a half mile or rarely a mile. Its widest tract seen at any place along the course of the Minnesota river is in this county, in the three miles northeast from Saint Peter, where its width is about one and a half miles.

Boulders. Lake-ridges. Boulders of granite, gneiss, schists, and limestone, in size seldom exceeding five feet, occur sparingly in the till of this region on its smooth and gently undulating areas, but are more numerous and in some spots abundant on the hilly and knolly morainic belts. On the shores of lakes they are often seen in unusual numbers, because the waves have washed away the fine material of the till, leaving its stones at the base of the eroded bank. Elsewhere, against low shores, these shallow bodies of water have been frozen in winter to their bottom; and the ice, by the slight expansion of freezing, has in the process of centuries slowly pushed many boulders outward from the lake-bed to its border. In this manner, at the head of lake Elysian, near Okaman, blocks of stone of all sizes up to six feet in diameter have been accumulated in a wall-like ridge four to six feet high and twenty rods or more in length.

More frequently the ice of the lakes has pushed out and heaped up at their edge a rather broad ridge of gravel and sand, with few or no boulders, having a hight of about five feet above the average level of the lake and often an equal or but little less elevation above the adjoining marsh or lowland, and varying in width from two to six rods. Such ridges were noted at the north side of Clear lake in Lexington, and the northwest side of lake Volney in the southeast corner of the same township, the latter extending an eighth of a mile.

A piece of copper, weighing about one pound, is reported to have been found in the drift at Ottawa. It was probably brought from the region of lake Superior in the early glacial epoch when the ice covered its greatest area; for the current of the last ice-sheet which overspread this region, forming the terminal moraines, was from the northwest, bringing, as ingredients of its drift, limestone pebbles and boulders, probably many of them from the vicinity of Winnipeg, and rare fragments of lignite and silicified wood, of which the last must be from Dakota.

Wells in Le Sueur county.

Examples of the sections of wells in the glacial and modified drift are as follows:

Lanesburg. The well at the elevator at New Prague, situated close east of the railroad and south of the main street, which runs on the county line, was bored to a depth of 192 feet. The section was soil and clayey loam, 6; gravel, 4; dark bluish till, 75; fine gravel and quicksand, 4; and again blue till, 103 feet, and extending below. Water, not in large enough amount, was found at 10 feet and again in the quicksand at 85 feet, but none below this, and the well is not used.

Frederick Gosewisch; sec. 7: well, 24 feet; soil, 2; yellow till, spaded, 10; harder blue till, picked, 12; water seeps from the lower part of the yellow till, not a large supply.

At Heidelberg, in the S. E. ¼ of sec. 19, Frank Maertz has made two wells: one, 76 feet deep, was yellowish till, so hard that it had to be picked, 12; and blue till, similarly hard, 64; no sand; water came from the bottom, very dark-colored, so offensive that horses would not drink it. The other well, 77 feet deep, a few rods from the last, went through the same material, finding the till softer and moist in the last ten feet, but yielding no water there. All the water of this well came from a small sand vein at one side of the well 35 feet from the surface; it issues very slowly, filling the well to this hight.

Montgomery. The deep well at Montgomery station, penetrating to the Saint Peter sandstone, has been described on page 640.

J. Brockway; sec. 31: well, 60 feet; soil, 2; yellow till, 28; harder blue till, 30; no water.

Kilkenny. County Poor-farm; sec. 6: well, 30 feet; soil, 2; yellowish till, 20; harder blue till, 8; water rose six feet from the bottom.

J. M. Babcock's steam-mill on the west side of Saber lake; sec. 30: well, 58 feet; soil, 2; yellow till, 6; much harder blue till, 50. Water rose thirty-two feet from the bottom, but is not a large supply and is drained by use for the engine.

Waterville. The well at L. Z. Rogers' elevator, at the same level with the railway station, is 92 feet deep, finding the upper yellowish till, 15 feet; then a small vein of gravel, with scanty water; succeeded by dry, blue till, 77 feet and extending lower. This well becomes filled with surface water, but not in sufficient supply for an engine. The well for the railroad water-tank, about twenty-five rods farther south, though only 15 feet deep, is ample for all demands. The common wells at Waterville are 15 to 25 feet deep, finding a good supply of water, which usually rises from the bottom a few feet.

Charles Slechta; sec. 34: well, 35 feet; soil, 2; yellow till, hard and picked, 31; still harder blue till, 2; with quicksand at the bottom, from which water rose two and a half feet.

Derrynane. Dennis Conway; S. E. ¼ of 20: well, 95 feet; soil, 2; yellowish till, mostly picked, 33; sand and very coarse gravel, containing rounded stones up to one foot in diameter, 2; blue till, harder than the upper till, 3; lighter gray till, very hard, 55 feet, containing no sandy layers, and continuing lower. No water was obtained. Pieces of lignite up to four inches in diameter were found in the dark blue till at 37 feet.

James Kilduff; N. W. ¼ of sec. 28: well, 30 feet; soil, 2; yellow till, 23; much harder blue till, picked, 5; water seeps, mostly at twelve feet below the top. Wells in Derrynane mostly are 15 to 40 feet deep, with water sometimes rising quickly several feet from the bottom, but more commonly seeping, needing a reservoir to be dug below it.

Lexington. Michael Leary; sec. 9: well, 45 feet; yellow till, 15; much harder blue till, 30; no water. Several pieces of lignite were found, up to three inches in diameter.

Cordova. The well at Adam Lucas' steam-mill, in the village and near the shore of lake Gorman, was bored to the depth of 85 feet. Its section was soil, 2 feet; yellow till, 11 feet; gravel, 6 inches; blue till, very hard, 72 feet, to sand, from which water rose to six feet below the top in two hours. The next day it had risen to only six inches below the top, which is estimated to be two feet above lake Gorman. Other wells in Cordova strike water at 30 to 40 feet, which rises ten to twenty feet.

James Brady's well, in the northwest part of this township, 80 feet deep, was soil, 2; yellowish till, 13; bluish till, 45; and dry, whitish sand, 20 feet, not passed through; no water; no fossils were observed.

Elysian. In the village, Edward Shave's well, 62 feet deep, found the following section: soil, 2; yellow till, 18; yellow gravel, 1; bluish till, harder than that above, 1½; again yellowish till, 7; bluish till, 1; gray till, 27; and quicksand, straw-colored, 5 feet, containing water which rises only about one foot above this quicksand.

Samuel Clark; sec. 34: well, 40 feet: soil, 2; yellowish till, 38; water at bottom, not rising.

Tyrone. Cesar Diagniu; sec. 34: well, 19 feet; soil, 2; yellow till, picked, 17; water rose from the bottom twelve feet in a half day.

Sharon. A well seen in sec. 1 of this township, on an extensive level area, was finely laminated, horizontal yellow clay for at least ten feet, to the water. This well was said to be 25 feet deep, being all the way yellow clay, easily dug; but it contains small stones, and is probably till, in its lower part. Such stratified clay is not common, the surface being usually till. Wells in this region are generally only 10 to 30 feet deep, obtaining a good supply of water, which often rises several feet. They seldom reach the blue till, which has a well-known reputation of being harder than the yellow till of the surface.

John Kuenkel; sec. 18 (on the Le Sueur prairie): well, 64 feet; soil, 2; sand, 15; sand and gravel, coarsest below, 47; water at the bottom two feet deep, an abundant supply.

Cleveland. Wells in this township are mostly 10 to 25 feet deep in till, with water rising several feet from the bottom.

F. S. Wilson; Cleveland village: well, 18 feet; soil, 2; yellow till, 12; sand and gravel, 6 inches; blue till, 4 feet. Water came slowly from the sand and gravel between the upper and lower till, filling the well to two feet below its top in two days.

Washington. John Kendall; sec. 6: well, 36 feet; soil, 2; yellow till, picked, 28; blue till, much harder, 6; water seeps from the lowest eight feet of the yellow till, filling the well ten feet deep in the dry season.

John Plant; S. W. ¼ of sec. 9: well, 40 feet; soil, 2; yellow till, so hard that it must be picked, 33; harder blue till, 5; water seeps, coming mostly from a vein of sand seen on the southwest side of the well at 30 feet, being scanty in a dry season.

Le Sueur. Reinhardt Wagner; southwest corner of sec. 1: well, 58 feet; sand and gravel, 56 feet; blue clay, 1 foot; greenish sand, 1 foot, with water rising from it three or four feet.

Ottawa. The wells described in this township, like the last preceding, are within the area of modified drift called the Le Sueur prairie.

E. T. Jones; N. E. ¼ of sec. 23: well, 110 feet; sand and gravel, 100, including a thin clayey layer at about 75 feet; gray till, 10 feet and extending below.

C. N. Pinney; southwest corner of sec. 24: well, 90 feet; consisting wholly of stratified drift, being mostly sand and gravel, the coarsest beds containing pebbles up to six inches in diameter, and also including occasional layers of clay, two to six inches in thickness. The lowest stratum dug through was quicksand, with water, which lasted several years, afterward failing. This lies on very hard bluish till.

J. G. Miller; N. E. ¼ of sec. 26, a quarter of a mile west from the last: well, 60 feet; sand and gravel, 57; blue till, very hard, 3. Another well a hundred feet southwest from this, at nearly the same hight, both being in a narrow valley fifteen feet or more below the general level was 58 feet deep; being sand and gravel, 7; then blue brick-clay, 14 (no corresponding layer was found in the other well); sand and gravel, 34; and yellowish till, 3 feet, much easier to dig than the blue till at the bottom of the other well.

H. F. Von Lehe; southeast corner of sec. 13: well, 55 feet; soil, 2; clayey loam, 5; sand, 30; gravel, fine above, growing coarse below, holding pebbles up to six inches in diameter, 18 feet; with an abundance of water at the bottom, three feet deep.

Kasota. S. D. Payne; S. E. ¼ of sec. 28, on the northern part of a terrace of modified drift which reaches thence three miles south: well, 60 feet deep, all the way in fine gravel and sand, finding no water.

Springs. Wells often encounter, within a moderate depth, copious veins of water which show that there is a subterranean as well as a superficial drainage. The former becomes tributary to the latter by the springs that occur frequently along ravines and water-courses, where these have been excavated so deeply as to intercept the underground currents. In many cases these waters are irony, and deposit a rusty sediment. The only spring noted as deserving special mention in this county is one of very large size, which issues from the foot of the bluff of limestone and sandstone in Ottawa, at a point about a quarter of a mile south of Mr. Schwartz' limekiln.

MATERIAL RESOURCES.

The resources of this county in its fertile soil and abundance of woodland have been noticed on page 636. Water-powers, valuable quarries of building stone, manufactures of lime and bricks, and deposits of peat, remain to be described here.

Water-powers. Four water-powers are used, for manufacturing flour, in Le Sueur county; two being on Shanaska creek within a mile east of Kasota, namely, the Kasota mill, near the center of section 33, having a head of twenty-nine feet, and John Henniker's mill, at the east line of this section, with a head of nineteen feet. The two other powers are afforded by Le Sueur creek, being the Glen mills, near the center of section 6, Sharon, with head of eighteen feet, and William Schlietter's mill, a half mile south of the last, also having eighteen feet head, each of these powers being obtained by carrying the water nearly a half mile in a canal or flume. These streams, and also Cherry creek, run very low in dry seasons, and in the gravelly and sandy lower part of their course, for their one or two miles in the Minnesota valley next to their mouths, were quite dry, but doubtless had some underground drainage, at the time of this examination, in November, 1879.

Building stone. Kasota has the best quarries found in the Shakopee limestone in this state. They are situated beside the railroad close west of Kasota village, about a mile south of Saint Peter. This stone is in beds from six inches to two and a half feet thick, pinkish buff in color, uniform in its texture, easily cut into any desired form, and durable under exposure to the weather. The most extensive business here is that of Breen & Young, who lease from Brackenridge, Stewart & Buttars. They employ thirty-five men and three teams at quarrying and loading upon the cars, the product in 1879 being worth $15,000 as rough stone; it is dressed after reaching their shops in Saint Paul, which brings their sales per year to about $30,000. The largest stone ever shipped by them weighed ten tons, its dimensions in feet being 14 by 8 by 1. Their quarry can supply blocks of large size and 2 or 2½ feet thick; slabs as for cemetery borders, 20 feet long; and flag-stones 10 or 12 feet square and eight inches thick. Examples of the stone from this quarry are the residence of H. J. Willing, of the firm of Field, Leiter & Co., in Chicago; the First Baptist church in Saint Paul; trimmings of the High school building in Minneapolis; and trimmings of the State prison in Stillwater.

The quarry of next importance, adjoining the foregoing, is owned by J. W. Babcock, by whom it has been worked fifteen years, his annual sales being from $5,000 to $10,000. He has used stone to cut up which formed an unbroken sheet sixty feet long. Examples from this quarry are the trimmings of Odd Fellows' hall in Saint Paul, and of Plymouth church in Minneapolis.

Between these quarries and the railroad bridge crossing the Minnesota river, another is owned by Malgren, Roseen & Downs, by whom it was worked from 1872 to 1876.

At Ottawa quarries are owned by Levi Case, John R. Clark, Robert Todd, John S. Randall, Robert Winegar and Casper Mader. Some of these quarries have been operated twenty-five years. The annual product is from 50 to 300 cords from each, sold at $1 to $2.50 per cord. The stone here is in layers from a few inches to one foot thick. It is sold mostly for use within ten or fifteen miles to wall cellars and wells, little being sent away on the cars.

Lime. At Caroline station, near the center of section 17, Kasota, Conrad Smith since 1876 has burned about 6,000 barrels of lime yearly, selling at 55 cents per barrel. Bass and elm wood costs $1.75 per cord.

A third of a mile southeast from Caroline station, George C. Clapp has burned lime twenty years, averaging 2,000 barrels yearly, but has done nothing in this business during the last few years.

Lime-burning was formerly carried on beside the railroad about a mile south of East Saint Peter, where the kiln yet remains.

In Ottawa, a mile north of the village, Charles Schwartz burns about 400 barrels of lime yearly for the demand in this vicinity, selling at 60 cents per barrel.

These lime-burners use the upper two to five feet of the terraces of Shakopee limestone in these townships, its lower portion being too arenaceous for this purpose. It yields excellent magnesian lime, of dark or yellowish brown color.

Limestone boulders, gathered from the drift, are burned for lime in a kiln owned by James Timpane, at the southeast edge of Waterville village, producing one or two hundred barrels yearly, worth $1 per barrel. This is also mostly a yellowish or brown lime, the greater part of the boulders being from the Shakopee formation. Lime is also occasionally made from boulders at several places in Elysian, the kilns, holding 40 to 100 barrels, being filled once or twice in a year.

Bricks. At Le Sueur, on the bottomland close southwest of the village, Henry Kruse has made bricks eighteen years, using the recent alluvium of the Minnesota river. His annual product is about 300,000, selling at $5 per thousand. He mixes one part of sand with two of the alluvial clay. These bricks in the outer part of the kiln are red, and gradually change to cream-colored in the central part of the kiln, where they were subjected to greater heat, while next to the fires they are greenish yellow.

Close northeast of Le Sueur, on the terrace of modified drift next below the Le Sueur prairie, J. Wetter has made bricks ten years, averaging 100,000 per year. His clay has a thickness of five feet, and is underlain by sand, the two forming a terrace about 110 feet above the river. The sand is mixed with the clay for tempering, in the proportion of one to three. The color of these bricks is deep red.

One mile south of Waterville, on land of Thomas Slechta in section 35, a kiln of red bricks of good quality was made in 1878, at the east side of the railroad. The clay was partly taken from a railroad cut, and has a thickness of six feet free from gravel. The cost of manufacture was too great for competition with the brick-makers of Mankato and Chaska. About a mile farther south, in the north edge of Waseca county, this business has been carried on several years by David Wood, averaging about 250,000 yearly. These are excllent, red bricks, here worth $7 to $8 per thousand.

Peat. Professor Winchell's description of the peat deposits of southern Minnesota, in the second annual report of this survey, mentions two localities in Le Sueur county. A marsh crossed by the Saint Paul & Sioux City railroad in Kasota showed on the east side of the railroad, six rods from the drift bluff, good peat, 8 inches, underlain by black, sandy clay, 2 feet, with frequent shells in each of these beds. In the same marsh, west of the railroad and fifteen rods from the drift bank, the section is:

"1. Roots and stems of grass, with some peaty, vegetable decomposition....... 8 in.
2. Black, peaty mud, with a few fragments of shells and some sand..........1 ft. 4 in.
3. Black or brown mud, with sand and fragments of shells..................4 ft."

At the head of lake Emily, in the same township, on M. L. French's land, is the following section:

"1. Roots and soft, fibrous lake sediment... ....1 ft.
2. Peaty lake sediment, with little or no sand.................................1 ft. 6 in.
3. Peaty mud, with a little sand..1 ft.
4. Black lake mud, sandy...2 ft."

An analysis by Dr. P. B. Rose of the peaty deposit at lake Emily gave hygroscopic water, 9.83 per cent; ash, mostly silica, 67.17; and organic matter, 23.00. A hundred pounds of this peat, air-dried, is estimated to have the same heating power as 34 pounds of oak wood.

ABORIGINAL EARTHWORKS.

Mr. J. Blackiston of Saint Peter describes an interesting group of several aboriginal mounds, nearly round, twenty to forty feet in diameter at the base and five to ten feet high, which were situated on the bottomland of the Minnesota valley in the north part of section 4, Kasota, about four miles north of St. Peter. It is reported that in 1847 the river's channel was nearly a mile west of these mounds, but since then it has gradually worked eastward, until in the freshet of April, 1881, the portion of the bottomland where they stood was washed away. A partial excavation of some of them had disclosed numerous relics, which Mr. Blackiston has deposited in the state museum, including human bones, a silver wristlet with "Montreal" stamped upon it, tubular copper ear-pendants (one having hair in it), a string of thirty white china beads, a large brown glass bead, four common pins, a needle, a small pearl ornament, and a quartz arrow-point.*

About a mile farther east, in the N. E. ¼ of section 3, Kasota, the top of the bluff a quarter of a mile north of the railroad water-tank bears three mounds, which are respectively two and a half, three, and five feet in hight. The first and second have the usual circular, dome-like form; but the third, which is south of the others, has a truncated top, with a level, circular, narrow rim, and inside this, instead of being flat, as one expects from seeing it at a distance, there is a bowl-like hollow two feet deep. The mound appears to remain in an undisturbed condition, retaining the same form in which it was left by the builders. If it had been completed in the usual manner, its hight would be about eight feet. The bluff on whose verge these mounds are situated has an elevation of about 225 feet above the Minnesota river, and commands a very beautiful prospect, looking up the valley.

*Ninth annual report, pp. 163-4.

CHAPTER XXIII.

THE GEOLOGY OF RICE COUNTY.*

BY N. H. WINCHELL.

Situation and area. Rice county is situated in the triangle between the Mississippi and that part of the Minnesota which flows northeastward, and nearly in the center. Northfield, near the northern boundary, is thirty-eight miles from St. Paul, and the eastern boundary of the county is about the same distance from lake Pepin. Faribault, at the forks of the Cannon river, the county seat, is about fifty miles south from St. Paul. The area of the county, which includes twelve sections more than fourteen government townships, amounts to 322,560.70 acres, of which 11,054.83 acres consist of water. The county is represented by plate 31.

SURFACE FEATURES.

Natural drainage. The main artery of surface drainage is the Cannon river, which flows nearly northeasterly through the central portions of the county. This stream, which moves with a smooth current, receives the Straight river from the south at Faribault, thus nearly doubling its volume. The Cannon river rises in the lakes at Shieldsville, a few miles northwest of Faribault, at an elevation of about 1090 feet above the sea, and after a circuitous route through Le Sueur county, enters the county again at a point about seven miles from the point at which it left it. Throughout its course it passes through numerous lakes, and its main channel in Rice county, before its union with the Straight river, is widened out in the form of lakes at four places. It has the aspect in this part of its course of having once been occupied by a larger stream than the present Cannon river. Thus the Cannon river carries off the surplus waters from most of the lakes

*Prof. L. B. Sperry, late of Carleton college, made a preliminary report on Rice county in 1877, but in the further working out of the geology of the county it became necessary to add so much to his report that he could not fairly be held responsible for it. His report has been used as a basis for this.

that are scattered throughout the western half of the county, though some of these waters seem to reach that valley by underground drainage, the lakes having no visible outlets. In the southeastern part of the county the north branch of the Zumbro rises in a long marsh which extends uninterruptedly to within a mile and a half of the Straight river. From that point another similar marsh extends westwardly and is drained by a creek into the Straight river. These marshes, and several others in the county, are caused by the impervious nature of the underlying Hudson River and Trenton shales, and mark the channels of glacial drainage. In a similar manner the valley of Prairie creek, which once was one of voluminous discharge, extends nearly as far southwest as to the valley of the Cannon river west of Cannon City. It is there partially filled up with drift.

To the most casual observer Rice county presents remarkable contrasts in its drainage features. That portion which lies east and southeast of the Cannon river is different from that portion lying to the west and northwest of that valley. The former is undulating, in long and gentle swells, with slow-flowing streams that are fringed with wide often marshy and quaking low-lands. The streams are insignificant in comparison to the valleys which they occupy; and they have a direct and well-established direction of flow, without much tortuosity. Where they leave Rice county their channels are sunk from one to two hundred feet below the general upland level. The country here drained is alike without lakes and timber. The latter is rolling in short and often steep and frequent hills that rise from fifty to a hundred feet above the surrounding country. Among these hills the crooked streams wander with every conceivable curve and change of direction, often encountering small lakes, and receiving small tributaries that drain others. They have no deeply eroded valleys, but run near the average lowland level of the country where the present contours of surface will permit. While there are frequent marshes here, they are isolated like the lakelets, and have a similar relation to the drainage. In this part of the county the precipitated moisture is retained by the more slow course of surface drainage as well as by the more gravelly and sandy nature of the surface drift materials. This part of the county also is heavily timbered, a circumstance that not only produces, but also is favored by, a greater amount of natural moisture within the drift-materials and on the exposed surface. This last has also retarded the former devastations by prairie fires. This wooded portion is on the eastern edge of the "big woods" of Minnesota, or *bois fort*, well and long known as one of the great physical features of the surface of the state. The underlying causes for this difference of surface and drainage features will appear in the description of the drift and geological structure.

Water-powers. Several valuable water-powers have been improved in Rice county. These are chiefly in the valley of the Cannon river, viz:

Northfield mills. Jesse Ames' sons, Northfield; in the *old mill* the present capacity is 80 barrels per day; 3 run of stone (two for feed), nine feet head; one 45-inch and one 35-inch Leffel wheel, two 27-inch Huston wheels and one 34-inch Huston wheel (one is for a machine shop); the 35-inch Leffel wheel has 20.7 horse-power, and the 34-inch Huston has 21 horse-power. The *new mill* has a capacity of 400 barrels; 9 feet head; two 54-inch Victor wheels, each having a rated capacity of 80 horse-power; one 35-inch Leffel wheel with 21 horse-power; twenty double rollers; three single rollers; Gray patent of Allis' roll; three flour buhrs.

Dundas mills. E. T. Archibald & Co.; Dundas, on the Cannon river; partly run by steam; full capacity 600 barrels per day; 10 feet head; two 48-inch Leffel wheels; four buhrs; 37 single rollers of Gray's Allis' patent. This mill is about half built of Trenton limestone, and the old Archibald mill, on an island in the river, now dismantled, is wholly of this stone. Another mill at Dundas is run wholly by steam.

Cannon Valley roller mill. S. E. ¼ sec. 8, Cannon City, on the east side of the Cannon river; owned by R. H. Scott and sons; seven feet head, four Leffel wheels, all 48-inch, and one La Croix wheel of 40 inches; three sets of double, smooth Allis rollers, and five sets of double, corrugated Allis rollers; one of Stevens single, smooth rollers; three buhrs (one for feed, run by the La Croix wheel); full capacity 130 barrels in twenty-four hours.

There is a fine water-power at Faribault in the Cannon river, between the railroads, owned by Mr. Mattison, where the mill was lately burned. The fall here is about six feet and will furnish several hundred horse-power.

The Polar Star mills, Faribault, owned by F. A. and S. L. Bean, on the south side of the Cannon river; run partly by steam; head eight to eleven feet, according to the season; one American, or Dayton, 75-inch turbine wheel, two Leffel wheels, one fifty-six and the other forty-eight inches; at eleven feet head these Leffel wheels produce, one, ninety and the other fifty-three horse power, and the American wheel one hundred and forty horse-power; in summer, however, steam is necessary to run the mill; rollers are made by Allis (Gray's), Cosgrove, Noye, and Dalton; three double smooth rollers. and five single smooth, seven sets of corrugated single rollers; full capacity 375 barrels in twenty-four hours.

The water-power mill at Morristown is owned by C. H. Hershey; head of water seven feet; Case turbine wheel, fifty-four inches, twenty-seven horse-power. Two buhrs (one for feed); full capacity thirty-eight barrels in twenty-four hours.

The mill at the outlet of Roberd's lake, N. W. ¼ sec. 22, Wells, owned by T. G. Scott, is known as the *Roberd's Lake mill.* In high water it has a head of sixteen feet, but in ordinary stage of water only twelve feet; one Small's turbine wheel of forty-eight inches and sixty horse-power (under twelve feet head); one double set of Allis' make of Wegmann's patent rollers; three buhrs (one for feed); capacity for wheat fifty barrels each twenty-four hours.

The following mills are on the Straight river:

The *Kendall mill* is at Faribault, N. W. ¼ sec. 29, Cannon City township, on the east side of the river, and is owned by Green and Gold; eight feet head of water; one 40-inch Leffel wheel, with thirty-five horse-power, and one 30-inch wheel, not used, maker unknown; seven sets of Stevens single rollers, two smooth and five corrugated; one porcelain roller (Wegmann's), and one smooth, small, old roller (maker unknown); two flour buhrs; full capacity 140 barrels in twenty-four hours. This mill never has water enough to run its full machinery, but is aided by steam.

Straight River mills, Faribault, owned by J. D. Green and Co.; head twelve feet; one Leffel 40-inch wheel; one double roller, sixteen sets of single rollers, Stevens' break roller (Noye make) and two wheat buhrs; capacity 350 barrels per day; partly run by steam.

Walcott mills, owned by M. B. Sheffield, S. W. ¼ sec. 16, Walcott, on the west side of the river; head twelve feet; one 48-inch new American wheel, and one 40-inch old American; two smooth and two corrugated sets (double) of Stevens rollers, one single set of Stevens corrugated rollers, one double set of Gray's smooth rollers, one double set of Rickerson's smooth rollers, one Wilmington (Del.) single smooth roller; four run of stone (one for feed); capacity of the mill, using water alone, 225 barrels per day, and when aided by steam 280 barrels per day.*

Topography. The eastern and southern portions of the county are broadly undulating or smoothly rolling, with long swells running so as to operate as the primary divides between the drainage valleys. The northeastern corner of the county, east of the Cannon river, is characterized by considerable differences of level, separated by plains that extend like terraces along the river courses. The Prairie creek valley is thus a wide, nearly level, expanse bounded by an abrupt ascent of about a hundred feet to a higher flat which extends, with an undulating surface, right and left. The Cannon valley is the great topographic feature of the county. Its outer bluffs rise about a hundred feet above the water, at Northfield, about two hundred and fifty at Dundas and two hundred feet at Faribault. The water surface of Straight river descends northward, within the county, from the level of about 1050 feet above the sea to about 950 feet. The Cannon river in like manner, descends, in crossing the county from about 1000 to 890 feet, its source in the lakes at Shieldsville being about 1090. The high prairies in towns of Wheeling and Richland are 1150 to 1250 feet above the sea. The high plateau east and southeast of Cannon City is in general about flat, but has numerous deep valleys that penetrate within the St. Peter sandstone. The head of Prairie creek runs thus south and southwest far enough to unite with the Cannon valley.

In the western, wooded portion of the county there is a greater diversity of the immediate surface contour, but the average elevation is not so great as in the eastern, no known elevations being above 1125 feet. The lakes that dot the surface here add much to the variety of topographic scenery. Some of these cover an area each of two to three square miles, and have a depth of ten to fifty feet.

*The mill at Medford, Steele county, partly run by steam, was burned about the year 1880. It had no rollers.

Elevations on the Iowa and Minnesota division of the Chicago, Milwaukee and St Paul railway.

From profiles in the office of George H. White, engineer, Minneapolis.

	Miles from St. Paul.	Feet above the sea.
Summit near line of Dakota and Rice counties, cutting 12 ft.: grade....	36.7	969
Northfield	38.1	915
Heath creek, water, 905; grade	39.2	921
Dundas	41.0	955
Wolf creek, water, 947; grade	42.3	974
Summit, cutting 9 ft.; grade	45.9	1037
Depression, grade	46.7	971
Summit, cutting 30 ft.; grade	49.5	1017
Cannon river, water, 959; grade on bridge	50.9	975
Faribault	51.7	1002
Summit, cutting 4 ft.; grade	54.3	1084
Summit, cutting 14 ft.; grade	56.8	1140
Straight river, water, 1069; grade	60.2	1090
Medford	60.4	1098

Elevations, Wisconsin, Minnesota and Pacific (or Cannon Valley) railway.

From profiles in the office of Robert Angst, engineer, Minneapolis.

	Miles from Waterville.	Feet above the sea.
Waterville, junction with M. & St. L. railway	0.0	1008
Line of Le Sueur and Rice counties, grade	2.5	1030
Summit, natural surface, 1067; grade	3.8	1056
Cannon river, water, 997; grade	6.0	1008
Morristown	6.3	1008
Cannon river, water, 975; grade	8.4	984
Warsaw	9.3	1007
Junction of spur track to Polar Star mills	15.3	979
Fair ground	15.6	976
Crossing C., M. & St. P. railway	16.3	981
Faribault	16.8	971
Cannon river, low water, 954; high water, 960; grade	17.3	966
Wolf creek, water, 925; grade	25.6	942
Dundas	27.0	926
Cannon river, low water, 900; high water	29.4	906
Northfield	29.9	910
Line of Rice and Dakota counties, grade	31.0	897
Waterford	32.0	903

The average elevation of the county may be estimated as follows, based on the contour lines shown on the county plate: Northfield, 990 feet above the sea; Wheeling, 1110; Richland, 1175; Bridgewater, 1010; Cannon City, 1085; Walcott, 1100; Webster, 1060; Forest, 1025; Wells, 1025; Warsaw, 1070; Wheatland, 1075; Erin, 1090; Shieldsville, 1075; Morristown, 1045. From these figures the average elevation of the county becomes 1065 feet.

Soil and timber. The soil of the upland prairies in the southeastern part of the county, including the towns of Richland, Wheeling, Cannon City, and much of Northfield, is a black loam underlain by clay. In the low grounds along the valleys this black loam is increased in thickness, and on some exposed knolls the underlying clay becomes the surface soil. In the low prairies of Northfield the subsoil is gravelly, and the soil itself, while rich and dark, is apt to become sandy, particularly in the immediate neighborhood of the bluffs where the St. Peter sandstone has opportunity to mingle with it. In the western part of the county, while the soil is a dark loam and equally fertile, generally, as that in the eastern, it has not yet been wrought so extensively, and is less highly prized. It has a subsoil, mainly, of stony blue clay, or a yellow pebbly loam, but on the gravelly hills, and on some of the lower ridges, in Morristown and Shieldsville, and particularly in Webster, the subsoil is gravel and sand. This is the case also in the terrace-flats that skirt the Cannon river. The soils in the western half of the county are much more stony than in the eastern.

The following *trees and shrubs* are native to this county. In ascending the Cannon valley from Northfield there is a marked change in the character of the forest growth at the point where the blue clay, pertaining to the drift sheet extending northwestwardly, approaches the river. About Northfield, and northwardly through Dakota county, the trees are mainly of oak and aspen, this region being occupied by the red drift derived from the northeastward. But here these trees give place to sugar maple, butternut, ironwood, bass, ash, &c. The shrubs are also affected by the same change. Different species of Lonicera, Spiræa, and Cornus make their appearance as undergrowth, sharing the shade with little aspens and wolfberries. The trees are arranged in the estimated order of frequency.

Tilia Americana, *L.* Basswood. Common throughout the county, and especially throughout the heavy timber in the flat or undulating tracts of Bridgewater, Forest, Erin and Shieldsville. At Morristown it is extensively wrought into barrel-heads and common lumber.

Ulmus Americana, *L.* (*Pl. Clayt.*), *Willd.* American or white elm, also known as water elm. At Morristown this tree is extensively used by J. B. Hopkins, and by H. H Osterhout and company, for the manufacture of "head lining" for flour barrels, this being the only place in the state where this industry is carried on. It is also wrought into common lumber.

Quercus coccinea, *Wang.*, var. tinctoria, *Gray.* Black oak. This is the usual oak. It is most abundant as small trees and shrubs; and in the high and rolling parts of Webster and Wheatland it is only found in this condition. Very large trees, however, are scattered numerously through the heavy timber everywhere. In Morristown and Warsaw townships it is considerably used for lumber.

Quercus macrocarpa, *Michx.* Bur oak. In exposed places, and particularly on the edges of the timber bordering the prairie, this is very abundant. It seems to endure fire better than the black oak, perhaps due to its more corky bark, but it does not succeed so well as the black oak on exposed and bleak hills or on poor soils. It occasionally furnishes a log for lumber and is apt to be confounded with the white oak, which is a much less common tree in the county.

Acer dasycarpum, *Ehr.* Silver maple. A common tree, sometimes growing very large and furnishing lumber, but generally not more than ten inches in diameter so far as now seen in the county. It is common as second growth after the cutting of the original forest.

Populus tremuloides, *Michx.* American aspen. Common on the outskirts of the timber, on exposed hillsides, as in Webster, and as second growth in all parts of the county; generally not exceeding ten inches in diameter.

Acer saccharinum, *Wang.* Sugar maple. This tree exhibits magnificent proportions in some heavily wooded tracts, as in western Shieldsville and Erin, where the old forests have not been cut. It also sometimes starts up more numerous than any other tree as a second growth. It is common throughout the timbered portions of the county, and has been set for ornamental purposes in most of the prairie portions. It furnishes considerable quantities of syrup and sugar in Rice county, and is sometimes found among the saw-logs at the mills at Morristown.

Ulmus fulva, *Michx.* Slippery elm, or red elm. This makes better lumber than the white elm, but it does not grow so large nor so straight.

Fraxinus sambucifolia, *Lam.* Black or water ash. Some very large trees are found in western Shieldsville.

Juglans cinerea, *L.* Butternut.

Ostrya Virginica, *Willd.* Ironwood.

Prunus Americana, *Marshall.* Wild plum.

Negundo aceroides, *Mœnch.* Box-elder. Not found in the heavy timber, but along streams and lakes. This makes a low-branched, rather small, irregular tree, and if it lives long it sustains a broad light-green mass of foliage supported generally by two or three, or more trunks from one root. It grows rapidly, has a dense wood, but is not durable.

Carya amara, *Nutt.* Bitternut or hickory.

Quercus alba, *L.* White oak. Furnishes a valuable and tough timber, and is occasionally cut for that purpose at Morristown.

Populus monilifera, *Ait.* Cottonwood. Along the river bottoms, but not generally through the county.

Carpinus Americana, *Michx.* Water beech.

Fraxinus Americana, *L.* White ash. Used for lumber. Some large straight trees were seen in Shieldsviile.

Prunus serotina, *Ehr.* Black cherry. Scattered through the heavy timber.

Quercus rubra, *L.* Red oak.

Acer rubrum, *L.* Red or swamp maple.

Juglans nigra, *L.* Black walnut.

Populus grandidentata, *Michx.* Large-toothed aspen.

Celtis occidentalis, *L.* Hackberry.

Pirus coronaria, *L.* American crab-apple.

Larix Americana, *Michx.* Tamarack. Shieldsville and Cedar lake.

Betula papyracea, *Ait.* Paper or canoe birch.

Amelanchier Canadensis, *Torr. and Gray.* Juneberry.

Populus balsamifera, *L.*, var. candicans, *Ait.* Balm of Gilead.

Pinus Strobus, *L.* White pine.

Cornus paniculata, *L'Her.* Dogwood.

Cornus circinata, *L'Her.* Dogwood.

Corylus Americana, *Walt.* Hazelnut.

Rhus glabra, *L.* Smooth sumac.

Prunus Pennsylvanica, *L.* Wild red cherry.

Cratægus Crus-galli, *L.* Thorn.

Juniperus Sabina, *L.*, var. procumbens, *Pursh.* Savin.

Lonicera grata, *Ait.* American woodbine.

Vitis cordifolia, *Michx.* Grape.

Ampelopsis quinquefolia, *Michx.* Virginia creeper.

Alnus incana, *Willd.* Speckled alder.

Spiræa opulifolia, *L.* Nine-bark.

Cornus stolonifera, *Michx.* Red-osier dogwood.

Celastrus scandens, *L.* Climbing bitter-sweet.

Rosa blanda, *Ait.* Rose.

Rosa lucida, *Ehr.* Dwarf wild rose.

Symphoricarpus occidentalis, *R. Br.* Wolfberry.

Rubus villosus, *Ait.* High blackberry.

Rubus strigosus, *Michx.* Red raspberry.

Ceanothus Americanus, *L.* New Jersey tea.

Amorpha fruticosa, *L.* False indigo.

THE GEOLOGICAL STRUCTURE.

The rocks of the county range from the Shakopee limestone to the upper portion of the Trenton period, probably including the actual representatives of the Hudson River group, though the latter cannot be subdivided, nor more exactly parallelized with any of the formations of the New York nomenclature. They will be considered in descending order, as follows: 1. Trenton rocks, 2. St. Peter sandstone, 3. Shakopee limestone.

The rocks of the Trenton period possess some characters that have been ascribed to the Hudson River and Galena formations, where they appear in southwestern Goodhue county, and these undoubtedly extend northwestwardly in Rice county, at least as far as to Cannon City, since the thickness of rock, referable to the Trenton period, at the latter place amounts to about a hundred and thirty feet. This is ascertained by aneroid measurements from the top of the St. Peter sandstone in the Cannon river valley west of Cannon City, combined with data learned from common wells at Cannon City which encounter limestone at the depth of about thirty feet. Nothing can be said of the lithology of these beds in Rice county, but the elevated prairie under which they lie includes Richland, Cannon City and Wheeling. These beds also probably extend with feathery edges into the elevated tracts in eastern Bridgewater and southwestern Northfield. The existence of a little lake at Cannon City is probably owing largely to the impervious shales of this formation; and the long bogs which accompany valleys of this part of the county are due to the same cause.

The limestones of the Lower Trenton are well displayed in Rice county. They are abundantly exposed along the valley of the Cannon river, and along Prairie creek, where they are somewhat quarried. The thickness of these beds is about fifteen feet. They are overlain by a heavy stratum of green shale, as in counties farther southeast, and there is a thickness of from six to ten feet between them and the St. Peter sandstone. They embrace, along Prairie creek valley, a carbonaceous layer of a few inches which, without previous drying, will ignite from a common match and burn with a flame.* The Trenton also underlies the southern part of Warsaw, extending probably into the southeastern part of Morristown.

In general the Lower Trenton limestone is but little affected with magnesia or alumina as impurities, in Rice county. It is compact, generally blue, and breaks sharply and somewhat conchoidally. Its bedding is in sheets convenient for quarrying, being about six or eight inches thick, and it is tolerably free from pyrites, though crystalline clusters of this are sometimes so frequent as to cause a rusty stain on the surface of the blocks prepared for building. As quarried at many places it is not blue, but has a faded ashen color, becoming also yellowish, but free from pyrites, due to long weathering and submergence by the waters of the glacial period.

Rice county affords the usual fossils that characterize this geological horizon, viz: large orthoceratites, such as *Endoceras magniventrum*, H., several species of *Strophomena*, *Orthis*, and of *Rhynchonella*, as well as specimens of a large coiled cephalopod like *Lituites undatus*, Con. †

At Faribault the strike of the Lower Trenton, on the west side of the Straight river, passes through the southern part of the city, producing its characteristic plateau. A similar wide plateau is conspicuously brought out on the east side of the same river. On this stand the state asylums for the blind and for the imbecile. Its hight above the sea is from 1080 to 1090 feet. At Mr. Doyle's quarry on the west side of the river, the top of the limerock is about 1080 feet. The rock here is all faded to an ashen or drab color, both by the oxidation of the contained pyrite, and by the further oxidation and hydration of the iron-protoxide of the original blue color. Thus the aluminous portions become more finely cemented than in the blue rock as seen at Mr. Cromer's quarry, though the bedding is split and broken more by the weathering. This faded rock is more

*This carbonaceous layer extends eastward into Goodhue county.

†Of the last a specimen is to be seen in the collections of Carleton college, and through the favor of Prof. L. B. Sperry a photographic copy has been furnished the survey. It will be described in the volume devoted to the palæontology of the state.

durable than the blue, but is not so advantageously quarried in blocks of uniform thickness and size.

Farther southwest from Faribault, across the creek that enters the Cannon river from the south near the fair ground, the Trenton evidently exists. This is evinced by the contour and abruptness of the bluffs. The southern part of Warsaw and probably of Morristown, are thus underlain by the Trenton.

The Trenton has been quarried in the bank of the river below the Walcott mill, from six to ten feet above the water. Above the dam this limerock formerly appeared in the bed of the river, but it is now covered by the water of the dam, the water-power being due to the passing of the river over this rock-horizon, the same as at the falls of St. Anthony. Stone from below the dam was used in the bridge piers, and in the building of the dam. Quarries are owned by Henry Hall and Gale Sexton. There is a small area of the Lower Trenton on the west side of the Cannon river in secs. 33 and 34, Bridgewater; and also in sec. 35, immediately west of St. Olaf's college, near Northfield.

The St. Peter sandstone begins to be seen in the banks of the Straight river about four miles north of the Steele county line, and at Faribault it reaches a hight above the river of eighty feet according to the following

Section at Faribault in the right bank of the Cannon river.

1.	Drift (water deposited) covering occasional exposures of the Trenton limestone, and one or more beds of green shale	26 ft. 4 in.
2.	Shaly bedded St. Peter sandstone	3 ft. 6½ in.
3.	Massive St. Peter sandstone	76 ft. 7½ in.
	Total	106 ft. 6 in.

The St. Peter sandstone, having a thickness altogether of about 115 feet, rises about 110 feet above the river, west of Cannon City. It is exposed at the Cannon Valley roller mill, S. E. ¼ sec. 8, Cannon City, in a perpendicular wall, in the west bluff of a conical isolated hill, and affords there a good opportunity to measure its thickness, since the river must be running very near the top of the Shakopee limestone. The top of this hill, though covered sparsely with a pebbly loam, is strown with bits of limerock due to the demolition of the Trenton *in situ.*

Fossils in the St. Peter. The sandrock here is pitted with circular holes, such as have been seen in a number of places in the state.* They are brought to view distinctly in the weathered and hardened surfaces, since the homogeneous sand on fresh fractures seems to constitute the entire rock, and no trace of these fossils is visible to the eye. They appear at this place on a lower bench, where the rock is hardened and reddened. They always run perpendicular, and can be traced to the depth of two and a half feet by the little furrows they cause on the face of the rock after the breaking and sliding down of masses of the bluff. This structure was first seen in this sandrock at the base of Dayton's bluff at St. Paul, and was ascribed to Cretaceous lithodomous shells, but it is more likely to be due to some marine vegetable, or to worm-burrowing, of Cambrian age. By examining areas that have suffered different degrees of exposure, there can be traced a connection from the actually empty porous openings, through different degrees of exposure and induration, including a simple annular spottedness, to an innate internal structure in the mass of the rock itself. It would be the same as if a multitude of horse-tail rushes, or others, were growing in the bottom of the sea when the sand was accumulating, and became gradually buried under the sand, and then were imprisoned and fossilized, their presence only being evinced

*They are conspicuous at Castle Rock, in Dakota county.

now by the cementation of the sand-grains about their exterior, or by a looseness of the same in their interior, thus not only forming a rude cast of each stem within the rock but also providing for the more rapid erosion and removal of the grains that may have reached within their cases. The spots are only seen on upper surfaces, and if they be not due to imprisoned rushes or stems of some sort, or to worm-burrowing, they are at present inexplicable. They are generally from an eighth to a quarter of an inch in diameter.

The Cannon river enters on the Shakopee, having cut through the St. Peter, in sec. 4, Cannon City. This sandstone is also abundantly exposed in the valley of Prairie creek, in a great many places. In the eastern part of Northfield it constitutes the isolated mound-like hills that rise above the lower prairie to the upland, marking the limit of the overlying Trenton limestone. The outrunning edge of the St. Peter sandstone is not visible in the drift-covered western portion of the county, its most westerly exposures being a perpendicular bluff in the west bank of Heath creek, S. E. ¼ sec. 34, Bridgewater, and an isolated mound facing the river on the S. E. ¼ sec. 26, Wells. This sandstone undoubtedly exists in considerable areas in that portion of Rice county, extending through Le Sueur county to the Minnesota valley, but with these exceptions not a single exposure of it has been recorded. In Wheatland and Webster it is also highly probable that the Trenton limestone caps the St. Peter sandstone in some of the hills that diversify those townships, since it is known to occur in such hills a few miles farther north in Dakota county, but as this is wholly conjectural, the plate of the county represents only drift in those townships.

The Shakopee limestone. This formation is exhibited at Northfield. It affords a thickness of about thirty-five feet in Rice county, its chief outcrops being in the Cannon valley between Dundas and the Dakota county line. At Dundas the depot of the Chicago, Milwaukee and St. Paul railway is twenty-two feet above the top of the Shakopee, and the Cannon Valley depot is about level with its upper surface. At the north county line the Iowa and Minnesota division of the Chicago, Milwaukee and St. Paul railway is ten feet above the top of the Shakopee, and at Northfield it is fifteen feet lower than its upper surface. A the county line the Cannon Valley railway is twenty-five feet below the top of the Shakopee and at Northfield it is about twenty feet. This formation is that which underlies immediately the drift in most of that part of the county west of the Cannon valley, but no outcrops of it are known there. At Northfield it is seen in the streets of the city, and is excavated for cellars and foundations for buildings. It is frequently seen along the "river road" below Northfield on the west side of the river, where it has been wrought for quicklime.

The lithology of the Shakopee at Northfield is variable, resembling that seen at its typical and original locality. The limestone is impure, and passes to a shaly magnesian rock. Some of it is in beds of three or of two inches, and some is coarse and vesicular, and in heavy beds. In the midst of the limestone are layers of white sand from three to six inches in thickness, two of them embraced in the interval of fifteen feet. One of these pinches out entirely in a distance of twenty feet, letting the limerock above lie on that below, and the other becomes mingled with lumps and lenticular masses of green shale. In other places, as at Tramm's limekiln, some of the limestone layers embrace, along with rounded grains of quartz sand, some pieces of, apparently, weathered chert, and indistinct remains of molluscs, probably of the same species as seen in the Shakopee at Cannon Falls, in Goodhue county.

The drift. Till. In the eastern part of the county, particularly in the northeastern, the unmodified drift is red or copper-colored, and in the rest of the county it is gray or bluish. In the eastern part of the county the unmodified drift, or till, is not abundantly exposed, but is covered by a loam of later date, and its character seems to blend rather more readily with the loam than does that of the gray till. There is also an abundant dissemination of gravel derived from the gray till throughout the valleys in the northeastern part of the county. This gravel occupies the immediate surface in some instances, only covered by a soil, but in others it is covered by a copious loam which often is rather sandy. This loam is sometimes ten or more feet in thickness, and frequently is seen to be somewhat pebbly and apparently to become mingled gradually with the upper portion of the underlying till, without the distinct intervention of the gray gravel. The most westerly point at which this red till has been recognized is at the roadside along the west side of section 9 in Cannon City, where it has been found to contain pieces of native copper. It here presents its usual facies, viz., reddish color, rather sandy composition, numerous red and green pebbles and stones of igneous origin and some red quartz-porphyry, referable to the copper-bearing series of the northeastern part of the state, with rarely a boulder or stone of gray granite, and more rarely still a piece of the foreign drift-limestone. At this place the red till lies directly on the St. Peter sandstone, but it is not everywhere present. It occupies, rather, the depressions in the eroded upper surface of the St. Peter, and is covered by a gray gravel which in numerous instances is itself deposited directly on the sandstone. Along the northwest quarter of sec. 9, Cannon City, the red till rises higher and constitutes an upper timbered flat, rising about 1075 feet above the sea. Here it lies on the Trenton limestone, and the bench which it apparently produces, in passing westward to the river, is sixty feet in hight. About half a mile still further west, lying on the St. Peter sandstone, is the great kame, or horse-back, as it is popularly known, running through the bottoms of the Cannon river, and consisting wholly of gray gravel. This red till seems to be the oldest part of the drift, and it is quite probable that remnants of it will be found still farther west in sheltered depressions in the St. Peter sandstone. Indeed, in the northeast part of sec. 5, the road that ascends the hill northward from Carr's crossing, passes over red till which here lies on the St. Peter and constitutes a flat exposure on which the kame runs, at considerable elevation above the rest of its course in secs. 8 and 5. Toward the west this quickly changes to blue till, and toward the east it seems to be overlain by blue till.

The gray, or blue, till which covers the most of the county, is easily distinguished, in general, from the foregoing. It has uniformly bits of Cretaceous shale, often known as slate, disseminated through it. It has fewer stones and pebbles than the red till, and is more impervious to water. Its contained stones are predominatingly granitoid, but sometimes dark with hornblende. Among the boulders, as gathered and piled by the farmers by the roadsides, on areas of the blue till, will often be seen masses of foreign, nearly white, limestone. These are generally rounded, and weathered from long exposure on the surface so as not to show any glacial markings. This gray till also is covered, in the southeastern and southern portions of the county by a loam, sometimes pebbly, the exact origin and relations of which to the rest of the drift cannot be stated. There are also tracts in the timbered district, north and west of the Cannon river, where this blue till is covered by a thickness of six to ten feet of pebbly loam, though in most of that portion of the county the only covering the blue till has seems to be the soil, formed by a change in the till itself. This yellowish loam in the valley of Straight river, between Faribault and the mouth of Fall creek, is enormously developed. It there has exposed sections that measure thirty feet perpendicular, and it is apparently as much thicker in most of section 33, Cannon City. In some places here this clay is without pebbles, and might be compared to the "joint clay", so called, of Rock county.* In nearly all exposures it holds a variety of pebbles, with occasional stones, and it seems to pass into the stony till by gradual changes. The blue till lies under the soil, except when the yellowish loam intervenes, in the southeastern and southern parts of the county, on both sides of the Straight river. The thickness of the gray till has been found at several places to exceed one hundred feet, but as these cases were in the digging of wells and the work ceased because of finding water, it is probable that the bottoms of these wells were near the bottom of the blue till, where water is generally obtained. The average thickness of the till for Rice would probably amount to about one hundred feet. In the high prai-

*See pages 544 and 551.

ries of Richland and Wheeling the elevation is due mainly to the underlying Hudson River and Trenton rocks which probably exist in their full thickness, although there is still a great thickness of blue till in these townships, the surface being smooth or broadly undulating.

Moraines and morainic belts.

The chief morainic accumulation in the county appears in the township of Webster and in the northwestern part of Forest. The surface here is very rough, generally exhibiting conspicuous ridges that have an approximate north and south direction, rising from 75 to 125 feet above the valleys, one of the highest points observed being in sec. 16, which is approximately 1150 feet above the sea. These ridges, and all the drift in the township, consist essentially of blue till, with disseminated Cretaceous debris. Yet, east of the hilly region, in some places on the Dodd road, considerable gravel deposits are seen, the result of drainage from the ice at the same time that it was bringing forward the drift itself. Toward the west further while the surface is rolling and perhaps is to be considered as included in the same general moraine, extending across the township of Wheatland, the hills rise only from fifty to seventy-five feet above the numerous lakes and long peat marshes.

The general direction of this very rough portion of the county is a little south of southwest, occupying the eastern part of Erin, the whole of Shieldsville, and the western two-thirds of Morristown, leaving the county on the south side of lake Sakata. In Shieldsville, and in western Erin, where this high rolling surface attains apparently its greatest average elevation, the highest hills become, rather, elevated plateaux, and the roughness of the surface pertains to their margins and lies somewhat lower than these higher flats. This flatness is due either to the existence of the Trenton formation, or to the lack of copious drainage at the time of deposition of the original till sheet. The southwest part of Morristown is very rough, with 75–80 feet between the hills and valleys, the higher points being 1150 to 1175 feet above the sea.

Both toward the east and west from this rolling tract the contour of the immediate surface is less rolling or becomes simply undulating, and in some places might be denominated flat. Such flat tracts are found in the northeastern part of Forest, including the western part of Bridgewater. The northern and central parts of Wells are undulating, but the northeastern is broken again with other morainic surfaces.

There is a second morainic belt, less distinctly continuous, lying east of that just described. Toward the north it begins imperceptibly, at least it is now impossible to define it. It does not appear distinctly in northwestern Bridgewater, although in northwestern Greenvale, Dakota county it is more plainly marked. There is a tract of country, in secs. 5, 6 and 8, Bridgewater, that rises about fifty feet in an undulating manner, above the average hight surrounding it, which perhaps should be placed in this moraine. But in the southern part of Bridgewater, especially on the west side of the Cannon river, there is a notable accumulation of hilly blue till rising 1120 feet above the sea about the center of sec. 33. This range extends toward the southwest through the west part of Cannon City and the east part of Wells, where it lies between the present Cannon river and an older channel lying further west. Just north of the junction of the Cannon and Straight rivers this moraine passes to the east side of the Cannon and covers a belt about two miles wide on the east side of that river. But at the great bend of the Straight river in sec. 5, Walcott, it crosses again to the west side, and thence continues S. S. W. to the southern boundary of the county. This morainic belt also consists of blue till, but its changes of outline are less abrupt than in the more westerly belt. It is also less broad, being generally about two miles in width. Its highest points are 1150 and 1200 feet above the sea, and from these elevations the surface slopes rather smoothly to 1050 and 1100 feet above the sea. Where this moraine comes in contact with the river, as in the valley of Fall creek, the drift consists very largely of a yellow loam, which, containing some stones and many pebbles, may be a modified condition of the till, as acted on by the waters of the river at the time of its deposition. This loam or yellow clay seems to be the same as that which spreads wider and covers more thinly the general sheet of till both east and west of the river, and in both cases it seems to graduate into the till itself.

There is another conspicuously rolling tract, entering the county from the south on the east side of Straight river, extending east from the river four miles. This continues along the east side of the Straight river through Walcott township. In Cannon City township it unites with the moraine already described, and further north its identity, separate from that moraine, can not be traced. It consists of gravelly, gray till, bearing granitic boulders and drift limestone. In northeastern Walcott some of the knolls of this rolling belt are from 75 to 100 feet high, above the valleys, and where it apparently blends with the moraine already described, in Cannon City, northeast of Faribault, the elevations are from 100 to 150 feet above the valleys. This rolling tract, in that portion of Walcott east of the river, does not produce any elevation above the adjacent prairie country lying next east. It is on the contrary, rather lower than the prairie upland, and on approaching it from the east the country seems simply to be affected by a generally undulating and rolling timbered descent to the river valley.

In delineating the morainic belts through Steele county, the outer one is shown to be suddenly deflected toward the east at a point about two miles south of Aurora station, and to extend in a broad curve through the eastern portion of that county, becoming continuous with this rolling tract in southeastern Walcott, in Rice county. If, instead of this sudden deflection toward the east, the outer moraine could have been traced through Somerset and, by way of Owatonna, into the northeastern part of Deerfield, it would then have maintained more nearly its normal course, and would also have articulated perhaps more completely, upon the outer morainic belt that crosses Rice county. It would also afford the usual explanation for the gravel terrace that accompanies the Straight river in Steele county, as seen at Medford. But it seems very reasonable and very probable that the line of accumulation should, at favorable places, be double, even during the same general period of accumulation; and that the action of the waters of the upper portion of the Straight river was such as to aid such apparent duplication. The effect of this moraine on the Straight river, where it crosses it in the northern part of Walcott township, was to dam it up, during the existence of the ice, producing a lake covering those portions of Walcott and Medford townships that lie below about 1150 feet. This lake had its outlet through Walcott township into the north branch of the Zumbro river. This fact requires the moraine at this time in Walcott, on the west side of the Straight river instead of on the east; and yet it is probable that at a slightly earlier period of time, it was heaped up farther east as represented on the map of Steele county.

Gravel and gravel terraces. The Cannon valley, through its whole course in Rice county, after entering it from Le Sueur county, is accompanied by abundant gravel deposits. The Prairie creek valley, in Northfield township, is also accompanied with abundant gravel. The same is true, but to much less extent, of the Straight river south of Faribault, and of the north branch of the Zumbro. Everywhere this gravel is of a gray color, and was derived from the blue till by drainage and wash from the ice-fields that spread over the most of the county in some portion of the glacial epoch. At the east end of Cannon lake the gravel of the beach is about one half limestone. In no place in the county has a red gravel been seen, such as appears in some places in Dakota county, referable to the red till.

Straight river terraces. If these gravel deposits be described in the order of their age, probably those of the Straight valley would come first. They lie highest and farthest south. They were deposited at the time of the last glacial epoch when the Straight river was dammed up by glacier ice and morainic accumulations a few miles south of Faribault, and north of Walcott's mill, so as to find an outlet to the Mississippi at a much higher level than it now has. In the still earlier part of the same period these waters, still closer confined by a greater extension of the ice, probably had a feeble, interrupted discharge southward through the old channels, though narrow and shallow, that cross the divide in Steele and Freeborn counties, reaching the Cedar or the Shell Rock river. But at the time of the most rapid accumulation of the gravel as it appears in Rice county along the Straight river, the water of that valley had its discharge through the north branch of the Zumbro eastward, through the broad valley that crosses Richland, now mainly occupied by a conspicuous grassy marsh that gives rise to the north branch of the Zumbro. These gravel deposits are found southward from the northeast quarter of sec. 17, Walcott, on the west side of the river, to the south county line, and to Medford, at least, in Steele county, where the flat terrace on the east side of the river, on which the village is built, consists of gravel, having an elevation of 1098 feet above the sea. This terrace, which begins first distinctly near Walcott's mill, seems to be only an alluvial flat subject to overflow by the present river, bounded on the west by a line of abrupt drift bluffs that rise at once about 60 feet. It is here plainly underlain by the Lower Trenton limestone, six to ten feet above the river, but toward the south it slowly ascends and exhibits its gravelly composition. At Mud creek, which enters the river from the west in sec. 21, the same plain occupies a broad sweep up that valley, and is about 25 feet above the Straight river. The underlying Trenton and green shales, which at first make this terrace very wet, sustaining a copious flow of water in Mud creek, are covered with only a few feet of gravel and soil. Sometimes also the gray till is found to extend under the gravel of the terrace. At Medford the immediate drift bluffs are from fifty to seventy-five feet higher than the terrace, and the terrace is thirty feet above the river. On the east side of the river the terrace extends from Medford at least to the county line northward, and probably about a mile into Rice county. The connection which is presumed to exist between this gravel-terrace and the gravel seen in sections 23, 14 and 11, Walcott, where the old outlet of the Straight river begins, has not been traced. The outlet itself, now, in section 14, probably somewhat silted up, is about 1150 feet above the sea, the old river banks rising abruptly on either side about fifty feet, and the country farther back from twenty-five to fifty feet more. The bluffs are continuous from the west-drained marsh to the east-drained, the actual divide being imperceptible and in the marsh in sec. 23, which is drained in both directions. The narrowest place in the marsh is where the road crosses, between sections 13 and 14, and it is here about a third of a mile across, the flow of water here being toward the east. There is a rough and rolling high, timbered, surface toward the west and north, but smooth and treeless toward the east and south. There is a general low tract through sections 10 and 11. Wells are shallow and enter gravel and quicksand. The low knolls have a remarkable amount of northern limestone.

There is a lower terrace, abutting on the St. Peter sandstone, running from Faribault south along the west side of Straight river. This terrace consists of yellow, pebbly clay, sometimes containing boulders, and rises from 25 to 30 feet above the Faribault plain when it first commences, but seems to rather fade and mingle, upwardly, with the Trenton flat above, over which is also spread a yellow, pebbly clay. This appears in ascending the river. This terrace is also visible in the Cannon valley, where the two streams combine, and its outline is visible in the valley of the creek that joins the Cannon near the fair-ground. Its line of strike passes through the Maple-Lawn cemetery, while the Catholic cemetery is higher, and on the undulating ascent over the St. Peter sandstone.

Cannon river terraces. As already noted, the Cannon valley is a remarkable one. Some of its remarkable features are exhibited in Rice county, and some of them only in Dakota county. It once conveyed the waters of the Minnesota river across Rice and Dakota counties to the Mississippi valley.* The lake that at first was formed by the damming up of the Minnesota by the ice of the glacial epoch has been described by Mr. Upham in the report on Faribault county. At a certain time during the period of its existence that lake had its discharge through the Cannon valley. Those waters must have entered the county, judging from the hight of the upper terrace-flat, at an elevation of about 1075 feet above the ocean. As the ice withdrew the lake was lowered by finding lower and lower avenues of discharge, some of which will be described in the report on Dakota county, till by the retreat of the ice-margin from the valley entirely, it was wholly drained, and the river assumed its present course to the Mississippi.

*See page 461, foot-note; also page 642.

The river from its source passes through a morainic tract extending over the eastern part of Le Sueur county and into Rice county, on both sides, as far as the center of Morristown township, and in this portion of its course its terraces are less distinct. The highest terrace is not well defined continuously, even after passing Morristown, but the lower is very marked and persistent. The following are the only points in Rice county at which the upper terrace deposits of gravel, probably pertaining to the earlier portion of the time of the eastward outflow of the Minnesota river, have been noticed. On sec. 24, Morristown, and thence extending toward Warsaw, this upper terrace exhibits an undulating upper outline, consisting of gravel, and reaches a hight of about sixty feet above Cannon lake. This terrace-like outline blends upward with the till, at least superficially, which at once ascends forty feet still higher and stretches off southward indefinitely as a smooth prairie. This till is covered with a copious yellow loam (or clay). West of Morristown, in secs. 20 and 21, the railroad enters an old valley apparently cut through the deposits of this upper terrace, leaving between it and the river (which lies farther north) an island which rises now about 105 feet. It is undulating, and apparently contains much till as well as gravel. The highest point on the railroad is in the south part of sec. 20, where the grade is 1056 feet above the sea, and the natural surface is 1067. The hill north of the Polar Star mill, S. E. ¼ of sec. 26, Wells, near the Cannon river, rises to 1095 feet, but consists mostly of St. Peter sandstone, capped with about twenty feet of yellow loam, semi-stratified. The top of the limerock at Doyle's quarry, on the west side of Straight river, sec. 31, Faribault, is 1080 feet above the sea. This quarry is covered by fifteen feet of fine mortar-sand, overlain by four or five feet of stony and pebbly loam. The rock is changed in color and water-worn. There is a terraced projection of high land jutting northward in section 27, Bridgewater, lying between the present valley of the Cannon and the old valley passing through sec. 28. The uppermost flat, which is approximately 1050 feet above the sea, is probably due to the action of the Cannon river when its waters flowed nearly at that hight. At Northfield the highest gravel deposits seem to be about 980 feet above the sea, but the site of the city is an undulating, ascending, terrace-like plateau, in which the strike of the Shakopee limestone, as cut by the Cannon river, remnants of the St. Peter sandstone, and the gravel deposits of the ice-period, though elsewhere exhibiting two distinct terraces, are all concerned as causes. The highest part of this plain, in the southeastern suburbs, rises fifty feet above the Milwaukee depot. The west side of the valley is similar to the east, rising by an undulating plain to sixty feet above the Milwaukee depot, where there is a rather more flat and terrace-like expanse. This is 975 feet above the sea, and wells here enter gravel. Beyond this, toward St. Olaf college, there is a further abrupt ascent to 125 feet above the same depot, or 1040 feet above the sea, passing over the St. Peter sandrock. Back of St. Olaf college, on the remnant of the Trenton limestone there quarried, at 1063 feet above the sea, the rock is simply overlain by a yellow loam four feet thick. This isolated area of the Trenton limestone is remarkable for having no signs of foreign drift strewn over it. The Trenton is simply covered with a spreading of yellow loam, varying to black, making a red brick. The rock itself is rotted and yellow with age and exposure, and only five feet thick, and water-worn on the upper surface. There is some drift visible on the St. Peter slope surrounding this plateau, appearing mainly as boulders of granite, but the great blue moraine must have passed to the west of this point. The water-worn condition of this Trenton limestone, which rises higher than the surrounding country toward the north and northwest, indicates that at some time during the flood-stage of the Cannon river, its waters spread widely over Bridgewater and Greenvale in Dakota county, and eastward over much of Northfield, forming rather a lake than a river; but a lake which though slowly flowing eastward, was annually frozen over in the winter. Ice thus annually formed would easily remove any boulders that may have once lain on the St. Olaf plateau, since the waters probably did not rise much above that level, and would have congealed about them. On the movement of the ice in the spring they would be carried away, and be dropped at lower levels.

These highest water-signs in the Cannon valley are doubtless much more numerous than here enumerated, but as these are the only definite field-observations that have been made respecting them, the outline of this terrace is not attempted on the plate representing Rice county. These gravel deposits and terraced forms in the bluffs of the river, between Morristown and Northfield require an elevation of at least 1065 feet for the surface of the river at Northfield. As there would be some slope northward, the same water surface would necessarily be at least 1070 feet at the Le Sueur county line. The gravel which is spread over the Trenton plateau at Doyle's quarry, and southwestward from there, having an elevation of 1090 feet above the sea, may have been deposited by the Straight river, as already mentioned, or by direct drainage from the wasting surface of the ice at the time of accumulation of the moraine in Walcott township.

The lower terrace, that on which the city of Faribault stands, is much more constant and conspicuous. At Faribault its elevation is 1002 feet, and forty-three feet above the river. At Warsaw it is 1007, and thirty-four feet above the river. At Morristown it is 1008, and about fourteen feet above the river. Below Faribault there are conspicuous morainic accumulations of gray till accompanied with considerable gray gravel that rise in the midst of this gravel terrace on the west side of the river; and on the east side it is quite narrow or entirely wanting. Through a valley in this rolling till area the Milwaukee road passes northward, after leaving the gravel plain at Faribault, the highest part of which valley has a natural surface 1047 feet above the sea, though the till itself rises in many places above 1100 feet. The Cannon valley railroad also follows a low spot through this moraine. Both roads re-appear on the gravel terrace, the former in sec. 13, Wells, and the latter in sec. 8, Cannon City, where it is approximately 975 feet above the sea. Again on secs. 33 and 27, Bridgewater, this plain is separated from the present river channel by extensive accumulations of till, whose hight, however, is not wholly due to an increase of the drift, but partly to the preservation of the St. Peter sandstone and the Trenton limestone. At a mile above the mouth of Wolf creek the river re-enters its old valley, and is skirted by the deposits of this terrace especially on the east side of the river, between Dundas and Northfield. The strike of the Shakopee, with its boggy bench, is introduced conspicuously at and below Dundas, disturbing the course of this gravel terrace, and introducing a lower terrace on each side, between which latter the river continues to the county line. At Dundas the real valley is about two miles wide, with gravel flats on both sides.

Gravel is spread over the lower prairies, at about an elevation of 950 feet, in the northeastern part of Northfield, tributary to this same terrace in Dakota county, and especially over the "Stanton flat" in northwestern Goodhue county. It is probable, however, that some part of this gravel reached the Cannon valley by way of the Prairie creek, at the time of the morainic accumulation between Faribault and Cannon City.

The Bridgewater kame. The most important phenomenon of the drift in Rice county is the kame in Bridgewater and Cannon City townships. It can be traced, with unimportant interruptions, from the N. W. ¼ of the

N. W. ¼ of sec. 21, Bridgewater, to the N. W. ¼ of sec. 17, Cannon City, on the west side of the river, a distance of five and a half miles. It crosses the river twice, once in the N. W. ¼ of sec. 4, and once in the E. ½ of sec. 8. It consists of gray gravel, with some larger stones, piled in a sharp ridge, about as steeply as such materials will lie. It is popularly known as a "horse-back." It shows where the river ran during some portion of the ice-age, while the ice itself was present as a glacier, and extended westward and northwestward indefinitely.

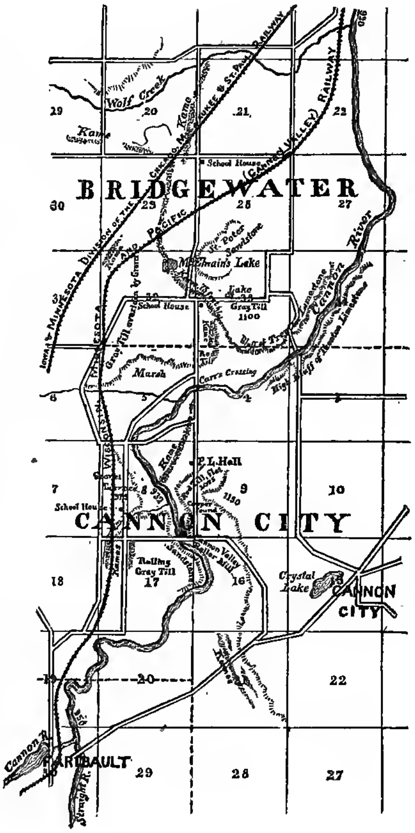


FIG. 52. THE BRIDGEWATER KAME.

This ridge rises conspicuously, first, on sec. 21, Bridgewater, not far from Wolf creek, on John Cowden's farm; crossing the land of Benj. Tupper, in the direction S. 25° W. (mag.), it is interrupted for about twenty rods. The country through which it passes is flat or slightly undulating. It rises again on the farm of Marshall Gates, and has about the same direction. It crosses the railroad near the southeast corner of section 20, and the north and south highway east of the railroad, and the east and west highway within a few rods of that. It has several short gaps then, but can be traced nearly to the Cannon river a little below Carr's crossing, on the N. W. ¼ of sec. 4, Cannon City, where it is very prominent. It re-appears in the S. E. ¼ of sec. 5, in the bottomlands of the river, but on the opposite side. This flat is seventy-five feet lower than the flat on which it lies in section 33. It is here lying on the Shakopee limestone, with occasional knobs of the St. Peter rising so as to be visible (one of them being visible under the gravel at the end of the kame where it is cut by the river in section 8), but in section 33, at its most eastern turn, it lies on a red till, though afterward, where it enters section 32, it lies apparently on a gray till, if not directly on the underlying Shakopee. On the N. ½ of N. E. ¼ of sec. 8, Cannon City, where it crosses the land of Mr. Peter LeClaire Hall, its upper outline is broken by rather abrupt changes. It continues in the bottomlands (or flood-plain), the strike of the St. Peter passing under it just where it reaches the river and considerably increasing its elevation. It here measures, by aneroid, 92 feet in hight. The flood-plain is about 940 feet above the sea (8 feet above the river), and the kame rises to 1032. The red till, and loam, about one eighth mile farther east, here rise in a timbered bluff in which the lower Trenton limestone is probably included, to 1075 feet. Where the kame ceases, on the west side of the river in section 8, the descent is as steep, to the very water, as on either side of the kame itself. The direction of the kame at this point would cause it to be expected on the west side of the river in the lowest part of the old channel in the northwest part of section 17. Here are found, actually, two ridges, but of less definite characters, and neither of them can be affirmed to be the extension of the kame, since they seem to blend with the generally bluffy till area which here lies between the Milwaukee railroad and the river. One of these lies on each side of the north and south highway (likewise of the Cannon valley railroad). That on the east side, though capped and flanked with gravel, at a hight above the lower gravel terrace, yet has a basis of St. Peter sandrock and red till with northeastern boulders. Its length is about an eighth of a mile. Further east and south the land soon rises into a rough moraine. Toward the west the surface also rises irregularly, though some what in the semblance of a ridge at first, on the west side of which runs a little creek northward-

This kame, the course of which has been described, consists entirely of gray gravel. It generally has not a sudden depression immediately alongside, in the average level of the country, but the kame rises abruptly from the general flat, the angle being from 25° to 35° from the horizon. Yet, although there is not a sudden depression where it lies, there is perceptible, in some cases, a broad, basin-shaped valley through the lowest parts of which it passes. This broad, smooth valley is from a hundred to a hundred and twenty rods in width. Such can be seen in sec. 21, Bridgewater. The hight of the ridge is usually from thirty to forty feet, with a smooth exterior; but near the school-house, in the west part of sec. 33, Bridgewater, its hight is from seventy-five to eighty feet, and in other places it has an average hight of fifty feet. The accompanying sketch-map of its course, fig. 52, was prepared with the assistance of Mr. W. H. Emery.

Conclusions respecting the Bridgewater kame. Some important and necessary conclusions result from the existence and nature of this kame.

1. As it contains only gray gravel it must have been derived from the gray, or northwestern till sheet.

2. Its composition being gravel, water-worn, it must have been deposited by water.

3. As it rises and falls, both on its upper and its lower surface, according to the surface on which it lies, it cannot have been caused by beach-action, and no other natural agent can be appealed to than a river in rapid flow.

4. The supply of the material of which it consists must have been rapid and long-continued; hence the glacier ice must have been present.

5. As a line of rolling morainic accumulations, the outer morainic belt of the county, here occupies in general the valley of the Cannon river from Faribault to sec. 33, Bridgewater, the kame must have been accumulated during that prolonged stationary stage of the ice.

6. As the ice would at that time have covered and enclosed the Cannon valley above Bridgewater, and also the Minnesota valley, the water concerned in its formation must have been that of the Straight river only. Again,

7. As the first outflow of the Minnesota through the Cannon valley was at an elevation of about 1075 feet, forming at Northfield rather a broad,

lake-like river, than a narrow rapid river required for this kame, it could not have been produced at the date when the Cannon first received the Minnesota; and again,

8. It could not have been produced by the Cannon when the Minnesota acquired its lower passage to the Cannon, forming its lower gravel terrace, since at that time the ice would have been withdrawn from the region in which it lies.

9. It must, hence, have been produced by the waters of the Straight river alone.

10. As there is evidence of the obstruction of the Straight river by the glacier south of Faribault, causing the discharge of the Straight river through the north branch of the Zumbro, it must have been produced at a later date, when the ice had shrunken so as to allow of the drainage of the Straight river toward the north.

11. Hence the lake that covered the upper portions of the Straight river valley was lowered to the level of the top of the ice.

12. The river flowed over the margin of the glacier, and presumably at first on its very surface.

13. As the river received the gravel from the glacier, the gravel must have been at the same level, or above it.

14. As the gravel is the result of washing of the till and the removal of the clay, the till itself must have been as high or higher than the surface of the river.

15. The till was therefore on the surface of the ice.

16. The kame was not formed by a sub-glacial stream but by an epi-glacial stream. This results from the foregoing conclusions, and also from the fact that the bottom of the kame actually rises about 75 feet at the point where it leaves the flood-plain on sec. 5, and ascends to the S.W. $\frac{1}{4}$ of sec. 33, where it lies on red till, the latter point being about three-quarters of a mile north of the former.

17. The ice bearing the gray till was projected eastward over the pre-existing sheet of red till, without entirely disrupting and removing the red till, at least where the red till lies on the St. Peter sandstone. At higher levels, over the Trenton limestone in sec. 33, Bridgewater, the red till is not found between the gray till and the rock.

18. The Straight river continued to flow about where the kame lies, after the withdrawal of the ice.

19. When the upper Cannon valley was freed from the glacier, and it received also the waters of the Minnesota, the volume of the river was so great that it not only covered the kame itself but spread eastward over the St. Peter sandstone.

20. As the stony till lately deposited by the glacier was less easily excavated than the St. Peter sandrock, gradually the greater volume of the river ran over the strike of that sandrock; and this may have taken place while only the Straight river occupied the valley, and perhaps when the ice still existed in the interval between the old valley and the new one.

21. Thus the river on the shrinkage again of the Cannon to its present size, or on the withdrawal of the ice, was permanently diverted from its course through or over the till deposits, marked by the present position of the kame in secs. 33, 32, 29 and 21, and remained in the narrower, but deeper, newly excavated gorge through which it flows from Carr's crossing to where it returns to its old valley in the north part of sec. 27.

22. A similar encroachment of the river on the St. Peter sandrock is witnessed in sec. 19, in the north part of Faribault, where also the river has abandoned its old valley, abundantly strewn with gravel, extending through secs. 23, 13, and the west half of sec. 7, and has followed a recently excavated narrow gorge through the St. Peter sandrock, a distance of about two miles, uniting again with the gravel-strewn wide valley just below the Cannon valley roller mill, S. E. cor. of sec. 8.

23. After the formation of this kame there was no re-advance of the ice over the same area.

Minerals from the drift. Several pieces of native copper were found near the Cannon Valley roller mill, S. E. ¼ of sec. 8, Cannon City, some in excavating for the foundation of the mill, and others along the road between secs. 8 and 9. They are from the red till which generally is there found lying in the eroded depressions of the St. Peter sandstone.

Several pieces of silicified wood have been found at Northfield. These evidently are referable to the gravel and till of the gray drift derived from the northwestward.

Among the specimens obtained from the drift, now in the collections of Carleton college, Prof. Sperry has preserved a boulder of very coarse porphyry. The crystals are apparently of albite, in a compact greenish diabase. They are about 1½ inches in length, the corners and edges somewhat rounded off, making the rock resemble a conglomerate.

In the same collection of drift-stones are several pieces, about six inches long, of the felsite of the Great Palisades, at lake Superior, with the disseminated crystals of quartz and translucent feldspar.

Small specimens of asbestus have been brought twice to Carleton college, once said to have come from near Shieldsville, and once from near Faribault. It is in silky threads, that are fine and from a vein in some rock. This vein is 2½ inches wide, the threads running transverse to the direction of the vein, and presenting a faulted structure near the middle of the vein. None of the rock is preserved in the samples seen, but as both specimens have the same faulted structure they probably came from the same vein, if not from the same boulder. The grain of the mineral, and its color, also indicate the same.

Mastodon remains. Concerning the mastodon tusk found at Northfield, Prof. Sperry writes as follows:

CARLETON COLLEGE, NORTHFIELD, MINN.,
April 8th, 1882.

PROF. N. H. WINCHELL, MINNEAPOLIS, MINN.

DEAR SIR: In reply to yours of 3rd instant making inquiries concerning some remains of a *mastodon* found in this city in 1879, and now in the cabinet of Carleton college, I would respectfully state that the remains found here consist only of a part of one tusk. This was exposed by some workmen, while digging in a deposit of drift, about ten feet below the surface.

The portion of the tusk found measured eight and one-half (8½) feet in length, and twenty-two (22) inches in circumference, at the base. When restored, by continuing its general line of taper to a point, it measures nearly twelve (12) feet.

The broken extremity of the part found was so eroded and rounded as to render it evident that it had been broken and separated from the terminal portion before being deposited where it was found. Its whole appearance indicates that it had shared the rough-and-tumble experience of its associated drift material.

Subsequent removal of much of the surrounding bank has not revealed the separated extremity. Exposure to the light and air has resulted in checking and slacking the discovered specimen, so that protection, by the use of glue, sizing and varnish, became necessary.

Yours cordially,
L. B. SPERRY.

Wells in Rice county.

Wheatland. Wells in Wheatland township are generally in blue clay after passing through two to four feet of yellow clay. The latter contains pebbles and bits of Cretaceous shale, and if not a weathered condition of the blue till, is closely connected with it in origin. William Sherack, S. W. ¼ sec. 16; well, 33 ft.; yellow clay, then blue clay.

Webster. Edward McFadden, S. E. ¼ sec. 17; well, 38 feet; all yellow and blue clay except at the bottom where water was found in gravel. Pieces of Cretaceous shale and lignite were found in this well. Thomas Reynolds, sec. 14; well, 42 ft.; yellowish-red clay, 18 ft.; the rest was blue clay. Martin Duffy, S. E. ¼ sec. 16; well, 54 feet.; said to be all in gravel, finding no water. This is on land about twenty feet higher than McFadden's well. ——— Burke, on the south half of sec. 8; well, 68 ft., yellow and blue clay. John Malloy, S. E. ¼ sec. 10; well, 30 ft.; yellow loam, 8-10 feet, then blue clay, and water in gravel. Mrs. Ann Kinsella, N. E. ¼ sec. 14; well, 25 ft., only yellow loam and blue clay.

Forest. Simon Taylor, N. W. ¼ sec. 13; well, 73 feet; dug all the way, yellow clay, blue clay, quicksand, the blue clay making up the greater part of the depth, and the quicksand and gravel at the bottom furnishing water. The blue clay had considerable slate, and occasionally other stones as large as six inches. John Beckley, S. W. ¼ sec. 12; well, 24 feet; yellow and blue clay; water in sand. Leonard Balleyett's well, east side of sec. 22, is 25 feet deep, mostly in yellow clay. James Strange, N. E. ¼ sec. 15; well, 18 feet, all in yellow and blue clay, with pieces of Cretaceous shale. Wm. F. Sloan, N. E. cor. sec. 10; well 96 feet; in clay all the way to the bottom, where quicksand was struck, furnishing water. This well was bored 18 inches in diameter, and planked with pine, thus rendering the water foul. George Parker, sec. 35; well, 110 feet; a bored well, formerly good water.

Bridgewater. At St. Olaf school, sec. 36, Bridgewater, near Northfield, the well is in sand 6-10 feet, sandrock, 80-90 feet, Shakopee, about 50 feet; water is raised by a windmill. I. I. Ilsley, N. E. ¼ sec. 33; four wells, all in blue clay; 45 feet in blue clay, then limerock, then soapstone, there finding water, at least stopping there; probably seep water; no red clay under the blue clay. Mr. Ilsley found a log thirty-five feet under the surface in blue clay. Levi Strader, sec. 17; well, 27 feet; soil and yellow pebbly clay, 25 feet; sand, 1 foot; cemented yellow clay (hardpan), 1 foot; water rose about 8 feet.

Shieldsville. Pat. McKenna, N. E. ¼ sec. 1; well, 20 feet; yellow clay, 10 feet; blue clay, 10 feet; both with small stones; water from the clay. Another well near was the same, though 8 feet higher at the surface. The lakes at Shieldsville do not supply the wells sunk near them, being in superficial basins in the impervious till. Some wells are sunk seventy feet, or more, near these lakes, without getting a permanent supply of water.

Wells. Edward La Croix, N. E. ¼ sec. 12; well, 47 feet; yellow clay, 20 feet; sand, 2 feet; yellow, hard clay, 1 foot; blue clay, 25 feet; this well is about on the contour-line of 1000, the west limit of the gravelly, terrace-like expanse that accompanies the Cannon valley. C. J. Winans, S. E. ¼ sec. 6; well, 33 feet; yellow and blue clay, with gravel at the bottom. J. G. Scott, sec. 21; well, 45 feet; yellow loam, 12 feet; blue clay, 28 feet; gravel, 5 feet; water. Tinus Rand, sec. 21; well, on the brink of Roberd's lake; 28 feet in blue clay; though situated but ten feet above the lake, this well had no water. Dennis Scott, N. W. ¼ sec. 6; well, six or eight feet deep in gravel; near the lake, but about 25 feet above the lake.

Cannon City. Well of John Gordon, at Cannon City village, passed through soil and clay, 30 feet, and into limerock, 3 feet. Wm. Eigers, south part of sec. 18 (west of the river); well, 38 feet; yellow loam and clay, 4 feet; blue clay, 30 feet; sand, 4 feet; no water; small pieces of lignite.

Morristown. At Morristown village wells are from 12 to 15 feet in depth, in gravel. Joseph Goar, N. E. ¼ sec. 33; well, 70 feet deep; only in drift deposits. When the wind is west air comes into this well through the gravel near the bottom, and when it is east air passes in the opposite direction through the gravel. The well becomes so cold by this circulation that in winter, at the depth of seventy feet, the bucket freezes fast if left in the water. This well is in the prairie country, about 1100 or 1125 feet above the sea, with a westward slope toward a marsh about a hundred rods from the well.

Warsaw. John O'Connor, S. E. ¼ sec. 34; well, 13 feet; all in yellow clay; water in a thin gravel bed. John Davis, N. W. ¼ sec. 34; well, 90 feet; yellow and blue clay; no water. Another well ten or twelve feet west of the last, 50 feet deep, had a little water, but not enough.

Walcott. Widow Hannah Myers, S. W. ¼ sec. 21; well, 6 feet; soil and sand, 5½ feet; then blue clay; water rises and falls with Mud creek, but is unfailing. This well is situated on the terrace-flat that accompanies the Straight river, and is about 25 feet above the river. Wells in secs. 14 and 11 are shallow, and often in gravel.

MATERIAL RESOURCES.

Besides its fertile soil, and the large supply of timber that covers most of the western half of the county, Rice county has natural means of wealth derivable directly from the bedded rocks, viz., building-stone, and lime. Bricks also are made in a number of places.

Building-stone. Numerous stone-quarries occur in the eastern half of the county. The bluffs throughout this region are capped by a layer of the Trenton limestone varying from two or three feet to twenty feet in thickness, and the same stratum outcrops favorably at many points along the Straight and Cannon valleys. This rock furnishes a useful stone for nearly all purposes in common building, and is relied on throughout the country for all walls and foundations. It has also, till very recently, supplied all the stone used in the principal buildings in Northfield and Faribault; but within a couple of years several varieties of stone from abroad have been sparingly imported into those cities for some of the larger structures.*

Prairie creek valley has scores of small quarries opened along its bluffs, and the valley of the Cannon looks up to as many more. Some of the latter are as follows: east of Dundas quarries are owned by Messrs. Lemont, Larkins, Mills, Kuntz, and by others. The quarries of Peter Oleson and Archie Stetson are on the east side of sec. 25, Bridgewater. Porter Gray's and C. A. Reed's quarries are on the N. W. ¼ sec. 34, west side of the river. Charles Sanford's and William Clelland's quarries, on the same quarter section, are run summer and winter. The stone obtained here is not blue, but ashen gray, similar to that at Doyle's quarry at Faribault. Stone of the best quality is furnished at Northfield at about six dollars per cord.

* Compare the chapter on the building-stones of the state, p. 171.

There are several quarries in the bluffs at Faribault, but the most of the stone used at Faribault is derived from the extensive quarry of Mr. Philip Cromer, situated about three miles east of Faribault, in the valley of Fall creek. The principal mass of rock here is about ten feet thick, and is nearly free from the objectionable shaly impurities seen at St. Paul and Minneapolis. It is compact and uniform in structure, though slightly clouded in color by fossiliferous bands and by a slight dissemination of shale. The layers are thick and persistent, but can be split into blocks from six to ten inches thick. The lowest layer is very similar to the lowest layer at Minneapolis, being somewhat vesicular, and darker colored. In the midst of the quarry also is a thickness of about a foot of very dark limestone, containing much carbonaceous sediment. The marble, so-called, which was once used somewhat in making table-tops and mantels, is the top layer, and really is embraced under and over shale, the upper shale being seen to be at least six feet thick, and containing thin bands of impure limerock, but non-fossiliferous. This marble layer is a little less than a foot thick. It is susceptible of a fine polish, and has a gray color. On a polished surface are shown numerous sections of fossils peculiar to the rock. This layer is not now quarried for its peculiar product, but is involved with the general quarry. Beneath the whole quarry are three or four feet of shale which separate it from the St. Peter sandstone. Mr. Cromer sells undressed stone for prices ranging from $2.50 to $5.00 per cord. The greater part of his business however is in the best varieties which he sells by the cubic foot at prices ranging from 25 cents to 75 cents. Cut stone is sold from 20 to 30 cents per surface foot. The quarry is overlain by 2½-4 feet of loose stone mingled with loam. It was opened first about the year 1865, but was not continuously wrought till 1867, since which time it has furnished a very large amount of stone, which may be seen in Faribault in such buildings as the asylum for deaf and mute, the Shattuck school and the surrounding buildings, the public schools, Episcopal church and many of the business blocks. Willis Hall, at Northfield, is also partly constructed of stone from this quarry.

Other quarries are owned by Michael Doyle and Frank Berry, the latter two miles south of Faribault on the west side of the river. Mr. Doyle's quarry is in the bank of the Straight river near the center of section 31, Faribault, on the west side, and was opened in 1856. The stone here is all changed in color to yellowish drab. It is a durable stone, superior in that respect to Cromer's. Common stone here sells for $3.50 per cord of 128 feet. Mr. Doyle states that about 10 feet of shale underlies the limerock.

In the vicinity of Northfield, quarries are owned, near St. Olaf college, by H. H. White, John Lanpher, and Saul Stewart. This stone is hauled fifteen and even twenty miles further west. Other quarrymen are J. Leonhart, A. Revere and D. Ferguson. In Wheeling township, in the valley of Prairie creek, quarries are owned by J. Thompson, A. Knapp, and S. Aslagson. In Richland township, bordering on Goodhue county, are quarries owned by Halver Johnson, and Peter Halverson.

Lime. The upper four strata of the Lower Trenton formation, as exposed in this county, furnish tolerably good material for quicklime, though in some places they are too siliceous and aluminous. Lime has been made from this formation in every township of the county east of Cannon river, but this is not now a regular and paying business except at Philip Cromer's kiln, near Faribault. Mr. Cromer uses a patent kiln and burns from 3,000 to 3,500 barrels per year. Other kilns near Faribault produce in the aggregate about 1,000 barrels per year. There is a kiln one mile north of Northfield, which burns lime from the Shakopee formation, and supplies Northfield and vicinity. It is owned by Michael Tramm. He burns 30 barrels in 24 hours, when running, and sells for seventy cents per barrel delivered in Northfield.

Brick have been made at numerous places in Rice county, and they are uniformly of a red color. They sell from six to eight dollars per thousand. One yard at Faribault has produced sometimes a million brick per year.

Sorghum. Among the important industries of the county should be mentioned the sugar and sorghum establishment of Mr. Seth H. Kenney, situated in the N. W. ¼ of sec. 6, Morristown. This is the pioneer establishment of the state, and it is equipped with the latest improved methods and machinery for the manufacture of sugar.

Lumber. The steam saw-mills at Morristown cut five or six hundred thousand feet of lumber, or its equivalent in "head-lining", annually. The head-lining, which is the narrow stripping placed round the heads of flour barrels to secure the heads of the barrels, is made of "water elm" but several varieties of logs are cut into common lumber of all dimensions. Other steam lumber mills, less extensive, are found in the same part of the county.

Artificial mounds. At one half mile north of the old Wheatland post-office, S. W. ¼ sec. 16, Wheatland, several artificial mounds appear. They lie along a small lake which is on the west side of the north-and-south road. They are rather small, not exceeding two feet in hight. Five or six are visible from the road. There are probably others.

In Webster township, sec. 17, an eighth of a mile north of Edward McFadden's, on the highest land, but yet surrounding a marsh, may be seen a number of mounds rising two and a half or three feet.

There was an "Indian mound" on sec. 2, Shieldsville, on the south side of the outlet of the middle lake. According to Mr. Patrick McKenna, one of the early settlers of Shieldsville, the Sioux Indians used to fix their camp at this place. They had a scaffolding upon it where they placed their dead, and afterward buried the bones in the mound. This mound was from ten to twelve feet high. It was removed by the owner of the land that the surface might be tilled. Flint arrow-points have been found in that neighborhood, but they are not known elsewhere in the vicinity.

Besides the mounds mentioned in Waseca county, on page 414, others are in the vicinity of Woodville. According to Mr. J. F. Murphy there are 21 mounds, from four to five feet in hight, near the center of section 3, between Watkins and Rice lakes, some of them thirty feet in diameter.

In Fillmore county several large mounds are to be seen on the tops of the bluffs near Rushford; and at the junction of the north branch of Root river with the main river, two miles below Lanesboro, are a great many mounds, probably forty in number. Several years since, on the discovery of human bones in plowing the fields in which they lie, about twenty of these mounds were examined by some citizens of Lanesboro. The human relics discovered on excavating consist of large human bones, several stone hammers, a copper spear-head, several clay pipes and beads, as well as a small clay image of the human face and head, the latter with a circlet of radiating feathers passing over the top.* Other earthworks are near Houston in the Yucatan valley.

*Some of these specimens have been placed in the general museum of the University, by the courtesy of Mr. B. A Man. For a representation of the image of the human face found in the Lanesboro mound, see *Popular Science Monthly*, XIX, 609.

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